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HIGH ENERGY PHYSICS DIVISION SEMIANNUAL REPORT OF RESEARCH ACTIVITIES

July 1, 2000 - December 31, 2000

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Abstract

This report describes the research conducted in the High Energy Physics Division of Argonne National Laboratory during the period of July 1, 2000 - December 31, 2000. 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.

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I. EXPERIMENTAL RESEARCH PROGRAM

I.A. EXPERIMENTS WITH DATA

I.A.1 Medium Energy Physics Program

The primary focus of the spin physics group during the period July - December 2000 was on the STAR endcap electromagnetic calorimeter (EEMC) project, and the shower maximum detector (SMD) for the EEMC, which is Argonne's responsibility. ANL physicists also participated in a successful spin commissioning run at RHIC. Papers from past experiments in nucleon-nucleon scattering at Saclay and measurements with the Crystal Ball at the AGS were also submitted and published.

A major milestone was achieved with the final extrusion of the polystyrene based scintillator strips for the SMD modules. The steps included mixing various chemicals and dopants with polystyrene pellets and reforming the mixture into new pellets. These were used in a test extrusion to fine tune the die dimensions, and then the final extrusion of 350 - 400 kg of scintillator strips took place. The strips are triangular in cross section, with a nominal base width of 10 mm and peak to base height of 7 mm. A 1 mm diameter hole for wavelength shifter fibers was extruded in the center of the triangle. Significant assistance was obtained from Fermilab scientists, who have previously worked on extruded scintillator for D0 and MINOS.

Many of the strips were wrapped in aluminized mylar using a winding machine at the Indiana University Cyclotron Facility. These were glued into test modules planned for insertion into an electron test beam at SLAC. Other gluings were also performed to develop methods to produce better quality modules.

Another major task was the construction of a cosmic ray test facility. The main purpose will be to map the response of the SMD modules once they are constructed. This mapping will be done strip by strip, as a function of position along the strips; an exponential decrease with decay distance of a few meters is expected. The unistrut support for the scintillation counters and multiwire proportional chambers (MWPCs) was completed. Two large MWPCs with active areas 0.76m X 1.02m were mounted on the support and attempts to repair all broken wires are presently underway. Two sets of seven existing plastic scintillation counters with photomultipliers on each end were mounted, cabled, and plateaued. A data acquisition system was set up, and the MWPC and ADC electronics were successfully read.

Argonne physicists were actively involved in a several week run for RHIC spin commissioning. The AGS polarimeter, consisting of a considerable amount of ANL hardware, was checked out and operated during the whole period. A major improvement was to provide control of many of the polarimeter functions from the AGS/RHIC control room. During this commissioning run, a new polarized ion source was used, and the beam was accelerated through the AGS with less polarization loss than previously from slightly above injection to the extraction momentum (24 GeV/c). Polarized protons were then delivered to one of the RHIC rings and stored. The beam polarization was measured at the RHIC injection energy with no snake magnet current, and also with this magnet ramped up to its nominal setting. Measurements indicated the beam was still polarized after acceleration to 30 GeV/c, but no asymmetry was observed (or expected) at 100 GeV/c. Future runs will have two snake magnets in each beamline, spin rotator magnets near the two large detectors (STAR and PHENIX), and other hardware.

The RHIC absolute polarization is presently tied to an AGS experiment, E925, run by a collaboration including our group and led by A. Yokosawa from ANL. An elastic scattering polarimeter in the extracted polarized proton beam was part of E925. Partial results of this experiment have been published. The final paper was begun by several physicists, including significant work by C. Allgower of ANL, and was to be completed by a BNL scientist. This task has now passed to two other ANL physicists to complete.

A paper on Saclay pp elastic scattering spin measurements was submitted for publication, and a second one published in this period (C.E. Allgower, *et al.*, Phys. Rev. **C62**, 064001 (2000)); both were written by an ANL physicist. The polarized beam -polarized target spin correlation parameter A_oonn was measured at many energies over a c.m. angular range ~ 60 - 100 degrees. The 90 degree values are plotted in Figure 1 and show a generally smooth behavior as a function of beam kinetic energy. Results from other experiments are also shown for comparison. A model prediction by E.L. Lomon is shown as the solid curve. This cloudy bag model includes nucleon-nucleon resonances and background partial waves. The prediction corresponds to one choice of the relative phase between the pp resonance amplitude (1S0 partial wave) and the background amplitude. The energy-dependent structure predicted is similar in shape to the data, but with marginal statistical significance, and perhaps is displaced in beam energy by ~160 MeV.

A paper was also submitted and accepted for publication from the Crystal Ball experiments ("A Measurement of Neutron Detection Efficiencies in NaI Using the Crystal Ball Detector", T.D.S. Stanislaus, *et al*.). This paper was the result of a collaborative effort between primarily Valparaiso University and ANL physicists. A second paper was published ("Measurement of pi0 pi0 Production in the Nuclear Medium by pi- Interactions at 0.408 GeV/c", A. Starostin, *et al*., Phys. Rev. Lett. **85**, 5539 (2000)). These results did not agree with those of the CHAOS collaboration in the inclusive pi+ pi- invariant mass spectrum. The data suggest that the pi0 pi0 interaction diminishes in the nuclear medium with increasing mass compared to hydrogen. A third paper is nearly ready to be submitted for publication.

Finally, several papers about heavy-ion physics measurements with the STAR detector at RHIC are about to be submitted for publication. A paper on elliptic flow in Au+Au collisions has been accepted.

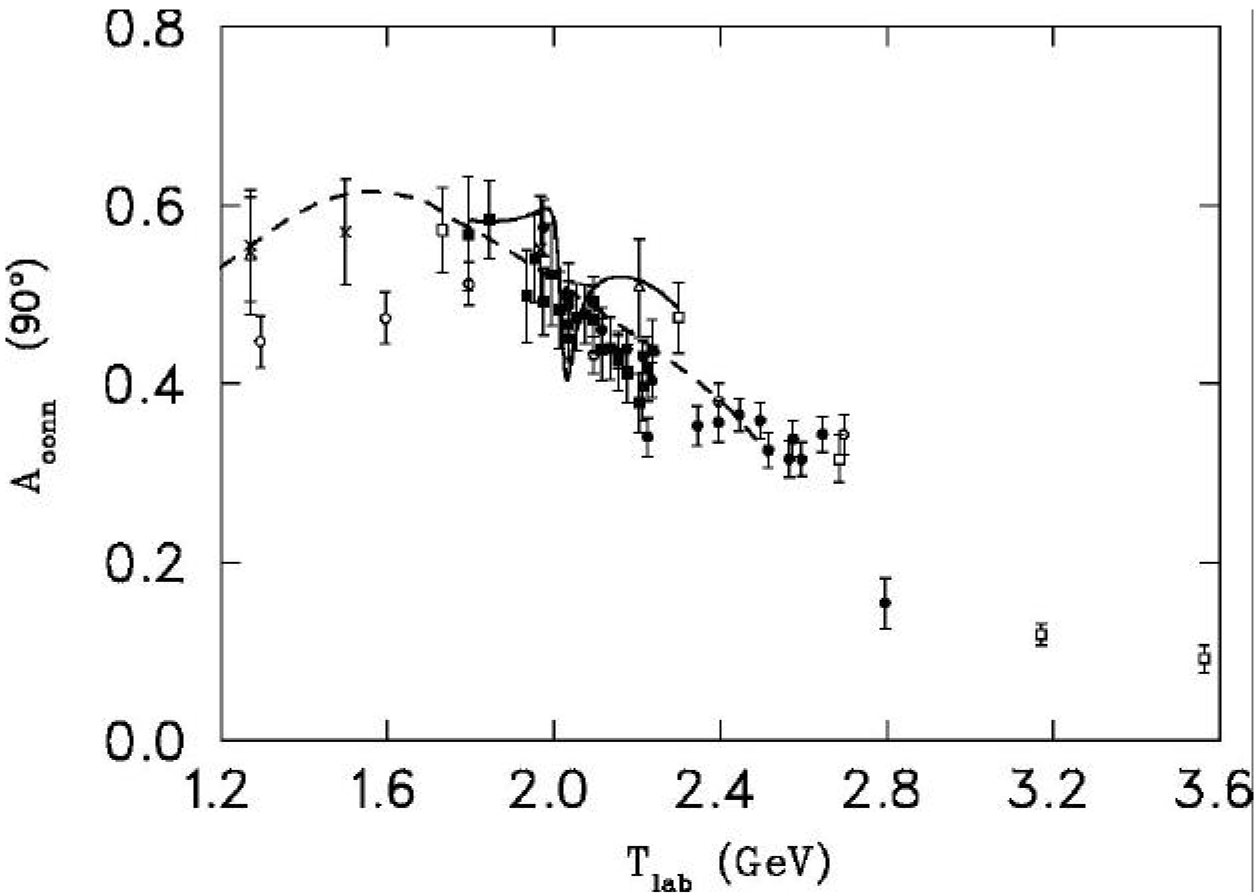

Figure 1. Experimental values of A_oonn at 90 degrees c.m. for pp elastic scattering, computed from data between 85 and 95 degrees. The solid circles and squares are from the Saclay measurements. The crosses are from Bell, *et al*.; the open squares from Lin, *et al*.; the open triangles from Miller, *et al*.; and the open circles from Lehar, *et al*. The dashed curve is a phase shift analysis prediction from Arndt, *et al*., and the solid curve is from E.L. Lomon.

(H. M. Spinka)

I.A.2 Collider Detector at Fermilab

a. Physics Results

The emphasis of the collaboration has largely shifted to getting the detector going for Run II. Some Run I analyses remain to be completed and submitted for publication. Will Bell is continuing to progress on his thesis analysis limit on the branching fraction for $B-S \rightarrow y h'$. Barry Wicklund completed his term as B physics convener, overseeing many such analyses. Bob Blair continues as QCD physics convener, where a few analyses remain pending. Steve Kuhlmann continues to help prepare the photon muon and inclusive photon analyses for publication.

b. Run II Planning

The Run II physics workshops were largely completed and written up. Steve Kuhlmann has taken a leading role in QCD issues as well as optimizing two *b* jet mass resolutions for Higgs searches. Thanks to a few four-jet events at Aleph, the Higgs search has become the flagship analysis of Run II. Larry Nodulman has been involved in the electroweak write-up, on *W* mass issues. The *b* physics workshop, organized with Barry Wicklund as one of the principal organizers, has write-up contributions from Karen Byrum and Will Bell on projections of possible CDF results from Run II on extending the transverse momentum reach for b production measurement and searching for $B_s \rightarrow y h'$.

(L. J. Nodulman)

I.A.3 Non-Accelerator Physics at Soudan

The existence of baryon-number violating processes is a generic prediction of Grand Unified Theories that attempt to unify the fundamental forces. Such processes can lead to nucleon decay into a non-baryonic system, with $\Delta B = 1$, or even to neutron oscillation into an anti neutron, with $\Delta B = 2$. No convincing experimental evidence for any of these processes has been reported, despite ever more sensitive searches using very large underground detectors (Groom, 2000).

Detailed imaging of non-relativistic as well as of relativistic tracks enables efficient identification and (kinematic) analysis of events which have four or more final state "prongs" (tracks/ showers). These high multiplicity final states are well suited to searching for neutron oscillation, since the resulting antineutron would collide with a baryon in the surrounding environment, and the subsequent $\overline{n} - N$ (where N = n or p) annihilation will usually yield a multipion final state. Here we describe a new search for baryon-number violating processes using the 5.56 fiducial kiloton year (6.96 kTy total exposure) of the Soudan 2 iron tracking calorimeter.

Most multiprong final states contain several pions. Secondary scatterings of pions are likely, both within the (iron) nucleus where the pions were produced, and as (charged) pions traverse the iron sheets of the detector. These secondary scatterings will often alter the number of prongs of the observed event, as well as its visible energy and momentum, so that it becomes difficult and inefficient to isolate a specific multipion final state. Our simulations of events arising from atmospheric neutrino oscillations or nucleon decay or $\overline{n} - N$ annihilation include a detailed model of intranuclear scattering of final state pions. Because secondary scatterings can alter the number of visible prongs, and because of the small numbers of data events, we have carried out an analysis which is inclusive of several kinds of observed event topologies.

Data acquired during a detector exposure of 5.56 kTy was processed through our standard data reduction chain. Randomly interspersed with data events were simulated events induced by atmospheric neutrino interactions. This simulation of the major background was based upon the Bartol model of atmospheric neutrino fluxes, and took into account both elastic and inelastic neutrino scattering, as well as the detailed imaging properties of the Soudan 2 detector. These background "n MC events" were treated identically to real data events at each step of the data analysis chain.

Several systematic uncertainties must be considered when using these n MC events as a measure of the background in our searches. Among these are normalization and solar cycle uncertainties in the atmospheric neutrino flux, possible effects of neutrino flavor oscillation upon the atmospheric muon neutrino flux, effects of poorly known partial cross sections for inelastic neutrino interactions at energies less than a few GeV, and uncertainties in intranuclear pion scattering effects in the final state.

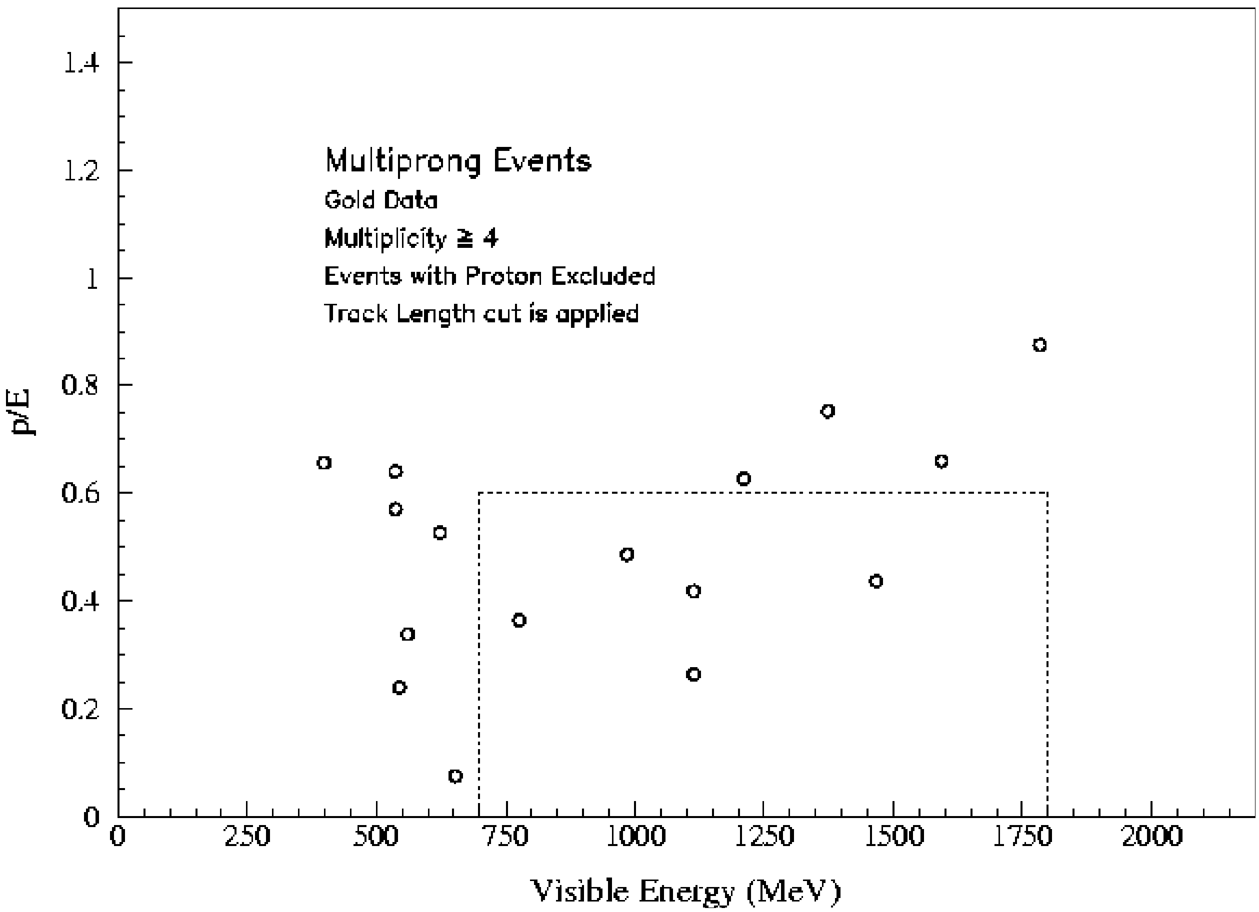

Figure 1. Data candidate $\bar{n} - N$ events after topology cuts.

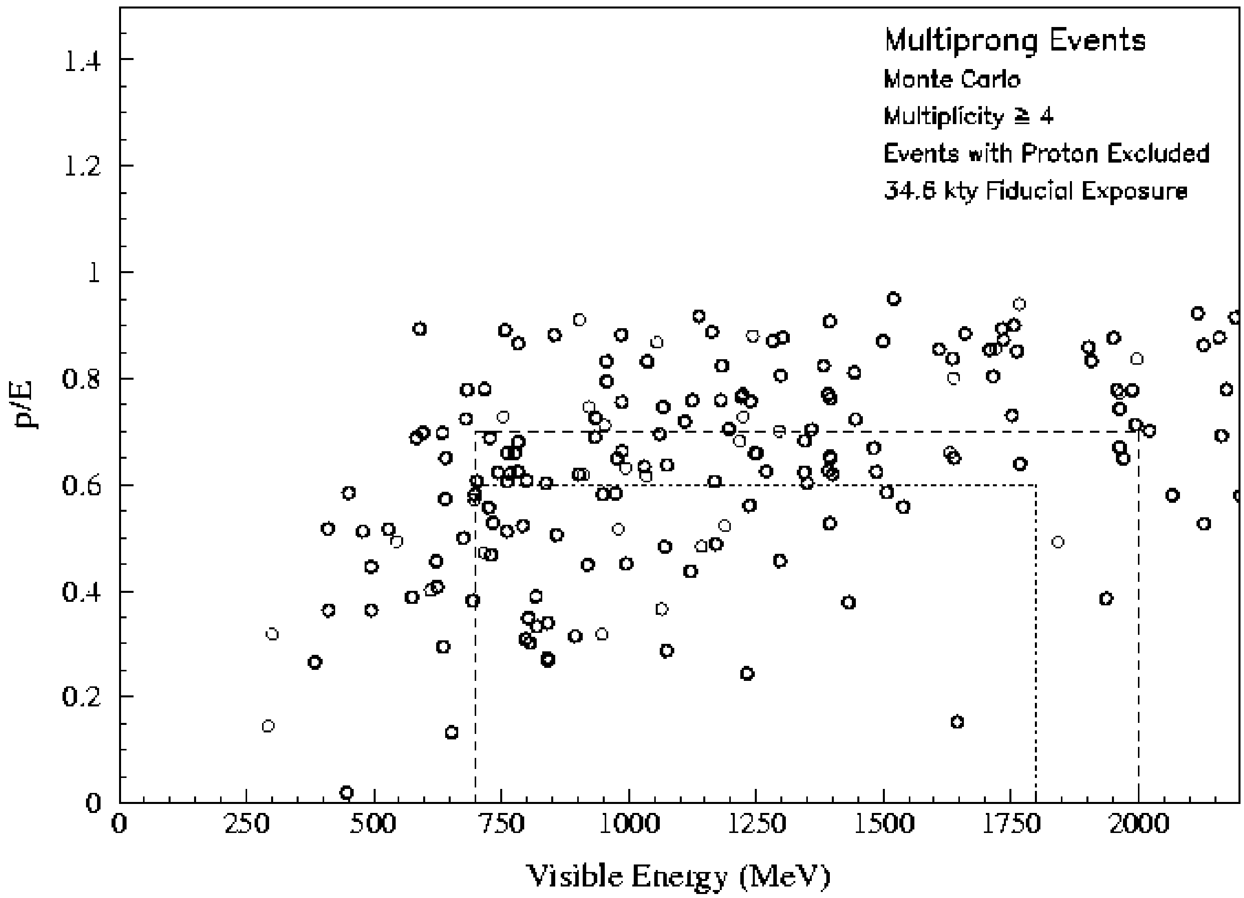

Figure 2. Monte Carlo neutrino events after $\bar{n} - N$ topology cuts.

