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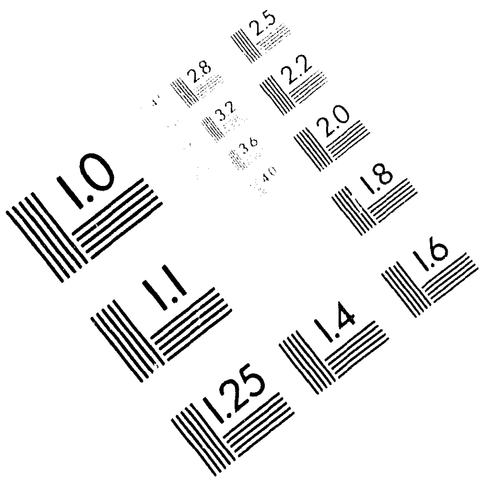

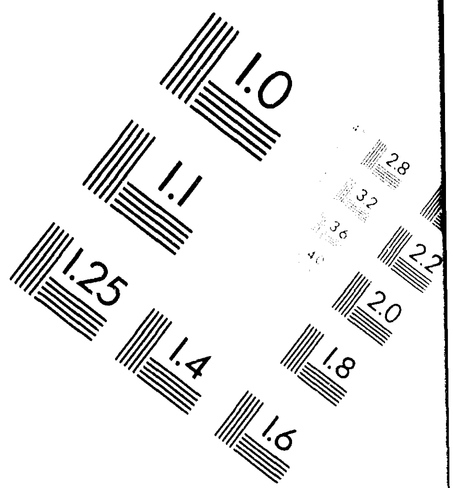

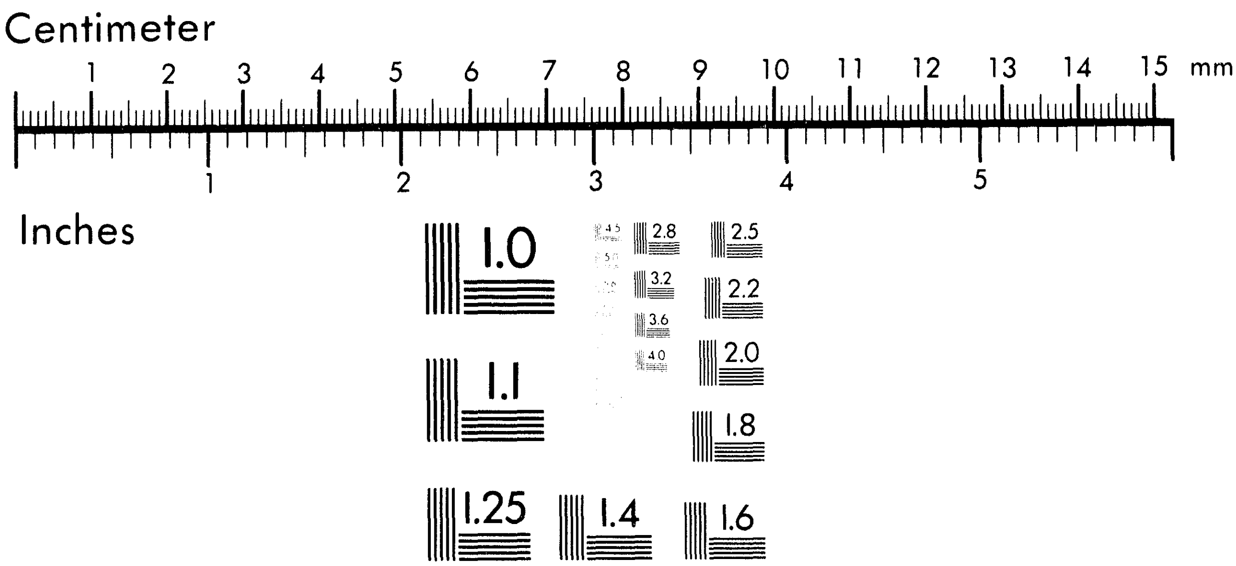


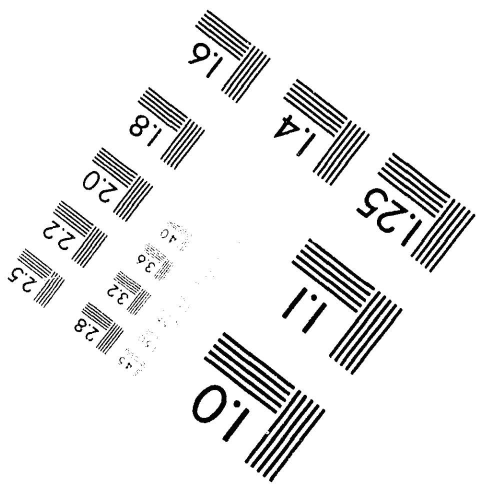

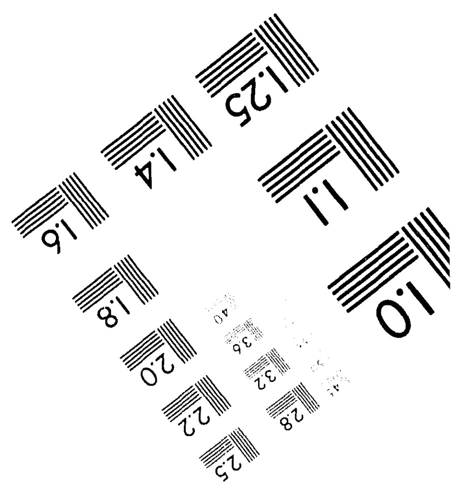

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Argonne National Laboratory
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# *HIGH ENERGY PHYSICS DIVISION SEMIANNUAL REPORT OF RESEARCH ACTIVITIES*

***July 1, 1993 - December 31, 1993***

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

Members: R. Wagner
P. Moonier
P. Schoessow
R. Talaga

May 1994

## *Table of Contents*

# *Abstract*

This report describes the research conducted in the High Energy Physics Division of Argonne National Laboratory during the period of July 1, 1993 - December 31, 1993. Topics covered here include experimental and theoretical particle physics, advanced accelerator physics, detector development, and experimental facilities research. Lists of division publications and colloquia are included.

# I. EXPERIMENTAL RESEARCH PROGRAM

## A. EXPERIMENTS TAKING DATA

### 1. Medium Energy Polarization Program

#### a. LAMPF Spin Physics Program

The primary goals of the medium energy polarization program are to determine the isospin zero (I = 0) nucleon-nucleon elastic scattering amplitudes above 500 MeV beam kinetic energy ($T_{kin}$), and to understand the origin of energy dependent structure observed near 2.1 GeV in pp elastic scattering and in other reactions.

There have been many experiments at LAMPF over the past ten years to determine the I = 0 amplitudes between neutron beam kinetic energies of about 500 and 800 MeV. The ANL polarization group was involved in many of these spin measurements. The last such experiment probably occurred this past fall, when the np polarization parameter was measured at small c.m. angles (~ 20° - 120° ) at 485 and 788 MeV using a polarized neutron beam incident on a liquid hydrogen target (E-1293). The scattered protons were detected in a magnetic spectrometer and the scattered neutrons in a large array of plastic scintillation counters. These neutron counters and some of the associated electronics were supplied by ANL. Two ANL physicists assisted with data acquisition part time during the runs. Data were collected at eleven angles. A large number of events were recorded, and these are being analyzed by a Los Alamos physicist. Expected errors on the polarization parameter are $\lesssim \pm 0.01$.

Data analysis continued on two other LAMPF np experiments. The final paper on the measurement of the np total cross section difference between antiparallel and parallel longitudinally polarized neutron beam and proton target (E-960) was essentially completed. It will be submitted to Physical Review early in 1994. The analysis of np elastic scattering data from a second experiment (E-665/770) was completed. Work continued on both the final paper for these data and on a second paper describing the np $\rightarrow$ d$\pi$ measurements. The first paper is the responsibility of the ANL group, while physicists from the University of Montana and Washington State University are working on the second. An amplitude determination at 484, 634, and 788 MeV will be performed in 1994 using these results.

#### b. Spin Physics Program at Saturne

The experimental program at the Saturne accelerator at CEA Saclay consists of additional measurements for the determination of I = 0 amplitudes above 1100 MeV, and pp elastic scattering experiments near 2.1 GeV. A polarized proton beam incident on a polarized deuterium target ($^6$LiD) has been used for quasifree pn measurements, and the analysis of these data is in progress at Saclay.

Elastic scattering of a polarized proton beam from a polarized proton target was performed in runs in March/April 1992 and in November/December 1993. A total of ten spin observables were measured at beam kinetic energies of 1800 and 2100 MeV, and four observables at 1850 and 2040 MeV in the most recent run. ANL physicists were heavily involved in developing a new data acquisition system and on-line software during this past year. The new system allowed data to be collected faster than before and with much improved monitoring of the experimental apparatus. The data tapes from the most recent run have been copied, and will be analyzed at Argonne during 1994 as part of the Ph.D. thesis for C. Allgower.

A paper has been written and accepted for publication in Physics Letters on the Spring 1992 pp elastic scattering data as shown in Figs. 1 and 2. A rapid energy variation is observed near 2.1 GeV. This behavior was predicted by E. Lomon of MIT using a cloudy bag model. In his model, the origin of the energy variation is a $^1S_0$ dibaryon resonance. Further analysis of these data will occur at ANL during 1994. (H. Spinka)

## 2. *Polarized Proton Physics at FNAL*

The final analysis on the analyzing power, $A_N$, of pp elastic scattering in the Coulomb-nuclear interference region with the 200-GeV/c polarized-proton beam was completed. The experimental result has been compared with a theoretical prediction.

It is commonly believed that polarization in elastic scattering vanishes at high energy where the amplitudes are eventually dominated by diffraction. However, several authors have shown that a small, but considerable, asymmetry was expected in high-energy pp elastic scattering at small $|t|$ ($\sim 10^{-3}$ - $10^{-2}$ $(\text{GeV/c})^2$) which arises from the interference between the hadronic nonflip and the electromagnetic spin-flip amplitude. If we can confirm the theoretical value, this is not only interesting physics but will be extremely useful for the purpose of a polarimeter to measure the beam polarization at high energies.

There are two major parts to the apparatus of the Coulomb-nuclear interference measurement: the forward spectrometer and the active trans-stilbene targets. The correlation between the scattering angle, measured by the spectrometer, and the pulse amplitude produced by the recoil protons in the active trans-stilbene targets constitutes the primary criterion in separating the elastic pp events from a number of different backgrounds.

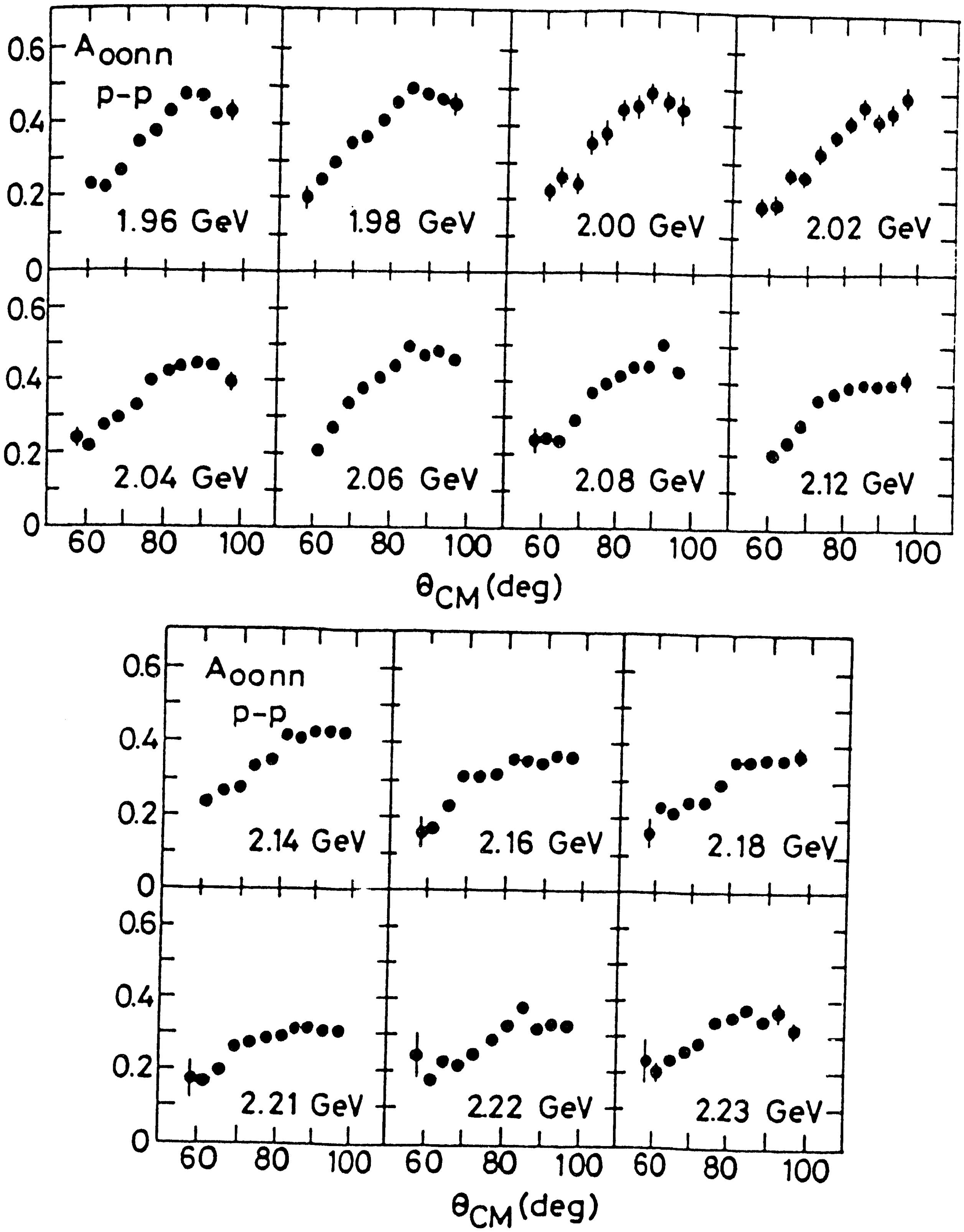



Figure 1 Measured values for the spin-spin correlation parameter $C_{NN} = A_{oonn}$ for pp elastic scattering at beam kinetic energies 1.96 - 2.23 GeV. These data were taken in Spring 1992 at the Saturne accelerator with a polarized proton beam incident on a polarized proton target.

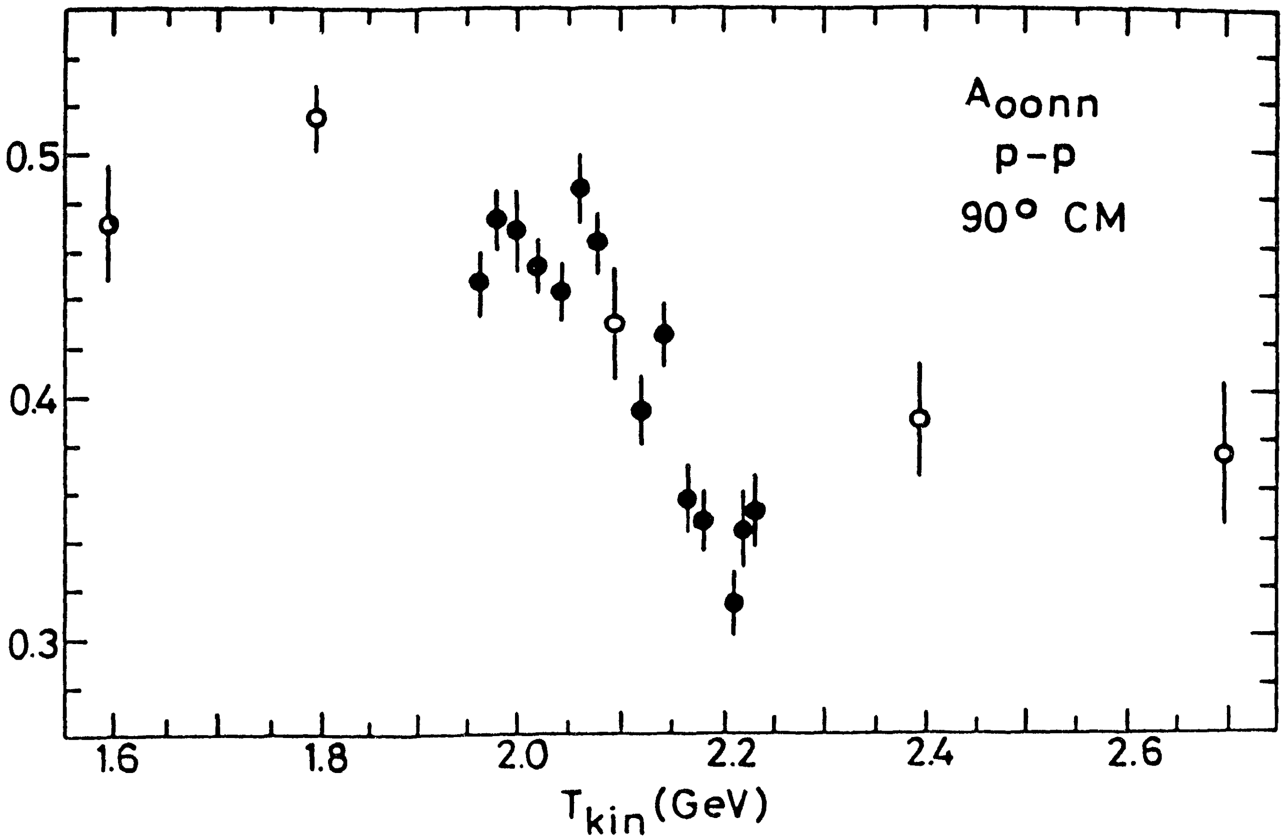



Figure 2 Measured values for $C_{NN} = A_{oonn}$ at $\theta_{c.m.} = 90°$ from the data in the previous figure (solid circles). The five points shown as open circles are from measurements several years ago at Saturne. The rapid variation with energy near 2.1 GeV is similar to that predicted by E. Lomon, and may suggest a dibaryon resonance.

The analyzing power, $A_N$, is shown as a function of -t in Fig. 3. The asymmetry expected for pure nuclear-Coulomb interference is represented with the solid line. The results presented here agree well with the theoretical prediction.

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

i) $\Delta\sigma_L$(pp and $\bar{p}$p), difference in total cross sections in pure spin states,

ii) Direct-gamma production data collected simultaneously with $\pi^0$ data in pp,

iii) Detailed analysis of $\pi^0$ and $\eta$ production, and

iv) K production in pp. (A. Yokosawa)

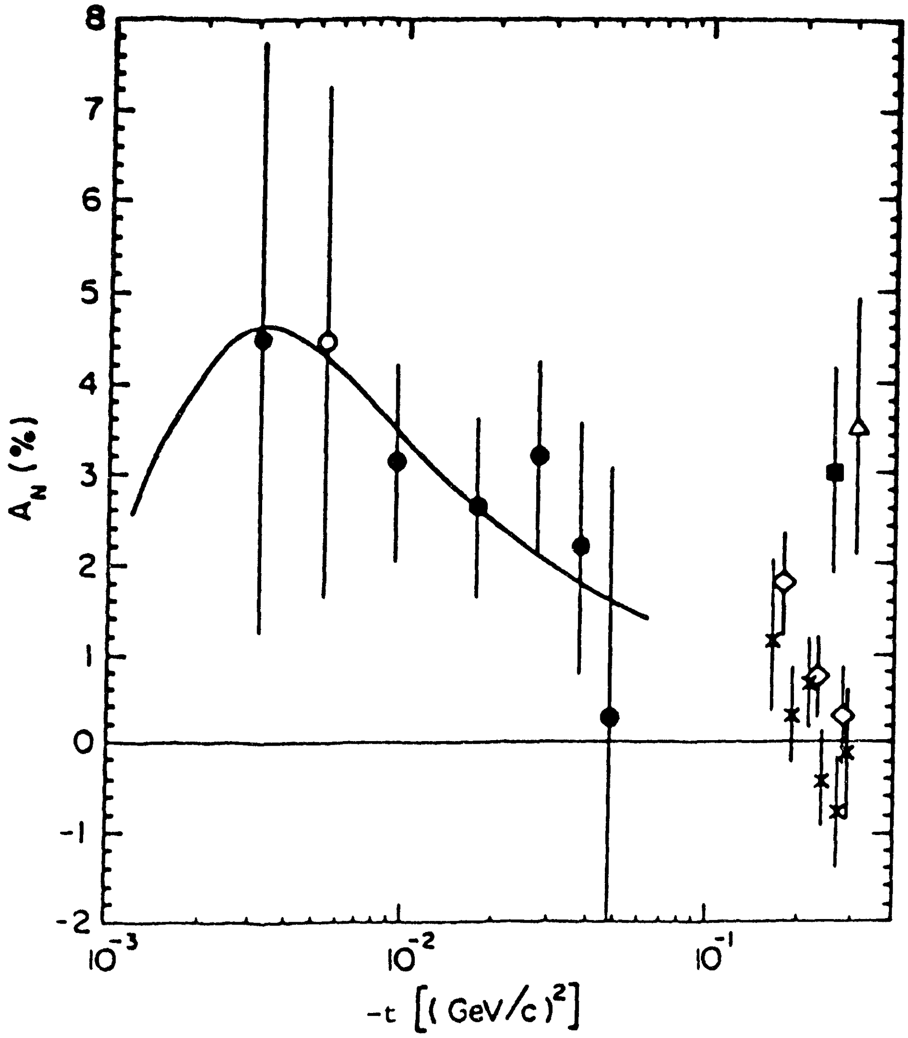



Figure 3 $A_N$ data for pp elastic scattering. o is measured at 185 GeV/c and ● at 200 GeV/c. Other symbols show data that existed at small |t| prior to these measurements.

### *3. Collider Detector at Fermilab*

#### *a. Physics Results*

The dominant physics activity of the CDF collaboration demanding attention from essentially the entire collaboration, has been the top search. A dilepton search has been done with appropriately tighter selection for the 20 $pb^{-1}$ of integrated luminosity from run 1a as opposed to the previous 4 $pb^{-1}$ from the 1988/89 run. Two candidates were found with a background estimated at about 0.6 events. Searches using both soft leptons (muons or electrons with $p_T$ down to 2 GeV/c) as b-tags and detached vertices as reconstructed with various algorithms in the silicon vertex detector (SVX) also produce a small excess of candidates above background. The combined significance is interesting rather than overwhelming. There is some support for a top signal from the kinematics of the lepton plus jet events without b tagging. The process of putting together a comprehensive presentation of these results is ongoing. Steve Kuhlmann is serving on the top analysis oversight committee. We hope that the process of finding a presentation of the results which is technically correct and acceptable to the collaboration will converge in the next six months.

Bob Wagner, Jimmy Proudfoot and Larry Nodulman have been active in electroweak physics. Jimmy has now completed a cycle as electroweak physics co-convener and Larry began a new cycle early due to a vacancy. Work on calibration issues for the central electromagnetic calorimeter is particularly relevant to W mass measurement, and Larry is serving on David Salzberg's thesis committee at the University of Chicago; David's thesis will be on the W mass as measured in the electron decay channel. The preliminary result, illustrated in Fig. 4, is $80.46 \pm 0.30$ GeV/$c^2$ of which 0.15 GeV/$c^2$ is the statistical error. Considerable refinement of the analysis is forthcoming. An equivalent preliminary result using muons should be available soon. There is strong participation in the W mass analysis from the University of Illinois and LBL.

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. They have observed a significant signal as illustrated in Fig. 5. Nonstandard couplings for the W would produce an excess of events at high transverse energy. The shape as well as the normalization of this distribution can be used to limit nonstandard couplings and preliminary limits are expected soon.

Karen Byrum and Barry Wicklund are continuing to study various aspects of b physics using the inclusive electron sample. Colleagues from the University of Pennsylvania and Johns Hopkins have joined in deriving b physics results from this

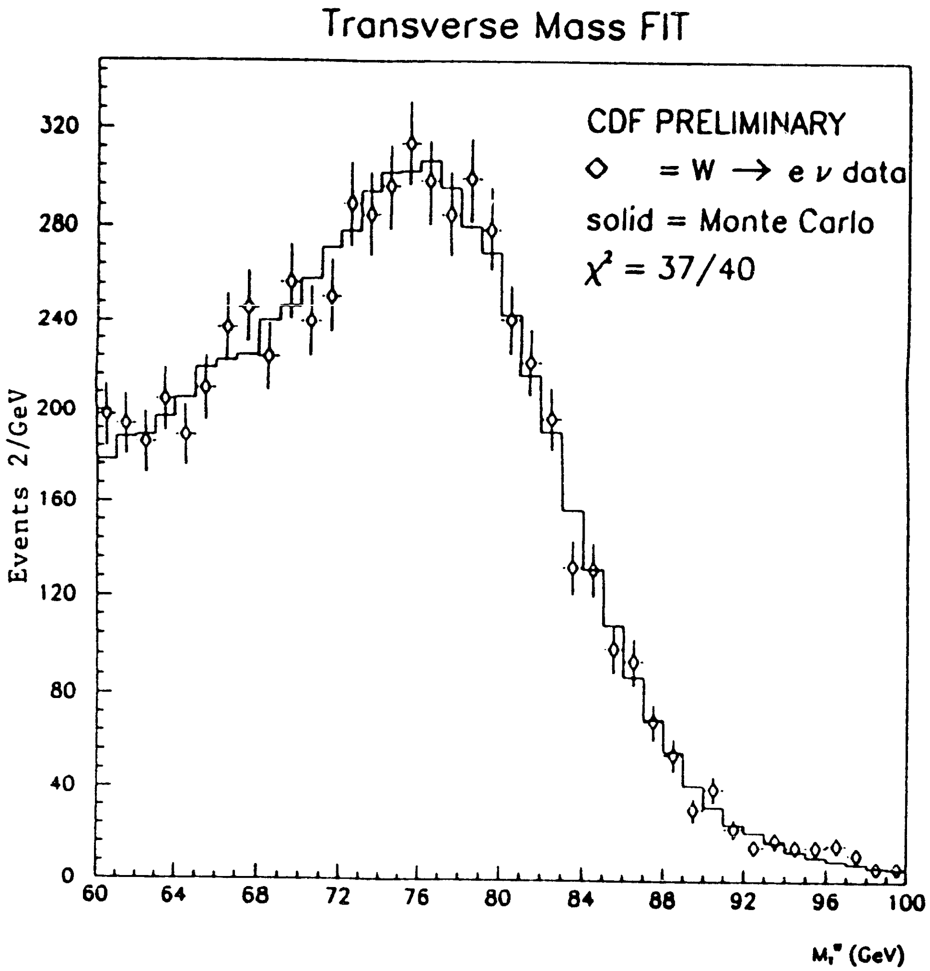



Figure 4 Fit to the transverse mass distribution of a sample of low $p_T$ W's. The statistical error on the mass is ± 150 MeV/$c^2$.

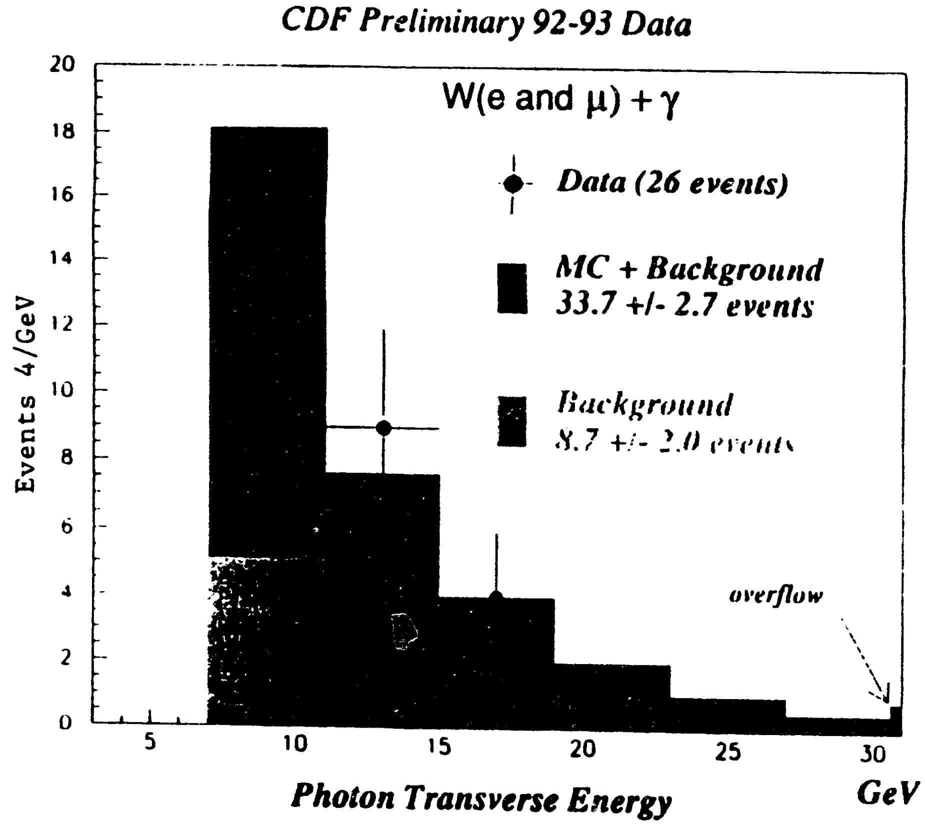



Figure 5 Photon transverse energy for photon candidates accompanying W events. The shaded areas are predictions from background studies and from Monte Carlo simulation of standard model radiative W production and decay.

sample, which is also used for calibration. One particularly interesting and illustrative study involves the issue of self tagging, that is can one infer from the sign of an accompanying $\pi^{\pm}$, say, from a B**, whether a fully or partially reconstructed B candidate contains b or $\bar{b}$ . If one could tell that, for example, a particular $\Psi$ $K_S$ was from a b or $\bar{b}$ decay without having to find and tag the other b decay, tests of CP violation would be much easier. For best statistical precision, rather than using fully reconstructed D's, two tracks with an offset vertex associated with the electron are labeled K$\pi$ if their mass is less than or equal to the D mass. One then looks at the mass difference adding another $\pi$, for a D* signal. A further $\pi$, is associated as a B** tag candidate, and the D* signal for same sign and opposite sign B** tags is shown in Fig. 6. The excess of D* in the same sign tags is evidence for self tagging. Other extra pions which might confuse the sign correlation may come from the D or a D**, but these are not expected to be an important background. A check of the kinematics is given by the alignment of the D* tag $\pi$, and the B** tag $\pi$ to the B and the production vertices, as shown in Fig. 7. Further systematic studies are in progress.