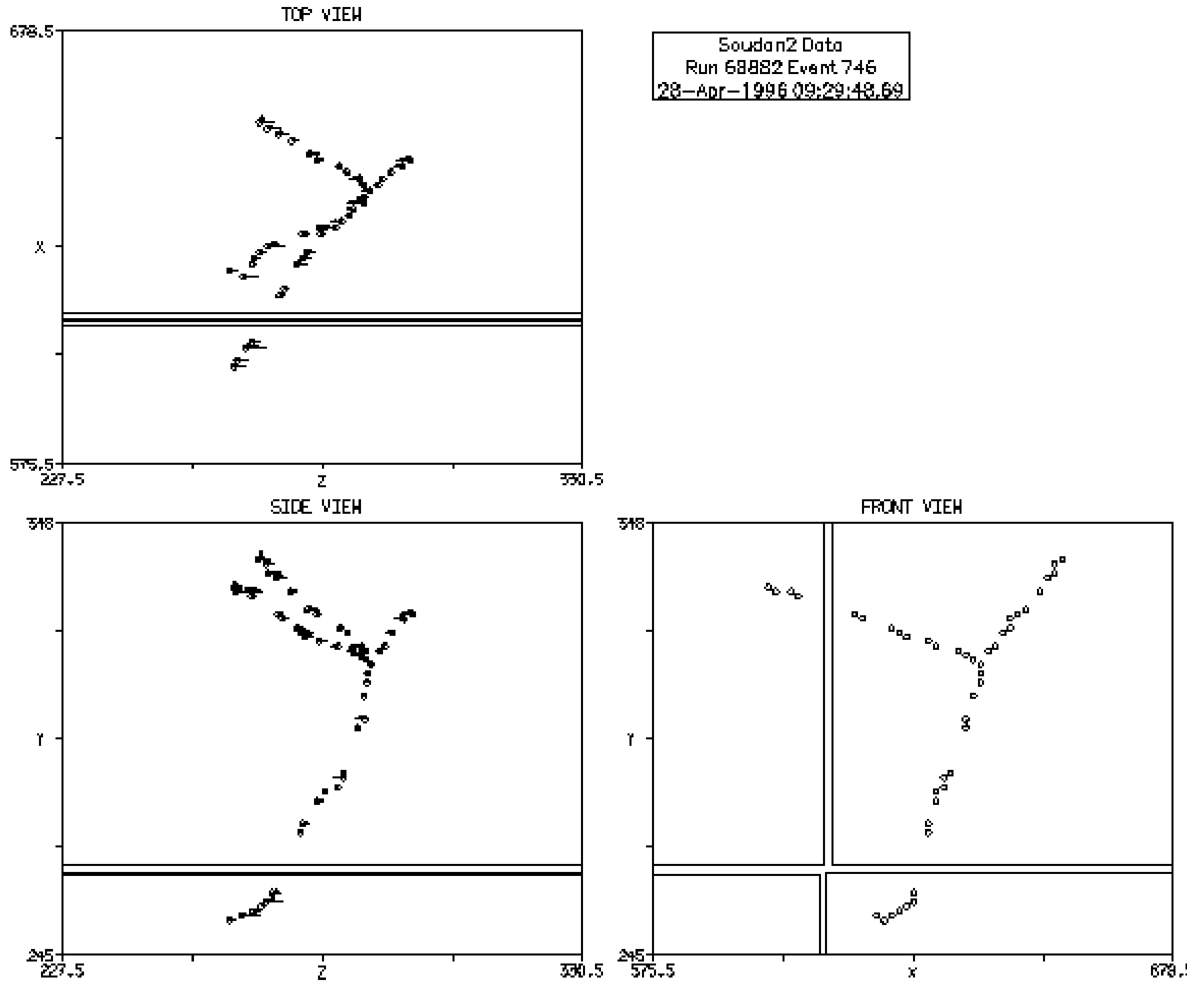

Figure 3. Data Event. Axes are in centimeters.

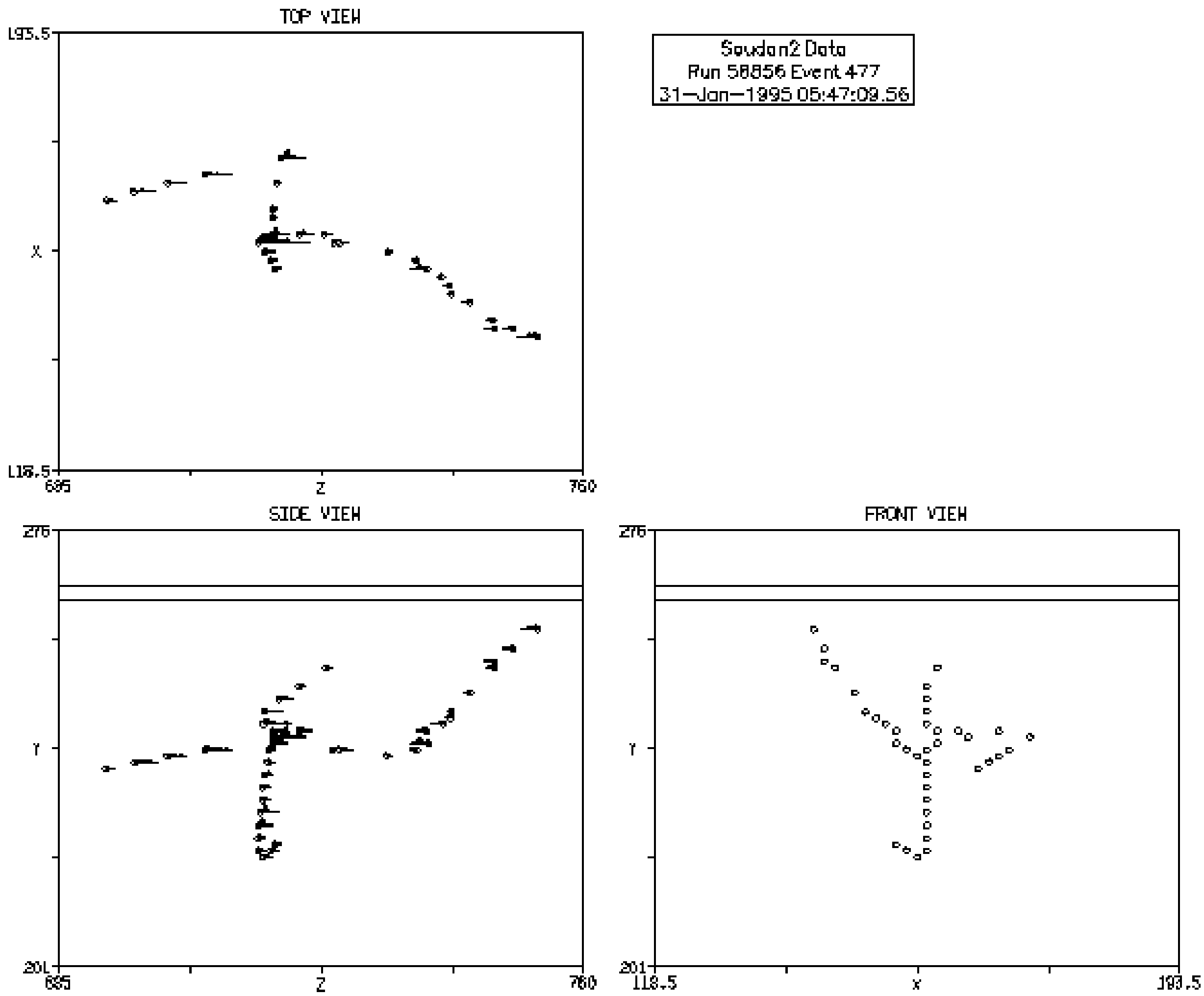

Figure 4. Data Event. Axes are in centimeters.

Two important event parameters which were used in this analysis are E_{vis}, the summed total energy of the visible final state prongs, and P_{net}, the vector sum of their 3-momenta. Electromagnetic showers were distinguished from muon and hadron tracks by their geometric structure.

The following topological selections were imposed upon all data events and simulated events: a) at least 4 prongs, including both prompt and remote prongs; b) no proton track; c) for nbar-n candidates, no non-scattering track of length >150 cm; and d) for nucleon decay candidates, at least 3 of the prongs must be tracks, not showers.

Then the "signal" regions were defined by the following kinematic requirements. For nucleon decay candidates, $700 < E_{vis} < 1000$ MeV and $P_{net} < 400$ MeV/c. For $\bar{n}$ annihilation events, $700 < E_{vis} < 1800$ ~MeV and $P_{net}/E_{vis} < 0.6$. These regions were chosen based upon detailed simulations of the physics of the processes being searched for, and represent compromises between high detection efficiency and good background rejection.

Figure 1 shows the distribution of the 16 data events, and Figure 2 shows the corresponding distribution for n MC events for a much larger exposure. (There is also a small background that we subtract from the data due to neutrons originating in the rock walls of the cavern.

For nucleon decay, we find no candidate events and 0.3 (normalized) n background MC events. The average estimated detection efficiency for various lepton plus 3 pion final states is $3.0 \pm 1.5\%$, corresponding to a 90% CL lower limit on nucleon lifetime / branching ratio of 6 x 10^{31} yr. For multiparticle final states with fewer pions, the estimated efficiency rises to $20 \pm 10\%$, and the limit for t /B becomes 4×10^{32} yr.

For neutron oscillation, the estimated detection efficiency is $18 \pm 2\%$. Figure 1 shows that there are five events in the selected region, and our preliminary estimate of the n MC background shown in Figure 2 is also approximately five events after normalization. Thus we have no evidence for a signal due to n oscillation.

Calorimeter views of two (of the five) data events which are in the selected $\bar{n} - n$ kinematical region of Figure 1 are shown in Figures 3 and 4. These two events are only slightly outside of the kinematic acceptance region which we had chosen (a priori) for nucleon decay. We have therefore analyzed these two events with particular care.

The four-track event in Figure 3 has E_{vis} of about 1100 MeV if each track is either a pion or a muon. If one of the visible tracks was in fact an electron, E_{vis} would be about 1000 MeV, which is the edge of our acceptance region for nucleon decay. However, detailed track shape measurements disfavor the electron hypothesis.

The event shown in Figure 4 has three tracks and two showers. Two of the tracks undergo large angular deflections in flight. We analyzed this event as a possible example of p goes to $m^{+}K_{s}{}^{0}p^{0}$. However, its P_{net} is 469 MeV/c, assuming that the scatterings of the two tracks are elastic. This is above our proton decay acceptance limit of 400 MeV/c. If the scatterings are inelastic, P_{net} will be even larger.

(M. C. Goodman)

I.A.4 ZEUS Detector at HERA

a. Physics Results

Three papers were published in this period and two more manuscripts were submitted for publication. In the following we shall summarize briefly the published papers.

i) Measurement of the Proton Structure F_2 at Very Low Q^2 at HERA

A measurement of the proton structure function $F_2(x,Q^2)$ was presented in the kinematic range $0.0045 < Q^2 < 0.65$ GeV^2 and $6{\cdot}10^{-7} < x < 1{\cdot}10^{-3}$. The results were obtained using a data sample corresponding to an integrated luminosity of 3.9 pb^{-1} in e^+p reactions. Information from a silicon-strip tracking detector, installed in front of the small electromagnetic calorimeter used to measure the energy of the final-state positron at small scattering angles, together with an enhanced simulation of the hadronic final state, has permitted the extension of the kinematic range beyond that of previous measurements. The uncertainties in F_2 are typically less than 4%. At the low Q^2 values of this measurement, the rise of F_2 are at low x is slower than observed in HERA data at higher Q^2 and can be described by Regge theory with a constant logarithmic slope $\partial \ln F_2 / \partial \ln(1/x)$, see Fig. 1. The dependence of F_2 on Q^2 is stronger than at higher Q^2 values, approaching, at the lowest Q^2 values of this measurement, a region where F_2 becomes nearly proportional to Q^2.

ii) Search for Resonance Decays to $\bar{\nu}$-Jet in e^+p Scattering at HERA

A study of the $\bar{\nu}$-jet mass spectrum in $e^+p \rightarrow \bar{\nu}X$ events has been performed using an integrated luminosity of 47.7 pb^{-1}. The mass spectrum is in good agreement with that expected from Standard Model processes over the $\bar{\nu}$-jet mass range studied. No significant excess attributable to the decay of a narrow resonance is observed. By using both $e^+p \rightarrow e^+X$ $e^+p \rightarrow \bar{\nu}X$, mass-dependent limits are set on the s-channel production of scalar and vector resonant states, see Fig. 2. Couplings to first-generation quarks are considered and limits are presented as a function of the e^+q and $\bar{\nu}q$ branching ratios. These limits are used to constrain the production of leptoquarks and R-parity violating squarks.

iii) Measurement of Exclusive ω Electroproduction at HERA

The exclusive electroproduction of ω mesons, $ep \rightarrow e\omega p$, has been studied in the kinematic range $3 < Q^2 < 20$ GeV^2, $40 < W < 120$ GeV and $|t| < 0.6$ GeV^2 using an integrated luminosity of 37.7 pb^{-1}. The ω mesons were identified via the decay $\omega \rightarrow \pi^+\pi^-\pi^0$. The exclusive cross section in the above kinematic region is $\sigma_{ep\rightarrow e\omega p} = 0.018 \pm 0.014(stat.) \pm 0.026(syst.)nb.$ The reaction $ep \rightarrow e\phi p$, $\phi \rightarrow \pi^+\pi^-\pi^0$ has also been measured. The cross sections, as well as the ratios $\sigma_{\gamma^* p\rightarrow\omega p} / \sigma_{\gamma^* p\rightarrow\rho^0 p}$ and $\sigma_{\gamma^* p\rightarrow\omega p} / \sigma_{\gamma^* p\rightarrow\phi p}$, are presented as a function of W and Q^2. In Figure 3 the ratios of

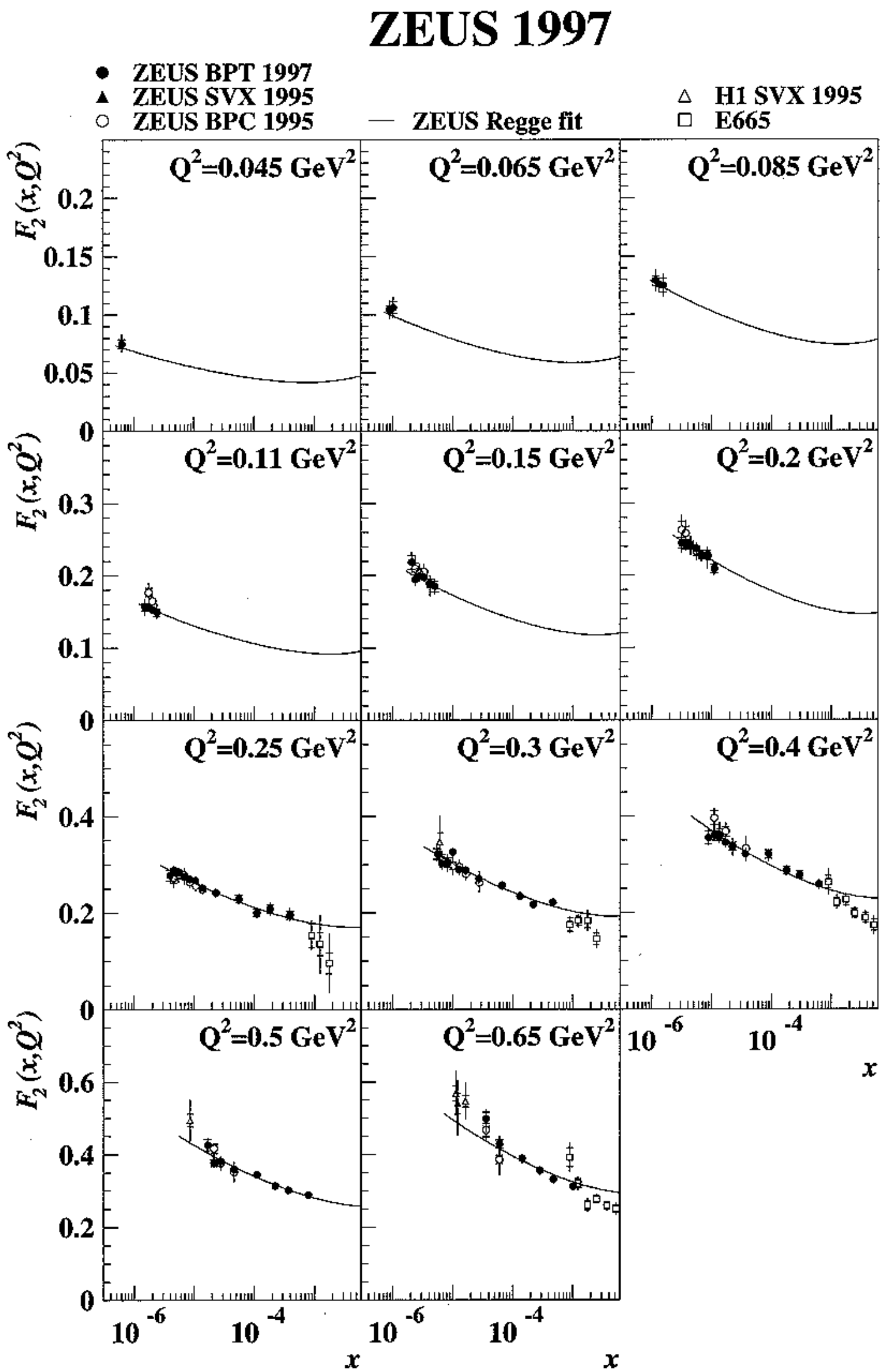

Figure 1. Measured F_2 versus x in bins of Q^2. The data from the present measurement are indicated by filled circles. The solid line shows the ZEUS Regge fit. Open circles denote the results from a previous analysis, filled and open triangles denote other measurements from ZEUS and H1, respectively, and squares denote results from E665.

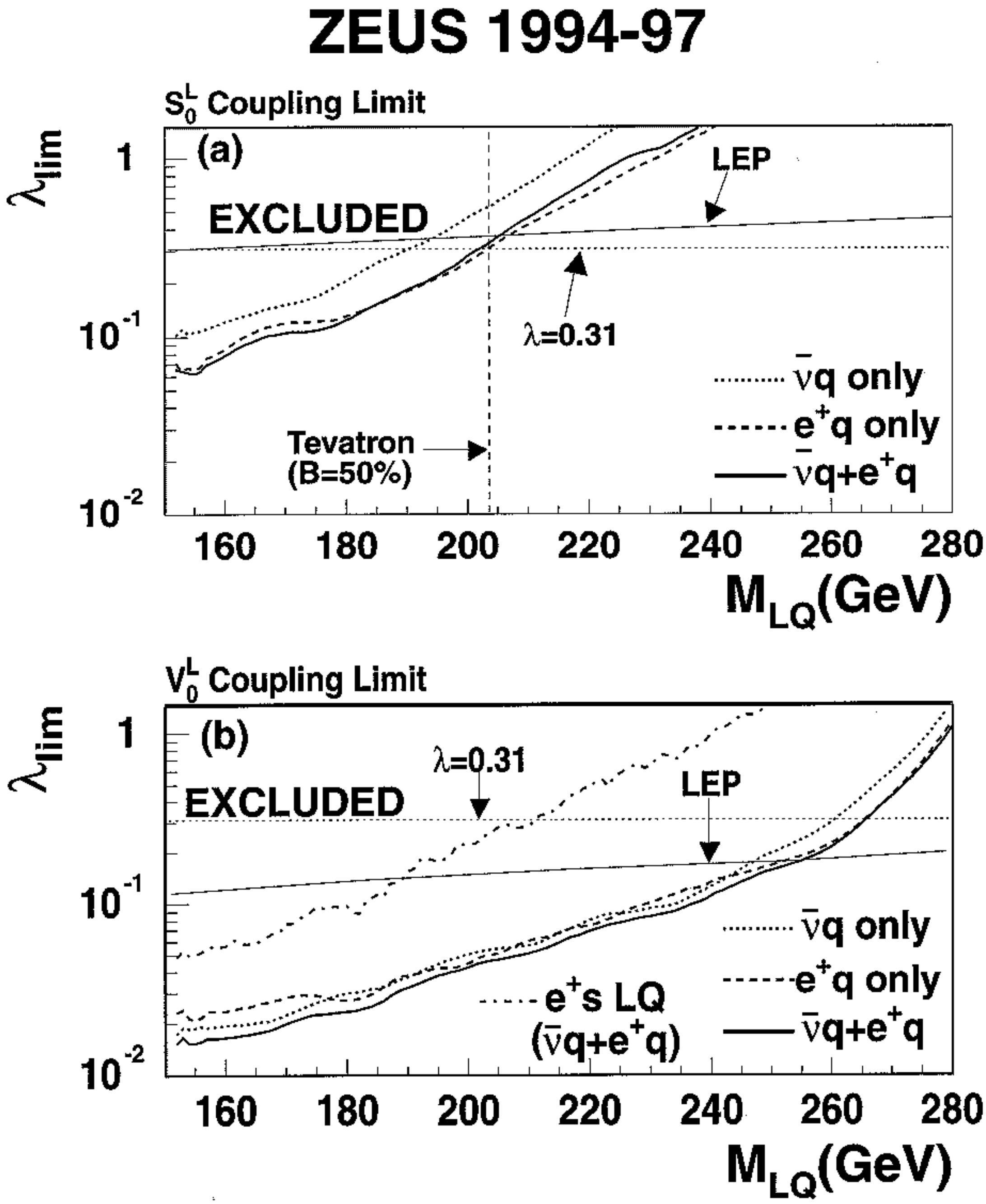

Figure 2. (top) The limits on the coupling λ_{lim} for an S_0^L Leptoquark. (bottom) The same for a V_0^L Leptoquark. Results from the $\bar{n}q$ and e^+q channels are shown, along with the limits obtained by combining the two channels. In both plots, the horizontal line indicates the coupling $\sqrt{4p\,a_{EW}} = 0.31$ of the electroweak scale. For comparison, coupling limits from the Tevatron and LEP are also shown.

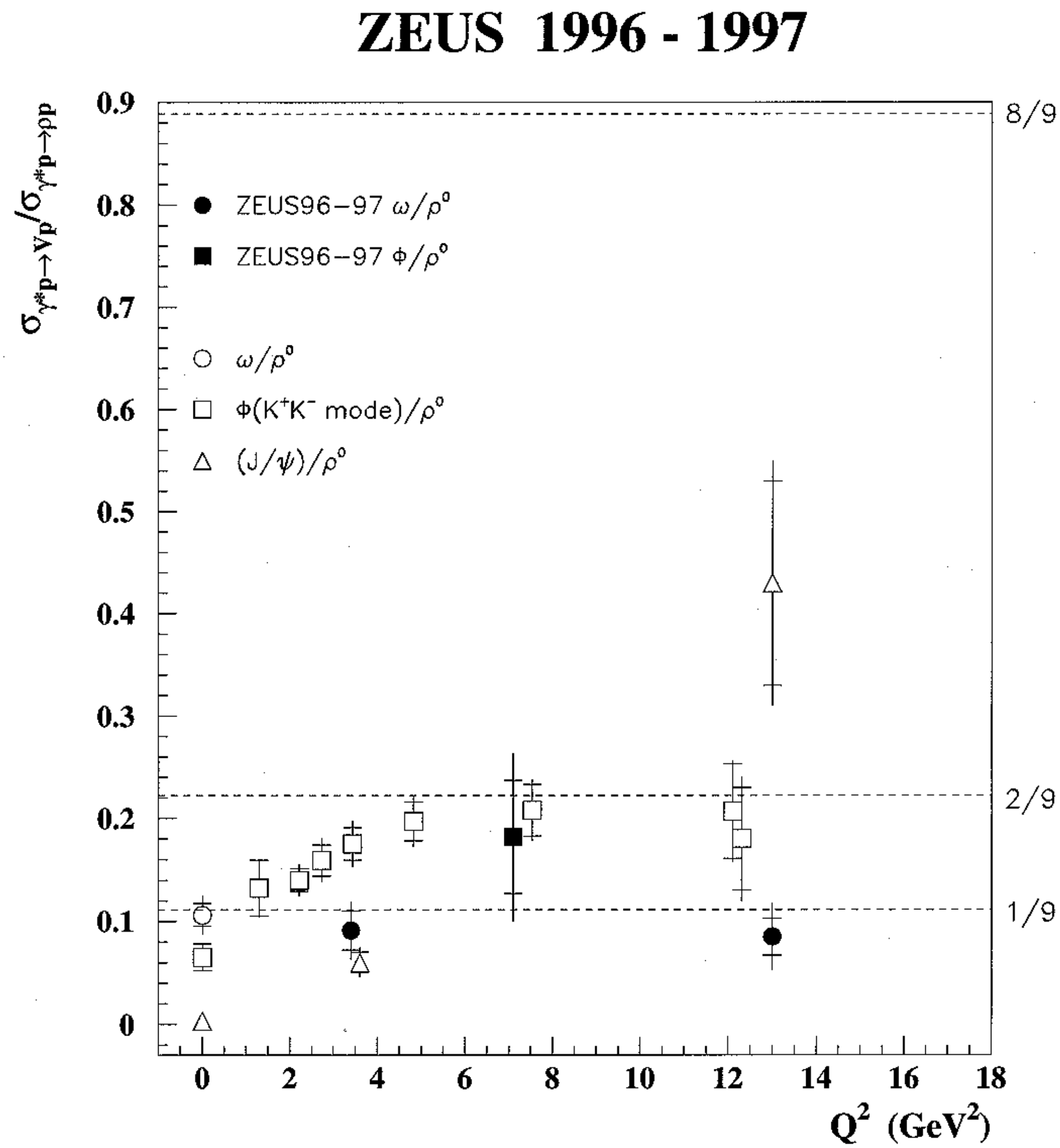

Figure 3. The ratios of the *w,f* and *J/j* exclusive cross sections to those for the r^0 meson are presented as a function of Q^2. The horizontal dashed lines correspond to the SU(4) expectations.

the *w*, *f* and *J/y* exclusive cross sections to those for the r^0 meson are presented as a function of Q^2. The predictions of SU(4), which ignore the vector meson mass differences, are also shown. With increasing photon virtuality Q^2, the measured ratios are observed to approach the predicted values. The $(J/y)/r^0$ ratio, on the other hand, is a factor of two below that of the SU(4) expectation even at Q^2 of 13 GeV^2.

b. HERA and ZEUS Operations

In the second half of calendar year 2000 HERA completed the positron run commenced in 1999. The machine performed exceptionally well and delivered collision rates corresponding to a total luminosity of 95 pb^{-1}. The run was terminated during the first week of September after which the machine started its shutdown. The machine is expected to be back in operation in summer 2001 with significant higher luminosities.

The ZEUS detector performed well in this period. The recently added components, such as the forward plug calorimeter and the barrel presampler, were fully operational.

Progress on the several upgrade projects for the high luminosity period was satisfactory. Both major tracking upgrade projects, the Microvertex detector and the Straw Tube Tracker for the forward region, claimed to be able to meet the tight installation schedule imposed by the DESY management.

(J. Repond)

I.B. EXPERIMENTS IN PLANNING OR CONSTRUCTION

I.B.1 MINOS -Main Injector Neutrino Oscillation Search

The MINOS experiment will study neutrino oscillations with significantly greater sensitivity than has been achieved by previous experiments. The phenomenon of neutrino oscillations allows the three flavors of neutrinos to mix as they propagate through space or matter. The MINOS experiment is optimized to explore the region of neutrino oscillation parameter space (values of the Δm^2 and $\sin^2(2\theta)$ parameters) suggested by previous investigations of atmospheric neutrinos: the Kamiokande, IMB, Super-Kamiokande and Soudan 2 experiments. The study of oscillations in this region with an accelerator-produced neutrino beam requires measurements of the beam after a very long flight path. This in turn requires an intense neutrino beam (produced for the MINOS experiment by the Fermilab Main Injector accelerator) and massive detectors. The rates and characteristics of neutrino interactions are compared in a “near” detector, close to the source of neutrinos at Fermilab, and a “far” detector, 735 km away in the underground laboratory at Soudan, Minnesota. The neutrino beam and MINOS detectors are being constructed as part of the NuMI (Neutrinos at the Main Injector) Project at Fermilab.

The MINOS detectors are steel-scintillator sandwich calorimeters, with toroidally magnetized 1-inch thick steel planes. The combination of alternating active detector planes and magnetized steel absorber planes has been used in a number of previous neutrino experiments.

The MINOS innovation is to use extruded plastic scintillator with fine transverse granularity (4-cm wide strips) to provide both calorimetry (energy deposition) and tracking (topology) information. The 5,400 metric ton MINOS far detector is also much more massive than previous experiments. Recent advances in extruded scintillator technology and in pixilated photomultipliers have made such a detector feasible and affordable for the first time.

Results from Super-Kamiokande, Soudan 2 and MACRO experiments provide increasing evidence that neutrino oscillations are taking place in just the region of parameter space that MINOS was designed to explore. Indications from Super-Kamiokande data that the value of Δm^2 is around $3.5 \times 10^{-3} eV^2$ have led to the design of a lower energy beam for MINOS than was initially planned, in order to improve sensitivity at low Δm^2. Argonne physicists and engineers have been involved in several aspects of the preparations for MINOS: scintillator-module factory engineering, near-detector scintillator-module fabrication, near-detector front-end electronics, far-detector installation and the use of the Soudan 2 detector with the NuMI neutrino beam (also known as Theseus).

One major focus of work by the Argonne MINOS group is scintillator module construction. During the summer of 2000 Argonne completed the engineering and prototyping of the semi-automated machines and tooling needed for mass production of scintillator modules. (MINOS detector modules are subassemblies of 20 or 28 extruded plastic scintillator strips.) Scintillator module assembly is now taking place at "factories" located at Caltech, at the University of Minnesota in Minneapolis and at Argonne (where all near detector modules will be constructed). Argonne physicists and engineers serve as NuMI Project Level 3 WBS Managers for the design and construction of the machines needed to construct scintillator modules and for the operation of the module factories. Previously, an Argonne physicist served as the Level 3 manager for scintillator strip fabrication and was responsible for the introduction of several important strip design innovations.

Argonne constructed and operated two prototype production facilities for scintillator modules in Building 366, the first in July 1999 and the second in May 2000, to produce prototype scintillator modules for evaluation of production procedures. The July 1999 prototype modules were used for performance studies in the Fermilab 4-plane prototype setup. The 4-plane prototype is a full-size assembly of MINOS far-detector steel and scintillator planes that has been in operation since late 1999. Modules built during the May 2000 prototype production run met all performance criteria and allowed the fabrication of module assembly equipment for the Caltech and Minneapolis factories to begin at Argonne. Figure 1 shows the average scintillation light output of the strips in one of the May 2000 modules, as measured by cosmic ray muons. Figure 2 shows the light output of the 20 individual scintillator strips in the same module.

Following the May 2000 prototype production run, Argonne built the assembly machines and tooling for the Caltech, Minneapolis and Argonne module factories. By the end of December the Caltech and Minneapolis factories had started production of far detector scintillator modules and had achieved about 80% of the planned assembly rate. The setup of the near detector module factory in Building 369 at Argonne was nearly completed by the end of the year. The prototype factory setup in Building 366 was dismantled and reconfigured in Building 369 in order to take advantage of the air conditioning and the larger floor space available in the new location. The preparation of Building 369 for MINOS use was made possible by substantial financial and logistical assistance from the Laboratory administration.

The second major focus of the Argonne MINOS group is electronics and data acquisition for the experiment. Argonne physicists and engineers serve as the Level 2 manager for electronics and the Level 3 manager for the near-detector front-end electronics. The 1999 decision to use single turn extraction (STE) from the Main Injector for the NuMI neutrino beam motivated the change to the current design of the near-detector front-end electronics, which is based on the Fermilab QIE ASIC chip. Two versions of prototype QIE chips produced during the spring of 2000 were evaluated by Fermilab and Argonne engineers during the second half of the year. These chips operate at 53 MHz and have no digitization deadtime, which is essential for the operation at the high instantaneous rates produced by STE. The prototype chips met or exceeded all performance requirements.

By the end of December Argonne engineers had also completed the design, fabrication and FPGA programming of the first prototype MINOS MASTER module, which receives and processes the data from the QIE chips. The experience of the Argonne engineers with this chip and its readout boards for CDF made this fast redesign possible. In order to test this complex VME board, a test stand was assembled using a prototype version of the MINOS 9U VME crate. Software was written to interface to the MASTER module. This made use of the VXWorks operating system, which will also be used for the final MINOS data acquisition software, to simplify the later porting of the test code to the DAQ. The MASTER module was extensively tested using its internal diagnostic memory to simulate real data from the QIE chips.

The Argonne group's work on the designs and layouts of the remaining near detector front-end circuits (the KEEPER, the MINDER and the Trigger cards, and the MINDER crate) was also progressing well at the end of the year. The protocols for communication among the various boards were developed along with the board designs. Specifications for the clock system were also decided and documented so that the Fermilab engineers could proceed with the design work.

An Argonne physicist also serves as Level 2 manager for far detector installation. Far detector installation work during this period involved close interaction with MINOS collaborators who are building detector and electronics components that will be installed at Soudan during 2001. Excavation of the MINOS far-detector cavern at Soudan began in May 1999 and was completed in December 2000. The construction of the MINOS surface receiving building was completed in December and outfitting of the building to receive and process detector steel plates and scintillator modules was started. The contractor for the cavern infrastructure installation was selected in late summer and started work at the end of the year. The infrastructure is scheduled to be completed in July 2001, and will be followed by the installation of the 5,400-ton far detector. The Argonne installation group continued work on the design of installation procedures for the detector at Soudan, in close collaboration with the University of Minnesota and Fermilab.

Argonne physicists also continued work to evaluate the sensitivity of the existing Soudan 2 detector for the study of neutrino oscillations in the NuMI beam. In this context, the Soudan 2 detector is referred to as Theseus (The Second Experiment Underground at Soudan). The MINOS collaboration has established a Theseus working group, led by an Argonne physicist, to examine the physics and technical issues relevant to this use of the Soudan 2 detector as part of the MINOS experiment. The working group described its simulation results, cost estimates and recommendations in a draft report that was presented at the MINOS Collaboration meeting in December. The MINOS Collaboration expects to make a final decision about the Theseus proposal at its meeting in March 2001.

(D.S. Ayres)

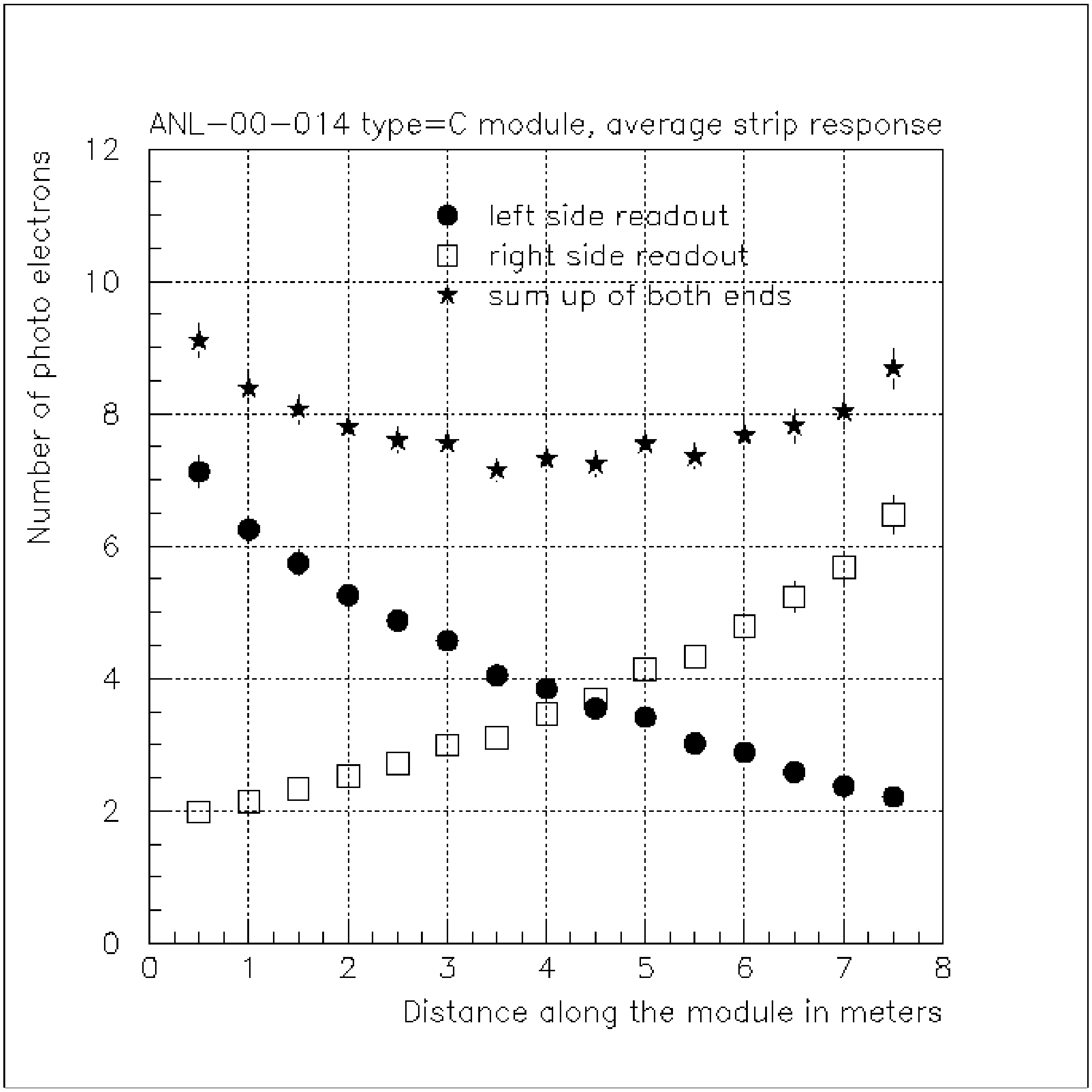

Figure 1. Scintillation light output of a prototype MINOS module from the May 2000 prototype factory production run at Argonne. The light output is measured with cosmic ray muons at discrete locations along the 8-m long plastic scintillator strips. Each of the 20 strips in the module is read out at both ends of its wavelength-shifting fiber using multi-anode photomultiplier tubes. The light output is measured in photoelectrons at the photomultiplier photocathode. The graph shows the average light output for the 20 strips, for the two ends separately and for the summed output of both ends.