Steve Kuhlmann has now completed his term as co-convener of QCD physics. Bob Blair continues to organize the photon group. The inclusive photon analysis has been completed for the run 1a dataset and the resulting prompt photon $p_T$ spectrum is shown in Fig. 8. Using the preradiator analysis, the systematic errors shown are expected to decrease by about a factor of 2.

***b. Apparatus Preparation***

We have put considerable effort into understanding the hardware behavior in the run 1a data in order to be ready for run 1b which is now beginning. The loss of response in the central EM calorimeter is on average 4% based on calibration from the source runs at the beginning of 1a to the source runs at the beginning of run 1b. A loss of 1.5% would be expected. The loss is best tracked using the inclusive electron sample, and the one significant correlation among tower gains was found to be the arches. Perhaps the arches are thermal masses. Fig. 9 shows E/p versus run number by arch with and without corrections.

The preradiators have been found quite valuable in soft electron identification as well as photon identification; this has been important in the soft electron tags for the top search. The capability of the preshower pulse height as a discriminant between electrons and hadrons is illustrated in Fig. 10 which compares the pulse height for conversion electrons and electron candidates with displaced tracks, most likely from b's, with the

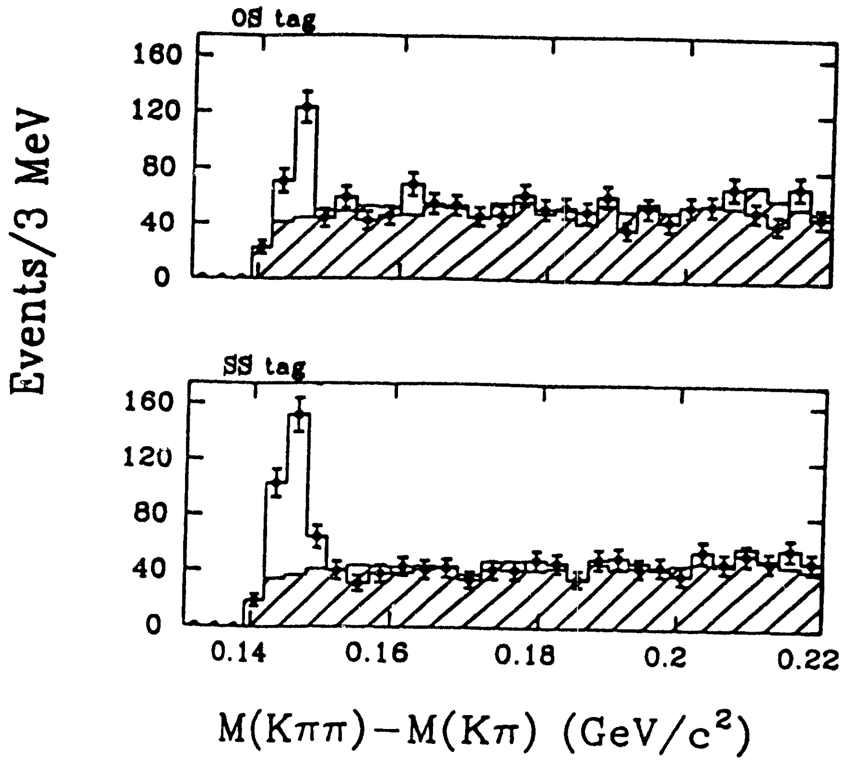



Figure 6 D* mass difference combinations for opposite sign and same sign B** tag candidates. The excess of same sign over opposite sign B** tagged D*'s is an indication of self tagging.

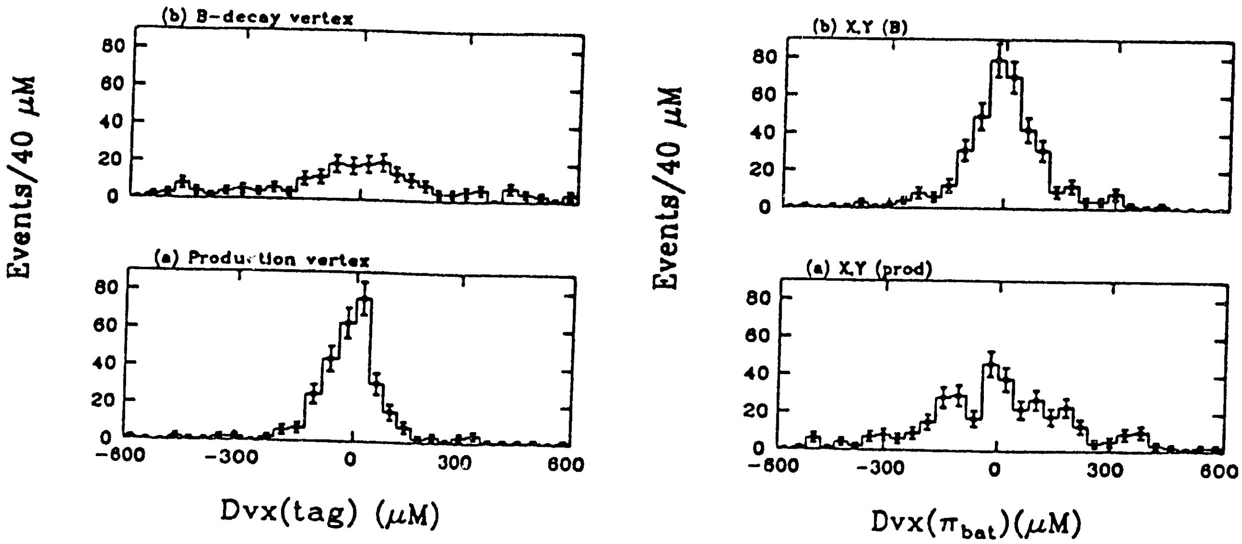



Figure 7 Distances of closest approach of tagging $\pi^{\pm}$ to the production and b decay vertices for the B** tag π's and the D* tag π's. The trend of the distributions is that the assignments are made correctly.

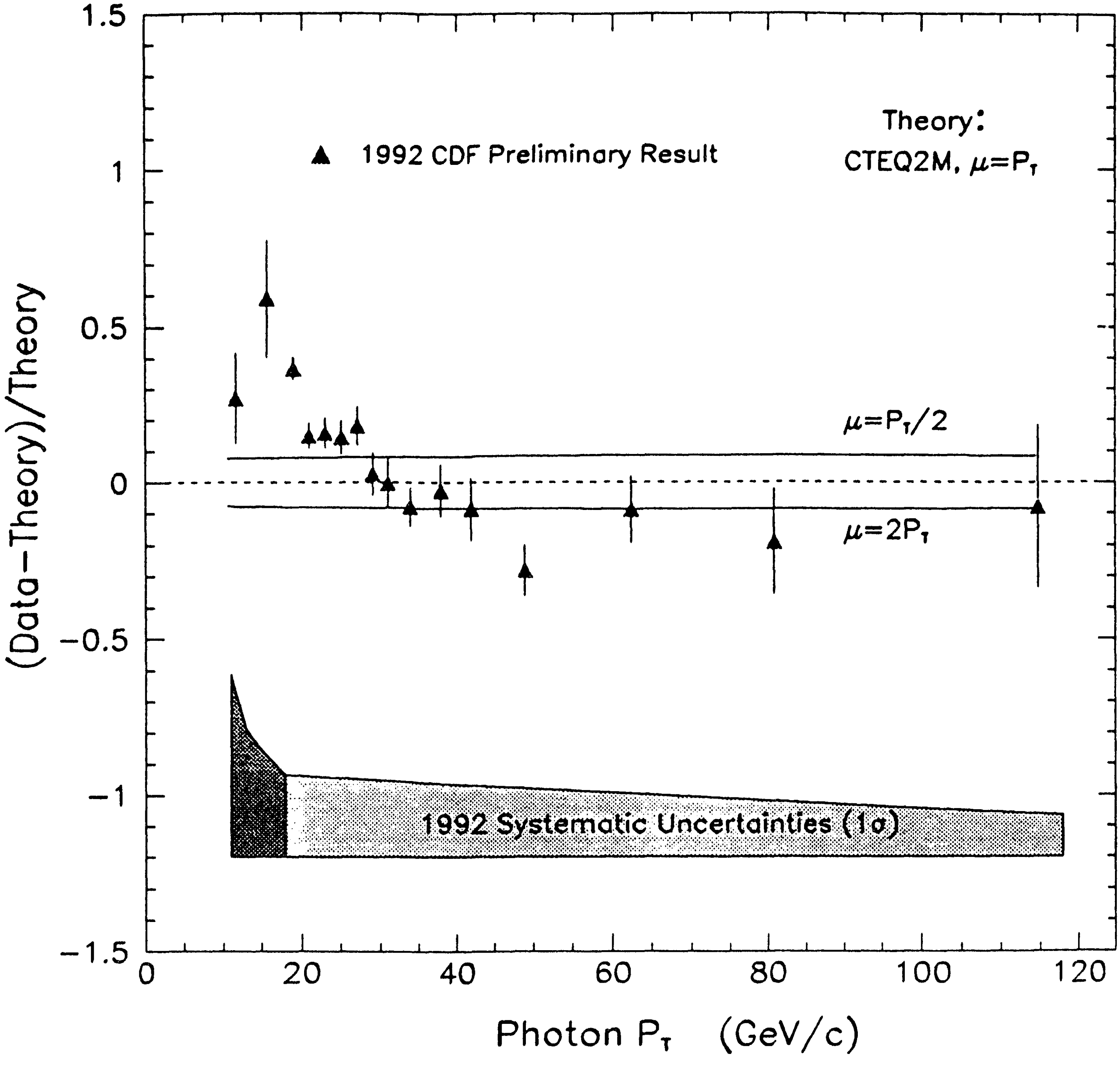



Figure 8 The deviation of the measured photon cross section from the NLO QCD predicted cross section is plotted versus $E_T$. The shaded band gives the size of the systematic uncertainties; this band is expected to narrow significantly as the analysis continues.

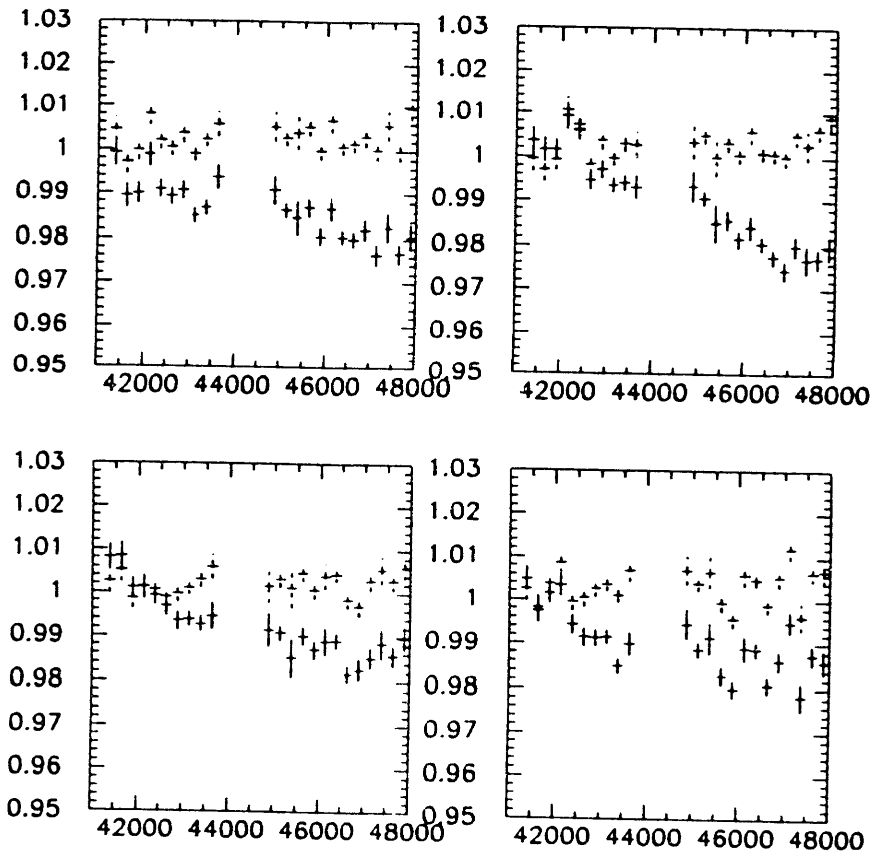



Figure 9 The central calorimeter of CDF is formed in four half arches. Average value of E/p for a tight selection of inclusive electrons, E + p > 22 GeV, is plotted versus run number before (solid) and after (dashed) corrections. The gap in the middle corresponds to an extended shutdown in January 1993, and the data on either side are treated separately.

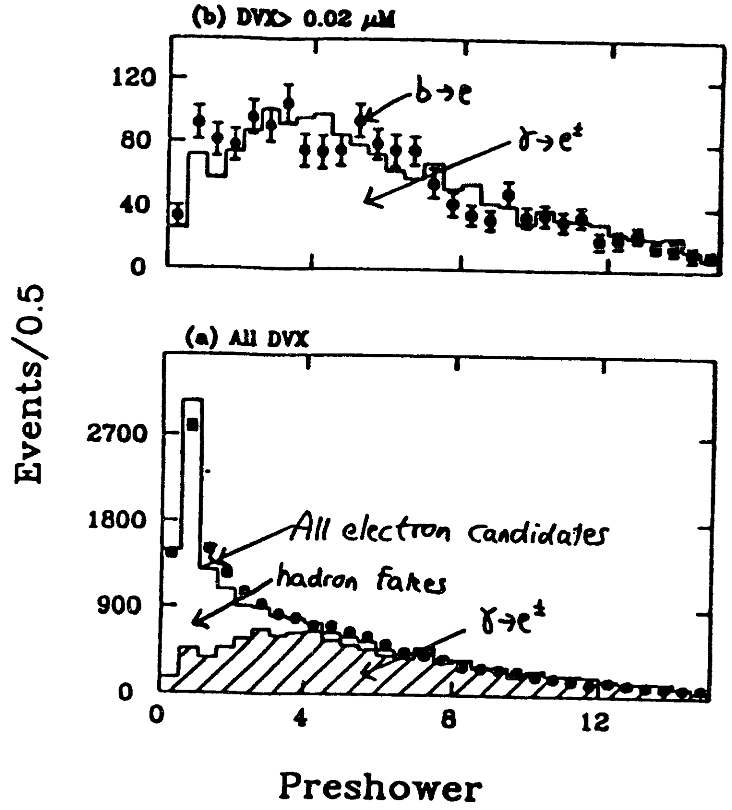



Figure 10 Preshower pulse height (in mips) for (a) all electron candidates and (b) candidates with displaced tracks. While the displaced candidate distribution agrees with the shape observed for conversion electrons, the inclusive spectrum is described by a sum of a conversion shaped spectrum and one corresponding to hadronic fakes.

inclusive spectrum. The inclusive spectrum is well described as a sum of real electrons, such as those from conversions, and hadrons that fake an electron signal.

The trigger hardware including spares supplied by Argonne for the strip chamber (shower max) trigger has been installed and checked out. Cabling for the trigger signals was installed before the pit was closed for run 1b. The front end cards have been completed by the Michigan group and were installed during access periods of the run 1b startup. The system is being checked out with beam as the run begins. Although there are still problems with some channels occasionally losing bits going into the trigger latches, the ability of the shower max bits to eliminate single phototube spikes is illustrated in Fig. 11. Although the systematics of track matching are still under study, the system is basically working as illustrated in Fig. 12 which plots strip chamber offline wire pulse height sums of the appropriate channels for electron triggers with and without the track match bit. The match is apparently more than 95% efficient for real electrons discounting known channel hardware problems. We expect the residual problems to be resolved before increased luminosity demands the rate reduction. Karen Byrum has been leading this effort for us.

When the pit closed for run 1b, we moved our studies of strip chamber noise to a RABBIT system setup with a spare strip chamber in an RF box at Argonne. Various studies by the PIG group at Fermilab and us (Marcus Hohlmann, in particular) have shown that the VME readout scheme for multibunch front ends will overwhelm the shower max signals with noise. We have not yet come up with a scheme to speed up the signal formation time which does not increase the noise; if no improvement along these lines is forthcoming, about eight 130 ns crossings will have to be integrated for strip pulse height measurements.

We will also need to become involved as consumers for the new fast tracker XFT to make sure that the strip chamber/track match functionality is retained. So far this is being designed at the University of Illinois for muons. It is anticipated that multibunch running will eventually include the main injector. Additional samples of 400 $pb^{-1}$ or more should be collected, perhaps by the end of the century.

### c. *Summary of Active Data Acquisition*

In general, the CDF detectors have settled out well for data taking in run 1b. The new silicon vertex detector is performing well, the data is essentially usable, and muon trigger improvements are being developed. The new DAQ system is still under study, but it should be ready once its rate capability is needed. New level 2 trigger processors have not yet been delivered by the University of Michigan. We are promised a new data

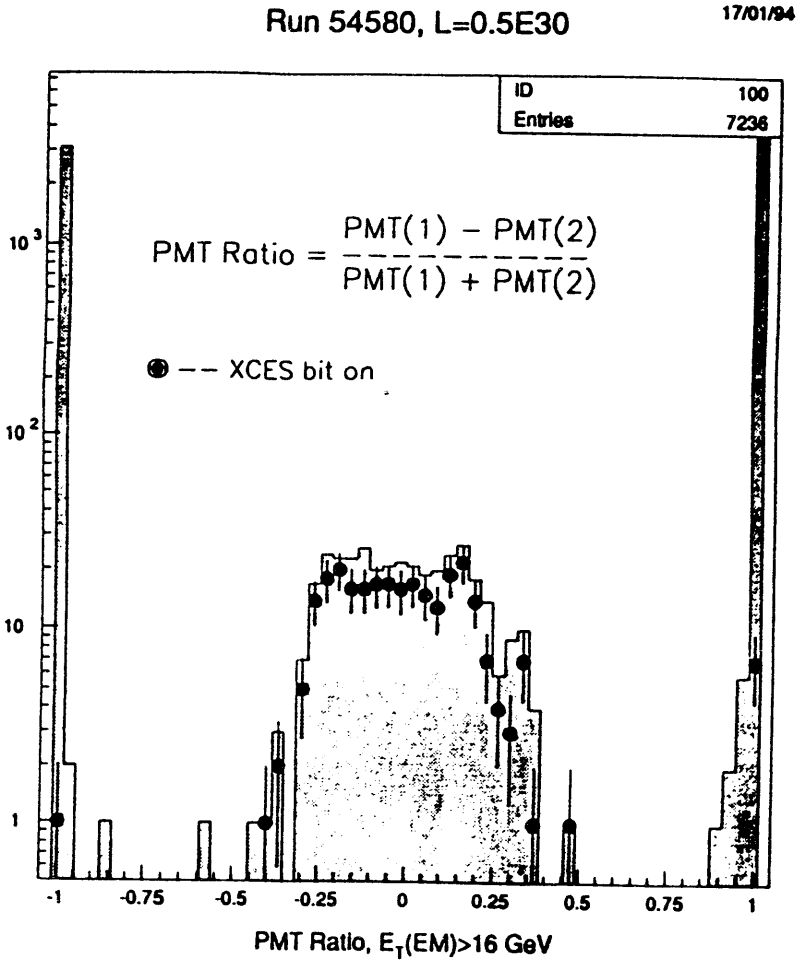



Figure 11 Normalized pulse height difference of the two phototubes in a tower for photon triggers. The shaded histogram is for all triggers and the points for those where an appropriate shower max chamber had a trigger bit. Note the suppression of the spikes at the sides which correspond to single tube discharges, and that 100% efficiency was not yet expected.

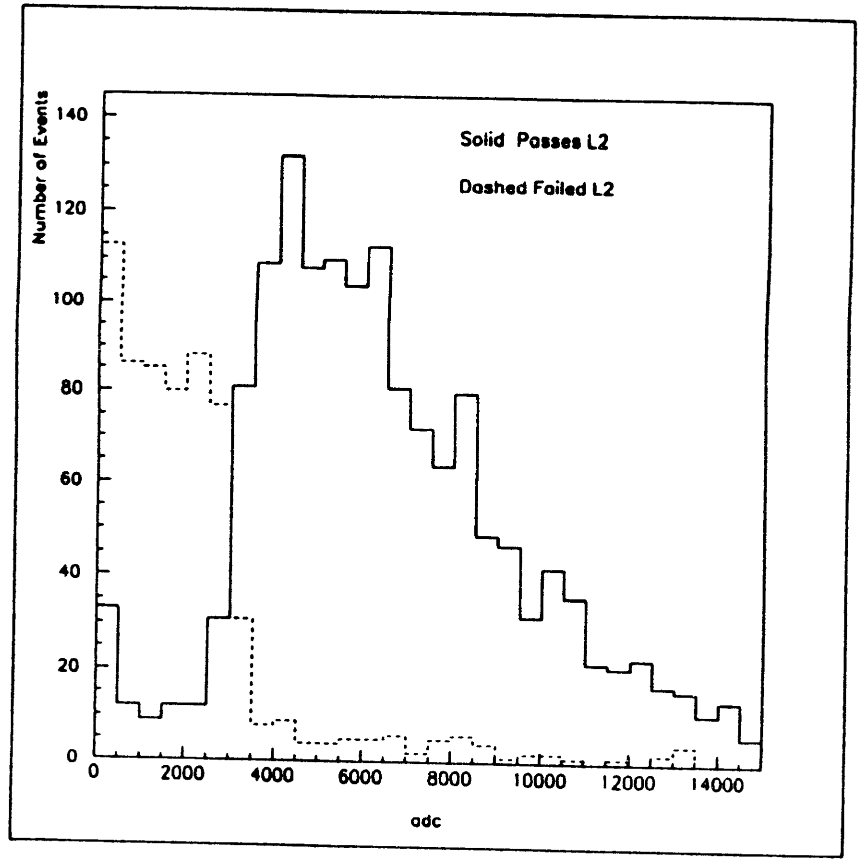



Figure 12 Offline reconstructed pulseheight in the appropriate trigger channels for Level 3 selected (loose) electron candidates which passed (solid) and failed (dashed) the Level 2 shower max track match.

sample of more than 60 $pb^{-1}$ on tape (75 $pb^{-1}$ delivered) for run 1b, but the duration of the data taking is uncertain at this time.

The central EM calorimeter is mainly in good shape although a few phototube changes and gain adjustments may be needed. Strip, crack, and preradiator chambers have no new problems beyond a few noise electronic channels which may be associated with the new front end cards discussed above. Larry Nodulman is continuing to develop and support low level online data monitoring, and Bob Wagner and Jimmy Proudfoot are members of a pool of 15 shift leaders or "Scientific Coordinators" who will help lead data taking for the next year. Marcus Hohlmann has been trained as a DAQ expert or "ace" and will serve DAQ expert shifts.

### d. *Planning Activities*

In November, 1993, the FNAL management issued a call for proposals to utilize the B0 and D0 collision regions during and after Run III. Run III is defined to be the second run of the main injector, with machine parameters expected to be:

a. 2 TeV energy
b. 7-8 $10^{31}$ $cm^{-2}$ $s^{-1}$ peak luminosity
c. 132 ns bunch spacing
d. 72-99 bunches as defined by the macrobatch structure
e. 40 cm bunch length

The proposal schedule calls for

a. Brief Expression of Interest (EOI) - May, 1994
b. Letter of Intent - January, 1995
c. Proposal - May 1995
d. Conceptual Design Rep - April, 1996
e. Design Report/Funding - November 1996

The CDF collaboration will submit an EOI document describing possible upgrades to CDF that would allow both B-physics and high-Pt physics under the conditions of Run III. This upgrade proposal will include new tracking systems in the existing CDF solenoid; additional muon coverage for pseudorapidity greater than one; kaon identification; and upgrades for low-$p_T$ electron identification. These are in addition to upgrades already planned and required for Run II: electronics and DAQ upgrade, new silicon vertex tracker, new plug calorimeter, and movement of forward-muon toroids closer to the central detector. The CDF collaboration intends to retain the existing solenoid, barrel calorimeter, and the new plug calorimeter. The main physics goals include high statistics measurements of CP violation in the self-conjugate B meson decay modes; $B_s$ mixing for values of $X_s$ up to 20; precision (3 GeV) top-mass determination; precision measurements of W and Z anomalous magnetic moments; and improved limits on physics beyond the Standard Model.

The optimization of CDF for Run III will be based largely on the existing sample of data from Runs 1 a, b. These data already provide the world's largest sample of exclusive B decays and the world's only sample of top decays. CDF already has sufficient particle identification (electron, muon, and via dE/dX, kaon) to be able to extrapolate the B-physics rates with confidence. By the end of Run 1b, the same should be true for top physics. Thus, the CDF collaboration will develop a realistic plan for competitive physics in the main injector era, even as the B-factories and LHC move closer to productive operation. (L. Nodulman, A. B. Wicklund)

### 4. *Non-Accelerator Physics at Soudan*

#### a. *Physics Results*

The preliminary measurement of the $\nu_\mu/\nu_e$ ratio from atmospheric neutrino interactions in Soudan 2 (described in the last Semiannual Report) was presented at four summer conferences: the 23rd International Cosmic Ray Conference, Calgary, Canada; the International Europhysics Conference on High Energy Physics, Marseilles, France; the 16th International Symposium on Lepton and Photon Interactions, Ithaca, NY; and the 3rd International Workshop on Theory and Phenomenology in Astroparticle and Underground Physics (TAUP 93), Assergi, Italy. This result used a total contained event exposure of 1.0 fiducial kiloton years. Although the statistics are still limited, the Soudan measurement of the ratio of muon to electron neutrinos appears to support the anomalously low values obtained by the IMB and Kamiokande experiments. The low value of this ratio has been interpreted as evidence for either neutrino oscillations or proton decay.

Analysis of contained event data from the third half kiloton year of Soudan 2 exposure was still in progress at the end of 1993. New data are being examined as they become available from the detector, and the characterization of neutrino interaction and nucleon decay candidate events has begun. While the event selection and characterization procedures are essentially the same as those used for the first kiloton year exposure, several new analysis activities are also under way. A major upgrade of the Monte Carlo simulation of neutrino interactions in Soudan 2 was nearly complete at the end of the year. This included improvements in the neutrino event generator, more accurate representation of the detector geometry, the use of actual detector parameters from the experiment database, and improved simulations of drifting and electronics. A large sample of new Monte Carlo events will be analyzed in parallel with contained events from the third half kiloton year data sample. Related analysis projects include work to isolate partially contained events (e.g. high energy neutrino interactions) and the first serious attempt to characterize non-quasi-elastic neutrino events.

Although contained events (neutrino interactions and nucleon decay) continue to be the major thrust of data analysis effort, the Soudan 2 detector also allows some interesting studies of cosmic ray physics. The search for astrophysical point sources of high energy cosmic rays using anisotropies in the flux of underground muons is continuing at Oxford and Minnesota. The Oxford group has begun a systematic study of the 14 million muon tracks recorded by Soudan 2 between January 1989 and February 1993. These muon tracks have been used to examine the entire sky, within the region $-15^{\circ} <$ declination $< +85^{\circ}$ and all right ascensions, for evidence of any possible steady sources of cosmic rays. The significance of regions with muon flux higher than the expected isotropic background was still under study at the end of the year.

***b. Experimental Apparatus Preparation***

The final two halfwalls of the Soudan 2 detector were brought into operation during the last half of 1993. (A halfwall is a subassembly of eight 5-ton modules, stacked four across and two high.) This increased the operating mass from 894 to 963 tons, and completed the assembly of the detector. The active shield is also nearly complete, with only a few small gaps in its coverage (less than 5% of the total solid angle) remaining to filled during 1994.

Three spare 5-ton modules were constructed in addition to the 224 modules now in operation in the main detector. Two of the spare modules were assembled and ready for use at the end of the year; the third module still requires repair of a drift high voltage fault. Assembly of the final three sets of module wireplanes has also been completed.