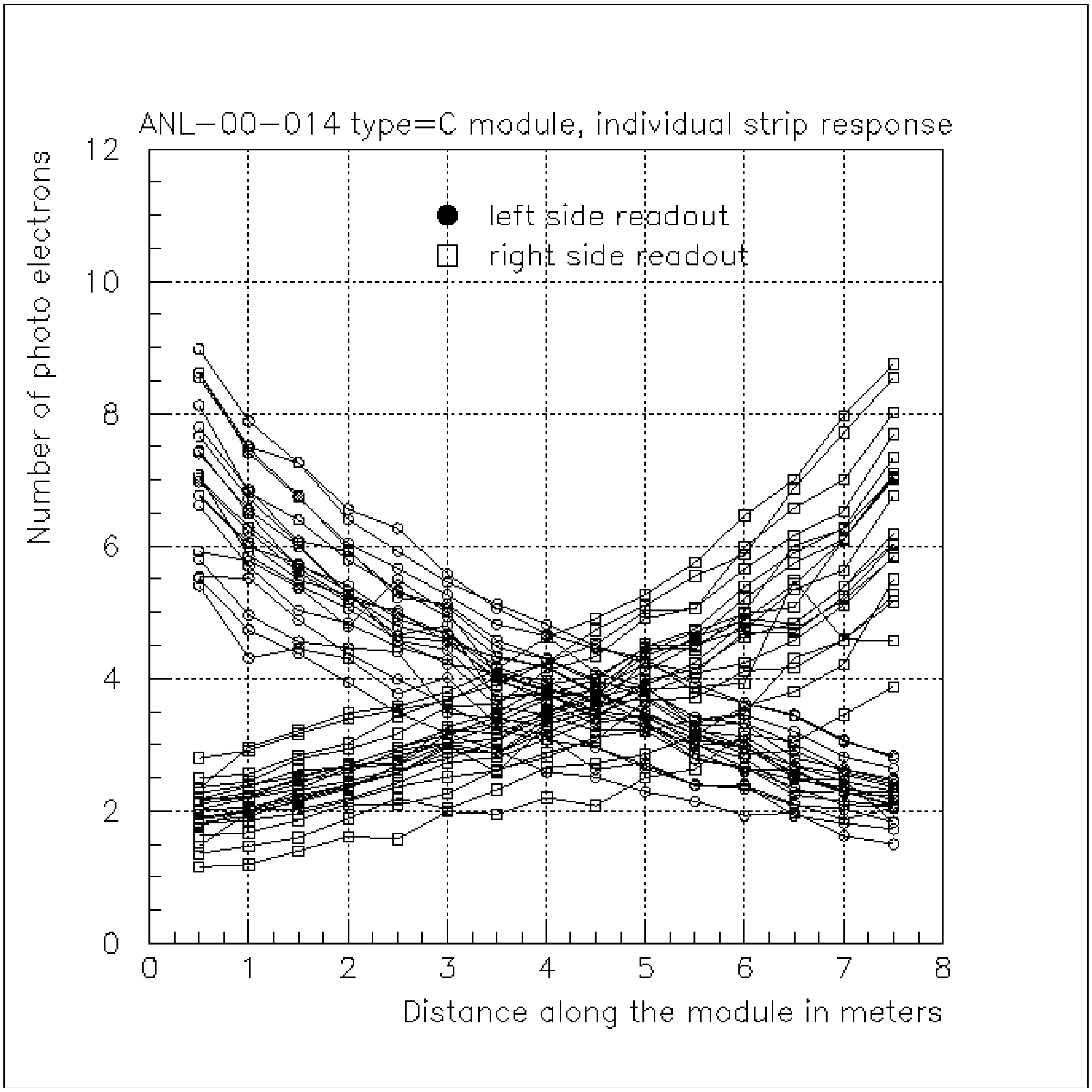

Figure 2. Scintillation light output of the individual strips of a prototype MINOS module from the May 2000 prototype factory production run at Argonne. This graph uses the same data as the previous figure except that the output of each of the 20 plastic scintillator strips is shown separately.

I.B.2 ATLAS Detector Research & Development

a. Overview of ANL ATLAS Tile Calorimeter Activities

The TileCal subsystem continued making excellent progress in the second half of 2000. Both submodule and module mechanical construction are proceeding on schedule (Figure 1) with 126 submodules and 24 modules constructed. Instrumentation is now approaching our original goal of 1 module per month with 8 modules having been instrumented at Argonne and tested. The shipping of modules to Michigan State University and to CERN has now become routine. Finally, after understanding some problems associated with variation in the scintillator light output, we developed the capability of running the cesium source in modules instrumented at MSU, without the need for rigging these modules into our own instrumentation area.

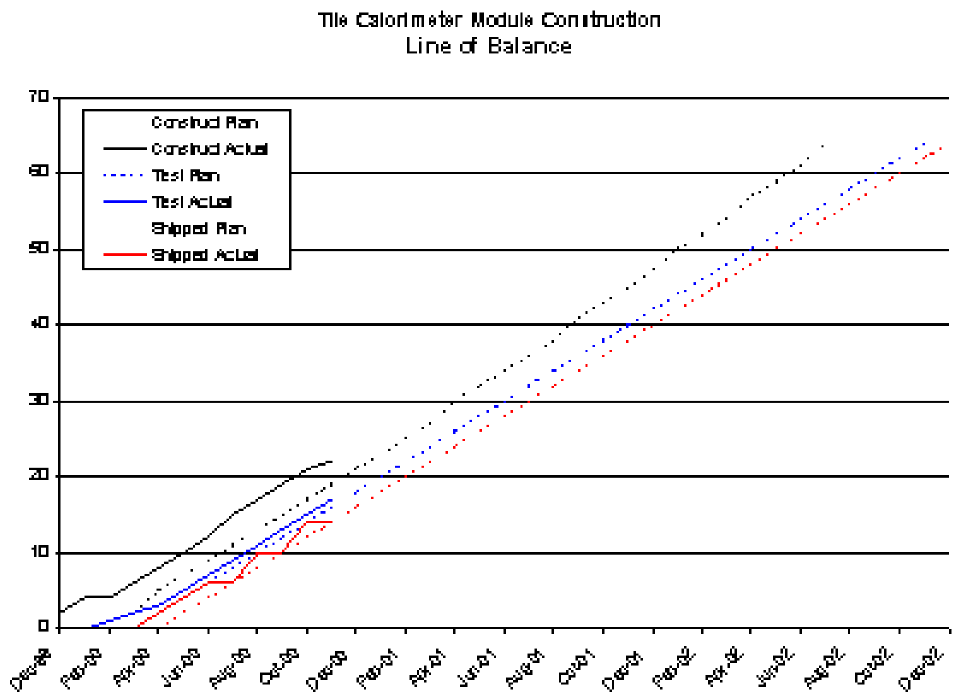

Figure 1. Calorimeter production comparison to baseline schedule.

(J. Proudfoot)

I.C. DETECTOR DEVELOPMENT

I.C.1 The CDF Upgrade Project

Shower Max calorimeter readout continues to be a major project for us; Karen Byrum is project manager and Gary Drake is chief engineer, and John Dawson has taken on several of the components. All of the multiple card components are in production or complete. The preamplifier design has been iterated with tests on the detector. Jimmy Proudfoot is working on testing and internal programming development for the VME readout boards "SMXR." Steve Kuhlmann, along with Larry Nodulman, is continuing to develop software to handle the hardware within the B0 online system. Karen continues working with Gary and Mike Lindgren to develop the plan needed for completing the instrumentation.

A highlight of the period was the commissioning run, when the detector, reasonably complete except for silicon, and with limited readout for the drift chamber and muon chambers, was rolled in and saw Tevatron collisions. The calorimeter and vertical regions of the drift chamber are illustrated in Figure 1. The drift chamber performance, including reconstruction, was quite impressive.

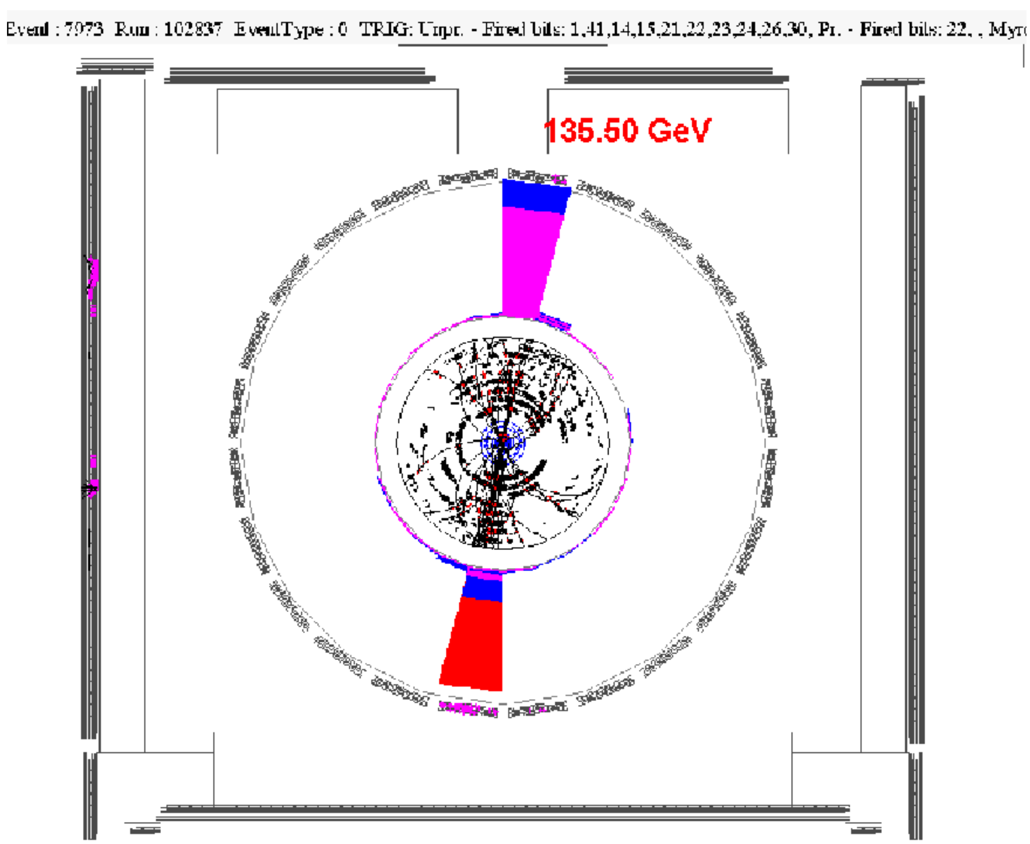

Figure 1. Event display of a conveniently vertical two jet event from the commissioning run, October 2000.

Two central wedges and most of the plug were instrumented with shower max and pre-radiator readout. Pedestals in actual data showed acceptable noise levels; we implemented coherent noise removal at the crate, illustrated in Figure 2. The readout represents the sum of charge for four successive 132 ns gates. To study the timing of the signals, we used "Myron mode"--four consecutive triggers--and modified the lookup table to use only one gate. For shower max, four gates is plenty, as illustrated by the timing curve for wire signals, Figure 3. Strips are similar and pre-radiator signals are a bit longer. The reality of the signal was verified by demonstrating the correlation to CEM calorimeter signals.

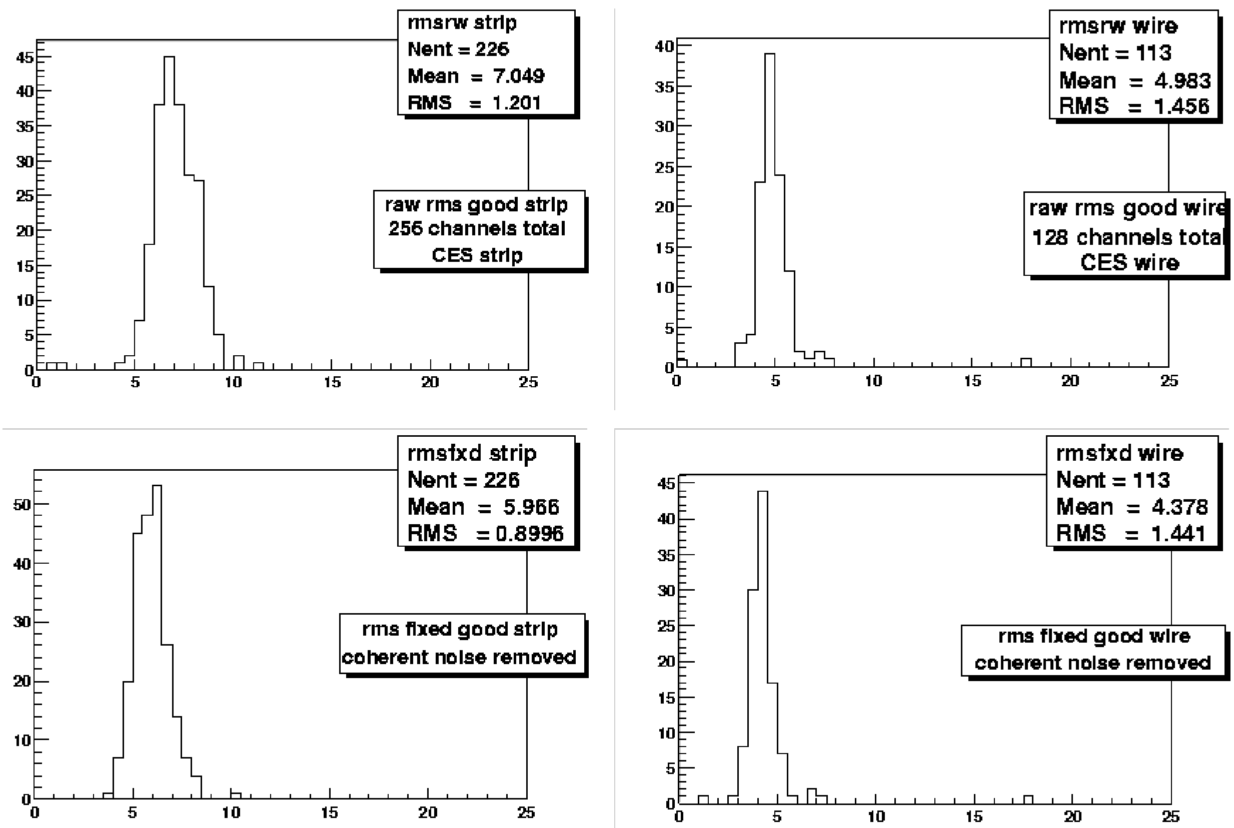

Figure 2. Pedestal widths for central Shower Max detectors from the commissioning run, October 2000.

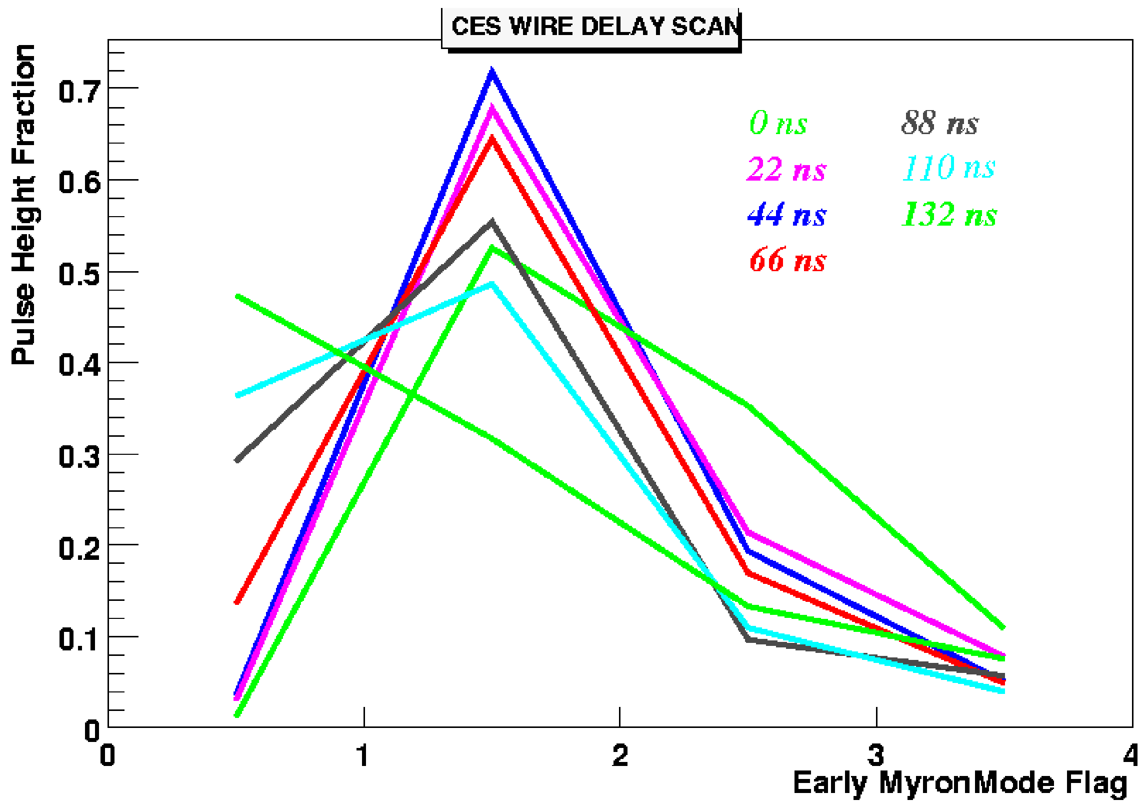

Figure 3. Timing curve for Shower Max wires, pulse height fraction in each of four consecutive gates for several time settings, from the commissioning run, October 2000.

Karen and John continue working with the Michigan group to integrate the Shower Max Level 2 trigger bit input card into the level 2 system. Steve, John and Bob Blair have isolation trigger electronics that is also being integrated.

Bob Wagner continues developing offline software for calorimeter reconstruction with emphasis on electron code. Bob, Steve and Barry Wicklund are involved in code for the wire chamber data reconstruction.

(L. J. Nodulman)

I.C.2 ZEUS Detector Upgrade

a. Straw Tube Tracker Readout Electronics

ZEUS plans to install a new forward tracking detector during the 2000/2001 machine shutdown. The new tracker is based on the straw tube technology and will consist of 48 sectors containing a total of 12,000 tubes. It is expected to greatly improve the detectors ability to measure high Q^2 neutral current events, to determine charged current event vertices, to tag heavy flavor decays in the forward direction, and to track charged particles in general. The detector is being built by a group of nine institutions which are all part of the ZEUS collaboration.

The Argonne group took over the responsibility of designing and building the front-end electronics consisting of shapers, discriminators, a multiplexing and a cable-driver circuit. The multiplexing is necessary to match the 12,000 channels of the new detector to the 2000 channel read-out system of the current forward detector.

As a first step Argonne built a prototype board containing the two-threshold ASDBLR chip developed by Penn University to shape and discriminate the signals and a circuit to drive the standard 42 m signal cable employed by the experiment.

Based on experience gained with the first prototype, a second prototype was built using the ASDQ chip which contains a one-threshold discriminator. The second prototype contains all elements of the readout system, including the multiplexing circuitry, and is very similar to the final production electronics. Extensive tests of the second prototype were performed in order to understand the threshold setting circuitry and the on-board pulser. Final adjustments were made before initiating production of both the main boards (containing the discriminators and multiplexing circuitry) and the cable driver boards. The latter will be produced by Tel-Aviv University.

Production of the main boards started in December with the first boards expected to arrive at Argonne in January. A computer-controlled test station for checking the finished boards is being built.

(J. Repond)

I.C.3 ATLAS Calorimeter Design and Construction

The ATLAS Tile Calorimeter construction effort is now fully into the production phase. The areas of ongoing work comprise: submodule construction; module assembly; instrumentation and testing; testbeam measurement of detector performance; engineering support of work at US collaborating institutes; continued engineering evaluation of specific elements of the detector and final design of areas in the detector where special constraints, such as the support of the liquid argon cryostats, must be accommodated.

a. Submodule Construction

Submodule production continued at the scheduled production rate. At the close of this reporting period, 129 submodules were stacked and welded, 126 painted and 126 fully completed and stored for mounting into modules. The height envelope for all submodules constructed to date is generally well within the tolerance envelope. Production at the other two US institutions is also proceeding well and the early schedule delays are being made up: University of Chicago has constructed 144 submodules and the University of Illinois 96 out of 192 total to be built at each location. Work is continuing on the design and fabrication of the special submodules required in the region of the endcap cryostat supports. A final design has been agreed upon with our collaborators and we are in the process of constructing one of these submodules to be used in a mechanical test of the support system, which is scheduled for early 2001.

b. Module Assembly and Shipping

Module production is also proceeding smoothly and at a somewhat higher rate than planned in the baseline schedule. A cumulative total of 24 modules have been constructed to date and we routinely construct one module every 2 calendar weeks. Girder production is still ahead of our requirement and the vendor is producing them at the rate of 8 every 3 months. Forty-two have been completed and we expect to complete the fabrication of this component in 2001. Witness inspection of each series of 8 girders has been successful in identifying minor problems and we will continue this through the remainder of the procurement. The timely delivery of the special ITC submodules from the University of Texas at Arlington is still a concern, but so far we have not been forced to halt production while waiting for the delivery of the next series.

The module design envelope is +/- 0.75mm (0.029in) and we verify this in two ways: using a plumb-bob prior to welding in the inner radius plate, and using a 10-ft. precision straight edge and feeler gauges to measure the relative non-planarity at many locations on the module surface. A summary of feeler gauge data is shown in Figure 2, which shows that by all measures our modules are meeting the design specification and are uniform on average from module to module.

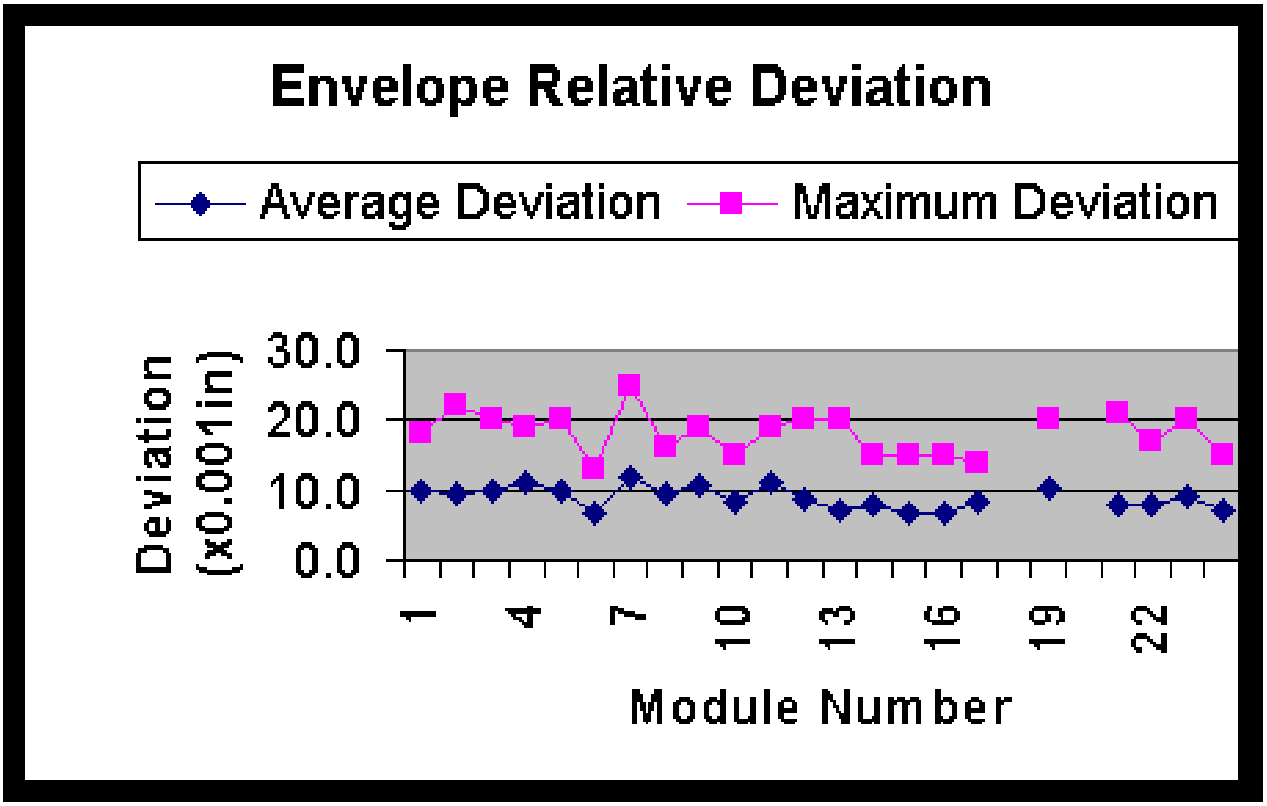

Figure 2. Module envelope deviation measured using a precision straightedge and feeler gauges at many points on the module surface.

c. Module Shipping

Shipping of modules to Michigan State University and CERN are now both routine operations. We have fabricated 8 sets of beams to be used to ship modules to CERN, 4 sets for the shipment of modules to MSU and 2 sets for module storage in Building 366. For shipment to Michigan State, the typical mode of operation has been to send a non-instrumented module to MSU early in the week with the truck returning two days later with an instrumented module. CERN shipments are in pairs of modules in a single container. Fourteen modules have now been sent to CERN and 6 are awaiting shipment. The final shipment of 2000 was delayed due to a crane failure, which occurred during the shipment of 4 modules to CERN. These will now be shipped in early 2001.

(J. Proudfoot)

d. Instrumentation and Testing

The focus of the instrumentation and testing work in this period was to establish a routine for all activities and to continue the training of several crews in the details of the operations. Procedure and quality control sheets were improved and a routine established. At the present time 8 modules have been instrumented at Argonne and 9 at Michigan State University out of a total of 32 to be instrumented at each location. Overall, we are meeting our planned schedule but there is some opportunity to improve our instrumentation time per module, which is presently around 35 calendar days. We now have good data on the duration of the various sub-tasks, and can vary the overlap of some of these tasks according to the manpower available. Using this in our planning, we believe it will be possible to reach our goal, which is to realize a routine instrumentation time per module of 28 calendar days.

The variation in light output with tile pack has continued to be a cause for some concern and we have now implemented a two-fold approach within the Tile Calorimeter subsystem. The tiles were sorted into groups at Argonne prior to being inserted into each module: first, as a function of light output and second, by order. The module average uniformity of response by layer is shown in Figure 3. The design requirement is an rms uniformity of 10%, which we are meeting. In addition, tile pack sorting started at Module 8 (amongst these modules) and the associated improvement is clear in Figure 3, which follows.

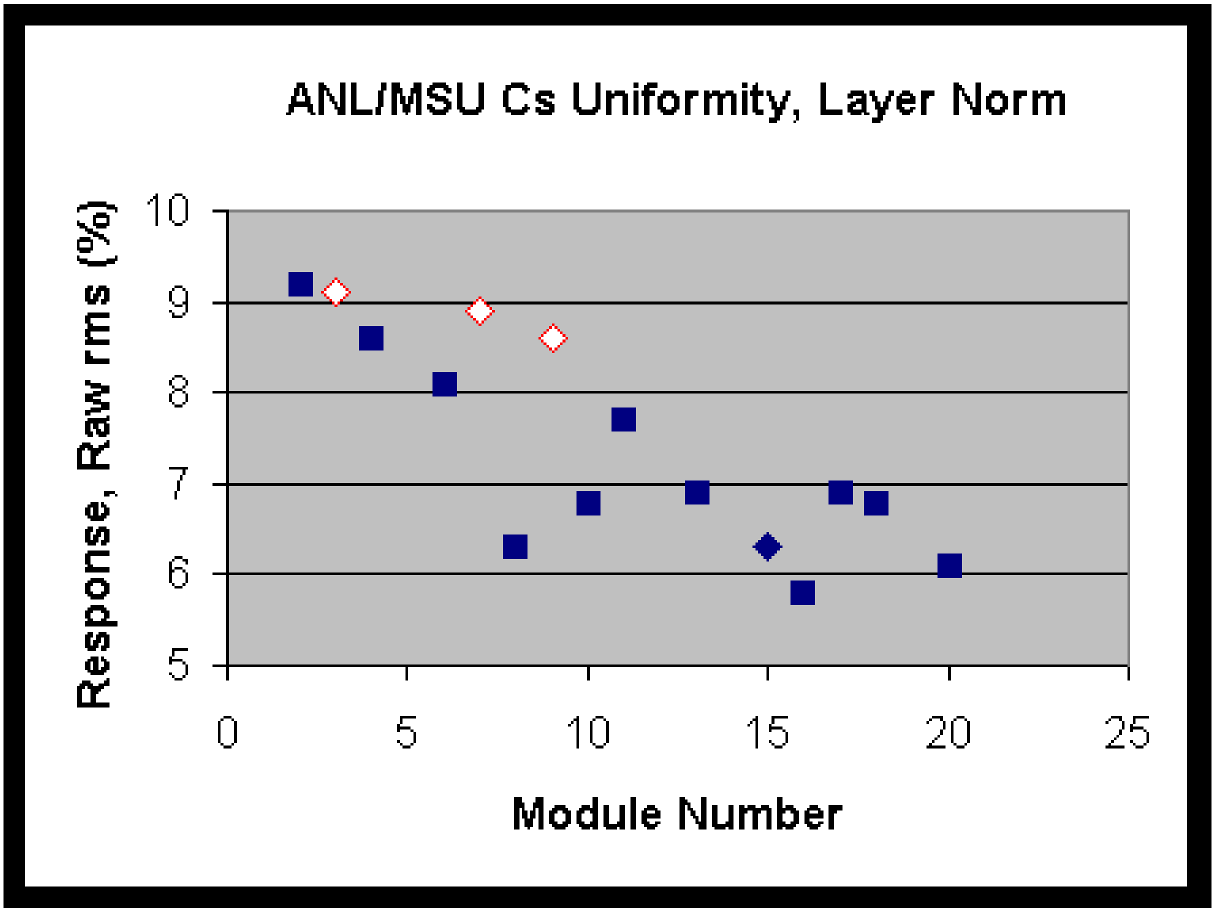

Figure 3. Uniformity of light output by layer, measured by the cesium source system.

One observation of note has been made in this period. Argonne has had to do far fewer fiber repairs than the other institutions participating in extended barrel module instrumentation, MSU and Barcelona. This appears to be due to the use of instrumentation to check the routing, and to having the EA and technicians do a close visual inspection of the seating of the fibers in the "Aspirin Tube" sleeves near the phototubes before gluing the fibers. Also, due to the Cs source scan, Argonne is unique in being able to find problems related to tile output as well as fiber coupling and transmission and to repair these before the modules are shipped to CERN. Doing such repairs at CERN will be problematic, because the CERN source tubes are soldered and glued in place before a Cs source scan can be done, and these tubes preclude tile replacement.

Finally, some additional work has been undertaken at Argonne to crosscheck the modules instrumented at Michigan State University using our cesium source. A dark tent was fabricated to allow us to carry out these measurements without impacting our own ongoing instrumentation work. The initial goal was to check the tile light output distributions using cesium, which excites the scintillator in comparison to the blue LED system, which is used at MSU and, which is primarily a measure of light transmission in the scintillator and coupling to the wavelength shifting fiber. The open diamonds in Figure 3 are the uniformity for 3 modules instrumented at MSU. Module 9 showed some particular problems associated with the instrumentation work and required several repairs to be made at Argonne. The setup is now well established and straightforward. The scans are accomplished within about a day by a combination of physicist, EA, and technician effort. On the basis of these scans, repairs can be made before the MSU modules are shipped to CERN, which is a major advantage if tile replacement is needed.

(J. Proudfoot and D. Underwood)

e. Test Beam Program

An Argonne staff physicist continues to be the coordinator of the TileCal testbeam program. In addition, a Division computer scientist continued to develop readout code for the new online data acquisition system. Two testbeam periods were allocated to the Tile Calorimeter in July and August. A lack of final drawer electronics made the July run a continuation of the May development program. However, the August run provided a wealth of experience in understanding the integration of the drawer electronics.

In July, the configuration of calorimeters in the beam was an uninstrumented Barrel Module 0 and a production barrel module having the 1999 drawer electronics for one-half of that detector. The electronics actually consisted of 1999 digitizers, production PMTs and a mixture of production 3-in-1 cards and 1999 cards. No serious attempt at production module calibration was made, although we tried to understand the EM scale with electrons at various angles. Correcting for the Cs decay, the ratio of electron response to Cs integral for 1998/1999/2000 was found to be 0.87/0.91/0.96 after previously unknown corrections for integrator gain. These preliminary numbers suggest we can indeed set the gain of the detector to our goal of 5% using the Cs system.

Further work on the DAQ proceeded smoothly with the implementation of trigger bits, TTCpr integration and testing read-in of 6 drawer sources into two RIO processors. An attempt to readout a University of Chicago digitizer/S-link interface board was made during the July run but was not successful at that time. However, this task was accomplished in November with HEP assistance at CERN. This hardware setup will most likely be used in the next year's testbeam program.

In August, we mounted one ANL extended barrel, one Barcelona extended barrel and the barrel from the previous months. Nearly final production electronics were incorporated fully in the extended barrels and in one-half the barrel. Due do some faulty components, however, all channels were not functional. Thus, this was the first time all production electronics were integrated and tested in the field. The DAQ was set up in its final configuration with 2 RIOs for RODs with 3 S-link inputs, a beam crate, an Event Builder Crate with a 100-Mb link to a PC, and a TTCpr in each of the 3 crates. Refinements were made in the software over previous runs to enable efficient Run Control.

The August run was invaluable in certifying the production hardware: only minor modifications are proposed. A major problem with these components coming together suddenly was the integration issue. The installation of a drawer was non-trivial. A major collaborative effort was launched in November at Clermont-Ferrand to address each area of concern. HEP personnel were key to this task. A solution was finally worked out and the drawer installation (Figure 4) looks orders of magnitude simpler now.

Figure 4. Drawer installation in the testbeam.

We took about 500 data runs with pions, electrons and muons. Again, the issues of Cs calibration were paramount, as was uniformity with muons. These data are being analyzed, but typically we find the EM scale is 20% higher, resulting from a larger light yield from the newer scintillator. At Argonne, we have looked at some data in a new fashion, trying to understand the time reconstruction and, if the detector operation is well understood. An example of the mean reconstructed bucket time is given in Figure 5. The data are for low- and high-gain channels, and for trigger types Beam, Laser, and Charge Injection. The times are plotted versus PMT positions within the Drawer.

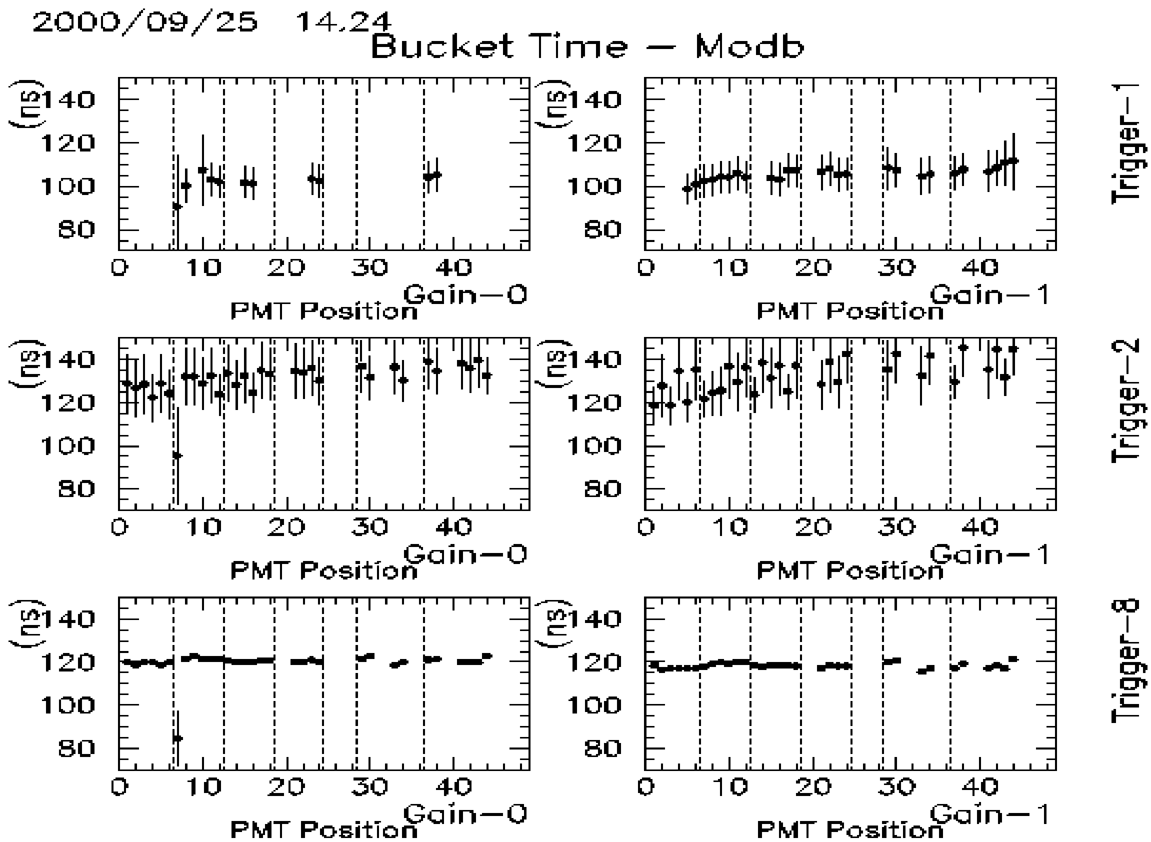

Figure 5. Reconstructed time as a function of photomultiplier position within the drawer.