Other installation activities included the deployment of 32 new active shield proportional tube manifolds; all of these were operational at the end of the year. The new shield tubes cover small holes and cracks along the edges of the floor panels. These are much less important for contained event physics than the large ceiling, wall, and floor panels which have been in operation for several years. An additional 53 tubes will be installed to cover the remaining small holes in the active shield coverage.

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

### 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 1993. In addition, data from the 40 $m^2$ surface array were recorded in coincidence with Soudan 2 in order to measure the energies of some of the cosmic ray air showers which produce underground muon events. The surface array was shut down at the end of the year in order to upgrade its data acquisition electronics. Data from a wide-angle air Cerenkov air-shower detector were also recorded in coincidence with Soudan 2 and the surface array on clear, moonless nights. The Soudan 2 detector itself recorded data for 131 days of livetime, giving a duty cycle of 70%. This brought the total Soudan 2 exposure to 3.8 years, or 1.6 fiducial kiloton years useful for nucleon decay and atmospheric neutrino physics.

Routine data taking was interrupted for a two week period during December in order to record high statistics data at reduced wireplane voltages on main detector modules. These data will provide information on the dE/dx resolution of individual modules by recording the apparent ionization deposited by relativistic cosmic-ray muon tracks at different gas gains. Data taken at the lowest voltages will not be useful for contained event physics.

Other activities during the last half of 1993 included major maintenance of the gas purification system. The 450 pounds of activated charcoal in the four gas recirculating systems was replaced, as was one of the oxygen-removal deoxo-catalyzer units. It was discovered that the oxygen removal capacity of the deoxo units has decreased markedly since they were last checked in 1992. A study is now under way to determine the cause of this degradation.

### d. *Planning Activities*

Preparations for a major upgrade of the Southwest quadrant of the Soudan 2 detector (8 of the 28 operating halfwalls) began during the last few months of 1993. Anode high voltage splitter hardware will be installed on two halfwalls, so that pairs of wireplanes are no longer required to operate at the same high voltage. In addition, sixteen of the oldest 5-ton modules in the Southwest quadrant will be removed to repair minor gas leaks or to improve the uniformity of their wireplane response using new alignment techniques. Preparations in 1993 included assembly of anode high voltage splitter hardware and measurement of the leak rate of all modules. The Southwest quadrant upgrade will begin in January 1994; the last halfwall is expected to be back in operation by March.

In December, the U.K. Particle Physics Committee approved the Soudan 2 collaboration's request for $100K to upgrade U.K. modules in the detector over the next two years. These funds will pay for materials, Soudan mine crew effort, and setup of the U.K. module compression fixture in the underground laboratory. This partially offsets a reduction in the DOE operating budget for the Soudan laboratory in FY 1994, and makes possible the upgrade of the older Soudan 2 modules (beginning with the Southwest quadrant, as described above). (D. Ayres)

## 5. *ZEUS Detector at HERA*

### a. *Physics Results*

Five physics papers were published in this period covering three basic topics: search for new phenomena, the structure of the hadronic final state in Deep-Inelastic Scattering (DIS) and inclusive measurements of DIS cross sections. Results of a search for excited electrons were reported in a Physics Letter. At HERA excited electrons of mass up to the present center-of-mass energy of 296 GeV could be produced in a t-channel photon exchange process via the reaction $ep \to e^*X$. The e* production cross section is given by:

$$\sigma(ep \to e^*X) = \frac{|C_{\gamma e^* e}|^2 + |d_{\gamma e^* e}|^2}{A^2}\,\sigma_o(m_{e^*})$$

where $\sigma_o$ depends on the proton structure function. The parameters c and d are the two coupling constants at the e*e$\gamma$ vertex and $\gamma$ is a compositeness scale. The e* will then decay to e$\gamma$, $\nu$W or eZ. All of these modes were studied looking for any evidence of a resonant signal.

No positive signal was observed and the resulting limits, based on an integrated luminosity of 26 $nb^{-1}$, are shown in Fig. 13.

The structure of the hadronic final state was reported in two papers. The first paper presented the energy flow distributions in the laboratory system and compared the results with various Monte Carlo models of the final state. Such models are an essential tool in interpreting high energy interactions. In measuring the proton structure function from the DIS data, it is essential to have a good representation of the final hadronic state to correctly calculate the acceptance. Various Monte Carlo models are available and have given adequate descriptions of lower energy DIS data as well as results from $e^+e^-$ annihilation. In the context of the Lund program, LEPTO, both pure matrix element (ME) and parton power (PS) parametrizations work well. The program also allows the combination (ME + PS) in which the initial hard parton emissions are given by first order matrix elements and the higher order processes are described by the parton showers.

Two additional approaches are the Color Dipole Model (CDM) and the shower model HERWIG. In the CDM the struck quark and the proton remnant form a color dipole that radiates emitting the observed hadrons. The radiation is damped by the finite size of the remnant. HERWIG is a parton shower model in which the emissions are confined to a cone of angular size set by the incoming and outgoing struck parton. This restriction, which results from gluon interference effects correlates the initial state and final state parton showers. This program also allows the option of including a soft underlying event (SUE) in addition to the hard scattering.

Comparisons of all of these models with the measured energy flow distributions are shown in Fig. 14. This three part figure shows the data for Bjorken $x < 0.001$ three times and compares them to these different models. The energy flow is measured relative to the direction of the struck quark in the Quark-Parton model. The proton remnant is at positive $\Delta\varepsilon$ values. It is notable that the energy flow is shifted from the quark direction given by QPM and is also broadened. Neither the ME nor the PS models, with any choice of virtuality scale, agree with the data. Both HERWIG, without the SUE, and the CDM model are in reasonable agreement with the measurements.

A search was made for jet activity in the event sample. Events with transverse energy greater than 10 GeV show jets within a cone of unit radius in $\eta-\phi$ space. Some typical events are shown in Fig. 15. The jet structure is rather clear as shown by the profiles in Fig. 15 (d, e).

Following the measurement of the DIS cross sections done with the first 3 $nb^{-1}$ of data, the full 1992 data sample was used to measure the proton structure function $F_2$ in

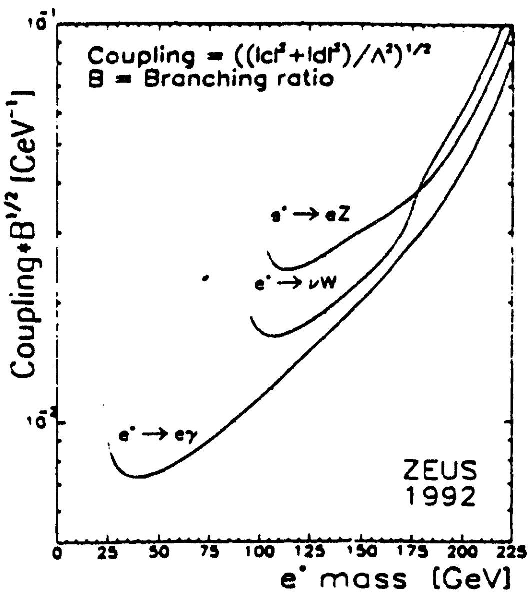



Figure 13 95% confidence level upper limits on the product of the coupling and the square root of the branching ratios $[(|c_{\gamma e^*e}|^2 + |d_{\gamma e^*e}|^2)^{1/2}/\Lambda]\beta^{1/2}$ for eγ, eZ, and υW final states.

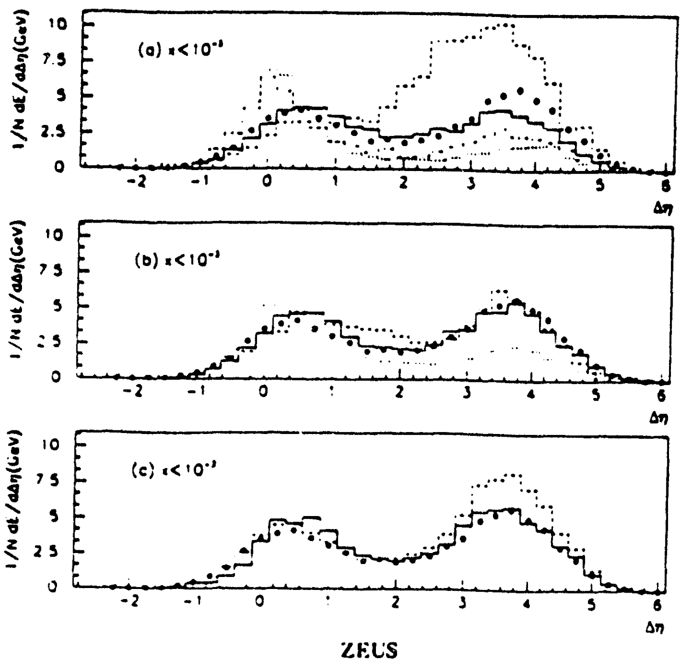



Figure 14 The energy weighted pseudorapidity difference, Δη, of the hadronic system calorimeter cells with respect to the struck quark from the quark-parton model. The ZEUS data points are shown as the dots. In (a) the full histogram is ME+PS, the dashed histogram PS($W^2$), the dotted histogram PS($Q^2$), and the dash-dotted histogram ME. In (b) the full histogram is CDM+BGF, the dashed histogram CDM and the dotted histogram PS($Q^2(1-x)$). In (c) the full histogram is HERWIG without the SUE and the dashed histogram HERWIG including the SUE.

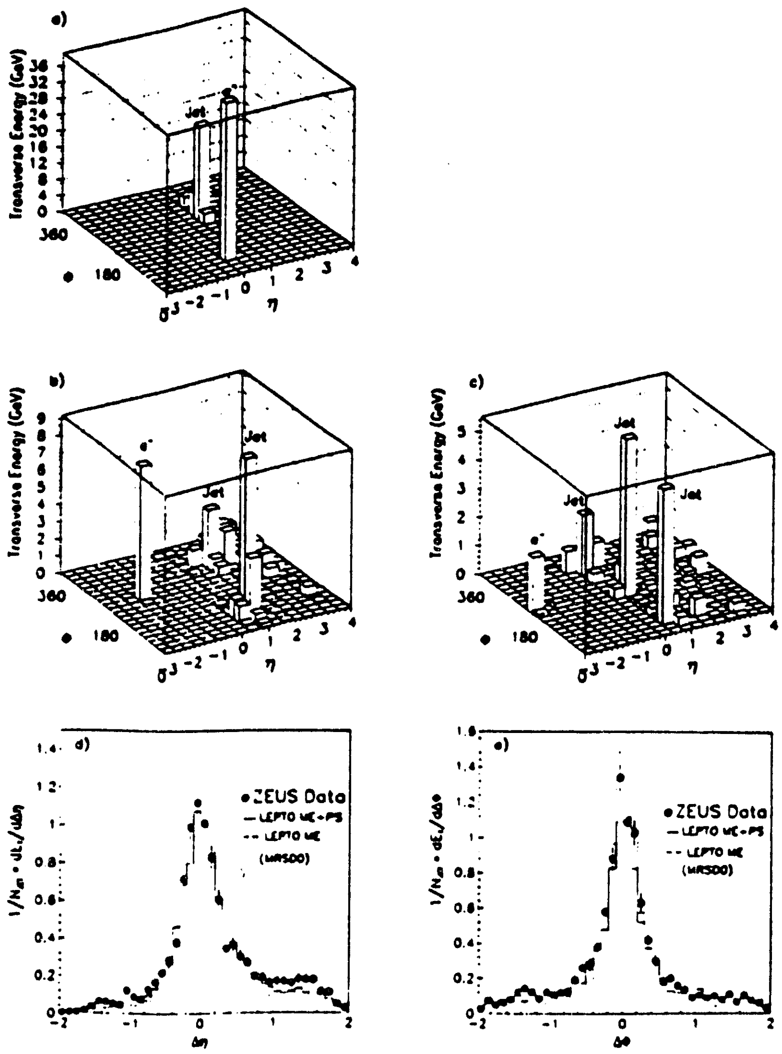



Figure 15 Transverse energy distributions of events with jets in the (η, φ) plane: (a) one-jet event, (b) two-jet event and (c) three-jet event. (d,e) The profile of jets belonging to the two- and three-jet sample with expectations from the LEPTO 6.1 (ME+PS) and LEPTO (ME) Monte Carlos.

the new regime of the kinematics that is opened up by HERA. The DIS cross section is given by

$$\frac{d^2\sigma}{dx\,dQ^2} = \frac{2\pi\alpha^2 Y_+}{xQ^4}\left[F_2(x,Q^2) - \frac{y^2}{Y_+}F_L(x,Q^2)\right]\left[1+\delta_r(x,Q^2)\right]$$

where $F_L$ is the longitudinal structure function and $Y_+ = 1+(1-y)^2$.

The event variables x and $Q^2$ were determined from the angle of the scattered electron and the final state hadronic system. The measured $F_2$ values are shown in Figs. 16 and 17 where they are compared to extrapolations of various parametrizations of lower energy data. The results clearly favor solutions that show an increasing gluon density as x decreases. This result suggests that we will be able to explore a regime with multiple partons, but yet a small coupling constant.

About 6% of the DIS events show no hadronic activity in the forward calorimeter. One such event is shown in Fig. 18 (c). These events come from a diagram such as that shown in Fig. 18 (b) as contrasted to the normal color connection between the struck quark and the proton remnant as illustrated in Fig. 18 (a) and as shown by the energy flow measurements previously discussed. The event distribution in the W:Mx plane is shown in Fig. 19 for the so-called rapidity gap events (heavy dots) and the normal events. The rapidity gap events have low values of Mx but are uniformly distributed in W consistent with the distribution expected from a diffractive process. This is the first observation of such events in DIS.

### *b. HERA and ZEUS Operations*

The 1993 data taking started seriously at the beginning of this period. By the time of the shutdown in early December, HERA had delivered over 1 $pb^{-1}$ of luminosity of which ZEUS logged 0.6 $pb^{-1}$. This is a factor of 20 more data than was collected in 1992. The 1993 operation used 100 bunches of which 84 were used for e-p collisions. Typical currents were 10-20 ma in each of the electron and proton rings.

In the beginning of the run, serious backgrounds were experienced leading to low data taking efficiency, but by the end of the period these problems were solved. In addition the 208 MHz proton RF system was implemented with a resulting reduction in the Z-extent of the interaction region to about 20 cm.

Major improvements had been made to the detector during the winter break period, in particular, the full FADC read out of the central tracker became available and

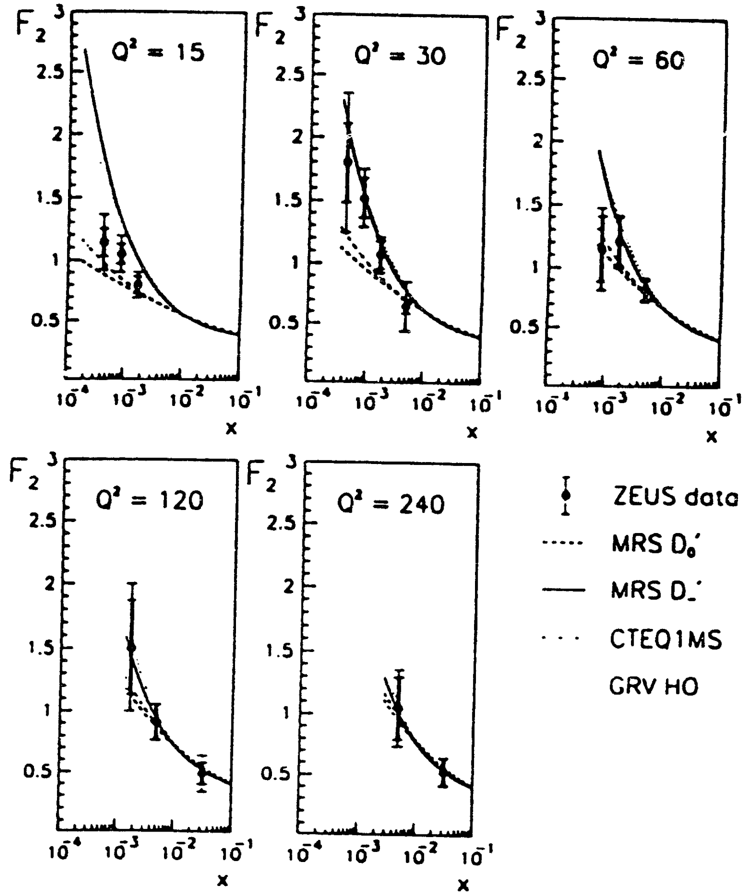



Figure 16 The structure function $F_2$ as a function of x for $Q^2 = 15\ GeV^2$, $30\ GeV^2$, $60\ GeV^2$, $120\ GeV^2$, and $240\ GeV^2$. The inner error bar is the statistical error, and the outer bar shows the systematic error added in quadrature. The overall normalization uncertainty of 7% is not included. In this figure we shown only the lowest five $Q^2$ bins. Also shown are several structure function expectations (all in DIS scheme).

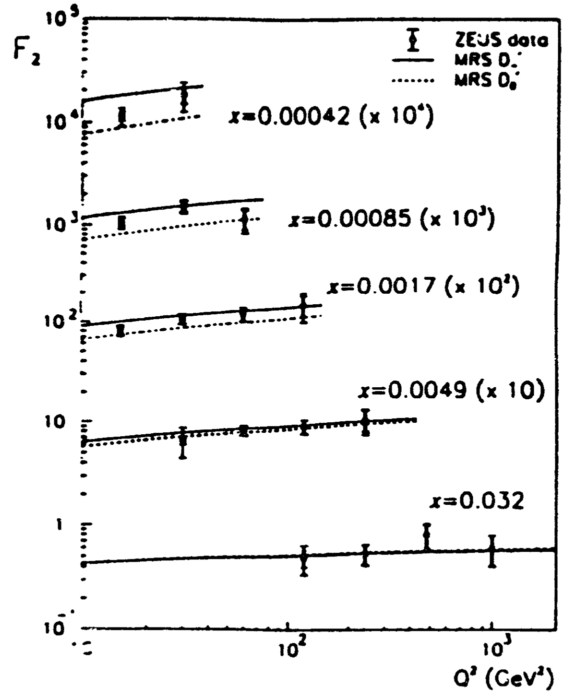



Figure 17 The structure function $F_2$ as a function of $Q^2$ for different values of x. The inner error bar is the statistical error, and the outer bar shows the systematic error added in quadrature. The overall normalization uncertainty of 7% is not included. Note that the $F_2$ values are multiplied by different factors (shown in parentheses) for the different x bins. Also shown are two structure function parametrizations.

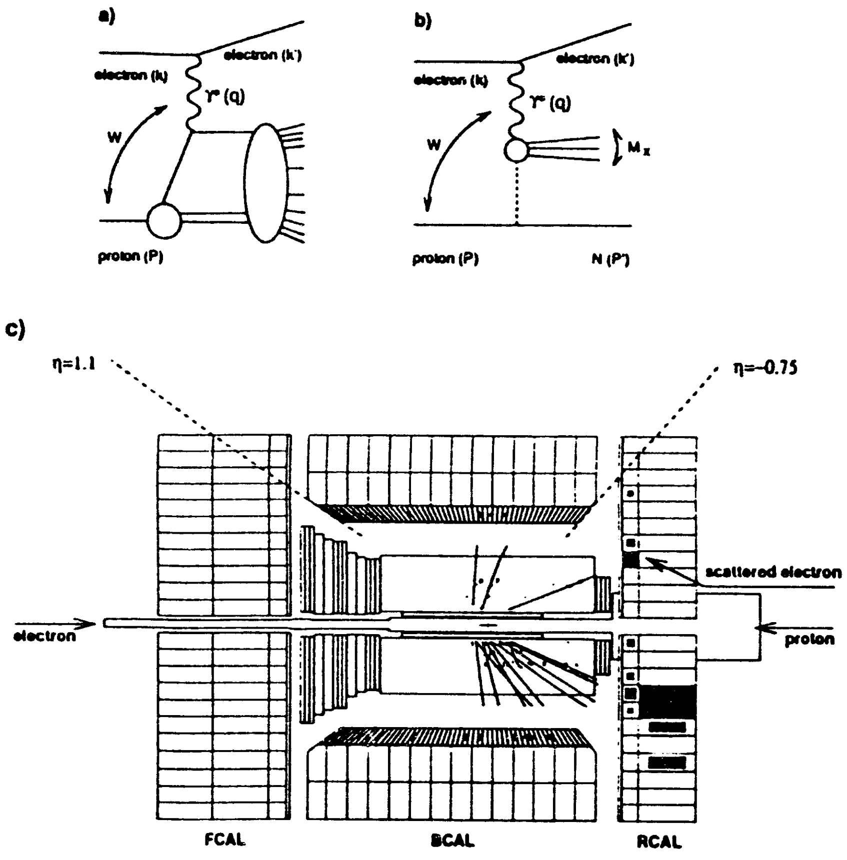



Figure 18 (a) Schematic diagram describing particle production in deep inelastic electron proton scattering. (b) Schematic diagram describing particle production by diffractive dissociation in a deep inelastic ep interaction. W is the center-of-mass energy of the $\gamma^*p$ system and $M_X$ is the invariant mass of the hadronic system measured in the detector. N represents a proton or low-mass nuclear system. (c) Schematic view of the ZEUS calorimeter and central tracking. Overlaid is an event with a large rapidity gap. Tracks are detected in the central tracking chamber and energy deposits are observed in the calorimeter. The electron is detected in the rear direction (RCAL).

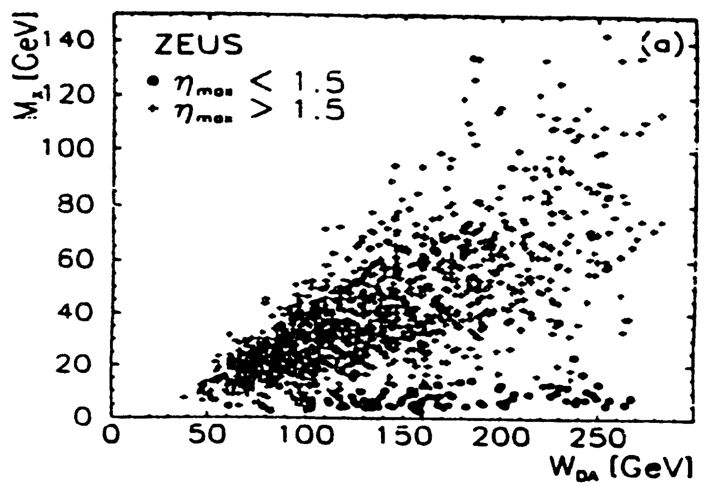



Figure 19

Correlation between the invariant mass $M_X$ of the hadrons observed in the calorimeter and the invariant mass, $W_{DA}$, of the $\gamma^*p$ system. Events with a large rapidity gap, $\eta_{max} < 1.5$ are shown as solid dots, and events with $\eta_{max} > 1.5$ are shown as crosses.

was in operation throughout the data taking period. The full muon system was also in operation. Most of the rear calorimeter was instrumented with the silicon pad system located at shower maximum in the electromagnetic section. The full system will become available in 1994.

A prototype of a forward neutron calorimeter located about 100 m from ZEUS in the direction of the proton beam also took data as did three (our of six) of the stations of the forward proton spectrometer. A prototype of the small angle rear tracking detector was also in operation.

A much more sophisticated trigger system was brought into operation including the full Calorimeter First Level trigger that is a US responsibility. As a result the data rate to tape did not change from 1992 even though the luminosity increased by a factor of twenty.

*c. Apparatus Development*

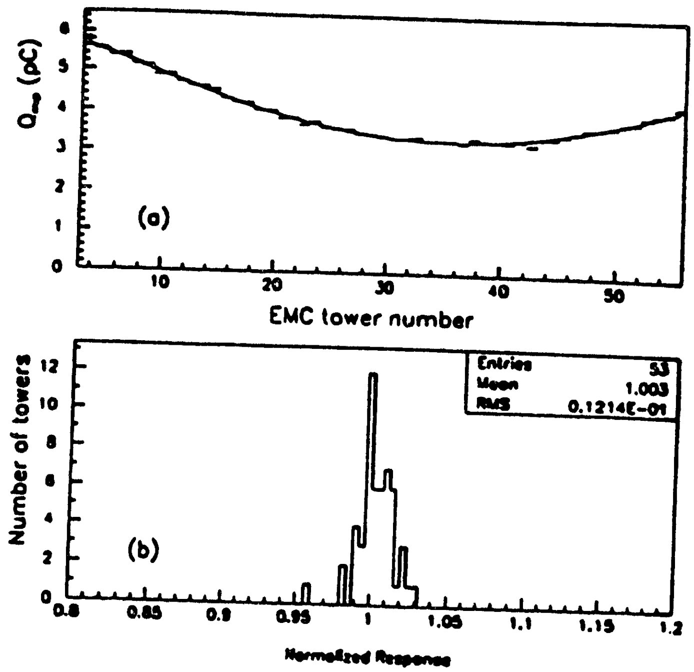
*i. Results from Beam Tests of the BCAL Modules*

A detailed NIM paper describing the results from the tests of the BCAL modules carried out at Fermilab was published in this period. Many measurements were made including studies of the tower-to-tower and module-to-module uniformities, the energy and position resolutions, and the linearity of the response. For example, the HAC tower response to 100 GeV muons for three modules shows a tower-to-tower non-uniformity well below the 1% level. Figure 20 shows results from a similar study of the EMC sections. In this case the spread is 1.2%. The measured energy resolution for 50 GeV pions is at the 35%/rtE design level as shown in Fig. 21. The deviation from linearity for electrons is also within 1% as illustrated in Fig. 22 for two modules. In the case of module 32 one radiation length aluminum was placed in front to simulate the effects of the ZEUS coil.

*ii. Barrel Hadron Electron Separator (BHES)*

The rear calorimeter (RCAL) of ZEUS is being equipped with a set of 3cm x 3cm silicon pad detectors as a fine grained position detector at the maximum of the electromagnetic showers. A similar system is planned for the forward calorimeter (FCAL). The barrel calorimeter has a surface area equal to the sum of the RCAL and FCAL and so the cost of a similar system using silicon technology is excessive. A more cost effective solution has been developed using a set of wire chambers with cathode strip read-out to provide a Z coordinate measurement.

Figure 20
(a) The DU corrected Q for each of the EMC towers in module 12 taken with 50 GeV muons. (b) Distribution of the EMC towers responses after they were normalized to the fit value. The rms deviation, $\simeq$ 1.2%, indicates the non-uniformity.



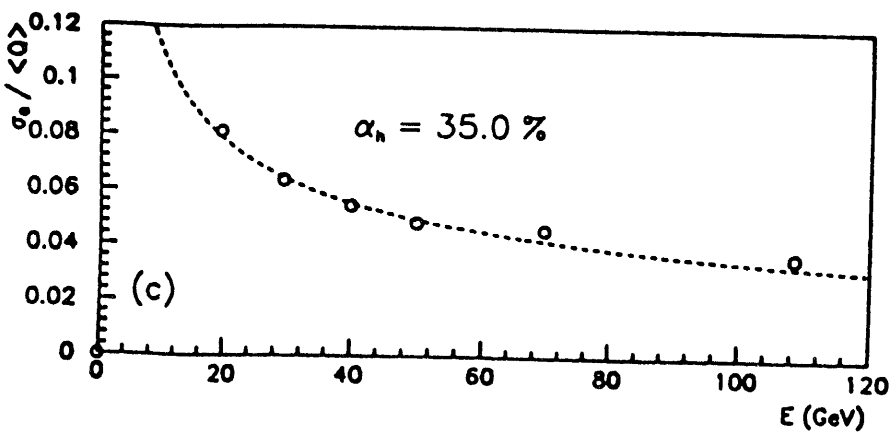




Figure 21 The relative error σ/E versus beam energy E for fully contained showers. The dashed line is a fit to the form $\alpha h/E^{0.5}$.

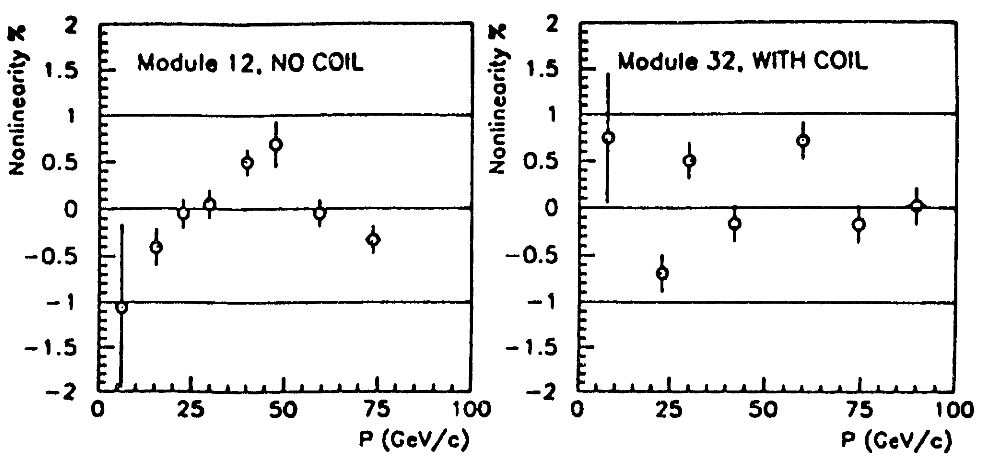



Figure 22 The measured non-linearities versus energy for: (a) module 12, no coil and (b) module 32, coil in place.

The 1024 barrel wires have a spacing of 0.8 cm and the cathode pads have a Z extent of 1.6 cm. These values may be compared with the 25 cm x 5 cm size of the BCAL electromagnetic towers.

A prototype system was built in the first half of 1993 and tested in this period. wire and pad scans were done using $Fe^{55}$ and $Cd^{109}$ sources and the response to cosmic ray muons measured both in the laboratory and when inserted in the prototype module. The latter measurement checked the effect of the signal coming from the uranium radioactivity on the pedestal.

Figure 23 shows the wire signal resulting from the two source measurements. Clear peaks are seen corresponding to the expected 5.9 KeV $Fe^{55}$ and 8 KeV $Cd^{109}$ gamma ray signals. The uniformity from wire to wire and along the chambers from pad to pad is at the 7% level as seen in Fig. 24. The response to cosmic rays is shown in Fig. 25 both in the lab and when the chamber was installed in the prototype module. The spectra are shown after pedestal subtraction. If the threshold is set equivalent to 0.3 minimum ionizing particles, than 1% of the wires will have a pedestal pulse above this value, coming from the uranium radioactivity. the linearity determined from these source and cosmic measurements is shown in Fig. 26.

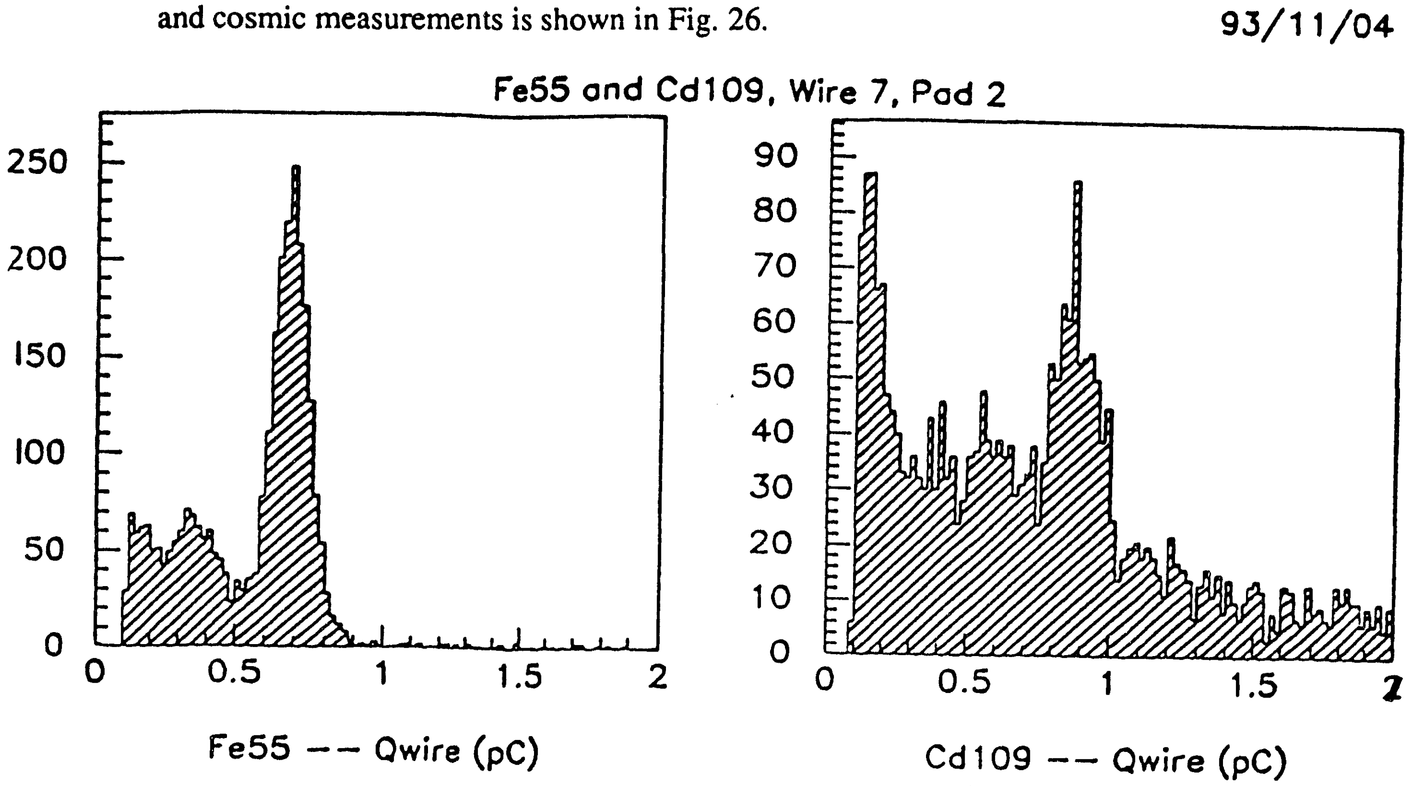



Figure 23 Wire signal from gamma ray source measurements on prototype BHES module.

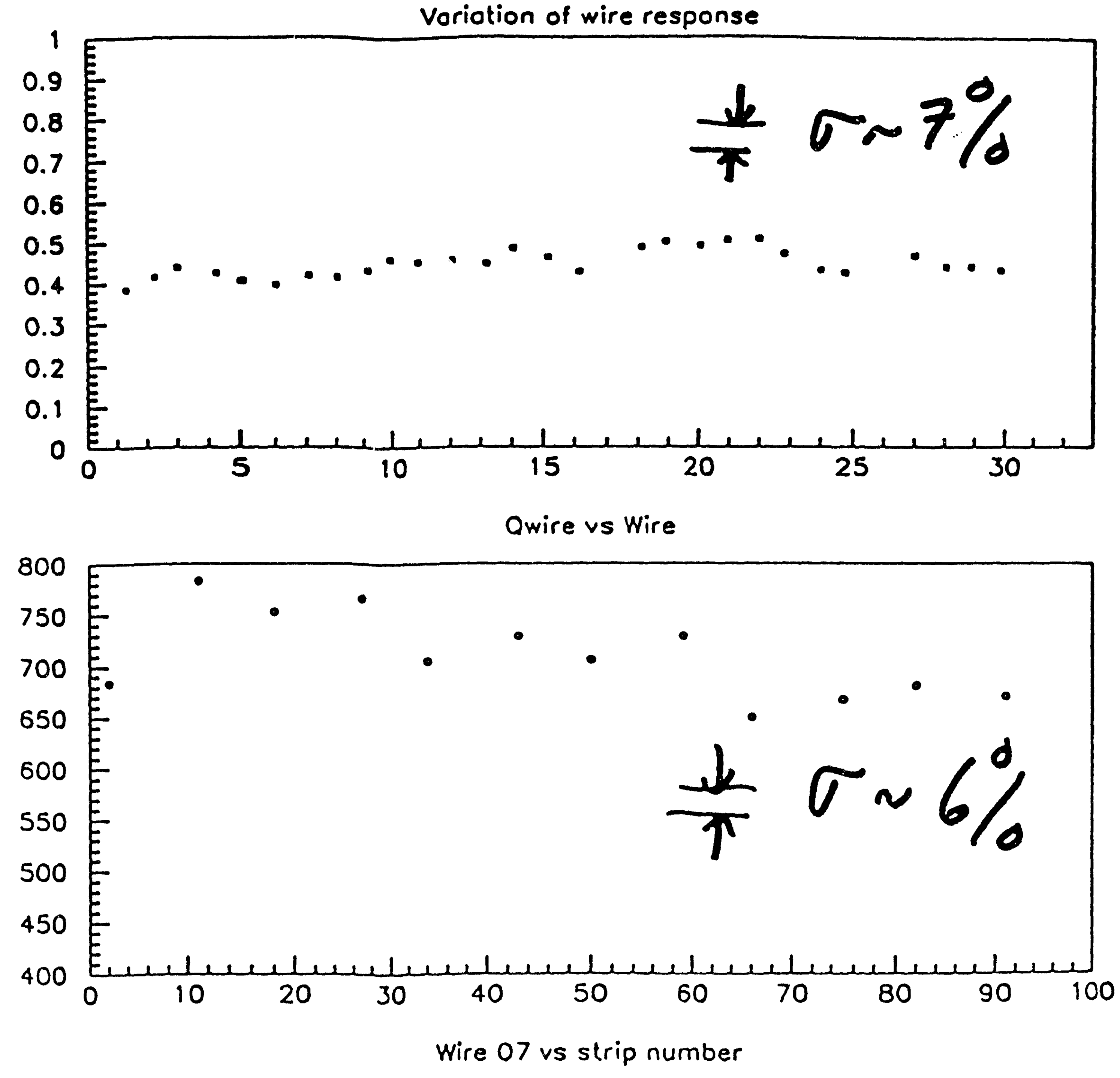



Figure 24 Signal uniformity from $Cd^{109}$ source scan on BHES prototype. Upper plot is wire-to-wire, lower is along the orthogonal pads.

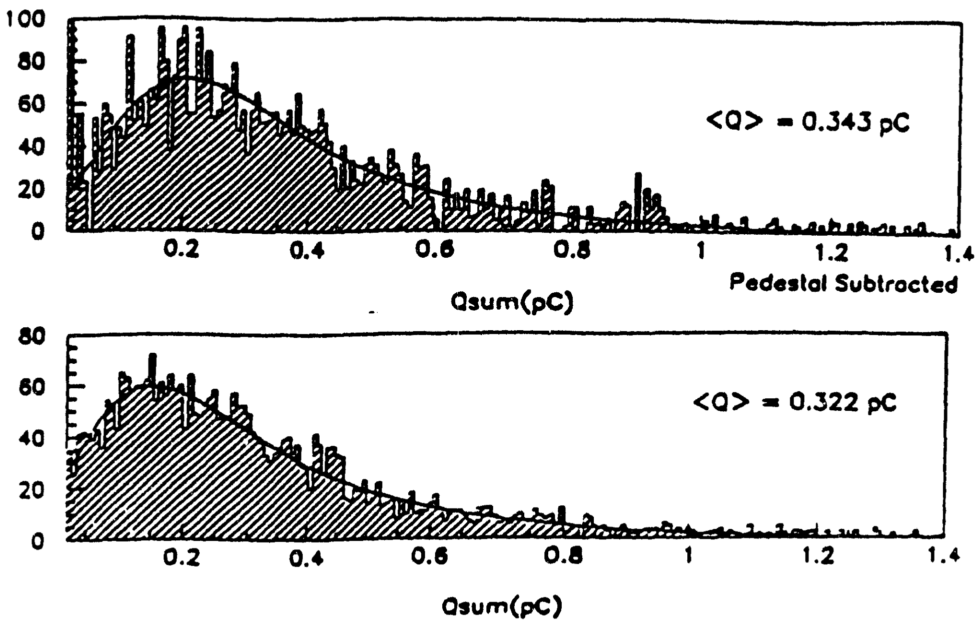



Figure 25 Response of BHES prototype to cosmic rays. Upper plot is in laboratory; lower plot is response with chamber installed in a prototype module.

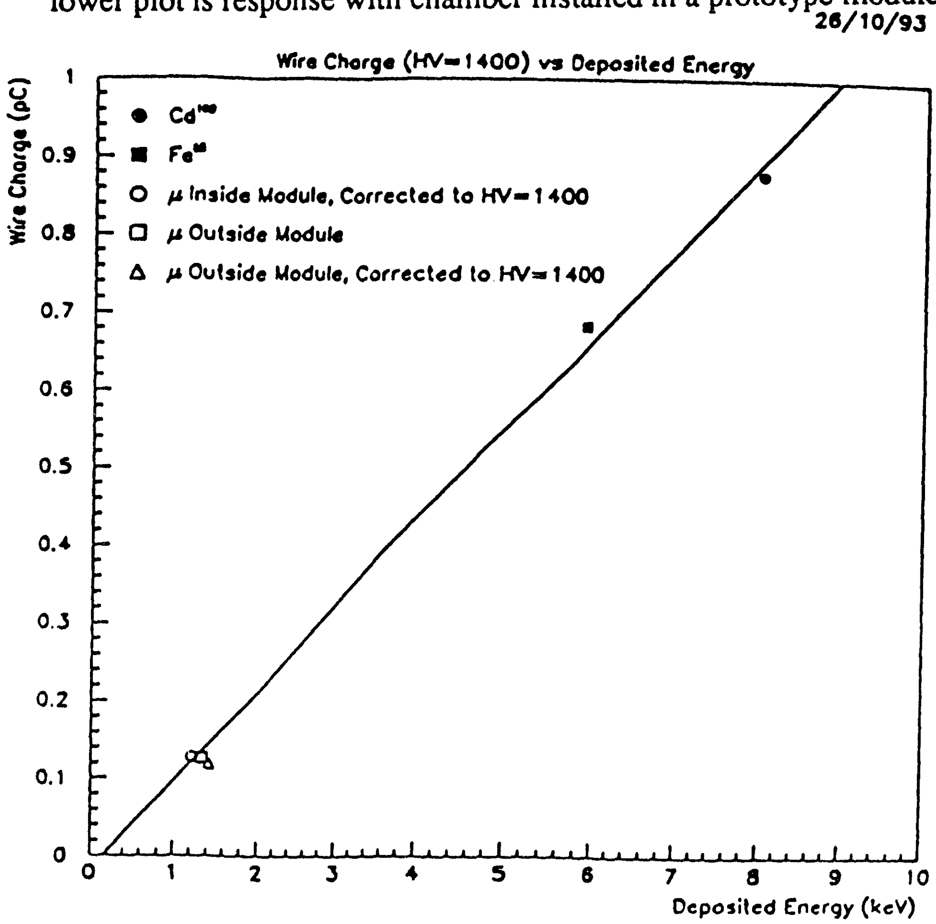



Figure 26 BHES prototype response vs. energy showing the design produces good linearity.

All of these results are as expected considering the earlier measurements made by the Argonne CDF group on a similar system that is used in that detector.

Plans for 1994 include installation and operation of the prototype BHES in ZEUS and measurements in a test beam at BNL.

A number of Monte Carlo studies of physics process have been made to check that the proposed system is matched to the physics requirements. The resolution in position for 5 GeV electromagnetic showers is 0.2 cm in the φ direction and 0.4 cm in Z. These values may be compared to a position resolution of about 1 cm that comes from the energy sharing between the two phototubes viewing one tower and between neighboring towers and, of course, the BHES has much finer granularity which is particularly important in identifying the two photons from π–0 decay.

The BHES will provide independent electron/pion separation from the measured pulse height distributions. Studies show that the pulse height in the pad with the maximum signal is an effective discriminator. for 90% electron acceptance the fraction of pions satisfying the cut falls from 7% at 2 GeV to about 2% at 9 GeV.

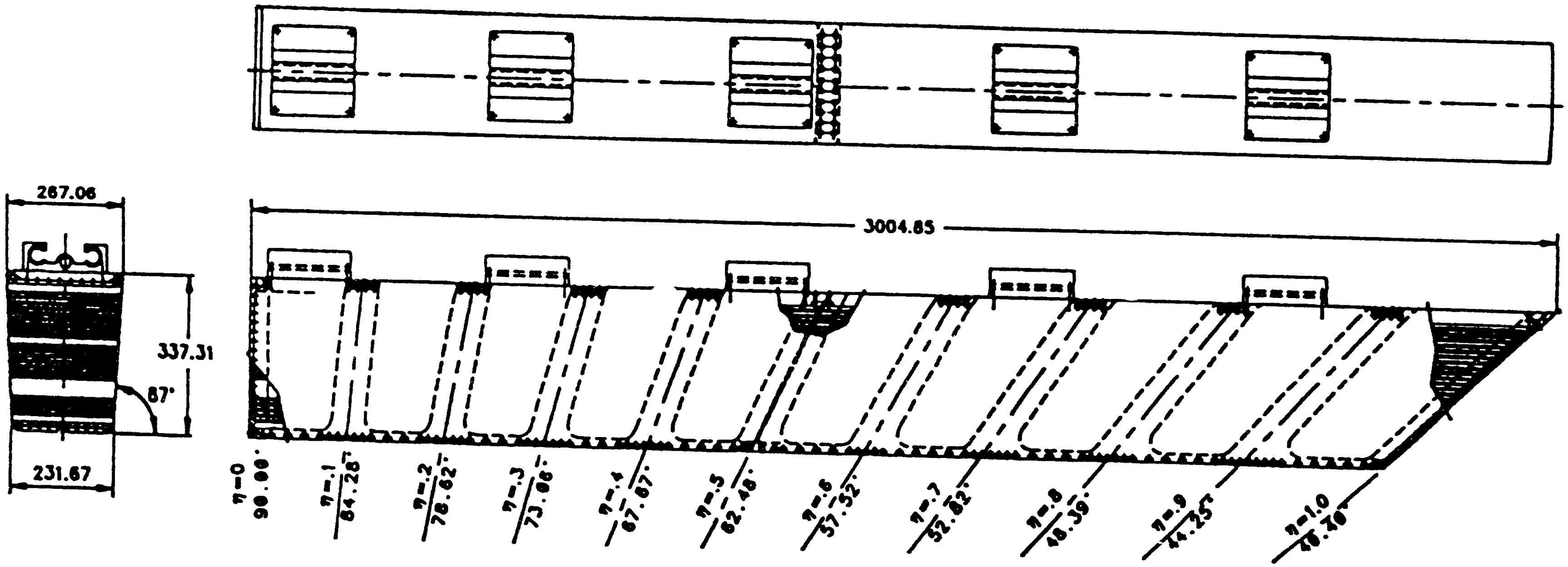
Detailed simulations of heavy quark production, both c and b, followed by the semileptonic decay, and of deep inelastic Compton scattering leading to final state photons have been made. The typical electron and photon spectra peak in the 1 to 2 GeV region but extend an order of magnitude higher in energy. After using the existing ZEUS electron and photon identification tools, the addition of the BHES gives a further factor of two rejection against background. (M. Derrick)

## *B. EXPERIMENTS IN PLANNING OR CONSTRUCTION*

### *1. Star Detector For RHIC*

#### *a. STAR Calorimeter*

The mechanical design of the STAR EM calorimeter (see Fig. 27) and the mechanical design for interfacing to STAR systems such as the magnet has progressed well. This work has been supported jointly by STAR R&D money and by Argonne. We are working on electronic integration and the level 0 trigger at a lower level due to limited resources. The mechanical engineering effort will be shifting from engineers within the Engineering Physics Division to engineers within the High Energy Physics Division after the demise of the SSC. Two people from Argonne and one from LBL visited several laboratories in Russia in October in order to meet with present and future collaborators on the RHIC spin effort and STAR.




RHIC-STAR-EMC
BARREL ENGINEERING MODEL
ASSEMBLY

Figure 27

A Conceptual Design Report on the EM calorimeter was completed. This report accompanied a proposal for NSF funding of the calorimeter and was also given to members of the BNL Program Committee before they approved the RHIC spin program that will utilize the calorimeter along with the heavy ion physics.

One of the mechanical issues was the support of the lead and scintillator. After finite element studies, cost estimates, and some component testing; an outside support structure that does not depend on the strength of the lead was chosen. A full-scale mechanical model to test this method has been designed. The model will use a stack of lead and wood to simulate the weight inside the real calorimeter. Testing with strain gauges with the model in various orientations will be done. A support for the model has been designed which is similar to the fixture for installing calorimeter modules into the STAR magnet.

Another mechanical issue is the support of the calorimeter modules by rings or brackets interleaved with the magnet coils. These transfer the 150 ton load of the calorimeter inside the magnet coil to the magnet return iron outside the coil. It appears that rings made of six cast aluminum pieces pinned together would cost a factor of five less than rings machined from large plates, and could be aligned a factor of ten faster than 270 individual brackets.

We have not yet made a choice of technologies for the shower maximum detector in the calorimeter, but cost and space requirements may eliminate phototubes; and reliability and speed may eliminate some other options, so that a wire/strip design may be the only viable choice. This would be similar to an existing detector in the CDF barrel and a proposed detector for ZEUS. We expect to test four technologies in a small calorimeter in a test beam at BNL this spring.

### *b. RHIC Spin Physics Program*

The proposal on spin physics at the RHIC collider was presented for the third time at the Brookhaven PAC meeting in October, 1993. At this time, we demonstrated the feasibility of experiments using the RHIC detectors by showing the result of simulation studies. Earlier the PAC endorsed the physics which constituted Phase I approval.

A letter from Mel Schwartz dated October 21, 1993 states "The Program Advisory Committee was enthusiastic about the potential for spin physics at RHIC and reiterated its approval of the proposal R5 as an essential part of the Brookhaven program". This is full approval of the proposal on spin physics using the RHIC polarized collider. The proposal R5 consists of three parts:

1) The hardware additions for the acceleration of polarized protons in RHIC
2) Experimental program using the STAR detector
3) Experimental program using the PHENIX detector

Our proposed experimen's would use the STAR detector. STAR utilizes a time projection chamber to measure hadron production over a large solid angle. Other important components of STAR, for which the Argonne group is responsible, include an electromagnetic calorimeter and a shower maximum detector. We describe here new physics introduced in the R5 update of the STAR/Spin polarized beam program.

## 2. *$W^\pm$ and $Z^\circ$ Production at 500 GeV*

### a. *Parity-Violating Asymmetry in W and Z Production*

$W^\pm$ and $Z^\circ$ are produced by a parity-violating mechanism assuming electroweak standard model couplings. The observable $A_L$ is defined as:

$$A_L = (1/P)\left(N^- - N^+\right)/\left(N^- + N^+\right),$$

where -(+) are minus (plus) helicity, and P is beam polarization.

When the helicities of both beams are the same, we define another observable as:

$$A_{LL}^{PV} = \left(1/P^2\right)\left(N^{--} - N^{++}\right)/\left(N^{--} + N^{++}\right).$$

where -(+) are minus (plus) helicity, respectively.

The reaction $pp \rightarrow W^\pm (Z^\circ) + X$ can be described in the Drell-Yan picture in terms of the dominant quark-antiquark fusion reactions $u\bar{d} \rightarrow W^+$, $\bar{u}d \rightarrow W^-$, and $u\bar{u}$ and $d\bar{d}$ annihilation $\rightarrow Z^\circ$.

For $W^+$ production,

$$A_L = \frac{\Delta u(x_1)\bar{d}(x_2) - \left(u \leftrightarrow \bar{d}\right)}{u(x_1)\bar{d}(x_2) + \bar{d}(x_1)u(x_2)},$$

where $x_1 = \sqrt{\tau}\, e^y$, $x_2 = \sqrt{\tau}\, e^{-y}$, y being rapidity, $\tau = M_w^2/s$, $\Delta u(x) = u^+(x) - u^-(x)$ being the helicity distribution of the quark, and $\Delta\bar{d}(x) = \bar{d}^+(x) - \bar{d}^-(x)$ being the helicity distribution of the $\bar{d}$.

$$A_{LL}^{PV}(y) = \frac{\left[\Delta u(x_1)\bar{d}(x_2) - \Delta\bar{d}(x_2)u(x_1)\right] - \left(u \leftrightarrow \bar{d}\right)}{\left[u(x_1)\bar{d}(x_2) - \Delta u(x_1)\Delta\bar{d}(x_2)\right] + \left(u \leftrightarrow \bar{d}\right)}.$$

Similarly for $W^-$ with $u \leftrightarrow d$.

For $y = 0$, $A_L^{W^+} = 1/2\left(\Delta u/u - \Delta\bar{d}/\bar{d}\right)$ and $A_L^{W^-} = 1/2(\Delta d/d - \Delta\bar{u}/\bar{u})$. A theoretical prediction is shown in Fig. 28.

***b. Parity-Conserving Asymmetry in W and Z Production***

In $W^\pm$ and $Z^\circ$ production with two beams longitudinally polarized, we can consider the parity conserving asymmetry $A_{LL}$ defined as

$$A_{LL} = \left(1/p^2\right)\left(N^{++} + N^{--} - N^{+-} - N^{-+}\right)/\left(N^{++} + N^{--} + N^{+-} + N^{-+}\right)$$

For $W^+$,

$$A_{LL} \sim \frac{\Delta u(x_1)\Delta\bar{d}(x_2)}{u(x_1)d(x_2)}$$

A similar expression for $W^-$ production is obtained by permuting u and d. A theoretical prediction is shown in Fig. 29.

***c. The Estimates for the Event Sample at 500 GeV***

The integrated luminosities used are

$$\mathcal{L}dt = 8 \cdot 10^{38}\ cm^{-2} \text{ at } 500\ GeV = 800\ pb^{-1},$$

which means 100 days of running ($4 \cdot 10^6$ sec, 50% eff.).

$W^+$: 62,400 events $W^-$: 13,700 events $Z^\circ$: 3,100 events

### *3. Measurements of $h_1(x)$ in $Z^\circ$ Production*

From deep inelastic scattering, one can measure $f_1(x)$ related to the longitudinal momentum distribution of quarks in the nucleon and $g_1(x)$ related to the helicity distribution in a polarized proton. There exists a third fundamental function, $h_1(x)$, which is a leading-twist (twist-2) distribution function like $f_1(x)$ and $g_1(x)$. $h_1(x)$ is related to the

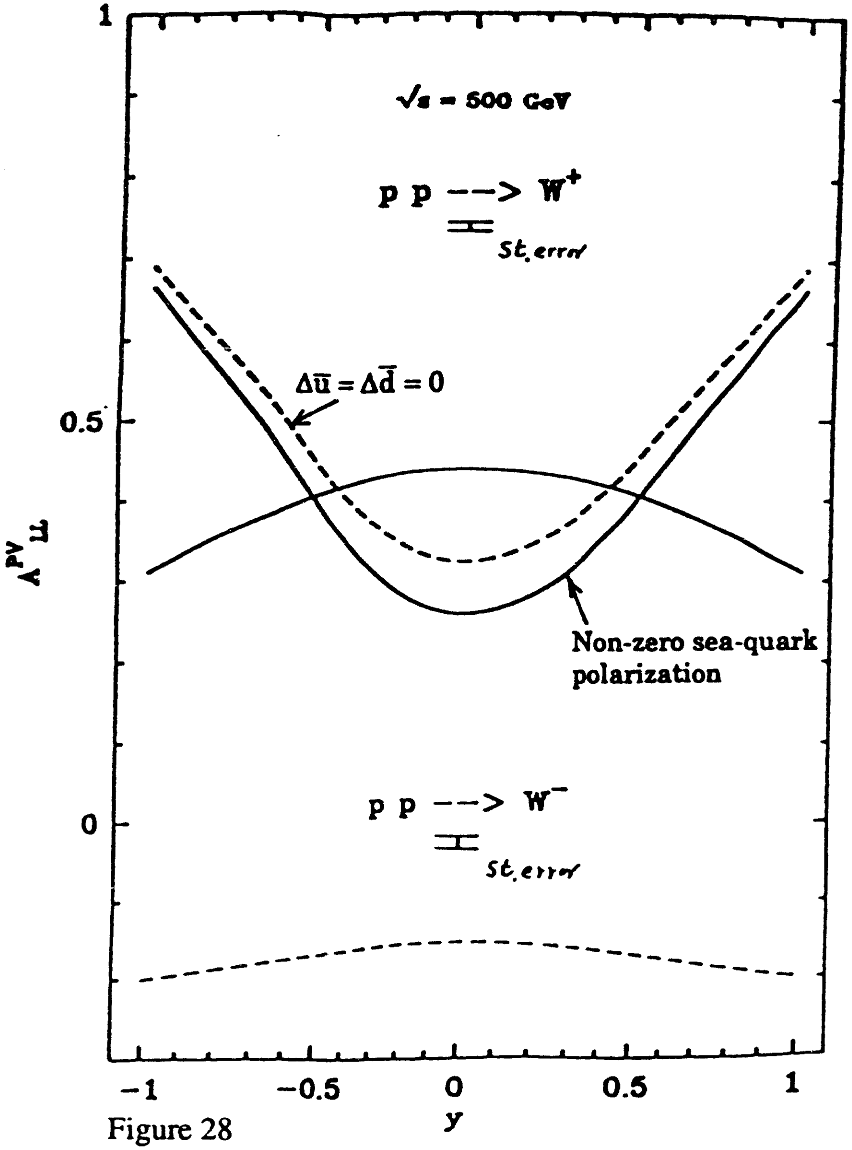



Figure 28

Theoretical prediction for the parity violating asymmetry $A_{LL}^{PV}$ as a function of rapidity, y. The proton beams are longitudinally polarized and have the same helicities.