(R. Stanek)

f. Engineering Design and Analysis

Substantial progress has been made in several areas of the engineering work in which Argonne staff have major responsibilities. The initial design of the special submodules required for the endcap cryostat support was completed. Construction of one to be used as a pre-production prototype and for use in a mechanical test to be conducted at CERN has begun. This test is scheduled for early 2001. A TileCal engineering group that will coordinate all engineering activities and, in particular, those associated with assembly of the full calorimeter, has been officially formed. The core group comprises: L. Mirales (IFAE), V. Guarino (ANL), N. Topilin (JINR), V. Romanov (JINR) with J. Proudfoot (ANL) and M. Nessi (CERN) as participating physicists. The specific Argonne contributions are to: engineering analysis in which V. Guarino is responsible for the summary of engineering calculations, finite element analysis of the cylinder and the design of the barrel and extended barrel saddle supports. The other engineers are contributing to assembly tooling, pre-assembly and assembly plan. Essentially, all engineers are involved in the engineering analysis.

Activity in the second half of 2000 focussed on the documentation, summary and cross-checking of the engineering analyses carried out over the last 5 years or so, modeling and analysis of the calorimeter cylinder assembly and the detailed design and analysis of the calorimeter support saddles.

Support Saddle: The design of the support saddle has evolved over the design life of the Tile Calorimeter. There have been three major analyses of the support saddle for the extended barrel. The first was a preliminary analysis that was done at the beginning of the design phase, which had the purpose of establishing the basic parameters of the support saddle for the extended barrel. The second analysis was much more detailed and consisted of an overall geometry that more closely represented reality in the extended barrel. These two analyses were used to establish the general features and parameters of the saddle such as: the position of the supports; the thickness and size of the supports; the maximum stresses within the constraint of the model approximations; radial location and size of support bolts. In addition, the resulting 3-D finite element model of the calorimeter itself has become a reference system for the model conditions and assumptions to be used in subsequent work and was also used to model the applied load. Our preliminary conclusions, using this rather coarse model of the saddle, were that the support should be as wide as possible and the saddle plates should have a thickness of 50 mm. There was no indication of any significant transverse load being applied to the ATLAS main rail system. The placement of the saddle, however, could strongly affect the localized forces in the calorimeter structure and required further study using a more accurate model of the Tile and Liquid Argon support.

The third and ongoing analysis has built upon the second. This third analysis, in particular, incorporates changes to the basic design, which have been needed to facilitate fabrication and assembly of the supports and the assembly of the Tile Calorimeter. It also includes elements pertaining to the design of the support beam between the saddle structure and the rail system. Some of the pertinent issues are:

a. Clearance of bolts and tools for connecting plates is required. Select a torque wrench for this evaluation.
b. Ease and cost of construction.
c. Ability to adjust for variation of connector plate angle – selected swivel bolts for this.
d. Minimization of stresses.
e. Try to stay within the existing envelope for the saddle.
f. Bearing points on the connecting plates should avoid the joint between connecting plates in Z.
g. Bearing points on connecting plates should fall between bolts on the girder.
h. The saddle design should accommodate the lifting fixture.

The geometry of the support saddle for the extended barrel is shown in Figure 6. The 3D model geometry was created in EUCLID and then directly transferred to ANSYS. The static loading due to the weight of the forward calorimeters (about 9,000kN) were applied with an earthquake load of 0.15g. The loads from the extended barrel were assumed to be an evenly distributed radial load over the top of the saddle with a radial and circumferential shear load occurring at the key surface on the saddle as shown in Figure 6. The load from the cryostat was applied through a stiff structure that was designed to transfer the load of the cryostat directly to the saddle. In total, there were five load cases examined:

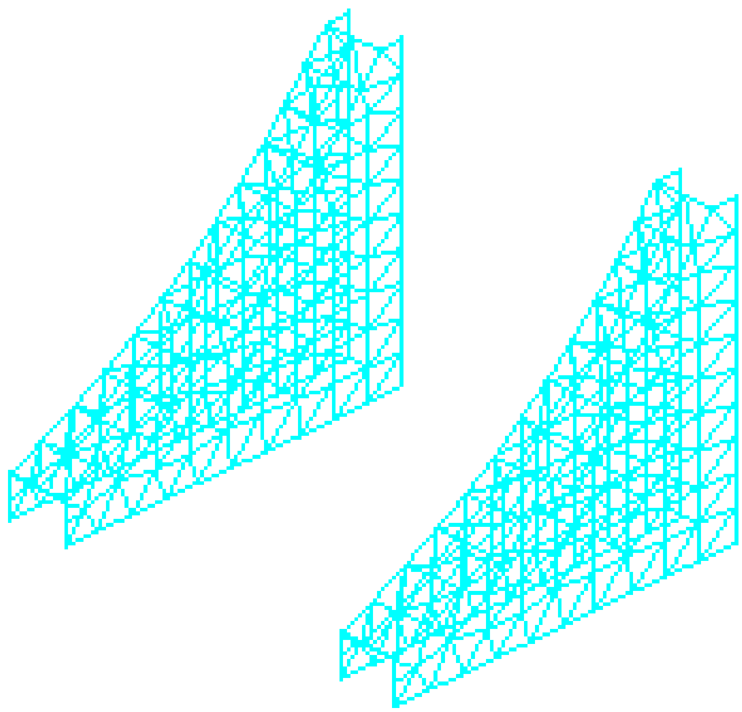

Figure 6. Geometry of 3D finite element model of the extended used for ANSYS calculations.

Case 1	Weight of only calorimeters
Case 2	Calorimeter weight and earthquake conditions in direction –Z
Case 3	Calorimeter weight and earthquake conditions in direction +Z
Case 4	Calorimeter weight and earthquake conditions in direction –X
Case 5	Calorimeter weight and earthquake conditions in direction +X

Tetrahedral 3D solid elements Solid92 were used to model the support and the lever arm whereas structural spar elements LINK8 were used to model the underlying belts. Approximately 30,000 nodes and 15,000 elements composed the model. The purpose of the lever arm was to transfer the earthquake load from the mass centroid to the saddles.

The maximum displacement and stresses are listed below:

Case	Max. Displacement (mm)	Max. Stress (Mpa)
Case 1	2.55	135
Case 2,3	2.70	150
Case 4,5	2.65	145

The earthquake simulation is based on the application of a static force equivalent to an inertia force of 0.15g applied on the forward calorimeters mass centroid. This inertia force can be interpreted as the maximum awaited load amplitude of earthquake induced vibrations applied on the forward calorimeters. The mechanical phenomena that can be observed by our analysis are only static. In addition, we used a lever arm to transmit the earthquake loads down to the supports. We considered, for simplification, the lever arm to be very stiff compared to the support. Hence, we have neglected the potential effect of any harmful interactions between forward calorimeters and the support.

Using this design criteria, the saddle design for the extended barrel was developed as shown in Figure 7. This design is comprised of three upright gussets that are 70mm thick and are tied together by cross bars. The cross bars support swivel bolts onto which the calorimeter is supported. Swivel bolts are used to accommodate minor differences in the angles of the modules and to allow the bolts to be moved radially without galling the surface of the link plate on which they bear. The cross bars have been sized to carry the load that will be applied radially to the swivel bolts. A special plate, which has the key machined into it, connects all three gussets. The key is 25mm wide by 260mm long, which is a sufficient cross section to carry the calculated shear force. Special care had to be taken in the location of the saddles, the gussets, and the swivel bolts in order to achieve the stated design criteria.

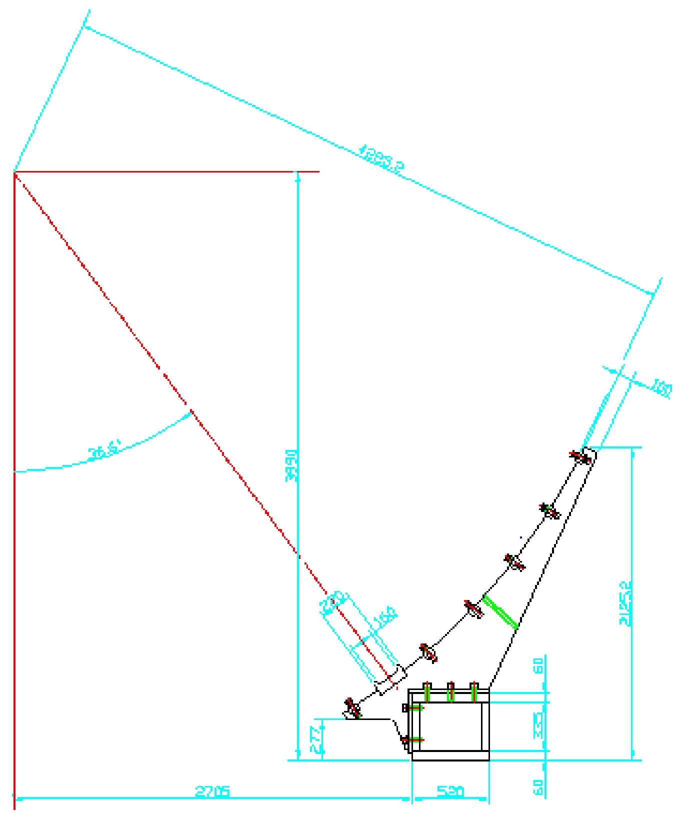

Figure 7. Present design of support saddle for the extended barrel sections of the calorimeter.

An initial FE model of this design has been performed. The forces that were calculated in Section 2.0 were applied directly on the swivel bolts. This preliminary analysis indicated that the stresses were approximately 120 N/mm2, which is acceptable. A further and more extensive analysis is progressing and will also include the support saddle for the barrel.

In summary, the basic design of the support saddle for the barrel and extended barrel has been completed. Engineering drawings and a specification for their fabrication have been developed. To date, there has not been a detailed study of the saddle for the barrel, but this is a currently scheduled activity. This and a final analysis of the saddles for the extended barrel still need to be completed. These analyses should include the supports for the cryostat and a model of the support beam on which the saddles are mounted.

<u>Assembly Analysis of EB</u>: The barrel and extended barrel will be assembled using specialized tooling to position the support saddles and then to support the modules that are located below the saddles until the final assembly of the calorimeter. There is a concern that, during the assembly of modules into place, specialized loading of the modules that has not been accounted for, will occur. A preliminary analysis was performed using the Fortran program. The assembly of the extended barrel has been modeled with modules being sequentially added and the inner radius bearing forces, the outer radius bearing forces and the outer radius shear forces calculated. As an example, the variation in inner radius bearing forces as the calorimeter is assembled is shown in Figure 8. This analysis shows that no unforeseen excessive forces occur during assembly and that the maximum loads occur in the final configuration.

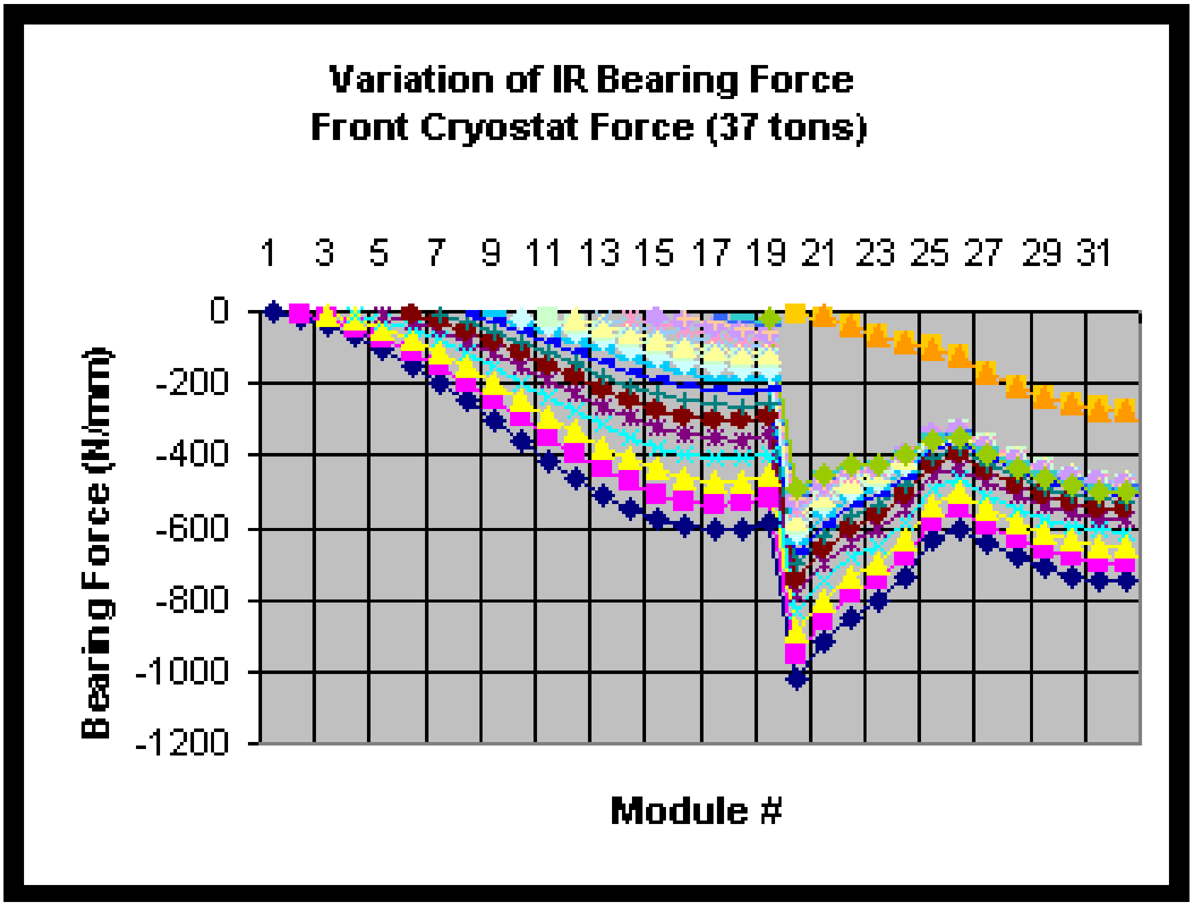

Figure 8. Inner radius bearing force during assembly.

Submodule and Module Support Activities: Argonne's scientific and technical staff has continued their support of the supported, submodule construction activities at the other US collaborating institutions. This has included:

- ITC construction and quality control
- Site checks of submodules at the University of Chicago
- Submodule quality control monitoring for the Tile Calorimeter subsystem as a whole.

(V. Guarino)

I.C.4 Computational Projects

a. ATLAS Computing

Argonne assumed joint leadership of the ATLAS database development effort just before the start of calendar year 2000, and has continued in that role. This effort includes not only a multi-petabyte event store (2PB/year is our present best estimate), but also databases for time-varying information such as calibrations, run conditions, slow control information, and alignment. The database domain is responsible as well for most detector description software, and for substantial components of the ATLAS event model.

The major task planned for this period was the integration of our baseline persistency technology (the Objectivity/DB database) with the prototype ATLAS reconstruction and analysis framework, called Athena. This was achieved on schedule with the release of the Naive Objectivity Conversion Services. (Here "naive" means that this service makes the assumption that any object being stored is self-contained; this is adequate for making existing objects persistent, but will need to be upgraded in the future as new programs fully exploit the functionality of Athena.) This enables ATLAS users to read and write pre-determined data (such as events) as well as user-defined data (such as histograms and other intermediate data).

Some of the detector description effort uses the XML meta-language to describe the geometry of the ATLAS detector, and Argonne focused on describing the tile calorimeter in this language. This strategy allows us to use a common set of tools to create, test and visualize the detector description for each subcomponent of ATLAS, even though the content of each description varies widely. Content on the Tile Calorimeter geometry was updated to reflect changes to the geometry that were incorporated after the Technical Design Report (Figure 1 shows an updated visualization of part of the calorimeter).

Extending the XML syntax to incorporate other detector description elements (for example, the readout geometry, as opposed to the materials geometry) has been considered, and specific proposals to accomplish this are being developed. Additionally, some difficulties in ATLAS' implementation of this (called AGDD, for Atlas Detector Generic Description) have been uncovered and potential solutions are also being developed. As an example, if ten tubes are identical except for their lengths, their radii have to be entered ten times. This increases the probability of an error. These solutions are based on the syntactical changes that reduce this unnecessary duplication.

Computational grids, which represent a vision of the future of high-performance distributed computing infrastructure, continue play a role in the direction of the evolution of ATLAS computing, and in HEP computing more generally. Argonne collaborates in the Particle Physics Data Grid (PPDG), both representing ATLAS and convening the Applications Working Group, where "Applications" here means high energy and nuclear physics. Argonne is continuing its contributions to the PPDG design and architecture, and is maintaining close contact with the rest of the collaboration both via regularly scheduled teleconferencing and the collaboration meetings held at Fermilab. ATLAS work within PPDG has centered on tools for and tests of grid-enabled replication and distribution of Objectivity/DB databases. Approximately 100 GB of tile calorimeter testbeam data is being used as the subject of these experiments, and data has been transferred between ANL, BNL and LBNL using these tools. Argonne HEP is in close collaboration with the MCS (Mathematics and Computer Science) Division in developing the LDAP based replication services. A similar grid initiative is GriPhyN, and ANL hosted the first All-Hands meeting, and is also participating in this project's management and design of the architecture.

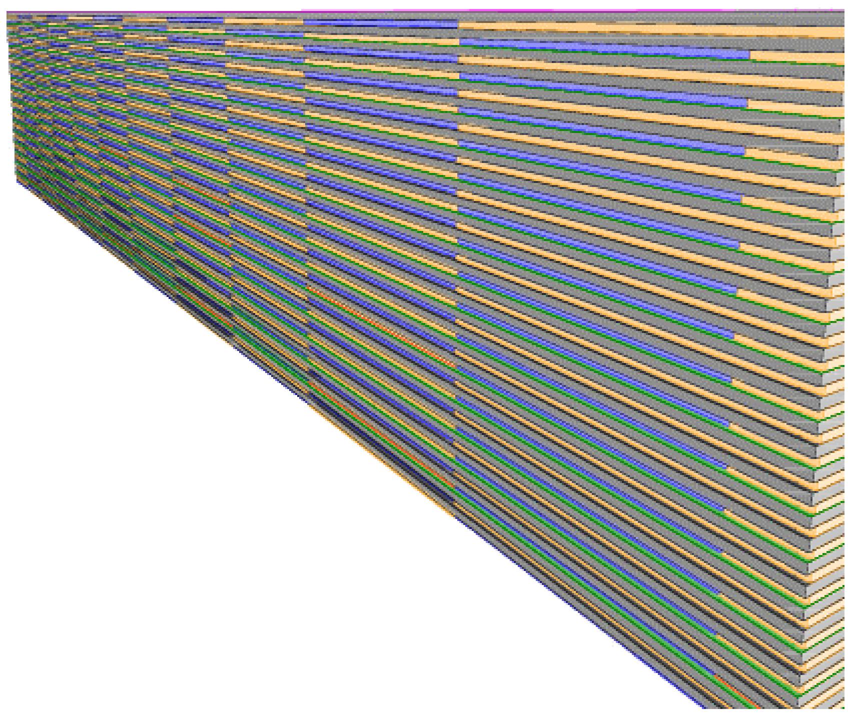

Figure 1. An updated visualization of part of the calorimeter.