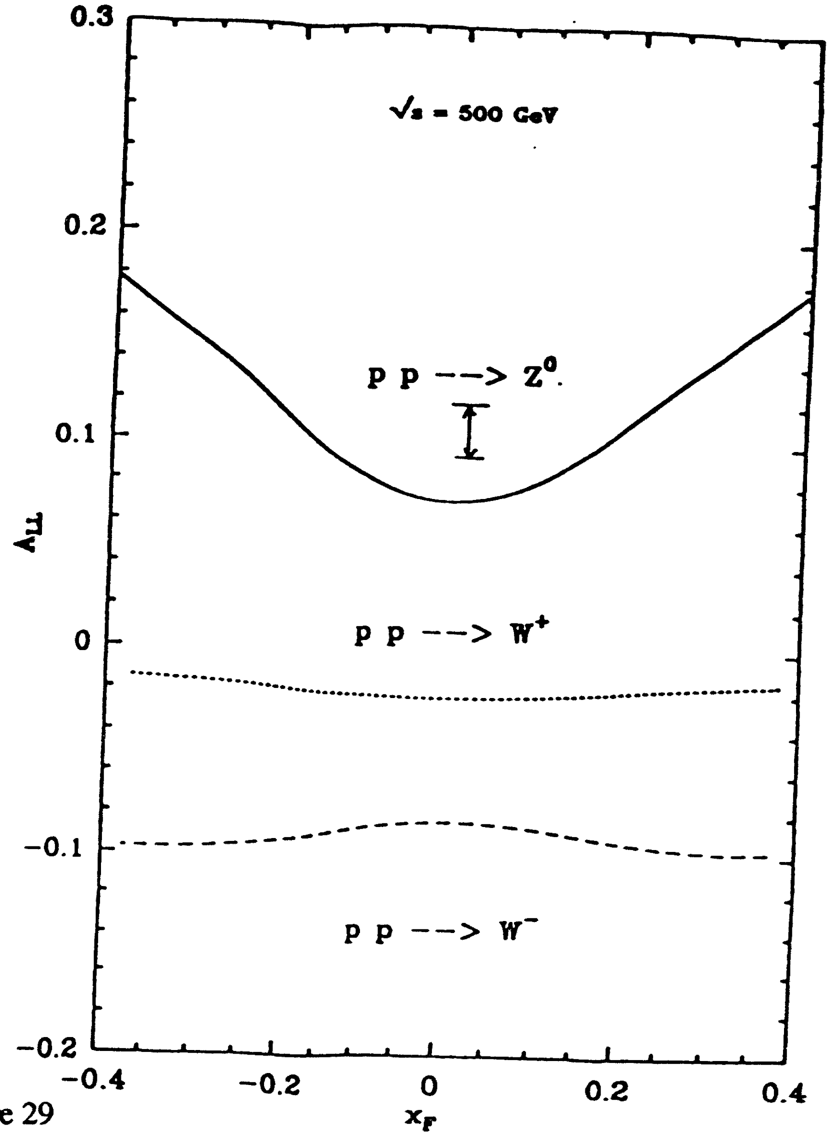



Figure 29

Parity conserving asymmetry $A_{LL}$ for Z°, $W^{\pm}$ production as a function of Feynman x, $x_F$. The asymmetry here is defined in terms of states with equal and opposite helicities (see text).

correlation between left-handed and right-handed quarks and can be determined by measuring the transverse spin correlation $A_{TT}$ in $Z^{\circ}$ production.

In terms of $h_1(x)$, $A_{TT}$ is given as (Jaffee, Ji):

$$A_{TT} = \hat{a}_{TT} \frac{\sum_i (a_i^2 - b_i^2) h_{1i}(x_1) \bar{h}_{1i}(x_2)}{\sum_i (a_i^2 + b_i^2) f_{1i}(x_1) \bar{f}_{1i}(x_2)},$$

where $a_i$ and $b_i$ are the vector and axial couplings of the $Z^{\circ}$ to the quark of flavor i, $\tilde{a}_{TT}$ is the partonic double-spin asymmetry, $\tilde{a}_{TT} = 1$ at the vicinity of $\theta_{c.m.} = \pi/2$ and $\phi_{c.m.} = 0$.

The statistical error will be $\Delta A_{TT} = (1/P^2) \cdot 0.025$. At a first approximation of $h_1 = g_1$, then $A_{TT}/\tilde{a}_{TT} \sim -A_{LL}$. (A. Yokosawa)

### *4. Partial Snake*

The partial snake experiment at the AGS, E-880, is an approved accelerator experiment. Of the 40 people in the collaboration, only six from Argonne have any connection with STAR or any other RHIC detector. The purpose of the experiment is to study the effectiveness of a partial spin precession in preserving proton polarization during acceleration to high energy. This is essential to the success of the RHIC spin program.

The partial snake in the AGS is expected to preserve the polarization in crossing imperfection resonances. This function was previously done with a large number of closed orbit correction coils which required weeks of tuning for a week of physics running. The intrinsic resonances, involving the betatron tune and the spin precession, will still be handled with pulsed quadrupoles to change the betatron tune slightly for jumping resonances. In a larger accelerator ring at higher energies a full snake would take care of both kinds of resonances. There is not room in the AGS for a full snake and the beam excursions at injection would be too large for some kinds of full snake as well.

The pulsed solenoid snake was purchased primarily with Argonne funding. It was delivered in June 1993 and powered in the ring during July and August. At this time studies were begun to determine the coupling between radial and vertical betatron oscillations due to the rotation caused by the snake solenoid. This mixing was found to be at least as small as expected, but may still eventually have to be compensated using skew quadrupoles in order to control emittance growth for injection into RHIC.

Argonne has primary responsibility for the internal polarimeter in the AGS ring which will be used to determine the preservation or loss of polarization during acceleration with the snake. New recoil proton detectors will be used with an internal target in order to do absolute measurements of polarization. These detectors will use an angle-energy correlation to distinguish elastic scattering from hydrogen vs. quasi elastic scattering from carbon near a momentum transfer squared of - 0.15 $GeV^2$. These detectors were built at Argonne and installed in the AGS by Argonne people in early August. They were tested as thoroughly as possible without the presence of the internal target.

Many of the components of the internal target mechanism were fabricated in the Argonne shops during October and November. A student from Indiana with some support from Argonne has gotten most of the target system working with an interface to a Macintosh computer. This interface is similar to that for the accelerator control system and the computer will be coupled to the accelerator control system. (D. Underwood)

### 2. *Long Baseline Neutrino Oscillation Experiment*

A possible follow up to the Soudan 2 nucleon decay experiment is a long baseline neutrino oscillation experiment from Fermilab's Main Injector to Soudan 2. This proposal to search for $\nu_\mu \rightarrow \nu_\tau$ oscillations was first submitted to Fermilab in 1991, but no presentation was made to the Fermilab Program Advisory Committee until November 1993. The collaboration revised its proposal by performing more detailed simulations of the beam and detector response in preparation for this presentation. The Argonne part of the Soudan collaboration has taken the lead role on proposing this experiment. The 822 collaboration includes the Soudan group and several Fermilab physicists.

The experiment proposes that a wide band neutrino beam be constructed at Fermilab aimed at the Soudan 2 detector. The Fermilab Main Injector can provide a high intensity 120 GeV proton beam to such a facility with a repetition rate of 2 seconds or less. The average neutrino event energy from such a beam would be 15 GeV. In two years of running, the Soudan 2 Detector could observe 6000 neutrino vertices in the detector. The hadron showers would be measured by the Soudan calorimeter, and the muons that exit the rear of the detector would be analyzed by a toroid magnet and muon counters that we propose adding to the detector. In addition, several Soudan 2 modules would be taken to Fermilab, where they would see a high rate of neutrino interactions in the same neutrino beam. A short baseline neutrino experiment, using an emulsion target to search for neutrino oscillations at low values of $\sin^2 2\theta$, was approved at the November PAC meeting (E-803).

A neutrino experiment with a detector far from Fermilab is sensitive to neutrino oscillations with a much lower $\Delta m^2$ than accelerator experiments have been able to reach in the past. This region of neutrino oscillation parameter space is just the region suggested by the apparent atmospheric neutrino deficit.

A recent site specific engineering study was completed by Fermilab on the costs and technical feasibility of creating a neutrino beam aimed at Soudan 2. Test holes were drilled at the position of the proposed beamline in order to design the civil facilities. A region of highly fractured rock seam was found which increased the cost of the civil construction. The estimated cost of the beam was $45.7M, including EDIA, contingency and management reserve. The hall for the short baseline and near detectors would be 60 meters underground.

Fermilab has stated its intention to make a decision on this proposal in June of 1994. A number of concerns have been expressed about systematic errors, which the collaboration is attempting to address. Whatever the fate of the 822 proposal, the open question of neutrino mass may only be resolved when a long baseline neutrino experiment is run. (M. Goodman)

### 3. *SDC Detector Research & Development*

#### a. *SDC Experiment for SSC Laboratory*

All aspects of work on the SDC detector continued during the second half of CY 1993, but the entire period was overshadowed by the forces which eventually led to the termination of the SSC project in October, 1993. Much of the funding which we were counting on for prototyping of the barrel electromagnetic calorimeter was not made available to us as the SSC Laboratory canceled the second half of the planned funding for laboratories. Because of the growing probability of ultimate cancellation of the SSC, our work during this period was a combination of moving forward where we could with diminished resources and positioning ourselves where possible to weather the possible cancellation.

In spite of the great difficulties, some projects were moved forward:

- The frame for the first lead absorber casting for the full-size prototype was completed. It was mated to and aligned on the mold base plate delivered to us by Westinghouse.
- QA was completed on the partial delivery of aluminum spacer plates received from Westinghouse and the plates were inserted into the towers of the frame.
- The extensive test of creep of the lead absorber was completed. The major portion of this test was an accelerated aging study conducted for 1820 hours at 55°C, which is equated by one standard methodology to 30 years at 30°C.

- The test of the effect of bending and compression on light output of scintillator was finished. Compressions and bending stresses far in excess of those expected in the module were tested. Only compressions showed any effect on the light output. A reduction in light of about 4% was seen with a time constant of 16 days. This effect is thought to arise from optical contact of the paper wrapping caused by the compression. Graphs of the effect of bending and compression are shown in Fig. 30.

- A number of high $\eta$ tests were made at Taracorp, the lead foundry with which we have been working, to test casting procedures and provide an additional sample for lead plate mechanical measurements in preparation for casting the full sized prototype.

- Neutron exposures were made to sample scintillator tiles in the program using the nuclear reactor at Washington State University. Extensive studies of the neutron spectrum and of techniques for dosimetry were made in support of these measurements. An improved method of monitoring neutron doses in real time and without sensitivity to the photon was invented that may be patentable.

In the computing area, Argonne continued as strong participants in the SDC Computing Working group as it has prepared requirements and a conceptual design of the SDC offline computing system. Argonne physicists also moved ahead with the PASS collaboration of physicists and computer scientists to carry out R&D on the single toughest computing problem facing experiments at the SSC: efficient means of storing and accessing data estimated at $2 \times 10^{15}$ bytes (2 Petabytes) per year of both raw and reconstructed data. Funding for the computer science portion of this collaboration were provided since FY 1991 from the High Performance Computing and Communication Initiative project through the DOE/Energy Research Office of Scientific Computing.

Extensive simulations continued until the final cancellation of the SSC. Comparisons of calculations with hanging file and other test beam data were completed and prepared for publication. New work was done on neutron fluxes which had recently been identified as a significant problem for both SDC and GEM. Argonne physicists used CALOR to determine neutron fluxes throughout the detector. These results were used to compare with other neutron codes, especially the MARS code that was used at SSCL for rapid evaluation of the evolving design for the beampipe and surrounding material. By the end of the year, the design had been modified to bring the neutron rates in the muon system, where it had initially been an order of magnitude too high, into a reasonable range. (L. Price)

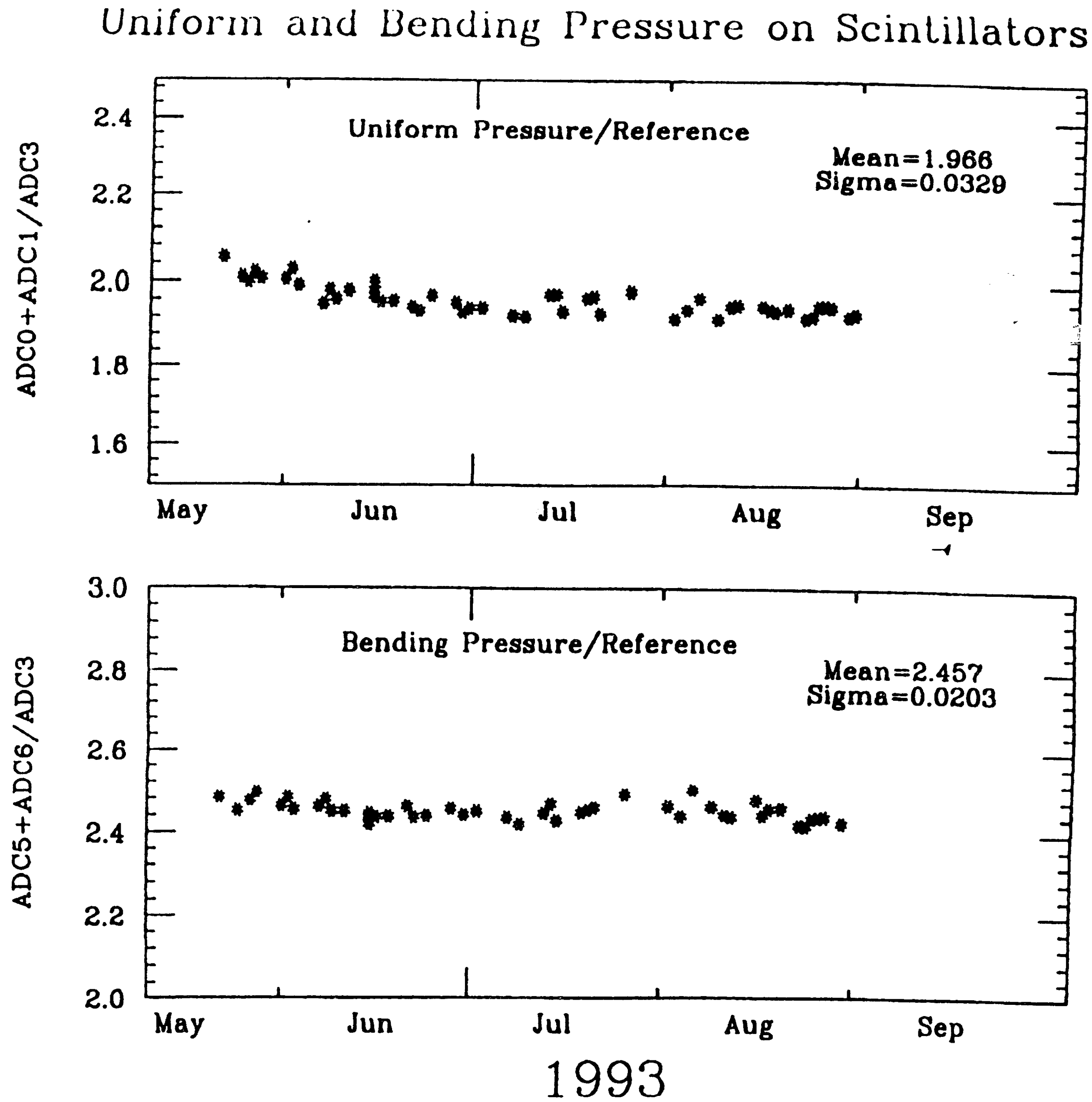



Figure 30 Normalized response versus time of test scintillator subjected to a uniform compression and a bending pressure.

*b. SDC Optics*

The long term tests of bending and compressing scintillator continued. The output is still constant after 190 days except for the initial falloff with a time constant of 18 days. This falloff may be due to the optical wetting of the surface when the paper is compressed. The fit with an initial exponential and a constant has a $\chi^2$ of one per degree of freedom. The test of long-term light output from bent scintillator show some systematic shifts both up and down which may be correlated with seasonal temperature or light baffling shifts. The systematic variation is about 1% over time periods of a couple of weeks while the fluctuations in measurements each day are of the same magnitude. In any case, after 190 days of stressing the materials at 3 to 10 times the level they would be stressed in a calorimeter, we see no obvious long term degradation.

*c. SDC Test Beam*

The Argonne design for the SDC test beam at Fermilab emphasized solving several problems simultaneously. These were small beam divergence for calorimeter tests, small momentum dispersion for calorimeter tests, small spot size for straw tube tests, Cherenkov tagging of electrons, synchrotron radiation tagging of electrons, and overall cost. There was an effort at the SDC Laboratory by some Russians on the secondary beam design. While they could make certain optical parameters such as spot size and dispersion somewhat better than the Argonne design, it was at the cost of a large number of new magnets and moving of the existing neutral beam dump.

Most of the Argonne work in this period was focused on studies of utilizing spin precision snake magnets in the existing beam as synchrotron radiators. The problem was to get sufficient radiation of momenta of about 100 GeV and to separate the radiation from the beam path at all momenta. This work was only partially successful and was discontinued for lack of time.

We also had discussions with Fermilab about the magnet system in the primary beam needed to get either forward targeting for $\pi^0$ to make electrons or 4 mr angle targeting to get negative pions using the same targeting/sweeping system. It would also be possible to transmit a limited flux of primary beam through hole collimators and the targeting/sweeping system. (D. Underwood)

# *II. THEORETICAL PROGRAM*

## A. *THEORY*

### 1. *Transverse Momentum Distributions for Heavy Quark Pairs*

The distribution in the transverse momentum ,$q_T$, of a heavy quark pair, $\overline{Q}Q$, produced in hadron-hadron interactions is of interest for elucidating the underlying quantum chromodynamics (QCD), and its understanding is important in studies of $\overline{B}B$ mixing and CP violation at hadronic facilities. Unlike the case of pairs of heavy quarks in $e^+e^-$ annihilation, $\overline{Q}Q$ pairs created in hadron-hadron collisions are often not in a back-to-back configuration (even in a plane transverse to the beam direction). The net transverse momentum of the pair measures the imbalance between the transverse momenta of the $\overline{Q}$ and the $Q$. In Argonne report ANL-PR-93-57, accepted for publication in Physical Review D, Ed Berger and Ruibin Meng examine the quantitative description in QCD perturbation theory of the expected imbalance. Their predictions for the region of large $q_T$ are based on exact order $\alpha_s^3$ QCD perturbation theory. For the regions of small and modest $q_T$, they employ an all orders resummation of leading logarithmic contributions associated with the emission of soft gluons from the initial-state partons that participate in the hard scattering process. This calculation addresses a practical question for heavy quark tagging at hadron facilities: if a $Q$ is tagged with a given transverse momentum, what distribution in transverse momentum should one expect to observe for the associated $\overline{Q}$?

Berger and Meng consider the process hadron + hadron $\to Q+\overline{Q}+X$. In the simplest parton model description, the underlying hard scattering process is parton + parton $\to Q+\overline{Q}$. At this level of approximation, no bremsstrahlung gluons are radiated from initial-state or final-state partons, and if one neglects intrinsic transverse momentum of initial state partons, $q_T$ is zero. Gluon bremsstrahlung is important in QCD and, in general, generates non-zero $q_T$. The single particle inclusive differential cross section for heavy quark production has been studied in detail at next-to-leading order in QCD. In the single particle inclusive approach, the kinematical variables of the heavy quark's (or antiquark's) partner and of the final state light partons are integrated over with the attendant limitation that it is not possible to examine quark-antiquark correlations or the cross section differential in the transverse momentum $q_T$, of the $\overline{Q}Q$ pair. One may expect that next-to-leading order QCD should provide reliable expectations for the distribution in $q_T$ at large $q_T$. At small $q_T$, the relatively large mass, $m_Q$ , of the heavy quark $Q$ justifies perturbation theory; but the presence of the two disparate scales, $m_Q$ and $q_T$, requires care. Perturbative QCD has been used for a successful description of transverse momentum distributions in massive lepton-pair production, the Drell-Yan process. Important for the quantitative description of the transverse momentum distribution at modest values of $q_T$ is the resummation of logarithmic contributions associated with emission of soft gluons in the initial state of the hard scattering process. Berger and Meng follow closely the analogy with the Drell-Yan case for the reaction hadron+hadron $\rightarrow Q+\overline{Q}+X$ and concentrate on the transverse momentum distribution of the $Q\overline{Q}$ quark pair. New complications arise from soft gluon emission from the final-state heavy quarks, effects that are absent in the Drell-Yan reaction. The convergence of the theory is governed by $\alpha_s \ell n^2(M^2/q_T{}^2)$ instead of $\alpha_s$; $M$ is the mass of the $Q\overline{Q}$ pair. The logarithms arise through emission of soft and collinear gluons. At sufficiently low $q_T{}^2$, $\alpha_s \ell n^2(M^2/q_T^2)$ is large even when $\alpha_s$ is small, and any fixed order calculation breaks down. In order to obtain a reliable prediction, one must resum the leading contributions to all orders in $\alpha_s$. In their paper, Berger and Meng present the perturbative calculation of the $q_T$ distribution using exact order $\alpha_s^3$ QCD matrix elements. They describe how to obtain the asymptotic expression at $q_T^2 \rightarrow 0$ from the exact order $\alpha_s^3$matrix elements, and they provide the formalism for resumming the initial soft and collinear gluon contributions. The resummed result in the low-$q_T$ region is matched to the exact order $\alpha_s^3$ result in the high-$q_T$ region. Explicit results are presented for $\bar{b}b$ pair production at the Fermilab Tevatron collider and for $\bar{c}c$ pair production at fixed target energies. (E. Berger, R. Meng)

## 2. *Inclusive Heavy Quark Production at Hadron Collider Energies*

Heavy flavor production has been of interest to Ed Berger because of the theoretical issues it raises in the theory of strong interactions and because of the discovery potential it presents, notably in searches for the top quark and in studies of CP noninvariance in the bottom sector. In next-to-leading order, $O(\alpha_s^3)$ quantum chromodynamics, gluon-gluon interactions are the dominant mechanism for the production of bottom quarks at CERN and Fermilab hadron collider energies and at values of momentum transfer currently accessible. The notable discrepancy between the Fermilab Collider Detector Collaboration (CDF) data and prior $O(\alpha_s^3)$ theoretical calculations continued to motivate R. Meng and E. Berger to seek adequate theoretical explanations. One of the approaches they took was to develop a new set of parton densities, described in prior semi-annual reports. At energies relevant for future hadron colliders, calculations of cross sections for heavy flavor production may assist in the design of experiments and in the evaluation of the merits of various options, such as the use of a supercollider in a fixed target mode. In Argonne report ANL-HEP-CP-93-63, Berger and Meng present calculations of inclusive cross sections for the production of bottom quarks in proton-proton and proton-antiproton collisions as a function of energy, transverse momentum, and Feynman $x_F$ for values of $\sqrt{s}$ ranging from 100 GeV to 40 TeV. In addition, they provide simple analytic parametrizations of their theoretical results that should facilitate estimates of rates, acceptances, and efficiencies for proposed new detectors. The computations are based on next-to-leading order matrix elements from perturbative quantum chromodynamics and on the most recently published sets of two-loop evolved parton densities. These results were valuable at the Snowmass workshop that took place in June, 1993. Variations of the behavior of the gluon density in the region of very small $x$ provide an estimate of the range of theoretical uncertainty.

(E. Berger, R. Meng)

### *3. Mechanisms of $J/\psi$ and $\chi$ Production*

Years ago, Dan Jones and Ed Berger originated what became known as the "color singlet" model for photoproduction and hadroproduction of the $J/\psi$ (Phys. Rev. D23, 1521 (1981)). The model has been widely cited and extensively used since its inception. Other contributions to $J/\psi$ and $\chi$ production include B decay and gluon and quark fragmentation. The different mechanisms tend to contribute to different regions of phase space. More recently, suppression of $J/\psi$ production has been advocated as a signal for formation of a quark-gluon plasma in relativistic heavy ion collisions. To assess quantitatively whether suppression has occurred, one must first have a good understanding of what is expected in the absence of plasma formation. Along with Helmut Satz and Reinhold Ruckl at CERN, Ed Berger is involved in a detailed study of the phenomenology of $J/\psi$ and $\chi$ production in hadron-hadron, proton-nucleus, and nucleus-nucleus interactions at fixed target and collider energies. Along with CERN theory group postdoctoral fellow K. Sridhar, Berger wrote a short paper on joint production of a $J/\psi$ and a photon $(\gamma)$. Their paper was published in Physics Letters B317, 443 (1993).

(E. Berger)

### *4. Light Quarks and the QCD Soft Pomeron*

In a paper (Argonne preprint ANL-HEP-CP-93-70) presented at the Vth Blois Workshop on Elastic and Diffractive Scattering, Alan White reviews the physical understanding that has emerged from his recently published long articles studying the Pomeron in QCD using Analytic Multi-Regge Theory. Beginning with the phenomenological origin of Reggeon Field Theory, the Pomeron phase transition is described in terms of the appearance of a Pomeron condensate and the emergence of a massive reggeized gluon. (The phase-transition converts divergences in rapidity to divergences in momentum transfer). This allows the Pomeron phase transition to be tied to properties of QCD, summarized in the β-function and the anomaly that appear as massless quarks are added to the theory and the asymptotic freedom constraint is saturated.

Implications of the analysis are also described, including arguments for the existence of a higher color quark sector responsible for electroweak symmetry breaking. Summarizing the implications, White concludes that understanding the Soft Pomeron in QCD may be the key to progress on many of the remaining puzzles of the Standard Model.

The importance of light quarks for the Soft Pomeron was also emphasized in an invited paper presented by White at the recent DESY Topical Meeting on QCD at HERA. The most important role of the "Soft Pomeron" at HERA may well be as a boundary condition for the "Hard Pomeron" seen in deep-inelastic, rapidity-gap events and in small-x structure functions. In the early part of the talk, White presented a heuristic explanation of his work based on the well-known phenomenological result that the Soft Pomeron behaves approximately like a simple Regge pole which couples to single quarks; just like an isoscalar photon. This strongly suggests that there should be a (singular) gauge in which the Pomeron can be identified as a single reggeized gluon with the color neutralized by some additional zero transverse momentum exchange. From this starting point it can be shown that properties of the triple Pomeron interaction in particular will not appear perturbatively, but instead require the instanton interactions associated with the anomaly and massless quarks. This line of argument does not lead to a calculational framework but does anticipate many of the results which emerge from the Analytic Multi-Regge Analysis which was summarized in the remainder of the talk.

(A. White)

## 5. *High Energy Behavior of Forward Scattering Parameters*

Recent experimental results, namely, the remeasurement of the ρ value by UA4/2 at $\sqrt{s} = 546$ GeV, and a new analysis by the E710 group of $\sigma_{tot},\rho$ , and $B$ at $\sqrt{s} = 1800$ GeV, as well as their measurement of $\sigma_{tot}$ and $B$ at $\sqrt{s} = 1020$ GeV, have provided important anchor points for the high-energy behavior of $\bar{p}p$ scattering. In a paper presented at the XXIII International Symposium on Multiparticle Dynamics (Argonne preprint ANL-HEP-CP-94-9), Alan White and coauthors Martin Block, Francis Halzen and Bernie Margolis, include the new experimental data in a previous asymptotic amplitude analysis by Block and White and in a comparison with experiment of a "QCD-inspired" eikonal model developed by Block, Halzen and Margolis. The amplitude analysis gives strong evidence for a $\log(s/s_0)$ dependence at current energies and not

$\log^2(s/s_0)$, and demonstrates that odderons are not necessary to explain the experimental data. (A. White)

### 6. *The Mass of the Heavy Axion $\eta_6$*

In a paper (ANL-HEP-CP-93-56) contributed to the XVIth International Symposium on Lepton-Photon Interactions, Alan White discusses how, when dynamical electroweak symmetry breaking is due to a condensate of color sextet quarks, dynamics analagous to "walking technicolor" provides an enhancement of the sextet chiral condensate by orders of magnitude compared to the electroweak chiral scale. This enhancement compensates for the exponential suppression of electroweak scale color instantons and, as a result, the $\eta_6$ axion, which at first sight appears to be a conventional Peccei-Quinn axion, can naturally acquire an electroweak scale mass. Therefore, the $\eta_6$ potentially provides a novel solution to the Strong CP problem. It could, perhaps, be observed decaying via massive photon pairs at LEP. (A. White)

### 7. *Decay and Production of Heavy Quarkonia*

Some time ago G. Bodwin, E. Braaten (Northwestern), G. P. Lepage (Cornell), and T. C. Yuan (Northwestern) presented new factorization theorems that allow one to express the production and decay rates of P-wave heavy quarkonia, to leading order in $1/M_Q$, as linear combinations of three nonperturbative parameters, with coefficients that are calculable as a power series in $\alpha_s$. These factorization theorems were used to discuss the phenomenology of the decay and production of P-wave charmonium states. (See the July 1, 1992 -- December 30, 1992 report for further details.)

Bodwin, Braaten, and Lepage are now in the process of writing a paper that describes the formal basis for the factorization theorems and presents in detail the procedures for carrying out new calculations in the field. The paper describes a heavy-quark effective field theory that is often a very convenient framework for carrying out heavy-quarkonium analyses. The nonperturbative parameters in the factorization theorems can be expressed in terms of matrix elements of operators in the effective theory; the perturbatively calculable coefficients correspond to the operator normalizations. In the context of the effective field theory, it is straightforward to generalize the factorization theorems to include contributions beyond the leading order in $1/M_Q$. Bodwin, Braaten, and Lepage work out the expressions for the first subleading corrections to decays of S-wave states explicitly.

In addition to setting out the heavy-quark formalism in this paper, Bodwin, Braaten, and Lepage present a number of new calculations. These include calculations of the order $\alpha_s$ and $\alpha_s^2$ contributions to the coefficient functions for the leading-order and next-to-leading order annihilation operators, calculations of the anomalous dimensions of the leading-order S-wave and P-wave annihilation operators and next-to-leading order S-wave annihilation operators, and calculations of the matching conditions that allow one to extract from existing calculations the order $\alpha_s^3$ contributions to the coefficient functions for the leading-order S-wave and P-wave annihilation operators. (G. Bodwin)

### *8. Lattice Regularization of Chiral Gauge Theories*

Over a course of several years, G. Bodwin and E. Kovacs (Fermilab) have presented a method for formulating gauge theories of chiral fermions (such as the standard electroweak model) on the lattice. (See the January 1, 1993 -- June 30, 1993 report for further details.) The basis for their proposal had been a perturbative analysis of the Green's functions of the theory in the limit of zero lattice spacing. Recently, Bodwin and Kovacs have shown that the perturbation series specifies the fermion determinant almost completely. The ambiguities have to do with the low-energy behavior of the fermion determinant and do not affect the renormalization arguments that are the key issues in analyzing the Bodwin-Kovacs proposal. Consequently, Bodwin and Kovacs have been able to establish quite generally that their proposal yields a satisfactory gauge theory of chiral fermions as one approaches the continuum limit. Their result holds even in the presence of nonperturbative gauge-field configurations. A paper describing this work is in progress. (G. Bodwin)

### *9. Currents, Charges, and Canonical Structure of Pseudodual Chiral Models*

In collaboration with T. Curtright (U. of Miami), C. Zachos investigated an intriguing field theory, the Pseudo-Dual Chiral Model [ANL-HEP-PR-93-85], which neatly illustrates a class of theories that possess an infinite number of conservation laws but allow particle production at variance with naive expectations. They identified the elusive symmetries of the pseudodual model, both local and nonlocal, as transmutations of the symmetries of the usual chiral model. They refined the conventional algorithm to more efficiently produce the nonlocal symmetries of this model, and produced the complete local current algebra for the pseudodual theory. They, finally, exhibited the canonical transformation which connects the usual chiral model to its fully equivalent dual, thereby further distinguishing the pseudodual theory. (C. Zachos)

### *10. High-Energy Asymptotics of Perturbative Multi-Color QCD*

The contributions of diagrams with many reggeized gluons are important for the unitarization of the perturbative Pomeron in QCD. In a paper (Argonne preprint ANL-HEP-CP-93-67) presented at the Vth Blois Workshop on Elastic and Diffractive Scattering, Lev Lipatov discusses the possibility of finding an exact solution for multi-gluon compound states in the leading log approximation, and in the limit $N \to \infty$, where $N$ is the number of colors. He shows that the Bethe-Salpeter equations for compound states of many reggeized gluons are conformally invariant in the two-dimensional impact parameter space. Their solutions can be written in holomorphically factorized form and there is a differential operator commuting with the holomorphic part of the corresponding Hamiltonian. (L. Lipatov)

### *11. Z′ Couplings*

In a paper (Argonne preprint ANL-HEP-CP-93-51) presented at the Workshop on Physics at Current Accelerators and the Supercollider, JoAnne Hewett and Tom Rizzo explore the possibility that $Z'$ couplings could be probed using decay modes which involve neutrinos once Standard Model backgrounds are directly determined using the data itself. For some models, sufficient statistics are available at the LHC to render these modes useful for coupling determinations, providing the mass of the $Z'$ is not much larger than 1 TeV, and assuming other new physics backgrounds are absent.

In another paper (Argonne preprint ANL-HEP-CP-93-50) also presented at the same workshop, Tom Rizzo discusses the possibility of extracting $Z'$ couplings from the two jet decay. The technique was found to be useful for some extended electroweak models provided that the $Z'$ is relatively light. In this paper the procedure is generalized to the LHC and to $Z'$s which are more massive than 1 TeV. (J. Hewett, T. Rizzo)

### *12. Vector Leptoquark Production at Hadron Colliders*

In a paper (Argonne preprint ANL-HEP-CP-93-52) presented at the Workshop on Physics at Current Accelerators and the Supercollider, JoAnne Hewett and Tom Rizzo, in collaboration with S. Pakvasa, H.E. Haber and A. Pomarol, explore the production of vector leptoquarks, at the Tevatron and the LHC, through both quark-antiquark and gluon fusion. The cross-sections are found to be somewhat larger than for scalar leptoquarks of the same mass, implying enhanced search capabilities.

(J. Hewett, T. Rizzo)

### *13. Extended Gauge Sectors at Linear Colliders*

Signatures of extended gauge models at high-energy $e^+e^-$ colliders are summarized by JoAnne Hewett in a paper (Argonne preprint ANL-HEP-CP-93-68) presented at the Workshop on Physics and Experiments with Linear $e^+e^-$ Colliders. She concludes that extended gauge sectors yield an abundance of exciting phenomenology. A hadron supercollider can discover new gauge bosons with masses up to several TeV, but will have more difficulty determining the extended model involved. The possible discovery of a "light" (~1 TeV) neutral boson at a hadron supercollider would provide an impetus for the construction of a TeV $e^+e^-$ linear collider as the on-resonance physics has an overwhelming potential. In the case of exotic fermions, there are many exciting production mechanisms and signatures which are unique to $e^+e^-$ collisions. The $e^+e^-$ collider may also provide a possible technique for finding striking and unique signatures for new physics. (J. Hewett)

### *14. $W_R$ Searches at the Tevatron*

The on-going Tevatron search for charged, right-handed gauge bosons is sensitive to various model dependent assumptions. In a recent paper (Argonne preprint ANL-HEP-PR-93-87), Tom Rizzo has explored the dependence on factors such as the magnitude of the $SU(2)_R$ coupling, the values of the right-handed Kobayashi-Maskawa mixing matrix elements, and the nature of the right-handed neutrino. The results also have important implications for HERA searches for right-handed currents. (T. Rizzo)

### *15. Monte Carlo Event Generators*

In collaboration with S. D. Protopopescu, Ian Knowles has produced a brief review of Monte Carlo event generators for simulating hadron-hadron collisions. The paper (Argonne preprint ANL-HEP-CP-93-95) was presented at the Workshop on Physics at Current Accelerators and the Supercollider. Particular emphasis is placed on comparisons of the approaches used to describe physics elements and identifying their relative merits and weaknesses. This review summarizes a more detailed report which is in preparation. (I. Knowles)

### *16. Principal Value Resummation in QCD*

Harry Contopanagos is continuing a program of developing a mathematically consistent formalism to resum all large perturbative corrections in Quantum Chromodynamics. In his most recent publication in collaboration with George Sterman (SUNY Stony Brook), "Principal Value Resummation" (ITP-SB-93-61/ANL-HEP-PR-

94-1, 19 October 1993, Nuclear Physics B, in print), a new method is presented of exponentiation of the large perturbative corrections in the Drell-Yan process which by-passes any infrared singularities by introducing a generalized exponent in the complex momentum-scale plane. This exponent is mathematically well defined, analytically calculated in terms of a series of special functions (exponential integrals) which depend on the inverse of the fixed strong coupling constant $\alpha_s \equiv \alpha_s(Q^2)$ ($Q^2$ being the invariant mass of the dilepton pair in the Drell-Yan cross section), and reproduces a perturbative exponent as an *asymptotic* series. Additional advantages of the new formalism are that the number of asymptotic terms is precisely determinable as a function of $Q^2$ and that a closed analytical expression for the short-distance part of the cross section (hard part) is now derivable:

$$I(z,\alpha_s) = \delta(1-z) - \left[ \frac{e^{E\left(\frac{1}{1-z},\alpha_s\right)}}{\pi(1-z)} \Gamma\left(1 + P_1\left(\frac{1}{1-z},\alpha_s\right)\right) \sin\left(\pi P_1\left(\frac{1}{1-z},\alpha_s\right)\right)\right]_+ ,$$

where $\Gamma$ is the Euler Gamma function, $z$ is the momentum fraction of the dilepton invariant mass with respect to the initial partons' one,

$$P_1(n,\alpha_s) \equiv \frac{\partial}{\partial \ln n} E(n,\alpha_s),$$

with the usual moment-space correspondence

$$n \leftrightarrow \frac{1}{1-z},$$

and, $E(n,\alpha_s)$ is the new resummation exponent, computed and shown in Fig. 31.

(H. Contopanagos)

*17. All-order Perturbative K-factor*

Currently Contopanagos and Lyndon Alvero (SUNY, Stony Brook) are writing a paper which will apply the above work to extract the state-of-the-art perturbative prediction for the K-factor, i.e., the ratio of the Drell-Yan to Deep-Inelastic-Scattering cross section. This result, including all large perturbative corrections, will provide the basis for quantifying any disagreement with the experimental results. These appear as non-perturbative higher-twist effects which now will be treatable in a mathematically consistent way.

(H. Contopanagos)

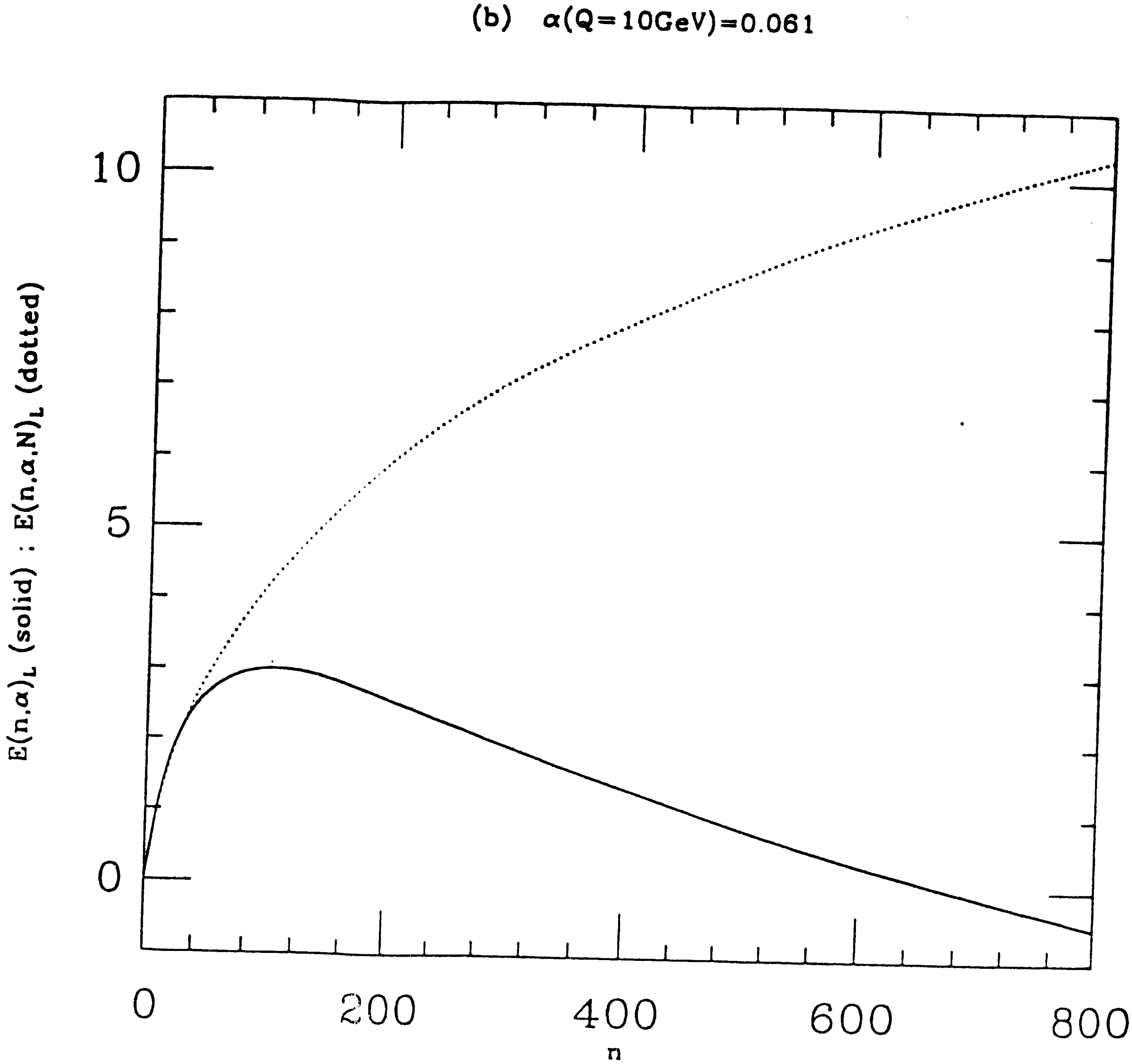



Figure 31 The exact principal value leading exponent (solid curve) versus its asymptotic approximation (dotted curve) as a function of n, for $\alpha(Q = 10\text{ GeV}) \simeq 0.061$.

### *18. All-order Perturbative Heavy-Quark Production*

Contopanagos and Eric Laenen (Fermilab) also are applying the QCD resummation formalism to heavy-quark production. This has been previously treated using methods that heavily depended on arbitrary infrared cut-offs that introduced large theoretical errors in the k-factor as well as in theoretical limits on the top-quark mass. This formalism will eliminate the bulk of these perturbative hadronic uncertainties, again giving a state-of-the-art predictions for the perturbative piece of the total cross section, transverse-momentum distribution and related quantities. (H. Contopanagos)

## *B. Computational Physics*

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

In collaboration with G. T. Bodwin of the theory group, we have been attempting to calculate, in a non-relativistic approximation, the matrix elements which describe the decays of the charmonium and upsilon states. For this we have been using gauge field configurations generated on a $16^3$ x 32 lattice at $g^2 = 1$, neglecting the effects of light quarks. The calculation is being performed on the CRAY C-90 computer at NERSC. In a first round of calculations (Fig. 32) using point sources for these quarkonium states, we were able to determine that, as predicted, the contributions where the quark-antiquark pair annihilate from a color singlet state are related to the wave function of the quarkonium state (or its derivative) at the origin. We also detected the presence of a contribution in which the quark-antiquark pair in a P-wave state decayed from a color octet S-wave state formed by the emission of a gluon. Our "data" was too noisy to extract a quantitative result. For this reason we are now studying the use of extended sources for these quarkonium states which should have a better overlap with the true states and should lead to a better signal/noise ratio.

In collaboration with J. B. Kogut and M.-P. Lombardo (University of Illinois) we have been studying lattice QCD at finite baryon number density (nuclear matter) in the quenched approximation on a $16^3$ x 32 lattice on the CRAY C-90 at NERSC. In our first round of simulations we were able to indicate that for small chemical potentials ($\mu$) for

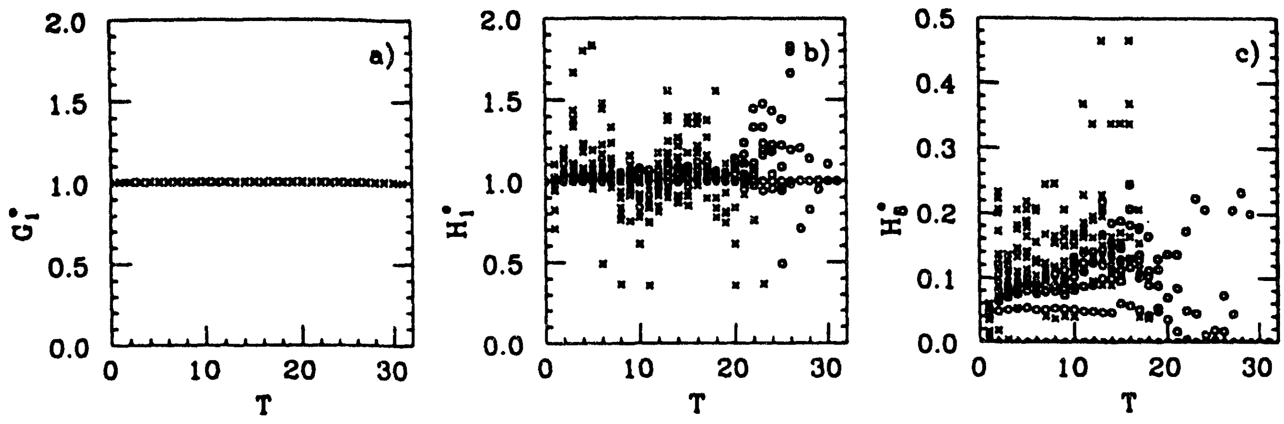



Figure 32 Matrix elements associated with quarkonium decay as functions of distance T from the source. For $G_1$ and $H_1$ a value of 1 would be predicted by the vacuum saturation approximation.

baryon number, the spectrum of mesonic excitations and the chiral condensate remained unchanged from their $\mu = 0$ values, while the nucleon screening mass was reduced by $3\mu$. This is consistent with the expected transition to a quark-gluon plasma at $\mu = m_N/3$. We have developed an understanding of why there is a qualitative change in the system at $\mu = m_\pi/2$. This has lead to much confusion in the past. We are seeking a Special Parallel Processing allocation at NERSC to continue our studies at larger $\mu$ on a $16^3 \times 64$ lattice. In addition we are seeking a Grand Challenge allocation of computing resources from the NSF to study lattice QCD at finite temperature and finite baryon number density with dynamical quarks using the CRAY T3D at PSC.

Our calculations of the spectrum of light hadrons in quenched QCD on a $32^3 \times 64$ lattice and lattice spacing ~0.1 fm have continued through this period on the Intel Touchstone Delta computer at Caltech. We have also started to perform calculations on a $16^3 \times 64$ lattice using the new Intel Paragon computer at Caltech to study finite volume effects on the hadron spectrum.

The simulations of finite temperature QCD with 2 light flavors of dynamical quarks has continued through this period, enabling us to obtain a good estimate of the position of the transition from hadronic matter to a quark-gluon plasma. These simulations are being performed on the CM-2 at PSC as part of the multi-institutional HTMCGC collaboration. The computer time was made available from an NSF Grand Challenge proposal.

One of us (S. Kim) has been involved in a study of theories with 4-fermi couplings in collaboration with J. B. Kogut. These studies are aimed at a better understanding of chiral symmetry breaking.

S. Kim has also been studying the domain structure and nature of the finite temperature transition in quenched lattice QCD with S. Ohta of the Riken Institute (Japan). This uses gauge configurations on a $48^3 \times 4$ lattice which were generated on the Intel Paragon at Caltech.

A new proposal was submitted to the DOE and NSF by the Teraflops collaboration (with which one of us (DKS) is involved) at the end of this period. It aims to provide the scientific community (and lattice field theorists in particular) with access to a computer with performance in the Teraflops range by the end of 1996.

(D. Sinclair, S. Kim)

# *III. ACCELERATOR RESEARCH AND DEVELOPMENT*

## *A. ARGONNE WAKEFIELD ACCELERATOR R&D*

### *1. Advanced Accelerator Test Facility (AATF)*

Decommissioning of the AATF began as components were salvaged for reuse at the AWA. The AATF was the first and so far only facility capable of direct wakefield measurements. Sited at the ANL chemistry division linac, the AATF was commissioned in 1987.

The highly successful experimental program included proof of principle studies of wakefield acceleration in conventional (iris-loaded) and dielectric structures, and wakefield acceleration and focussing in plasmas. More recently the AATF was used to perform measurements of parasitic wakefields in accelerating devices and beamline components developed by other laboratories, such as X-Band NLC structures for SLAC and SSC beamline liners.

The AATF program will be taken over by the AWA, due to come on line in 1994. The AWA will allow measurements of wakefield devices to be made at much higher gradients than were possible at the AATF, with the goal of demonstrating wakefield acceleration as a viable technology for the next generation of linear colliders.

## 2. *Argonne Wakefield Accelerator (AWA)*

### a. *Construction Highlights*

- The radiation and laser safety systems were installed in the AWA vault.
- Measurements showed that the heat transfer between the original cooling tubes and the accelerating cavities was not adequate. New cooling channels were designed and attached to the linac cavities and the photocathode gun cavity.
- Machining for the witness gun is well along. Final cuts are being made based upon rf measurements of the gun cells.
- The LCW water system is completed and operational.
- Based on the shielding analysis performed by ANL Health Physics, extra shielding was added to the vault. Electrical services were rerouted from the west wall of the vault to provide clearance for some of the extra shielding.

### b. *RF System*

Tests of the low-level (500 watt) rf amplifier chain indicated a deficiency in the power output and the presence of unacceptable "droop". The droop problem was corrected by additional bypasses on a biasing circuit. Full power operation will require replacement of the output transistor stage and retuning of matching sections. The amplifier has been returned to the manufacturer for these repairs.

Delivery was made of the last large items for the modulator, the klystron tank and the klystron lead shielding. The klystron solenoid power supply was installed and is operational. The klystron x-ray shield was fabricated and installed along with the klystron and its magnet on the klystron tank. All high-power rf loads have been retuned to accommodate the use of non-toxic propylene glycol as a coolant/attenuator.

The rf modulator was pulsed into a dummy load successfully. Diode tests of the klystron will begin early in CY 1994.

### c. *Laser*

Operational improvements to the laser system continue. The laser beam transport to the linac vault has been completed. Since most of the high gradient wakefield acceleration techniques involve the use of multiple drive bunches, we have begun working with Lambda Physik of Germany to explore the possibilities of active multiple pulse formation in the laser, as opposed to the use of passive arrays of beamsplitters and mirrors.

*d. Controls*

Control software development proceeded during this period to the point where the dummy load rf test could be run entirely under computer control. The decision was made to use the Berkeley TCL/TK software for Graphical User Interface building in all AWA control software. This was found to be more convenient than writing applications in Motif.

Electronics acquisition for phase I is largely complete. Fabrication work on a central control station for all stepping motors used in the facility was initiated.

*e. Wakefield Device Physics*

Wei Gai and Jim Simpson have searched for ways to utilize multiple pulses from the drive linac to achieve accelerating gradients of a few hundred MeV/m in dielectric wakefield structures, a regime of great interest for future linear colliders.

They found that passing a train of appropriately spaced drive bunches through a single coupled wake tube structure can produce sustained high gradients without requiring the use of complicated staging optics. An experimental test of this concept is planned for the AWA.

The idea bears some similarities to the CLIC (CERN Linear Collider) scheme, except that the use of dielectric structures permits longitudinal and transverse compression of the wakefield. (The idea is described in detail in WF-173 which is available via anonymous ftp from AWA0.HEP.ANL.GOV. on the WWW server on PC5.HEP.ANL.GOV.).

Low phase velocity ($\beta \simeq 0.1$) structures were examined analytically and numerically. The existence of very high dielectric constant ($\varepsilon$=35), low-loss ceramics with stable temperature coefficients suggest that dielectric wakefield acceleration may find applications in heavy ion acceleration.

A copy of the MAFIA 3D electromagnetic simulation package was installed on the HP workstation. These codes will be useful for the study and design of exotic accelerating structures.

*f. AWA Experimental Program*

A series of simulations were performed to examine the utility of diagnosing the 2 MeV drive bunch as it emerges from the gun. Preliminary results indicated that the large space charge forces present in the 100 nC bunch essentially wash out all bunch shape and energy spread information by the time it reaches the position of the closest feasible diagnostic port. The beam intensity and radial profile remain as the only useful parameters measurable at that point.

Initial wakefield experiments at the AWA will use dielectric structures. The device geometries for these experiments have been determined, and manufacturers capable of supplying the requisite low loss, high frequency ceramic dielectrics have been identified.

Work has begun on the new plasma wakefield experiment for the AWA, which will study the nonlinear blowout regime. The regime is attained for a sufficiently large drive beam density in which all electrons are expelled by the wake of the drive beam, resulting in accelerating gradients. The original plasma cell used at the AATF is being modified by the UCLA group anticipating the considerably higher drive beam deceleration in this regime. Plasma diagnostics being installed include Langmuir probes and a 140 GHz interferometer. Beamline design is underway, including a solenoid lens to reach the desired beam spot size, and a differential pumping section.

#### *g. Safety Review*

A safety review of the AWA (PSAD, hardware, documentation, etc.) was completed. The review committee concluded that when a short list of action items is complete, the AWA is considered operationally ready to run. DOE verification/confirmation of a low hazard classification and of the PSAD is expected soon.

### *B. High Resolution Profile Monitor Development*

We are proposing a measurement of the beam profile at the focus of the SLAC Final Focus Test Beam. This method should have a resolution of about 20-30 nm, better than the 60 nm spots expected there. Following the Nov. 12 meeting of the SLAC Experimental Program Advisory Committee, our group was told to contact approved experiments at the FFTB facility and make arrangements to incorporate this measurement into the approved program, following completion of the test run elsewhere.

During the period electronic hardware was built to support the acquisition of seismometer data. A low noise amplifier with a gain of approximately 120 and a bandwidth of 100 Hz was designed and built. The noise level of this amplifier appears to be a few nanovolts rms referred to the input, although our test equipment is not really adequate for making noise measurements at these levels. A CAMAC interface was built for receiving the amplified seismometer data from the low noise amplifier, digitizing the signals, and formatting them for acquisition through CAMAC. This interface will support two clocks and four seismometer inputs, and provides a dynamic range of 64,000.

Test data was recorded from the Streckeisen STS-2 seismometer positioned on a support anchored in bedrock at the old ZGS ring building. An analysis of FFT spectra showed clear signals due to 30 and 60 Hz noise, calibration signals in the range 1-10 Hz, and the IPNS ring magnet power supply when this accelerator was running. A background noise was also seen at the 100 nm level at frequencies around 0.1 Hz. This noise seems to be associated with surf on beaches around the world.

A technique has been developed to infer the parameters of the interaction point from the azimuthal distribution of beamstrahlung photons from linear colliders such as the Stanford Linear Collider. Calculations have shown good sensitivity to the beam height, which is difficult to measure at the SLC using flat beams, when the beam height is less than 1 micron. (J. Norem, J. Dawson)

# *IV. EXPERIMENTAL FACILITIES RESEARCH*

## *A. Mechanical Support*

During the period of July-December 1993, the Mechanical Support Group was involved in prototype construction and design work for the Soudan Proton Decay experiment, the ZEUS BHES shower max detector, the SDC barrel EM calorimeter, the RHIC STAR barrel EM calorimeter, and the Argonne Wakefield Accelerator facility. The specifics of the mechanical work for each of these experiments is covered in the appropriate section of this report for each experiment and the reader is referred to these sections for details.

## *B. Electronic Support*

Work continued in support of the Nucleon Decay experiment, Soudan 2. Our involvement during the period was one primarily of construction and maintenance. We produced and/or repaired 360 front/back splitter boards, produced 80 front/back H.V. feeder boards, 3 anode H.V. distribution boxes, and repaired 34 analog cards. Miscellaneous other pieces of electronic equipment were maintained as necessary. We developed a conceptual framework for the trigger and data acquisition electronics for the RPC's in a detector for the P822 Long Baseline Detector.

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

During the period, our major effort for ZEUS was to complete the design of the SRTD trigger electronics. The trigger cards for this system are located on the RCAL and are extremely dense. There are four 14 layer cards, each with 650 IC's and 4000 discrete components. These cards will be extremely difficult to produce. The system also includes a EVB/FLT card which will be in the Rucksack and will tie the trigger cards to the GFLT and the data acquisition.

A proposal was made by ANL that a shower max chamber for the barrel calorimeter be developed using proportional wires and strips to be implemented instead of the silicon Barrel Hadron Electron Separator (BHES) which had previously been proposed. During the period a prototype system with four skis for one barrel module and the associated electronics was built and tested intensively. The system looks reasonable and in the next period we expect to install prototype hardware at DESY and run prototype hardware in a test beam.

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 expect to have a part in the upgrade to 132 ns operation, and during the period spent considerable time studying noise problems which may exist in the new environment. We hope to have a significant part in this upgrade in the areas of data acquisition from the shower max and preshower chambers and formulation of the trigger using shower max and tracking data.

In support of the Bremsstrahlung Beam Profile Monitor development effort underway in High Energy Physics, we produced the low noise amplifiers and data acquisition hardware, and were involved in the operation of the seismometer system. This effort yielded interesting data and correlated well with data taken at SLAC. We look forward to participating in test beam running in the next period.

During the period we built several small pieces of hardware for the Wakefield Accelerator Development project and the ANL Physics Division. The trigger which we had built for the APEX experiment in the ATLAS accelerator was brought into operation and worked well. (J. Dawson)

### *C. Computer Support*

The Computer Support Group completed the acquisition and installation of various computing resources during the summer of 1993. A Silicon Graphics Indigo workstation was added to the existing network, a DEC Alpha 3000/400 was installed for use by the theory group and two VAXstations were installed. Additional disk capacity, totalling approximately 25 GB, was added to the NFS and VMS cluster. Several high capacity 8 mm tape backup systems were also added. A color laser printer and several new X-terminals were installed. A new server running Windows-NT was installed for use by the DOS and Windows based PCs in the Mechanical Support Group. The Macintosh computers, used by the administrative staff were upgraded with Ethernet LAN adapters.