(T. LeCompte)

I.C.5 MINOS Detector Development

By the end of December 2000 the Argonne MINOS scintillator group had nearly completed the transition from detector development to production fabrication. The Argonne mechanical support group built and installed most of the equipment for the Caltech and University of Minnesota module factories and participated in the commissioning of both factories. By the end of the year both factories were producing far detector modules of high quality at about 80% of the expected full rate. The only remaining development task is to commission the Argonne near-detector module factory. The installation of factory equipment in Building 369 (which is air conditioned) is essentially complete. Near-detector modules are read out from one end of each scintillator strip, unlike the longer far detector modules that are read out from both ends. The wavelength-shifting fiber at the far end of each near detector scintillator strip is mirrored to increase the light output at the readout end of the fiber. A mirroring technique was developed using single strips and fibers but has not yet been tried for mass-production. Production of the first near-detector modules in the Argonne factory is scheduled for early 2001.

During the second half of 2000 the Argonne electronics group completed the specification, design and layout of the MASTER readout board, a complicated 9U VME module, for the MINOS near detector. They built the first prototype MASTER module and evaluated its performance, which met all specifications after correction of some minor errors. During this period the group also began the detailed design and layout of the MINDER and KEEPER modules and the MINDER crate.

Finally, the Argonne electronics group continued to provide support for a number of Rabbit electronics readout systems for MINOS scintillator test setups at Argonne, Caltech, Fermilab, Minnesota, the University of Texas and the University of Athens in Greece. These systems make use of existing Rabbit electronics cards and crates, which became available after the CDF upgrade at Fermilab. MINOS uses these systems for the module mapper readout, photomultiplier testing and for data acquisition from the 4-plane prototype. Several MINOS Rabbit systems have been brought into operation and are now in routine use.

(D. S. Ayres)

1.C.6 Electronics Support Group

CDF: We continued with our work in the development of front-end electronics for the Shower Max Detector of the CDF Upgrade at Fermilab. For this project, we have major responsibilities for the electronics engineering of the system. The primary responsibility involves the coordination of the design engineering and system integration for the entire system, overseeing the production of all components, and ensuring that the overall system meets performance requirements. The development work is a collaborative effort between Argonne and Fermilab.

Argonne is also responsible for the design and development of several components of the system. One project is the design, testing, and production of the ~6000 daughter boards used in the front end electronics, which contain a custom integrated circuit designed at Fermilab called the SMQIEs. The daughter boards are called SQUIDs. Each SQUID contains two SMQIEs, and also other support circuitry for calibration. The SMQIEs digitize charge inputs from the detector continuously, without deadtime. The digitized data is stored locally in a pipeline inside the chip pending a trigger decision. The data is read from the chip when there is a trigger accept. The final design of the SQUID was completed and tested in the spring of 2000, and the design was signed off for production. We have ordered all of the parts, and have had the boards fabricated. Assembly began in September, and checkout is in progress. We are overseeing the checkout effort, which is being done by a crew of 8 technicians at Fermilab. The production is scheduled to be completed by the early part of 2001.

We are also responsible for the design, testing, and production of ~15,000 preamplifiers, used in the front-end electronics of the Shower Max system. These are used on the strip chambers in the Central Barrel of the detector to provide additional signal amplification before the charge signals are sent to the SQUIDs. The preamp provides amplification to the charge pulse from the detector using low-noise, high-speed analog circuitry. The preamps are constructed as small SIPs (Single In-Line Package) using surface mount parts. Testing of the prototype was completed in the fall of 2000, and the design was signed off for production. To date, all of the parts have been ordered, and the board fabrication has begun. Assembly and checkout will begin by the early part of 2001. Technicians at Argonne will do the checkout work. After the preamp SIPs have been tested, they will be mounted on motherboards. The boards will then be tested at Argonne before being installed in the CDF detector.

Another project for the Shower Max system that Argonne has direct design responsibility for is the design and production of a VME-based readout board, called the SMXR. This is a sophisticated data processor. It receives digitized data in floating-point form from the front end electronics at the rate of 300 MByte/Sec, adds together up to four words as sampled in time to reconstruct long signals from the detector spread out in time, and also forms trigger bits from the reconstructed signal. The data is stored in a buffer pending read-out by the data acquisition system. The design has a large number of high-speed programmable logic devices, which allows the logic to be reconfigured as needed after the board design is completed. The design was signed off for production in the spring of 2000. The fabrication and assembly of the production boards was completed in this period. Checkout of the ~100 modules was completed in the summer of 2000. All boards have now been installed on the CDF detector.

ATLAS: We have major responsibilities in the development of electronics for the Level 2 Trigger of the ATLAS Detector at CERN. Working with colleagues from Michigan State University, we are responsible for the development of two parts of this system: the Level 2 Trigger Supervisor, and the Region of Interest (ROI) Builder.

The ROI Builder is the interface between the first level trigger and the second level trigger. When an event occurs in the detector, signals are sent from the front-end electronics to the Level 1 Trigger. The Level 1 Trigger collects event fragments from all over the detector, and stores them in a buffer. The Level 1 Trigger boards then send lists of addresses to the ROI Builder, identifying where the event data from the "Region of Interest," can be found. The ROI Builder collects the addresses for the event, and "builds" the event. It then sends the result to the Trigger Supervisor for distribution to Level 2 processors. The board is highly complex, using fast, high-density Field programmable Gate Arrays (FPGAs) to implement the functionality.

In this period, testing continued on the prototype system. We have a working system at CERN, where system tests are being performed. We are providing much of the software development and support for this phase of the project.

Another project that we are doing for ATLAS is the development of an interface card for the clock system, called the TTC Mezzanine card. Clock and control information is passed to different parts of the detector on optical fiber in an encoded format. Engineers at CERN have developed a custom integrated circuit called the TTC. The device receives the serial data, and converts it to the appropriate control signals needed by the various subsystems. The card designed at Argonne hosts the device, which is implemented using ball grid array (BGA) technology. The card itself has a PCI format, which is a standard used by digital processors to interconnect auxiliary data streams. To date, we have designed a prototype, and have built 4 cards for evaluation. We expect that we will iterate on the design in the next year, and may stage a small production run to aid in the evaluation of prototypes of different system subcomponents in small system tests.

MINOS: We continued our involvement with MINOS, the Neutrino Oscillation Experiment at Fermilab and the Soudan mine. There are two detectors for this experiment. The Far Detector is located in the Soudan Mine in northern Minnesota. The Near Detector is located at Fermilab. A beam of neutrinos is created from a beam "spill" of protons at Fermilab. The neutrinos pass through the Near Detector, and are directed through the earth towards the Far Detector. The two detectors are used in conjunction to study how the neutrinos change nature as they pass through the earth. We have major responsibilities for this experiment, including Level 3 Management responsibility for the front end electronics for the Near Detector, as well as responsibility for a large portion of the front end design for that detector.

The heart of the front-end electronics for the Near Detector is a custom integrated circuit designed at Fermilab, called the QIE. The QIE digitizes continuously at 53 MHz. The operations are pipelined so that there is no deadtime due to digitization. The digitized data will be stored in a local memory during the entire period of the beam spill. The data will be sent from the local memory to a VME read-out board after the spill is over. In between spills, the electronics will record data from cosmic rays. The QIEs and associated circuitry will be built on small daughter boards resembling memory SIMMs, using surface mount parts. The VME read-out board, called the MASTER Module, will contain a high level of programmable logic to do the complex processing of data.

The chip design, and the development of the QIE daughter board, are responsibilities of Fermilab. Argonne is responsible for the design the MASTER Module, and also the mother boards that host the QIE daughter boards, which are called MINDER Modules. We also have overall responsibility for the design of the rest of the system for the Near Detector, including the specifications for the QIE performance.

In this period, we completed the design of the first prototype for the MASTER Module. The board has been fabricated, assembled, and tested. Testing to date shows good performance, with no major problems in the design. We have also been working on other aspects of the system design, including the definition of the front-end crate, and the design of the MINDER Module. We plan to complete the design in the early part of 2001, and develop prototypes for all components for a system test by early summer.

ZEUS: Work continued at the ZEUS experiment at DESY to replace the tracking detector in the forward region during the shut down in 2000. The new detector will use straw tubes, rather than the older-style wire chamber technology. The detector produces a pulse in response to a charged particle passing through the detector. The front-end electronics is situated directly on the detector. It receives charge pulses from the detector, and sends a digital signal to the “back end” electronics located off the detector in a counting room, where a timestamp for the signal is recorded. The back end processors then use the timestamps to reconstruct the trajectory of the particle through the tracking detector. There are ~12,000 channels in the detector in total, although the front end electronics multiplexes 6 detector channels into each readout channel to reduce the number of signal wires between the front end and the back end.

The front-end electronics uses a custom integrated circuit designed at PENN, called the ASDQ. The chip was designed for use with the tracking detector in the CDF experiment, and performs the front end analog signal processing. We completed the prototype design in the summer of 2000, and it has been evaluated in tests both at Argonne and at DESY. The tests were successful, and the design has been signed off for production. We have procured parts, and have fabricated 200 boards. Assembly is now in progress. We will perform the checkout out of the boards at Argonne, beginning in December of 2000. We plan to complete the production by February 2001.

(G. Drake)

II. THEORETICAL PHYSICS PROGRAM

II.A. THEORY

II.A.1 Single-Top-Squark Production Via R-Parity-Violating Supersymmetric Couplings in Hadron Collisions

Ed Berger, Brian Harris, and Zack Sullivan examined the s-channel production of a single top squark through an R-parity violating mechanism. Their focus was on the relatively light top squark and its subsequent R-parity conserving decays. The R-parity violation penalty is paid only once, in the initial production, and it is offset by the greater phase space relative to pair production. Their first paper on this topic was published in Physical Review Letters **83**, 4472 (1999). In the present reporting period, they carried out a much more detailed analysis and issued a long article, ANL-HEP-PR-00-062 (hep-ph/0012184), since published in Physical Review **D63**:115001 (2001).

The motivation for this investigation is to identify supersymmetry processes that stand a good chance of observation at the Tevatron collider. The Tevatron's energy is limited, so it is essential to focus on supersymmetry reactions, such as the production of relatively light states, that do not require the maximum possible center of mass energy.

The particles of the Standard Model have even R-parity, and their corresponding superpartners have odd R-parity. The bounds on possible R-parity violating couplings are restrictive for the first two generations of quarks and leptons, but much less so for states of the third generation. If R-parity is conserved, as is often assumed, superpartners must be produced in pairs. The production rates for pairs of strongly interacting supersymmetric particles, the squarks and gluinos, benefit from the large color couplings of these superpartners to the incident light quarks and gluons in hadronic scattering subprocesses. However, in many models, the squarks and gluinos are heavy, and therefore their pair production incurs a large phase space suppression. Single squark production has obvious kinematic advantages.

For top-squark masses in the range of 180 to 325 GeV, Berger, Harris, and Sullivan did a full simulation of both the signal and standard model background processes. For the case in which the squark decays through an R-parity-conserving process into a bottom quark, a lepton, and missing energy, they showed that the top squark can be discovered if its mass is less than 400 GeV, or that the current bound on the size of the R-parity-violating couplings can be reduced by up to one order of magnitude with existing data and by two orders of magnitude at the forthcoming run II of the Fermilab Tevatron. The reach in R-parity-violating coupling l'' is shown in Figure 1 for $165 < m_{\tilde{t}_1} < 550$ GeV for run I and run II of the Tevatron, and with the first $10 fb^{-1}$ at the LHC.

With an integrated luminosity of $2fb^{-1}$ at 2 TeV center-of-mass energy, discovery of the top squark at the level of 5 standard deviations is possible provided that the R-parity violating coupling is greater than 0.02 to 0.05. Otherwise, a 95% confidence level exclusion can be set for R-parity violating coupling greater than 0.01 to 0.03. For the lower integrated luminosity and energy of the existing run I data, values of R-parity violating coupling greater than 0.05 to 0.2 can be excluded at the 95% confidence level if the top squark mass is in the range 165 to 350 GeV. These limits would constitute a significant improvement over the current 95% confidence-level upper bound of about 1 for R-parity violating couplings of third generation squarks. With the large increase in cross section at the CERN Large Hadron Collider, the discovery region and limits may be improved by another order of magnitude in coupling strength and extended to top-squark masses approaching 1 TeV. The discovery reach, or exclusion limits, at the Tevatron and LHC depend almost exclusively on the value of the top-squark mass, largely independent of other supersymmetry model parameters. Figure 1 follows.

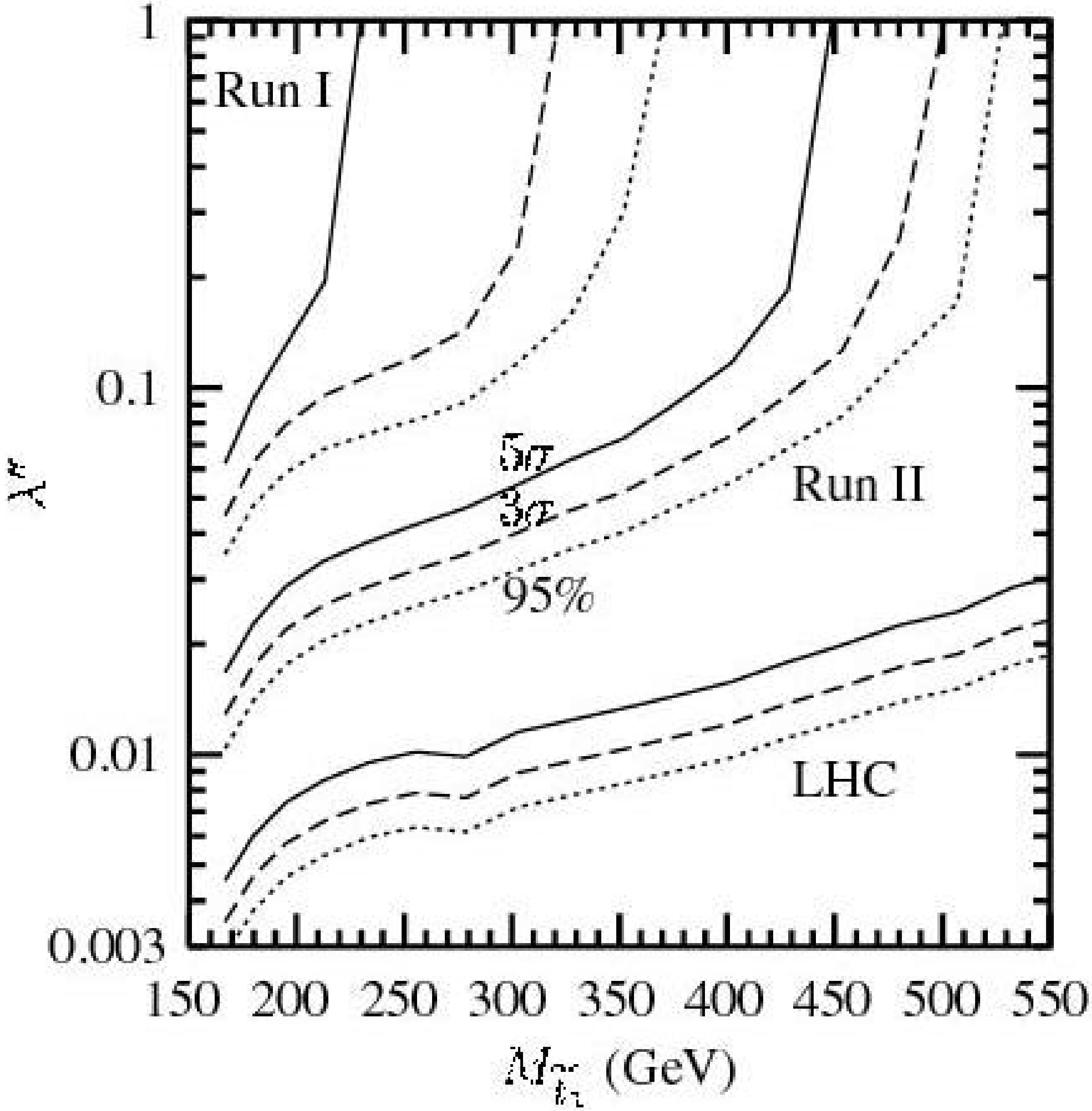

Figure 1. Lower limits on discovery (S $\sqrt{B}$ = 5, solid), evidence (S $\sqrt{B}$ = 3, dashed), and 95% confidence-level exclusion (S $\sqrt{B}$ = 1.96, dotted) for the R-parity-violating coupling l'' versus top-squark mass in run I of the Tevatron ($\sqrt{S}$ = 1.8 TeV, 110 pb^{-1}), run II of the Tevatron ($\sqrt{S}$ = 2 TeV, 2fb^{-1}), and one year at the LHC ($\sqrt{S}$ = 14 TeV, 10fb^{-1}).

(E. L. Berger)

II.A.2 Supersymmetry Contribution to Bottom Quark Production at Hadron Colliders

The cross section for bottom-quark production at hadron collider energies exceeds the central value of predictions of next-to-leading order (NLO) perturbative quantum chromodynamics (QCD) by about a factor of two. In Argonne report ANL-HEP-PR-00-116, hep-ph/0012001, accepted for publication in Physical Review Letters, Ed Berger, Brian Harris, David Kaplan, Zack Sullivan, Tim Tait, and Carlos Wagner describe an explanation for this discrepancy within the context of the minimal supersymmetric standard model. They propose the existence of a relatively light gluino $\tilde{g}$ (mass $\simeq$ 12 to 16 GeV) that decays into a bottom quark b and a light bottom squark $\tilde{b}$ (mass $\simeq$ 2 to 5.5 GeV). The gluino decays instantly with 100% branching fraction into the b and $\tilde{b}$, but the $\tilde{b}$ is either long-lived or decays via R-parity violation into a pair of hadronic jets. Among the predictions of this supersymmetry scenario, the most clearcut is pair production of like-sign charged B mesons at hadron colliders, B^+B^+ and B^-B^-. The assumptions made in this work are consistent with all constraints on the masses and couplings of supersymmetric particles.

The light gluinos are produced in pairs via standard QCD subprocesses, dominantly $g + g \rightarrow \tilde{g} + \tilde{g}$ at Tevatron and Large Hadron Collider (LHC) energies. Figure 1 shows the integrated p_{Tb} distribution of the b quarks that results from $\tilde{g} \rightarrow b + \tilde{b}$, for $m_{\tilde{g}}$ = 14 GeV and $m_{\tilde{b}}$ = 3.5 GeV. The results are compared with the cross section obtained from next-to-leading order QCD. A relatively light gluino is necessary in order to obtain a bottom-quark cross section comparable in magnitude to the pure QCD component, but values that are too small produce more cross section than seems tolerated by the ratio of like-sign to opposite-sign leptons from b decay. After the contributions of the NLO QCD and SUSY components are added, the magnitude of the bottom-quark cross section and the shape of the integrated $p_{Tb}^{\min}$ distribution are described well.