A study of a LAN wiring upgrade was done with members of the Electronics, Computing and Telecommunications Division. They proposed a plan using hybrid cable, with both twisted pair and fiber capable of up to 1 Gb/sec transmission speed. We plan to do the wiring in two or more phases starting in 1994. (J. Schlereth)

# V. PUBLICATIONS

## January - June 1993*

* In the previous semi-annual report we had the wrong list of publications, so we are providing the January through June 1993 publications in this report in addition to the current list.

### A. Journal Publications, Conference Proceedings, Books (January - June 1993)

Argonne's New Wakefield Test Facility
J. Simpson (ANL)
Proceedings of the XVth Int'l. Conference on High Energy Accelerators, HEACC'92, Hamburg, Edited by J. Rossbach, p. 525 (1993)

A Streamlined Method for Chiral Fermions on Lattice
G. Bodwin (ANL) and E. Kovacs (FNAL)
Nuclear Phys. Section B, LATTICE 92: Proceedings of the Int'l Conference on Lattice Field Theory, edited by J. Smit and P. Van Ball, (1993)

Apparatus for the Measurement of Spin Dependent Observables in np and pp Elastic and Quasi-elastic Scattering
H. Spinka (ANL) and the Saclay Collaboration
Nuclear Instruments and Methods in Physics Research, Section A327, p. 308, (1993)

Comparison of Jet Production in $\bar{p}p$ Collisions at $\sqrt{s}$ = 546 and 1800 GeV
ANL: R. Blair, K. Byrum, S. Kuhlmann, L. Nodulman, J. Proudfoot, R. Wagner, A. B. Wicklund, and the CDF Collaboration
Phys. Rev. Lett. 70, p. 1376, (1993)

Comparison of Lattice Coulomb - Gauge Wave Functions in the Quenched Approximation and with Dynamical Fermions
D. Sinclair, (ANL); K. Bitar, R. Edwards, U. Heller, A. Kennedy (Florida St.); S. Gottlieb (Indiana U.); J. Kogut (U. of IL); W. Liu (Thinking Machines); M. Ogilvie (Washington U.); R. Renken (U. of Central Florida); R. Sugar (U. of California); K. Wang (U. of South Wales, Australia)
Phys. Rev. D47, p. 285 (1993)

Constraints on the Charged Higgs Sector from B Physics
J. Hewett (ANL)
The Fermilab Meeting, DPF92, edited by C. Albright, P. Kasper, R. Raja, J. Yoh, (1993)

Constraints on the Gluon Density from Bottom Quark and Prompt Photon Production
E. Berger, R. Meng (ANL), J. Qiu (Iowa State)
AIP Conference Proceedings of the 3rd Int'l Conference on High Energy Physics, Am. Inst. of Physics, Vol. 2, Dallas, TX (1993)

Hadron Spectroscopy with Dynamical Wilson Fermions at $\beta = 5.3$
D. Sinclair (ANL); K. Bitar, R. Edwards, U. Heller, A. Kennedy (Florida St.); S. Gottlieb, A. Krasnitz (Indiana U.); J. Kogut (U. of IL); W. Liu (Thinking Machines);M. Ogilvie (Washington U.); R. Renken (U. of Central Florida); R. Sugar (U. of California); D. Toussaint (U. of Arizona); K. Wang (U. of South Wales, Australia)
Nucl. Phys. B (Proc. Suppl.) 30, p. 401 (1993)

Hadron Spectrum of Quenched QCD on a $32^3 \times 64$ Lattice
S. Kim, D. Sinclair (ANL)
Nucl. Phys. B, (Proc. Suppl.) 30, p. 381 (1993)

Hadronic Energy Distributions in Deep-Inelastic Electron-Proton Scattering
ANL: M. Derrick, D. Krakauer, S. Magill,, B. Musgrave, J. Repond, R. Stanek, R. Talaga, J. Thron, and the ZEUS Collaboration
Zeitschrift fur Physik C, p. 231 (1993)

Heavy Fermion Mass Predictions and Renormalization Group Equations
I. Knowles(ANL), C. Froggatt, R. Moorhouse (Glasgow U.)
The Fermilab Meeting, DPF92, edited by C. Albright, P. Kasper, R. Raja, J. Yoh, (1993)

Implications of $\tau$ Decays into Strange Scalar Axial Vector Mesons
H. Lipkin (ANL)
Phys. Lett. B303, p. 119, (1993)

Initial Study of Deep Inelastic Scattering with ZEUS at HERA
ANL: M. Derrick, D. Krakauer, S. Magill,, B. Musgrave, J. Repond, R. Stanek, R. Talaga, J. Thron, and the ZEUS Collaboration
Phys. Lett. B303, p. 183

Interactions of Atmospheric $\nu_\mu$ and $\nu_e$ Observed in Soudan 2
M. Goodman (ANL) for the Soudan 2 Collaboration
The Fermilab Meeting, DPF92, edited by C. Albright, P. Kasper, R. Raja, J. Yoh, (1993)

Lepton Number Violating Radiative W Decay in R-Parity Violating Models
T. Rizzo (ANL)
Phys. Rev. D47, p. 4991 (1993)

Longitudinal Structure Function at Intermediate x and the Gluon Density
E. Berger, R. Meng (ANL)
Phys. Lett. B304, p. 318, (1993)

Measurement of the Cross Section for Production of Two Isolated Prompt Photons in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV
ANL: R. Blair, K. Byrum, S. Kuhlmann, L. Nodulman, J. Proudfoot, R. Wagner, A. B. Wicklund, and the CDF Collaboration
Phys. Rev. Lett. 70, p. 2232, (1993)

Measurement of Jet Multiplicity in W Events Produced in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.8 TeV
ANL: R. Blair, K. Byrum, S. Kuhlmann, L. Nodulman, J. Proudfoot, R. Wagner, A. B. Wicklund, and the CDF Collaboration
Phys. Rev. Lett. 70, p. 4042, (1993)

Measurement of Jet Shapes in $\bar{p}p$ Collisions at $\sqrt{s}$ = 1.8 TeV
ANL: R. Blair, K. Byrum, S. Kuhlmann, L. Nodulman, J. Proudfoot, R. Wagner, A. B. Wicklund, and the CDF Collaboration
Phys. Rev. Lett. 70, p. 713, (1993)

Neutron-Proton Elastic-Scattering Spin-Spin Correlation Parameter Measurements Between 500 and 800 MeV
ANL: D. Hill, .K. F. Johnson, T. Shima, H. Shimizu, H. Spinka, R. Stanek, D. Underwood, A. Yokosawa and the LAMPF Collaboration
Phys. Rev. D47, p. 29, (1993)

Nuclear Rescattering Effects in Massive Dihadron Production
T. Fields (ANL), M. Corcoran (Rice U.)
Phys. Rev. Lett. 70, p. 143 (1993)

Nuclear Rescattering Effects in pA → Dihadrons
T. Fields (ANL), M. Corcoran (Rice U.)
The Fermilab Meeting, DPF92, edited by C. Albright, P. Kasper, R. Raja, J. Yoh, and Phys. Rev. Lett., 70, p. 143, (1993)

Observation of Two-Jet Production in Deep Inelastic Scattering at HERA
ANL: M. Derrick, D. Krakauer, S. Magill,, B. Musgrave, J. Repond, R. Stanek, R. Talaga, J. Thron, and the ZEUS Collaboration
Phys. Lett B306, p. 158, (1993)

Probing New Gauge Boson Couplings via 3-Body Decays
T. Rizzo, J. Hewett (ANL)
Phys. Rev. D47, p. 4981 (1993)

QCD with 2 Light Quark Flavours: Thermodynamics on a $16^3$ x 8 Lattice and Glueballs and Topological Charge on a $16^3$ x 32 Lattice
D. Sinclair, S. Kim (ANL), K. Bitar, R. Edwards, U. Heller, A. Kennedy (Florida St.); S. Gottlieb, A. Krasnitz (Indiana U.); J. Kogut (U. of IL); W. Liu (Thinking Machines); M. Ogilvie (Washington U.); R. Renken (U. of Central Florida); R. Sugar (U. of California); M. Teper (U. of Oxford); D. Toussaint (U. of Arizona); K. Wang (U. of South Wales, Australia)
Nuclear Phys. Section B, LATTICE 92: Proceedings of the Int'l Conference on Lattice Field Theory, edited by J. Smit and P. Van Ball, p. 315 (1993)

Quenched Hadron Spectrum of QCD
S. Kim (ANL)
The Fermilab Meeting, DPF92, edited by C. Albright, P. Kasper, R. Raja, J. Yoh, (1993)

Quenched QCD Spectrum on the Delta
S. Kim (ANL)
Proceedings of the Second Intel Delta Applications Workshop, Norfolk, VA (1993)

Requirements for a System to Analyze HEP Events Using Database Computing
E. May, D. Lifka, E. Lusk, L. Price (ANL); C. Day, S. Loken, J. MacFarlane (LBL); A. Baden (U. of Maryland); R. Grossman, X. Qin (U. of IL); L. Cormell, A. Gauthier, P. Leibold, J. Marstaller, U. Nixdorf, B. Scipioni (SSC)
12th IEEE Symposium on Mass Storage Systems, Monterey, CA, (1993)

Rigorous QCD Predictions for Decays of P-Wave Quarkonia
G. Bodwin (ANL), E. Braaten (Northwestern U.), G. Peter Lepage (Cornell)
The Fermilab Meeting, DPF92, edited by C. Albright, P. Kasper, R. Raja, J. Yoh, (1993)

Search for $\Lambda_b \to J/\psi \Lambda^\circ$ in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.8 TeV
ANL: R. Blair, K. Byrum, S. Kuhlmann, L. Nodulman, J. Proudfoot, R. Wagner, A. B. Wicklund, and the CDF Collaboration
Phys. Rev. D47, p. 2639, (1993)

Search for Leptoquarks with the ZEUS Detector
ANL: M. Derrick, D. Krakauer, S. Magill,, B. Musgrave, J. Repond, R. Stanek, R. Talaga, J. Thron, and the ZEUS Collaboration
Phys. Lett. B306, p. 173, (1993)

Signals for Virtual Leptoquark Exchange at Colliders
J. Hewett (ANL), M. Doncheski (U. of Wisc.)
The Fermilab Meeting, DPF92, edited by C. Albright, P. Kasper, R. Raja, J. Yoh, (1993)

Simple Hadronic Matrix Elements with Wilson Valence Quarks and Dynamical Staggered Fermions at $6/g^2 = 5.6$
D. Sinclair (ANL); K. Bitar, R. Edwards, U. Heller, A. Kennedy (Florida St.); S. Gottlieb, A. Krasnitz (Indiana U.); J. Kogut (U. of IL); W. Liu (Thinking Machines); M. Ogilvie (Washington U.); R. Renken (U. of Central Florida); R. Sugar (U. of California); D. Toussaint (U. of Arizona); K. Wang (U. of South Wales, Australia)
Phys. Rev. D48, p. 370 (1993)

SO(10) Grand Unification with a Low $M_R$
T. Rizzo (ANL); N. Deshpande, E. Keith (U. of Oregon)
Phys. Rev. Lett. 70, p. 3189 (1993)

Study of Four-Jet Events and Evidence for Double Parton Interactions in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.8 TeV
ANL: R. Blair, K. Byrum, S. Kuhlmann, L. Nodulman, J. Proudfoot, R. Wagner, A. B. Wicklund, and the CDF Collaboration
Phys. Rev. D47, p. 4857 (1993)

Supersymmetry and the Nonlocal Yanglian Deformation Symmetry
C. Zachos (ANL) and T. Curtright (U. of Miami)
Nucl. Phys. B420, p. 640 (1993)

Symmetry of Wavefunctions in Quantum Algebras and Supersymmetry
C. Zachos (ANL)
Proceedings of XXIst Int'l Conference on Differential Geometric Methods in Theoretical Physics, World Scientific, Vol. 2, Tianjin, China (1993)

The Argonne Wakefield Accelerator (AWA) Laser System and Its Associated Optics
W. Gai, R. Konecny, J. Power (ANL)
Proceedings of the XVth Int'l. Conference on High Energy Accelerators, HEACC'92, Hamburg, Edited by J. Rossbach, p. 525 (1993)

The Gluon Density
E. Berger, R. Meng (ANL)
The Fermilab Meeting, DPF92, edited by C. Albright, P. Kasper, R. Raja, J. Yoh, (1993)

The $\eta_6$ and Massive Photon Pairs at LEP
A. White, I. Knowles (ANL), K. Kang (Brown U.)
The Fermilab Meeting, DPF92, edited by C. Albright, P. Kasper, R. Raja, J. Yoh, (1993)

The Production of Z' Associated with Jets or Photons as a Probe of New Gauge Boson Couplings
T. Rizzo (ANL)
Phys. Rev. D47, p. 956, (1993)

Thermodynamics of Lattice, QCD with Two Light Quarks on a $16^{3*8}$ Lattice
D. Sinclair (ANL), A. Krasnitz (Indiana U.), U.Heller, A. Kennedy (Florida State U.), J. Kogut (Illinois U., Urbana), R. Renken (Central Florida U.), R. Sugar (U. of California), D. Toussaint (Arizona U.), K.Wang (New South Wales U.)
Phys.Rev. D47 p. 3619, (1993)

## *B. Papers Submitted for Publication and ANL Reports (January - June 1993)*

The $\eta_6$ at LEP and Tristan
A. White (ANL)
ANL-HEP-PR-93-04
Submitted to Phys. Rev. Lett.

Constraints on New Physics from Tevatron Dijet Data
T. Rizzo (ANL)
ANL-HEP-PR-93-08
Submitted to Phys. Rev. D

A Prompt Photon Cross Section Measurement in $\bar{p}p$ Collisions at $\sqrt{s}$ = 1.8 TeV
ANL: R. Blair, K. Byrum, S. Kuhlmann, L. Nodulman, J. Proudfoot, R. Wagner, A. B. Wicklund, and the CDF Collaboration
ANL-HEP-PR-93-09
Submitted to Phys. Rev. D

np-Elastic Analyzing Power $A_{NO}$ and Spin Transfer $K_{NN}$
H. Spinka (ANL) and the LAMPF Collaboration
ANL-HEP-PR-93-10
Submitted to Phys. Rev. C

Observation of a Narrow Structure in the pp Elastic Scattering at $T_{kin}$ = 2.11 GeV
ANL: M. Beddo, D. Grosnick, T. Kasprzyk, D. Lopiano, H. Spinka and the Saclay Collaboration
ANL-HEP-PR-93-13
Submitted to Nuclear Physics B

Analytic Multi-Regge Theory and the Pomeron in QCD: II. Gauge Theory Analysis
A. White (ANL)
ANL-HEP-PR-93-16
Submitted to the Int'l. Journal of Mod. Physics

Extraction of Coupling Information From $Z' \to jj$
T. Rizzo (ANL)
ANL-HEP-PR-93-18
Submitted to Phys. Rev. D

Constraints on Anomalous Gauge Boson Couplings from $b \to s\gamma$
T. Rizzo (ANL)
ANL-HEP-PR-93-19
Submitted to Phys. Lett. B

A Model of Universality Violation Revisited
T. Rizzo (ANL)
ANL-HEP-PR-93-20
Submitted to Phys. Rev. D

Measurements of the Total Cross Section Difference $\Delta\sigma T$ in np Transmission Between 0.86 and 0.94 GeV
ANL: D. Lopiano, H. Spinka and the Saclay Collaboration
ANL-HEP-PR-93-27
Submitted to Nuclear Physics B

Measurement of the $D_{onon}$ and $K_{onno}$ Observables in np Elastic Scattering 0.80 and 1.10 GeV
ANL: D. Lopiano, H. Spinka and the Saclay Collaboration
ANL-HEP-PR-93-28
Submitted to Nuclear Physics B

The Light Hadron Spectrum of Quenched QCD on a $32^3 \times 64$ Lattice
S. Kim, D. Sinclair (ANL)
ANL-HEP-PR-93-29
Submitted to Phys. Rev. D

Measurement of the Bottom Quark Production Cross Section Using Semileptonic Decay Electrons in $\bar{p}p$ Collisions at $\sqrt{s}$ = 1.8 TeV
ANL: R. Blair, K. Byrum, S. Kuhlmann, L. Nodulman, J. Proudfoot, R. Wagner, A. B. Wicklund, and the CDF Collaboration
ANL-HEP-PR-93-30
Submitted to Phys. Rev. Lett.

Using b $\rightarrow$ s$\gamma$ to Probe Top Quark Couplings
J. Hewett and T. Rizzo (ANL)
ANL-HEP-PR-93-37
Submitted to Phys Rev. D

Transverse Momentum Distributions for Heavy Quark Pairs
E. Berger, R. Meng (ANL)
ANL-HEP-PR-93-57
Submitted to Phys. Rev. D

## C. *Papers or Abstracts Contributed to Conferences (January - June 1993)*

Overview of Spin Physics
A. Yokosawa (ANL)
ANL-HEP-CP-93-01
Submitted to the Proceedings of the RCNP Kikuchi School on Spin Physics at Intermediate Energies, Osaka, Japan, 16-19 November 1992

Spin Observables in Large t Elastic N-N Scattering
G. Ramsey (ANL)
ANL-HEP-CP-93-02
Submitted to the Proceedings of the 10th Int'l Symposium on High Energy Spin Physics, Nagoya, Japan, 9-14 November 1992

Recent Experiments on Spin Physics in High Energy Hadron Interactions
A. Yokosawa (ANL)
ANL-HEP-CP-93-06
Submitted to the Proceedings of the 10th Int'l Symposium on High Energy Spin Physics, Nagoya, Japan, 9-14 November 1992

Incident Energy Dependence of Hadronic Activity
P. Job (ANL), T. Gabriel (ORNL), D. Groom (LBL), N. Mokhov (IHEP), G. Stevenson (CERN)
ANL-HEP-CP-93-12
Submitted to the Workshop on Simulating Accelerator Radiation Environments Los Alamos, 11-15 January 1993

Experiments to Measure the Gluon Helicity Distribution in Protons
H. Spinka (ANL) and the Saclay Collaboration
ANL-HEP-CP-93-23
Submitted to the Workshop of Future Directions in Particle and Nuclear Physics at Multi-GeV Hadron Facilities, Brookhaven, 4-6 March 1993

Inverse Neutrinoless Double β-Decay at the NLC?
T. Rizzo
ANL-HEP-CP-93-24
Submitted to the Workshop on Physics & Experiments at Linear $e^{\pm}e^{-}$ Colliders, Waikoloa, Hawaii, April 26-30, 1993

Status of the Soudan 2 Detector Experiment
ANL: I. Ambats, D. Ayres, L. Balka, W. Barrett, J. Dawson, T. Fields, M. Goodman, N. Hill, J. Hoftiezer, D. Jankowski, F. Lopez, E. May, L. Price, J. Schlereth, J. Thron, H. Trost, J. Uretsky (ANL) and the Soudan Collaboration
ANL-HEP-CP-93-32
Submitted to the Proceedings of the 23rd Int'l Cosmic Ray Conference, Calgary, July 1993

Are There Atmospheric Neutrino Oscillations?
M. Goodman (ANL)
ANL-HEP-CP-93-33
Submitted to the Proceedings of the 23rd Int'l Cosmic Ray Conference, Calgary, July 1993

Contained ν Events Observed in Soudan 2
ANL: I. Ambats, D. Ayres, L. Balka, W. Barrett, J. Dawson, T. Fields, M. Goodman, N. Hill, J. Hoftiezer, D. Jankowski, F. Lopez, E. May, L. Price, J. Schlereth, J. Thron and the Soudan 2 Collaboration
ANL-HEP-CP-93-34
Submitted to the Proceedings of the 23rd Int'l Cosmic Ray Conference, Calgary, July 1993

Thermodynamic q-Distributions that Aren't?
C. Zachos (ANL)
ANL-HEP-CP-93-39
Submitted to the Proceedings of the 2nd Prague Colloquium on Quantum Groups, Prague, Czech Republic, June 24-26, 1993.

Control, Timing, and Data Acquisition for the Argonne Wakefield Accelerator (AWA)
P. Schoessow, C. Ho, J. Power, E. Chojnacki (ANL)
ANL-HEP-CP-93-40
Submitted to the Proceedings of the IEEE Particle Accelerator Conference, D.C., 17-20 May 1993

The Argonne Wakefield Accelerator (AWA) Laser System and Its Pulse Shaper
W. Gai, N. Hill, C. Ho, P. Schoessow, J. Simpson (ANL)
ANL-HEP-CP-93-41
Submitted to the PAC'93, D.C., 17-20 May 1993

The Argonne Wakefield Accelerator-Overview and Status
P. Schoessow, E. Chojnacki, W. Gai, C. Ho, R. Konecny, J. Power, M. Rosing, J. Simpson (ANL)
ANL-HEP-CP-93-42
Submitted to the PAC'93, D.C., 17-20 May 1993

Drive Linac for the Argonne Wakefield Accelerator
E. Chojnacki, R. Konecny, M. Rosing, J. Simpson (ANL)
ANL-HEP-CP-93-43
Submitted to the PAC'93, D.C., 17-20 May 1993

Construction of a High Resolution Electron Beam Profile Monitor
J. Norem, J. Dawson, W. Haberichter, W. Novak (ANL)
ANL-HEP-CP-93-44
Submitted to the PAC'93, D.C., 17-20 May 1993

Digital Electronics for the Inclusion of Shower Max and Preshower Wire Data in the CDF Second-Level Trigger
J. Dawson, K. Byrum, W. Haberichter, L. Nodulman, A. Wicklund (ANL), K. Turner (Fermilab), D. Gerdes (U. of Michigan)
ANL-HEP-CP-93-48
Submitted to the Int'l Industrial Symposium on the SSC, San Francisco, 6-8 May 1993

Extraction of Z' Coupling Data from Z' $\rightarrow$ jj at the LHC and SSC
T. Rizzo (ANL)
ANL-HEP-CP-93-50
Submitted to the Proceedings of the Workshop on Physics at Current Accelerators and the Supercollider, June 1993.

Using 'Invisible' Decay Modes as Probes of Z' Couplings
J. Hewett and T. Rizzo
ANL-HEP-CP-93-51
Submitted to the Proceedings of the Workshop on Physics at Current Accelerators and the Supercollider, ANL, June 1993.

Vector Leptoquark Production at Hadron Colliders
J. Hewett, T. Rizzo (ANL); S. Pakvasa (U. of Hawaii); A. Pomarol (U. of Oregon)
ANL-HEP-CP-93-52
Submitted to the Proceedings of the Workshop on Physics at Current Accelerators and the Supercollider, June 1993.

The Mass of the Heavy Axion $\eta_6$
A. White (ANL)
ANL-HEP-CP-93-56
Submitted to Proceedings of the XVI International Symposium on Lepton-Photon Interactions, Cornell University, Ithaca, NY (1993)

Extended Gauge Model Working Group Summary Report
S. Godfrey, T. Rizzo (ANL)
ANL-HEP-CP-93-60
Submitted to the Proceedings of the Workshop on Physics at Current Accelerators and the Supercollider, ANL (1993)

FNAL Polarized Beams and Spin Dependence at RHIC
A. Yokosawa (ANL)
ANL-HEP-CP-93-61
Submitted to the Proceedings of the Int'l Conference on Elastic and Diffractive Scattering Brown U., Providence, RI, June 1993.

Bottom Quark Cross Sections at Collider and Fixed - Target Energies at the SSC and LHC
E. Berger, R. Meng (ANL)
ANL-HEP-CP-93-63
Submitted to the Proceedings of the Workshop on B Physics at the Hadron Colliders Snowmass, Colorado, June 1993.

B-Quark Production at Hadron Colliders
R. Meng (ANL), S. Riemersma
ANL-HEP-CP-93-66
Submitted to the Proceedings of the Workshop on B Physics at Hadron Accelerators, Snow Mass, Colorado, June 1993.

High Energy Asymptotics of Perturbative Multi-Color QCD
L.N. Lipatov (ANL)
ANL-HEP-CP-93-67
Presented at the International Conference (Vth Blois Workshop) on Elastic and Diffractive Scattering, Brown University, Providence, RI, June 8-12, 1993.

Extended Gauge Sectors at Linear Colliders
J. Hewett (ANL)
ANL-HEP-CP-93-68
Submitted to the Workshop on Physics and Experiments with Linear Colliders, Waikoloa,
Hawaii. April 1993.

The Pomeron and QCD with Many Light Quarks
A.R. White (ANL)
ANL-HEP-93-70
Presented at the International Conference (Vth Blois Workshop) on Elastic and Diffractive Scattering, Brown University, Providence, RI, June 8-12, 1993.

High Energy Behavior of $\sigma_{tot}$, $\rho$, and B-Asymptotic Amplitude Analysis and a QCD-Inspired Analysis
A. White (ANL), M. Block, F. Halzen, R. Margolis
ANL-HEP-CP-93-71
Presented at the International Conference (Vth Blois Workshop) on Elastic and Diffractive Scattering, Brown University, Providence, RI, June 8-12, 1993.

Status of Elastic Scattering: Total Cross Sections, Real Parts and $d\sigma/dt$
A. White(ANL), K. Kang, P. Valin
ANL-HEP-CP-93-72
Presented at the International Conference (Vth Blois Workshop) on Elastic and Diffractive Scattering, Brown University, Providence, RI, June 8-12, 1993.

## *D. Technical Notes (January - June 1993)*

Precision of Source Response Inside Dimpled HAD Brass Tubes
D. Jankowski, R. Stanek (ANL)
ANL-HEP-TR-93-14 and SDC Note 92-453

Progress on Polarized Target Materials with Pure Carbon Background
D. Hill (ANL)
ANL-HEP-TR-93-15

HEP Division Semi-Annual Report, July - December 1992
P. Schoessow, P. Moonier, R. Talaga, R. Wagner (ANL)
ANL-HEP-TR-93-22

Measurement of Source Tube Radial Position in Cast EMC Testbeam Module
R. Stanek (ANL)
ANL-HEP-TR-93-36, SDC Note 93-499

Calculations on the STAR Conventional Magnet Design
H. Spinka (ANL)
ANL-HEP-TR-93-45, STAR Note #115

| | |
|---|---|
| AGN-22 | Results from the SSC Liner Run<br>P. Schoessow |
| AGN-23 | A String of Beads Pulse Monitor<br>J. Simpson |
| AGN-24 | Vacuum Test System for AWA<br>M. Rosing |

| | |
|---|---|
| CDF Note 1941 | Measurement of $\sigma$*BR (W + $\gamma$) and $\sigma$*BR (Z + $\gamma$) in the Electron and Muon Channels in $\sqrt{s}$ = 1.8 TeV $\bar{p}$ - p Collisions<br>R. Wagner et al. |
| CDF Note 1954 | Drell-Yan Backgrounds for Inclusive Electron Sample<br>A. B. Wicklund and F. Ukegawa |
| CDF Note 1963 | Inclusive Photon Cross Section 1992<br>S. Kuhlmann and A. Maghakian |
| CDF Note 1971 | Inclusive Jet Cross Section from 1992-93 Data Set<br>S. Kuhlmann and A. Bhatti |
| CDF Note 2046 | A First Pass Attempt at a Data Determined Response Map for CEM<br>L. Nodulman and K. Byrum |
| CDF Note 2059 | The Inclusive Electron Binary Files for the 1992/93 Run<br>K. Byrum and A. B. Wicklund |

CDF Note 2069 Digital Electronics for the Inclusion of Shower Max and Preshower Wire Data in the CDF Second-Level Trigger
J. W. Dawson, K. L. Byrum, and W. N. Haberichter, L. Nodulman, A. B. Wicklund, et al.

CDF Note 2070 The Diphoton Rate in the '92-'93 Data Sample (A First Look)
R. Blair, S. Kuhlmann, et al.

CDF Note 2074 A Study of Events Containing a Photon and Two Jets Obtained from $\bar{p}p$ Collisions at $\sqrt{s} = 1.8$ TeV
P. Maas, R. Blair and S. Kuhlmann

CDF Note 2079 Identification of Conversion Electrons in the Inclusive Electron Sample
F. Ukegawa and A. B. Wicklund

CDF Note 2080 Separation of QCD Prompt-$\gamma$ and $\pi^{\circ}$ Production in the Conversion Electron Sample
F. Ukegawa and A. B. Wicklund

CDF Note 2081 Lateral Shower Size for Hadrons
F. Ukegawa and A. B. Wicklund

CDF Note 2082 E/p Systematics from the W-Electron Sample
K. Byrum and A. B. Wicklund

CDF Note 2115 A First Look at 1992-93 Minimum Bias Data
H. Frisch, M. Hohlmann

CDF Note 2119 Detector Counting Rates in the 92-93 Run
L. Nodulman

CDF Note 2143 Preliminary Measurement of $\sigma$*BR (W + $\gamma$) and $\sigma$*BR (Z + $\gamma$) in the Electron and Muon Channels with the 1992/1993 Data
R. Wagner et al.

PDK-544 Soudan 2 Experiment Quarterly Status Report, October-December 1992
D. Ayres

PDK-547 Proton and Negative Pion Interactions in Soudan 2
T. Fields

PDK-548 Soudan 2 Experiment Quarterly Status Report, January-March 1993
D. Ayres

PDK-551 Preliminary Specifications for the Long-Baseline Neutrino Oscillation Surface Building and Underground Cavity Area at Fermilab
D. Jankowski

PDK-552 Decisions of the Bellingham Collaboration Meeting, April 16-19, 1993
D. Ayres

PDK-559 Some Information About 3C273
M. Goodman

PDK-561 June 1993 Update to the 822 Proposal for a Long Baseline Neutrino Oscillation Experiment from Fermilab to Soudan
M. Goodman

WF-171 Conceptual Outline for Wakefield Diagnostic
M. Rosing

ZEUS Note 93-43 Study of Multi-jet Production in Deep Inelastic Scattering using Cluster Algorithms
S. Magill et al.

ZEUS Note 93-68 ZEUS Results from the First Year - DIS Cross Section and Hadronic Final States
Stephen R. Magill

# V. PUBLICATIONS

## July - December 1993

### A. Journal Publications, Conference Proceedings, Books (July - December 1993)

A Model of Universality Violation Revisited
T. Rizzo (ANL)
Phys. Rev. D48, p. 5286 (1993)

Analytic Multi-Regge Theory and the Pomeron in QCD: II. Gauge Theory Analysis
A. White, I. Knowles (ANL) and K. Kang (Brown U.)
Int'l. J. of Mod. Phys., A8, p. 4755 (1993)

Analyzing Power Measurement of pp Elastic Scattering in the Coulomb-Nuclear Interference Region with the 200 GeV/C Polarized-Proton Beam at Fermilab
ANL: D. P. Grosnick, D. A. Hill, M. Laghai, D. Lopiano, Y. Ohashi, T. Shima, H. Spinka, R. W. Stanek, D. G. Underwood, A. Yokosawa and the Fermilab E-581/704 Collaboration
Phys. Rev. D48, 3026 (1993)

Angular Dependence of Analyzing Power in np Elastic Scattering Between 0.312 and 1.10 GeV
ANL: D. Lopiano, H. Spinka and the Saclay Collaboration
Nucl. Phys. A559, p. 489 (1993)

Angular Dependence of the Beam and Target Analyzing Powers $A_{oonn}$ and $A_{ooon}$ in np Elastic Scattering Between 0.477 and 0.940 GeV
ANL: D. Lopiano, H. Spinka and the Saclay Collaboration
Nucl. Phys. A559, p. 477 (1993)

Angular Dependence of the Spin Correlation Parameter $A_{oonn}$ in np Elastic Scattering Between 0.8 and 1.1 GeV
ANL: D. Lopiano, H. Spinka and the Saclay Collaboration
Nucl. Phys. A559, p. 511 (1993)

Are There Atmospheric Neutrino Oscillations?
M. Goodman (ANL)
23rd ICRC Calgary 1993, Canada, edited by D. Leahy, p. 446 (1993)

Beam Tests of the ZEUS Barrel Calorimeter
ANL: M. Derrick, D. Krakauer, S. Magill,, B. Musgrave, J. Repond, R. Stanek, R. Talaga, J. Thron, and the ZEUS Collaboration
Nucl. Instru. Meth. A336, p. 23 (1993)

Bremsstrahlung Contributions to Hadronic $W^{\pm}\gamma$ and $Z\gamma$ Production
J. Ohnemus (ANL) and W. Stirling (Univ. of Durham)
Phys. Lett. B298, p. 230 (1993)

Can b $\rightarrow$ s$\gamma$ Close the Supersymmetric Higgs Production Window?
J. Hewett (ANL)
Phys. Rev. Lett. 70, p. 1045 (1993)

Center-of-Mass Angular Distribution of Prompt Photons Produced in p$\bar{p}$ Collisions at $\sqrt{s}$ = 1.8 TeV
ANL: R. Blair, K. Byrum, S. Kuhlmann, L. Nodulman, J. Proudfoot, R. Wagner, A. B. Wicklund, and the CDF Collaboration
Phy. Rev. Lett. 71, p. 679 (1993)

Constraints on Anomalous Gauge Boson Couplings from b $\rightarrow$ s$\gamma$
T. Rizzo (ANL)
Phys. Lett. B315, p. 471 (1993)

Constraints on New Physics from Tevatron Dijet Data
T. Rizzo (ANL)
Phys. Rev. D48, p. 4470 (1993)

Construction of a High Resolution Electron Beam Profile Monitor
J. Norem, J. Dawson, W. Haberichter, W. Novak (ANL)
Proceedings of the IEEE Particle Accelerator Conference, 17-20 May 1993 Washington, D.C., edited by S. T. Corneliussen (1993)

Contained $\nu$ Events Observed in Soudan 2
ANL: I. Ambats, D. Ayres, L. Balka, W. Barrett, J. Dawson, T. Fields, M. Goodman, N. Hill, J. Hoftiezer, D. Jankowski, F. Lopez, E. May, L. Price, J. Schlereth, J. Thron and the Soudan Collaboration
23rd ICRC Calgary 1993, Canada, edited by D. Leahy, p. 446 (1993)

Control, Timing, and Data Acquisition for the Argonne Wakefield Accelerator (AWA)
P. Schoessow, C. Ho, J. Power, E. Chojnacki (ANL)
Proceedings of the IEEE Particle Accelerator Conference, 17-20 May 1993 Washington, D.C., edited by S. T. Corneliussen (1993)

Direct Photon Production
E. Berger (ANL), X. Guo, J. Qui
Proceedings of the 7th Meeting of Division of Particles and Fields of the American Physical Society, edited by C.H. Albright, P.H. Kasper, R. Raja, J. Yoh, World Scientific, Singapore, p. 957 (1993)

Drive Linac for the Argonne Wakefield Accelerator
E. Chojnacki, R. Konecny, M. Rosing, J. Simpson (ANL)
Proceedings of the IEEE Particle Accelerator Conference, 17-20 May 1993 Washington, D.C., edited by S. T. Corneliussen (1993)

Extraction of Coupling Information from Z' $\rightarrow$ jj
T. Rizzo (ANL)
Phys. Rev. D48, p. 4236 (1993)

Final State Interaction of Longitudinal Vector Bosons
E. Berger (ANL), J-L Basdevant (Inst. de Phys.), D. Dicus (U. of Texas), C. Kao (Florida State), S. Willenbrock (FNAL)
Phys. Lett. B313, p. 402 (1993)

Inclusive $\chi_c$ and b-Quark Production in $\bar{p}p$ Collisions at $\sqrt{s}$ = 1.8 TeV
ANL: R. Blair, K. Byrum, S. Kuhlmann, L. Nodulman, J. Proudfoot, R. Wagner, A. B. Wicklund, and the CDF Collaboration
Phys. Rev. Lett 71, p. 2537 (1993)

Measurement of the Average Lifetime of B Hadrons Produced in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.8 TeV
ANL: R. Blair, K. Byrum, S. Kuhlmann, L. Nodulman, J. Proudfoot, R. Wagner, A. B. Wicklund, and the CDF Collaboration
Phys. Rev. Lett. 71 p. 3421 (1993)

Measurement of Bottom Quark Production in 1.8 TeV in $p\bar{p}$ Collisions Using Muons from b-Quark Decays
ANL: R. Blair, K. Byrum, S. Kuhlmann, L. Nodulman, J. Proudfoot, R. Wagner, A. B. Wicklund, and the CDF Collaboration
Phys. Rev. Lett. 71, p. 2396 (1993)

Measurement of Muons in the Soudan 2 Detector
ANL: I. Ambats, D. Ayres, L. Balka, W. Barrett, J. Dawson, T. Fields, M. Goodman, S. Heilig, N. Hill, J. Hoftiezer, D. Jankowski, F. Lopez, E. May, L. Price, J. Schlereth, J. Thron and the Soudan Collaboration
23rd ICRC Calgary 1993, Canada, edited by D. Leahy, p. 458 (1993)

Measurement of the Bottom Quark Production Cross Section Using Semileptonic Decay Electrons in $\bar{p}p$ Collisions at $\sqrt{s}$ = 1.8 TeV
ANL: R. Blair, K. Byrum, S. Kuhlmann, L. Nodulman, J. Proudfoot, R. Wagner, A. B. Wicklund, and the CDF Collaboration
Phys. Rev. Lett. 71, p. 500 (1993)

Measurement of the Dijet Mass Distribution in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.8 TeV
ANL: R. Blair, K. Byrum, S. Kuhlmann, L. Nodulman, J. Proudfoot, R. Wagner, A. B. Wicklund, and the CDF Collaboration
Phys. Rev. D48, p. 998 (1993)

Measurement of the Proton Structure Function F2 in e p Scattering at HERA
ANL: M. Derrick, D. Krakauer, S. Magill,, B. Musgrave, J. Repond, R. Stanek, R. Talaga, J. Thron, and the ZEUS Collaboration
Phys. Lett. B316, p. 412 (1993)

Mossbauer-Type Sum Rules for Heavy Quark Meson Decays
H. Lipkin (ANL and Weizmann Institute)
Nucl. Phys. A560, p. 548 (1993)

np-Elastic Analyzing Power $A_{NO}$ and Spin Transfer $K_{NN}$
H. Spinka (ANL) and the LAMPF Collaboration
Phys. Rev. C48, p. 256 (1993)

Observation of the Decay $B^o{}_s \rightarrow J/\psi\ \phi$ in $\bar{p}p$ Collisions at $\sqrt{s}$ = 1.8 TeV
ANL: R. Blair, K. Byrum, S. Kuhlmann, L. Nodulman, J. Proudfoot, R. Wagner, A. B. Wicklund, and the CDF Collaboration
Phys. Rev. Lett. 71, p. 1685 (1993)

Observation of Events with a Large Rapidity Gap in Deep Inelastic Scattering at HERA
ANL: M. Derrick, D. Krakauer, S. Magill,, B. Musgrave, J. Repond, R. Stanek, R. Talaga, J. Thron, and the ZEUS Collaboration
Phys. Lett. B315, p. 481 (1993)

Probing the Weak Boson Sector in $Z\gamma$ Production at Hadron Colliders
E. Berger (ANL), U. Bauer (Florida State U.)
Phys. Rev. D47, p. 4889 (1993)

Prompt Photon Cross Section Measurement in $\bar{p}p$ Collisions at $\sqrt{s}$ = 1.8 TeV
ANL: R. Blair, K. Byrum, S. Kuhlmann, L. Nodulman, J. Proudfoot, R. Wagner, A. B. Wicklund, and the CDF Collaboration
Phys. Rev. D48, p.2998 (1993)

QCD Calculation of $J/\psi + \gamma$ Mass Distributions
E. Berger(ANL) and K. Sridhar (CERN)
Phys. Lett. B317, p. 443 (1993)

Search for Excited Electrons Using the ZEUS Detector
ANL: M. Derrick, D. Krakauer, S. Magill,, B. Musgrave, J. Repond, R. Stanek, R. Talaga, J. Thron, and the ZEUS Collaboration
Phys. Lett. B316, p. 207 (1993)

Search for First-Generation Leptoquarks in $\bar{p}p$ Collisions at $\sqrt{s}$ = 1.8 TeV
ANL: R. Blair, K. Byrum, S. Kuhlmann, L. Nodulman, J. Proudfoot, R. Wagner, A. B. Wicklund, and the CDF Collaboration
Phys. Rev. D48, (Rapid Communications) p. 47 (1993)

Search for Quark Compositeness, Axigluons, and Heavy Particles Using the Dijet Invariant Mass Spectrum Observed in $p\bar{p}$ Collisions
ANL: R. Blair, K. Byrum, S. Kuhlmann, L. Nodulman, J. Proudfoot, R. Wagner, A. B. Wicklund, and the CDF Collaboration
Phys. Rev. Lett. 71, p. 2542 (1993)

Status of Soudan 2 Detector Experiment
ANL: I. Ambats, D. Ayres, L. Balka, W. Barrett, J. Dawson, T. Fields, M. Goodman, N. Hill, J. Hoftiezer, D. Jankowski, F. Lopez, E. May, L. Price, J. Schlereth, J. Thron, H. Trost, J. Uretsky and the Soudan Collaboration
23rd ICRC Calgary 1993, Canada, edited by D. Leahy, p. 688 (1993)

Supersymmetric Renormalization Group Fixed Points and Third Generation Fermion Mass Predictions
I. Knowles (ANL), C. Froggatt, R. Moorhouse (U. of Glasgow)
Phys. Lett. B258, p. 356 (1993)

Symmetry of Wavefunctions in Quantum Algebras and Supersymmetry
C. Zachos (ANL)
Proceedings of XXIst Int'l Conference on Differential Geometric Methods in Theoretical Physics, World Scientific, Vol. 2, Tianjin, China (1993)

The Argonne Wakefield Accelerator (AWA) Laser System and Its Pulse Shaper
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Proceedings of the IEEE Particle Accelerator Conference, D.C., 17-20 May 1993
Washington, D.C., edited by S. T. Corneliussen (1993)

The Argonne Wakefield Accelerator-Overview and Status
P. Schoessow, E. Chojnacki, W. Gai, C. Ho, R. Konecny, J. Power, M. Rosing, J. Simpson (ANL)
Proceedings of the IEEE Particle Accelerator Conference, 17-20 May 1993
Washington, D.C., edited by S. T. Corneliussen (1993)

The $\eta_6$ at LEP and TRISTAN
A. White, I. Knowles (ANL), K. Kang (Brown U.)
Mod. Phys. Lett. A8, p. 1611 (1993)

The Light Hadron Spectrum of Quenched QCD on a $32^3 \times 64$ Lattice
S. Kim, D. Sinclair (ANL)
Phys. Rev. D48, p. 4408 (1993)

## B. *Papers Submitted for Publication and ANL Reports (July - December 1993)*

Energy Dependence of Hadronic Activity
P. Job (ANL), T. Gabriel (Oak Ridge), D. Groom (LBL), N. Mokhov (IHEP), and G. Stevenson (CERN)
ANL-HEP-PR-93-69
Submitted to Nucl. Instru. and Meth.

Simulation of The Reconfigurable-Stack Test Calorimeter Experiments with CALOR89
P. Job, L. Price, J. Proudfoot (ANL); T. Handler (Univ. of Tenn.) T. Gabriel (Oak Ridge)
ANL-HEP-PR-93-80
Submitted to Nucl. Instru. and Meth.

Currents, Charges, and Canonical Structure of Pseudodual Chiral Models
C. Zachos (ANL) and T. Curtright (Univ. of Miami)
ANL-HEP-PR-93-85
Submitted to Phys. Rev. D

Model Dependence of $W_R$ Searches at the Tevatron
T. Rizzo (ANL)
ANL-HEP-PR-93-87
Submitted to Phys. Rev. D

## C. *Papers or Abstracts Contributed to Conferences (July- December 1993)*

Bubble Chamber Measurements of Cascade Times in Mesic Atoms
T. Fields
ANL-HEP-CP-93-76
Submitted to the Proceedings of the Conference on the Bubble Chamber and Its Contributions to Particle Physics, CERN, Geneva Switzerland

Giant Chambers
M. Derrick (ANL)
ANL-HEP-CP-93-78
Submitted to the Proceedings of the Conference on the Bubble Chamber and Its Contributions to Particle Physics, CERN, Geneva Switzerland

Automatic Scanning and Measuring Using POLLY
T. Fields
ANL-HEP-CP-93-79
Submitted to the Proceedings of the Conference on the Bubble Chamber and Its Contributions to Particle Physics, CERN, Geneva Switzerland

Rescattering and Energy Loss of Fast Partons in Nuclear Matter
T. Fields (ANL) and M. Corcoran (Rice Univ.)
ANL-HEP-CP-93-86
Submitted to the Proceedings of the Marseille European Physical Society Conference, Marseille, France

Proceedings of the Workshop on Physics at Current Accelerators and Supercolliders
J. Hewett, A. White, D. Zeppenfeld (ANL)
ANL-HEP-CP-93-92

Report of the Subgroup on the Top Quark
L. Nodulman (ANL) and C. Yuan (Michigan State)
ANL-HEP-CP-93-94
Submitted to the Proceedings of the Workshop on Physics at Current Accelerators and Supercolliders, Argonne, IL

Monte Carlo Event Generators for Hadron-Hadron Collisions
I. Knowles (ANL) and S. Protopopescu (BNL)
ANL-HEP-CP-93-95
Submitted to the Proceedings of the Workshop on Physics at Current Accelerators and Supercolliders

Progress in SSC Higgs Physics: Report of the Higgs Working Group
R. Blair, J. Hewett, T. Rizzo (ANL) J. Gunion (Davis Inst. for HEP), *et al.*
ANL-HEP-CP-93-96
Submitted to the Proceedings of the Workshop on Physics at Current Accelerators and Supercolliders

Elastic Spin Observables and Proton Wave Function Normalization at Large t
G. Ramsey (ANL)
ANL-HEP-CP-93-93
Submitted to the Proceedings of the V International Workshop in High Energy Spin Physics, Protvino, Russia

Quenched QCD Spectrum on a $32^3 \times 64$ Lattice
S. Kim and D. Sinclair (ANL)
ANL-HEP-CP-93-98
Submitted to LATTICE 93: Proceedings of the International Symposium on Lattice Field Theory, Dallas, Texas

Deep Inelastic Scattering Results from the First Year of Hera Operation
S. Magill (ANL)
ANL-HEP-CP-93-99
Submitted to the Proceedings of the Workshop on Physics at Current Accelerators and Supercolliders

Matrix Elements for the Decays of S- and P-Wave Quarkonium: an Exploratory Study
G. Bodwin, S. Kim, and D. Sinclair (ANL)
ANL-HEP-CP-93-102
Lattice 93: Proceedings of the International Symposium on Lattice Field Theory, Dallas, TX, 12-17 October 1993

Physics at HERA
M. Derrick (ANL)
ANL-HEP-CP-93-105
Submitted to XXIII Int'l Symposium on Multiparticle Dynamics, Aspen Colorado, (September 12-17, 1993)

ANL/WSU Radiation Damage Studies
D. Jankowski, D. Lopiano, J. Proudfoot, D. Underwood (ANL);and L. Miles, J. Neidiger, G. Tripard (Washington State Univ.)
ANL-HEP-CP-93-107
Submitted to SCIFI93: Workshop on Scintillating Fiber Detectors, Notre Dame, Indiana

## D. *Technical Notes (July - December 1993)*

Thermal Distortion Tests of Aluminum and Stainless Steel Plates
E. Bielick, T. Fornek, H. Spinka, and D. Underwood (ANL)
ANL-HEP-TR-93-55, Star Note #118

STAR Electromagnetic Calorimeter R&D Progress Report
H. Spinka (ANL)
ANL-HEP-TR-93-73

A Conceptual Design for the STAR Endcap Electromagnetic Calorimeter
E. Bielick, T. Fornek, H. Spinka, and D. Underwood (ANL)
ANL-HEP-TR-93-62, Star Note #120

High Energy Physics Division Semiannual Report of Research Activities January 1, 1993 - June 30, 1993
R. Wagner, P. Moonier, P. Schoessow and R. Talaga (ANL)
ANL-HEP-TR-93-88

$W^{\pm}$ and $Z^{o}$ Event Rates and Background Estimates for the STAR Detector at RHIC in pp Collisions
V. Rykov and K. Shestermanov (IHEP)
ANL-HEP-TR-93-89

Selection and Characterization of Lead Alloys for Use in the SDC EM Calorimeter
J. Nasiatka (ANL)
ANL-HEP-TR-93-90

An Electromagnetic Calorimeter for the Solenoidal Tracker at the Relativistic Heavy Ion Collider
D. Underwood (ANL) and G. Westfall (Michigan State Univ.)
ANL-HEP-TR-93-97

Proposal for the Completion of Outstanding Work on the Mechanical Absorber Structure of SDC Barrell Electromagnetic Calorimeter
V. Guarino, N. Hill, T. Kicmal, J. Nasiatka, E. Petereit, L. Price, J. Proudfoot, R. Stanek (ANL) and D. Scherbarth (Westinghouse Sci. and Tech. Ctr.)
ANL-HEP-TR-93-100

Proposal for the Completion of Outstanding Work on the Installation Scheduling and Alignment of SDC Center Calorimeter
V. Guarino, N. Hill, T. Kicmal, J. Nasiatka, E. Petereit, L. Price (ANL)
ANL-HEP-TR-93-101

AGN-25 The AWA Linac Chiller and Frequency Response
C. Ho, M. Rosing

AGN-26 Frequency Response of AWA Modulator Voltage - Frequency Signal Converters
E. Chojnacki

AGN-27 Wakefield Technical Drawing Categorization
E. Chojnacki

AGN-28 Witness Gun Temperature Stabilization
M. Rosing

CDF Note 2159 Direct Photon Results from CDF
CDF Collaboration, C. Hawk. S. Kuhlmann

CDF Note 2195 Implications of the CDF Diphoton Measurements for the SSC
R. Blair

CDF Note 2196 Proposal for a Special Run at $\sqrt{s}$ = 630 GeV
T. Lecompte, S. Kuhlmann, S. Behrends, B. Flaugher, J. Huth, R. Plunkett

CDF Note 2214 Isolation Cut Efficiency in Direct Photon Analysis
A. Maghakian, S. Kuhlmann

CDF Note 2229 Measurement of QCD Background in the $W\gamma/Z\gamma$ Analysis
R. Wagner, D. Benjamin, S. Errede, M. Lindgren, T. Muller, D. Neuberger, M. Vondracek

CDF Note 2234 Analysis of Charm + Photon Events (I)
S. Kuhlmann, B. Flaugher, R. Oishi

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| CDF Note 2239 | A Measurement of the Photon-Muon Cross Section<br>R. Hamilton, D. Crane, B. Flaugher, J. Huth, S. Kuhlmann, J. Troconiz |
| CDF Note 2280 | A Study of Time Drifts in the CEM Using Calibration Data for the 1992-93 Run<br>S. Hahn, M. Hohlmann, G. Houk, D. Saltzberg |
| CDF Note 2291 | Tuning up CEM Using Inclusive Electrons<br>L. Nodulman, K. Byrum |
| CDF Note 2295 | Prospects For Measuring $B_s$ Mixing at CDF<br>J. Skarha, B. Wicklund |
| CDF Note 2300 | Standard Overlay Slides for Ymon<br>L. Nodulman |
| CDF Note 2313 | A High-Statistics Look at Minimum Bias Data From Run Ia<br>H. Frisch, M. Hohlmann |

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| PDK-563 | Soudan 2 Experiment Quarterly Status Report, April-June 1993<br>D. Ayres |
| PDK-566 | Progress in the Search for Neutrinos from Active Galactic Nuclei<br>A. Ryerson, M. Goodman |
| PDK-569 | Muons in the Soudan Mine<br>J. Uretsky |
| PDK-571 | Soudan 2 Experiment Quarterly Status Report, July-September 1993<br>D. Ayres |
| PDK-572 | Decisions of the Minneapolis Collaboration Meeting, October 1-5, 1993<br>D. Ayres |

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|---|---|
| WF-172 | Propagation of Short Electron Pulses in Underdense Plasmas<br>N. Barov, J. Rosenzweig |
| WF-173 | Parameter Study for a Step-up Dielectric Wakefield Accelerator Experiment at the AWA<br>W. Gai, J. Simpson |

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|---|---|
| ZEUS Note 93-78 | A Determination of $F_2$ with the 1992 Data<br>J. Repond et al. |
| ZEUS Note 93-94 | Study of Global Event Shape Distributions Using the ZEUS Calorimeter<br>B. Musgrave et al. |
| ZEUS Note 93-130 | A First Look at Multiplicity Distribution in DIS Events with 1993 CTD Data<br>M. Derrick et al. |

# *VI. COLLOQUIA AND CONFERENCE TALKS*

D. Ayres

"Nucleon Decay and Other Physics at the Soudan Mine"
ANL Physical Research Highlights Colloquium (October 1993)

R. Blair

"Diphoton Physics at CDF"
Michigan State Unviersity (October 1993)

G. Bodwin

"A Lattice Method for Chiral Fermions"
University of Kentucky (November 1993)

J. Dawson and R. Talaga

"A Sub-Nanosecond SRTD First Level Trigger for the Zeus Detector at HERA"
Nuclear Science Symposium, San Francisco

M. Derrick

"Giant Chambers"
CERN Bubble Chamber Conference CERN, Geneva, Switzerland (July 1993)

"Physics at HERA"
Aspen Multiparticle Conference, Aspen, CO (September 1993)

"Physics at ZEUS"
Argonne HEP Seminar (October 1993)
University of Pittsburgh (October 1993)
University of Kansas (October 1993)
University of Minnesota (October 1993)

T. Fields

"Bubble Chamber Measurements of Cascade Times in Atoms"
Conference on History of the Bubble Chamber, CERN, Geneva, Switzerland (July 1993)

"Rescattering and Energy Loss of Fast Partons in Nuclear Matter"
European Physical Society, Marseille, France (July 1993)

"The Underground Frontier of HEP"
University of Illinois at Chicago (October 1993)

## M. Goodman

"Atmospheric Neutrinos"
Division of Nuclear Physics Annual Meeting, Asilomar, CA (October 1993)

"Status of the Proposal for a Long Baseline Neutrino Oscillation Experiment from Fermilab to Soudan"
Argonne-HEP Seminar (November 1993)

## S. Kim

"Quenched QCD Spectrum on a $32^3$ x 64 Lattice"
XI International Symposium on Lattice Field Theory, Dallas, TX (October 1993)

## S. Kuhlmann

"Recent Resulls on QCD from CDF"
9th Topical Workshop on Proton-Antiproton, Tsukuba, Japan (October 1993)

## L. Nodulman

"Physics Considerations on Calorimeters in SDC"
"Photon Physics at CDF"
INFN, Pisa, Italy (July 1993)

## J. Norem

"Beam Profile Monitors at the Linear Collider IP"
"Laser Noise Eaters"
SLAC Linear Collider Workshop, LC93 SLAC, Stanford, CA (October 1993)

"High Resolution Beam Profile Measurements for a Linear Collider Final Focus"
Linear Collider Workshop (LC93) SLAC (October 1993)

"Laser Stabilization using Active and Passive Noise Eaters"
Linear Collider Workshop (LC93) SLAC (October 1993)

"A Proposed FFTB Experiment to Measure the Final Focus Profile"
SLAC, Stanford, CA (November 1993)

"A Proposal to Test a High Resolution, Single Bunch, Beam Profile Monitor at the SLAC Final Focus Test Beam"
EPAC Meeting, San Francisco, CA (November 1993)

## L. Price

"European connectivity requirements"
ESnet Steering Committee, Gaithersburg, Md., (December 1993)

J. Repond

"Recent Results from the ZEUS Experiment at HERA"
CNRS Strasbourg, France (November 1993)

D. Sinclair

"Matrix elements for the decays of S- and P-wave quarkonium: an exploratory study"
LATTICE '93, Dallas, Texas

H. Spinka

"The Electromagnetic Calorimeter for STAR"
JINR, Dvona, Russia (November 1993)
MEPHI, Moscow, Russia (November 1993)
IHEP, Protvino, Russia (November 1993)

A. White

"Light Quarks and the soft Pomeron in QCD"
Topical Meeting on QCD at HERA, Hamburg, Germany (October 1993)

# *VII. HIGH ENERGY PHYSICS COMMUNITY ACTIVITIES*

E. Berger

Member, Committee on Meetings, American Physical Society, 1991-
Member, High Energy Physics Advisory Panel 1991-
Member, Department of Energy Strategic Planning Team for Science and Technology, 1993-4;
Table Leader for the Focus Area Fundamental Research in Energy and Matter
Member, U.S. Contact person, Scientific Program Committee, XXIX Recontre de Moriond, "QCD and High Energy Hadronic Interactions", Meribel, France, March 1994
Organizing Committee, Fifth Conference on the Intersections between Particle and Nuclear Physics, St. Petersburg, FL, May 1994

M. Derrick

Organizing Committee, Jet Workshop at Fermilab
Organizing Committee, 24th International Conference on Multiparticle Dynamics December 1993, Vietni sul mare, Italy, September 1993

T. Fields

Organizing Committee for Symposium on 30th Anniversary of ZGS, Argonne National Laboratory, May 6, 1994

S. Kuhlmann

Organizing Committee, "QCD at 2 TeV" Workshop at Michigan State University, September 29 - October 1, 1993

S. Magill

Co-chairman of Organizing Committee - Workshop on Jet Production in Deep Inelastic Scattering on Nucleons and Nuclei, Fermilab, December 3-4, 1993

L. Nodulman

Subgroup report editor, Workshop on Physics at Current Accelerators and Supercolliders, Top Subgroup (with C.-P. Yuan), ANL, June 1993

L. Price

Member, Esnet Steering Committee

Member, SSC Detector R&D Committee

Member, SSC Computer Planning Committee

Chairman, ANL Computer and Information Policy Committee

A. White

Co-chairman, XXIII International Symposium on Multiparticle Dynamics, Aspen, Colorado, September 12-17, 1993

# VIII. HIGH ENERGY PHYSICS RESEARCH PERSONNEL

*Administration*

L. Price
P. Moonier

*Accelerator Physicists*

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

*Experimental Physicists*

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

*Theoretical Physicists*

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

*Engineers, Computer Scientists and Applied Scientists*

E. Chojnacki
J. Dawson
V. Guarino
W. Haberichter
N. Hill
J. Nasiatka
J. Schlereth
X. Yang

*Technical Support Staff*

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

*Laboratory Graduate Participants*

C. Allgower
H. Gallagher
M. Hohlmann
H. Huang
J. Power