Since the $\tilde{g}$ is a Majorana particle, its decay yields both quarks and antiquarks. Gluino pair production and subsequent decay to b's will generate bb and $\bar{b}\bar{b}$ pairs, as well as the $b\bar{b}$ final states that appear in QCD production. The new supersymmetry mechanism leads therefore to an increase of like-sign leptons in the final state after semi-leptonic decays of the b and $\bar{b}$ quarks. This increase could be confused with an enhanced rate of $B^0 - \bar{B}^0$ mixing in hadron reactions relative to that observed in e^+e^- processes. Time-integrated mixing analyses of lepton pairs observed at hadron colliders are interpreted in terms of the quantity $\bar{c}$. To estimate the theoretical $\bar{c}_{\text{eff}}$, Berger, Harris, Kaplan, Sullivan, Tait, and Wagner assume that the Particle Data Group world-average $\bar{c}$ = 0.118 $\pm$ 0.005 represents the contribution from only the QCD $b\bar{b}$ component. They compute $\bar{c}_{\text{eff}}$ = 0.17 for $m_{\tilde{g}}$ = 14 GeV, and $\bar{c}_{\text{eff}}$ = 0.16 with $m_{\tilde{g}}$ = 16 GeV, with an uncertainty of $d\bar{c}_{\text{eff}} \simeq \pm 0.02$. Comparing with the CDF value, $\bar{c}_{\text{eff}} = 0.131 \pm 0.02 \pm 0.016$, they conclude that values of $m_{\tilde{g}} >$ 12 GeV lead to a calculated $\bar{c}_{\text{eff}}$ that is consistent with the data within experimental and theoretical uncertainties. With

$\sigma_{\tilde{g}\tilde{g}}/\sigma_{qcd} \sim 1/3$, they can satisfy the magnitude and p_T dependence of the b production cross section and the mixing data. A very precise measurement of $\bar{\chi}$ in run II of the Tevatron is obviously desirable.

A light $\tilde{g}$ with mass about 15 GeV and a light $\tilde{b}$ slow the running of α_s and modify $\alpha_s(M_Z)$, determined by extrapolation from experiments performed at energies lower than $m_{\tilde{g}}$. The result is a shift of 0.007 in α_s derived from these experiments, to $\alpha_s(M_Z) \simeq 0.125$, at the upper edge of the uncertainty band. Greater precision on the determination of $\alpha_s(M_Z)$ from evolution would be valuable. Possible bound states of bottom squark pairs could be seen as $J^P = 0^+, 1^-, 2^+, \ldots$ mesonic resonances in gg reactions and in $p\bar{p}$ formation, with masses in the 4 to 10 GeV range. They could show up as narrow states in the $\mu^+\mu^-$ invariant mass spectrum at hadron colliders, between the J/Ψ and Υ.

Strict R-parity conservation in the MSSM forbids $\tilde{b}$ decay unless there is a lighter supersymmetric particle. R-parity-violating ($\not{R}_p$) and lepton-number-violating decay of the $\tilde{b}$ into at least one lepton is disfavored by CLEO data and would imply the presence of an extra lepton, albeit soft, in some fraction of b jets observed at hadron colliders. The possible $\not{R}_p$ and baryon-number violating decay channels for the $\tilde{b}$ are $\bar{\tilde{b}} \to u$+s; $\bar{\tilde{b}} \to c$+d; and $\bar{\tilde{b}} \to c$+s. The hadronic width is

$$\Gamma(\tilde{b} \to \text{jet} + \text{jet}) = \frac{m_{\tilde{b}}}{2\pi} \sin^2 \theta_{\tilde{b}} \sum_{j<k} \left| \lambda''_{ij3} \right|^2. \qquad (1)$$

If $m_{\tilde{b}} = 3.5$ GeV, $\Gamma(\tilde{b} \to ij) = 0.08 \left| \lambda''_{ij3} \right|^2$ GeV. Unless all λ''_{ij3} are extremely small, the $\tilde{b}$ will decay quickly and leave soft jets in the cone around the b. b-jets with an extra c are possibly disfavored by CDF, but a detailed simulation is needed. If the $\tilde{b}$ is relatively stable, the $\tilde{b}$ could pick up a light $\bar{u}$ or $\bar{d}$ and become a $\tilde{B}^-$ or $\tilde{B}^0$ "mesino" with $J = 1/2$, the superpartner of the B meson. The mass of the mesino would fall roughly in the range 3 to 7 GeV.

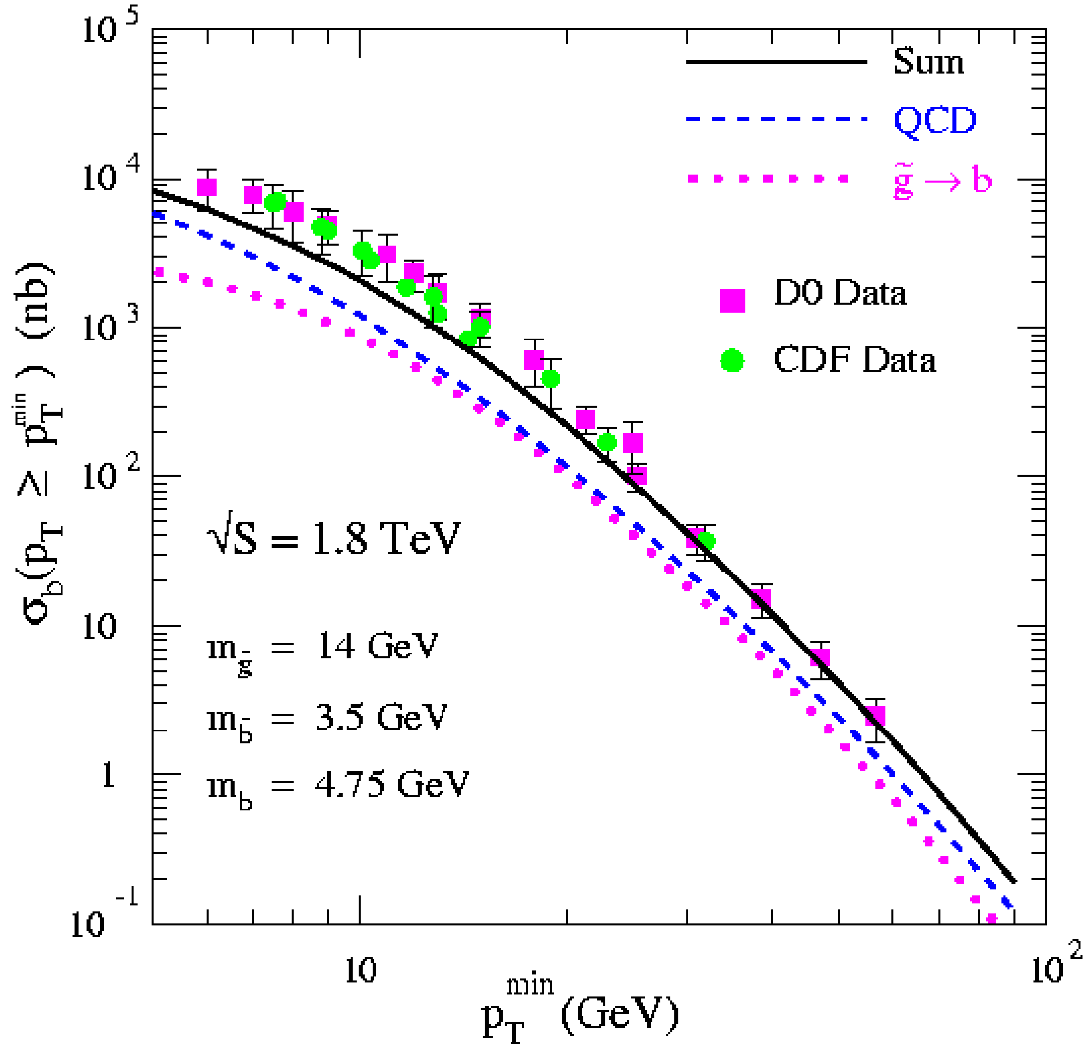

Figure 1. Bottom-quark cross section in $p\bar{p}$ collisions at $\sqrt{S}$ = 1.8 TeV for $p_{Tb} > p_{Tb}^{min}$ with a gluino of mass $m_{\tilde{g}}$ = 14 GeV and a bottom squark of mass $m_{\tilde{b}}$ = 3.5 GeV. The dashed curve is the central value of the NLO QCD prediction. The dotted curve shows the p_T spectrum of the b from the supersymmetry (SUSY) processes. The solid curve is the sum of the QCD and SUSY components.

(E. L. Berger)

II.A.3 Compatibility of Approaches to Heavy-Quark Fragmentation

G. Bodwin and B. Harris investigated the compatibility of several widely used approaches to heavy-quark fragmentation.

One such approach is the general analysis of Jaffe and Randall, which is based on Heavy-Quark Effective Theory (HQET). Bodwin and Harris found that the definition of the heavy-quark fragmentation function given by Jaffe and Randall differs from the standard

Collins-Soper definition by a factor of the longitudinal-momentum fraction z. This factor is essential to the interpretation of the fragmentation function as a probability distribution. Once this factor was taken into account, Bodwin and Harris found that the perturbative model of fragmentation of Braaten *et al.* is in agreement with the general predictions of Jaffe and Randall.

It had long been thought that the shape of the fragmentation function in the popular model of Peterson *et al.* is incompatible with the general analysis of Jaffe and Randall. However, Bodwin and Harris re-examined the model of Peterson *et al.* and found that the quoted values of the width and of z at the maximum were in error. The corrected values that Bodwin and Harris obtained are consistent with the analysis of Jaffe and Randall.

This work is reported in ANL-HEP-PR-00-093 (hep-ph/0012037).

(G. T. Bodwin and B. W. Harris)

II.A.4 Decay Matrix Elements from Lattice Measurements

Several years ago, G. Bodwin, D. Sinclair, and S. Kim (Sejong Univ.) completed a calculation in lattice field theory of the nonperturbative operator matrix elements that appear in the factorization formulae for the decays of S-wave and P-wave charmonium and bottomonium. Such a calculation involves two steps. First, one measures the relevant operator matrix elements in a lattice numerical simulation. Then one computes, in lattice perturbation theory, the relations between the lattice matrix elements and the continuum matrix elements, which are used in phenomenology.

The results of this initial calculation include values for the color-octet P-wave matrix elements, which agree, within errors, with matrix elements extracted from measurements of the decay rates of the J/ψ and the χ_c states. A value for the Upsilon decay matrix element was also obtained. However, it is about 40% below the value extracted from experiment.

One of the shortcomings of this initial calculation is that it was carried out in the quenched approximation. That is, the effects of light-quark dynamical loops were neglected. Bodwin, Sinclair, and Kim suspected that the discrepancy in the Upsilon decay matrix element was caused by this use of the quenched approximation. During the current reporting period, they completed a new calculation of the matrix elements, including the effects of dynamical light quarks.

Preliminary results indicate that the Upsilon decay matrix element, extrapolated to the case of three dynamical light quarks, is about 15% above the experimental value, but agrees with it, within errors. The matrix element that governs the order-v^2 corrections to the Upsilon decay rate is poorly determined, as in the quenched case, owing to large corrections to the perturbative coefficients that scale as a power of the cutoff. The color-singlet P-wave matrix element is about twice as large as in the quenched case. The color-octet matrix element that appears in P-wave decays is about 30% larger than in the quenched case. There are, at present, no experimental data on the c_b decay rates into light hadrons. However, these new results could be used to predict those decay rates.

A paper describing these results (ANL-HEP-PR-01-026) is in preparation.

(G. T. Bodwin and D. K. Sinclair)

II.A.5 Computational Physics

The major thrust of the lattice gauge theory effort has been continuing our simulations of a simple model, two-colour QCD at finite quark-number density. This is achieved by adding a chemical potential for quark-number to the theory's action. The reason for using this simple model is that true (three-colour) QCD has a complex fermion determinant, which makes it intractable using current simulation methods. For large enough chemical potential this model undergoes a phase transition to a state where quark-number is spontaneously broken by a diquark condensate. Since such behaviour is expected for true QCD, it is hoped that these model studies will improve our understanding of this phenomenon. During this 6-month period, we extended our simulations on an 8^4 lattice at 3 different quark masses and on a $12^3 \times 24$ lattice at the largest of these quark masses. We are now able to see clear evidence of a phase transition to this state with a diquark condensate on both lattice sizes (see Fig. 1), while for the larger lattice we are able to observe the expected Goldstone boson. This work is being performed on CRAY SV1's at NERSC and IBM SP's at NERSC and NPACI.

During this period, we have produced code for simulations of true QCD with a finite chemical potential for isospin, which is closely related to the work described above. However, since nuclear matter has finite isospin density as well as baryon-number density, this will probe a surface in the phase diagram for nuclear matter, that at zero baryon-number density (but finite isospin density). This theory has a real, positive, fermion determinant and so is amenable to standard simulation techniques.

In addition, during this period, we performed analyses of our simulations of zero mass lattice QCD, with an action modified by the addition of chiral 4-fermion interactions, which allowed us to work at zero mass. This further analysis was needed after our observation that the finite temperature chiral (deconfinement) transition on a lattice of temporal extent 6 (lattice units) appeared to be a tricritical point. We are still simulating on lattices of temporal extent 4 on the NERSC SV1's where the nature of this transition is still unclear.

Finally, we are continuing our studies of the chiral properties of domain-wall fermions, especially with regard to their interaction with gauge fields of non-trivial topology. Again these studies are being performed on the CRAY SV1's at NERSC.

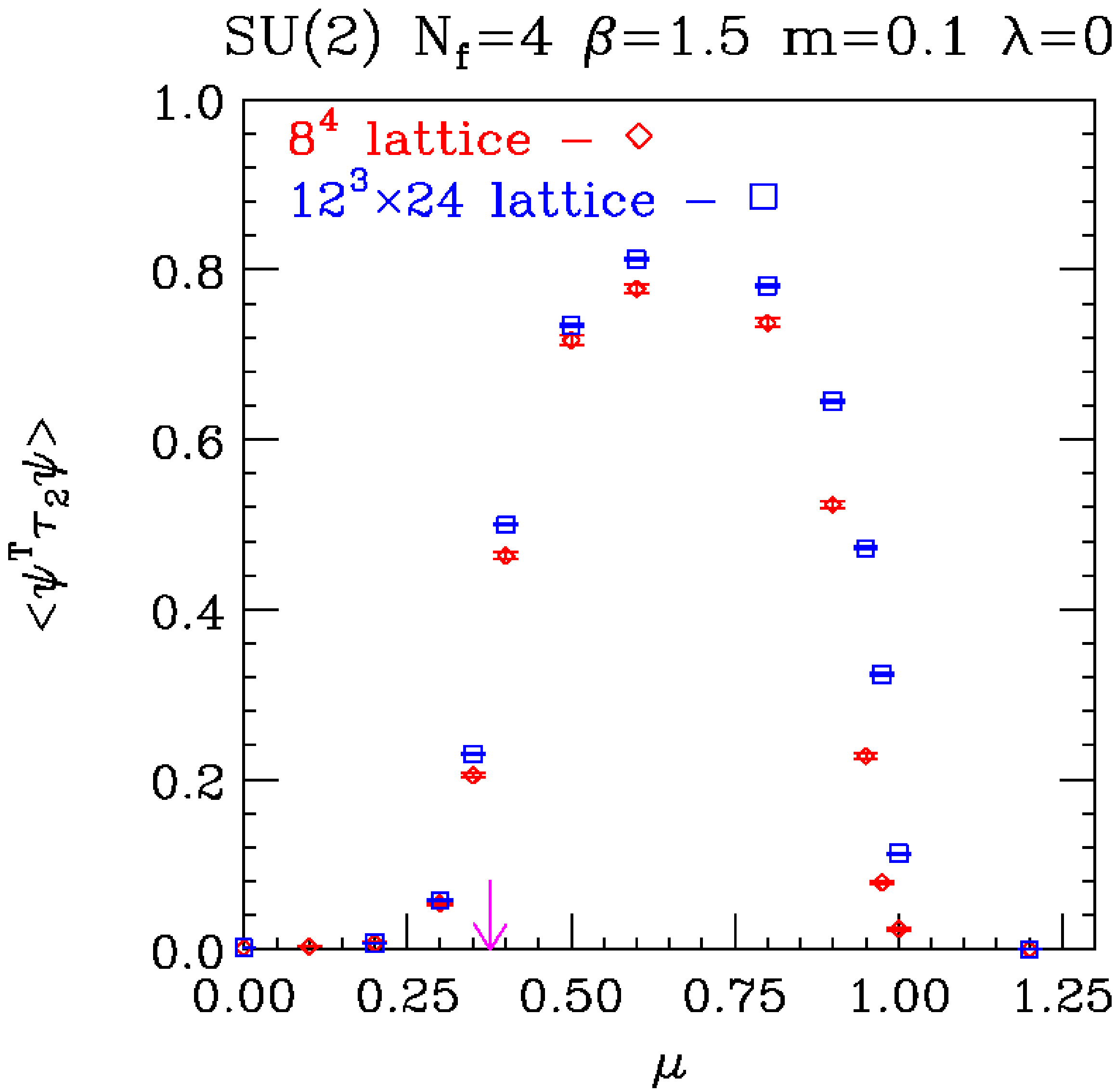

Figure 1. Diquark condensate as a function of chemical potential m .

(D. K. Sinclair)

II.A.6 Chirality Violation in the QCD High-Energy S-Matrix

In a talk presented at the International Euroconference on Quantum Chromodynamics (QCD 00), Montpellier, France, July 6-13, 2000, and published as Nucl. Phys. Proc. Suppl. **96**, 277-286 (2001), Alan White describes the appearance of the U(1) anomaly in the interactions of reggeized gluons. Also discussed is the crucial role the anomaly can play in providing the non-perturbative properties necessary for a transition from gluon and quark reggeon diagrams to hadron reggeons and a reggeon field theory description of the pomeron.

In a recently published paper, Phys. Rev. **D63**:016007 (2001), consisting of 52 pages, it has been shown that the infra-red divergence associated with the triangle graph axial anomaly can occur in triple-regge multi-reggeon interactions due to unphysical asymptotic triple discontinuities. In a new paper, in preparation, an asymptotic discontinuity analysis is applied to high-order Feynman diagrams to show that the anomaly exists in contributions to the triple-regge nine-reggeon interaction. This implies that the anomaly occurs in the interactions of reggeon states that have the quantum numbers of the anomaly current and establishes a direct connection with the well-known U(1) problem.

(A. R. White)

II.A.7 Generation of All Wigner Functions

C. Zachos has advanced a long-term project on Deformation Quantization, which provides, among others, the technical tools for constructing the solitons of noncommutative field theories. These theories are currently the most dynamic area of development in open (tachyonic) string physics.

In an invited talk [ANL-CP-00-085, hep-th/0008010] on his computational technique for the star product, beyond covering his published method, he further explains the emergence of noncommutativity from background field physics. Specifically, he details how simple Landau orbits in a constant magnetic field specify *classical* noncommutative structures in general, through their Dirac brackets; and the special (all but miraculous) circumstances actually obtaining for the deformation quantization of those--so that star products apply, instead of Kontsevich's celebrated but intractable generalization thereof. He further demonstrates why his method of evaluation, by dint of its recursive nature, is far more efficient for applications than an alternative elegant construction introduced by Almeida.

In collaboration with T Uematsu (Kyoto) and T Curtright (Miami), an extensive work on generating functions for complete sets of Wigner functions has been completed [ANL-HEP-PR-00-115, hep-th/0011137, J. Math. Phys., in press]. Wigner Functions are density matrices represented in phase-space, in the Weyl correspondence scheme, which makes phase space quantization possible. Unfortunately, calculations of and with them are technically involved, and no broadly applicable sourcebook is at hand today, so computational advances have to be laboriously devised and collected.

This contribution starts by arguing for the advantages of generating functions in computing matrix elements in phase space, given the underappreciated *complete bases for star-expansions*: several works in the contemporary literature appear misguided about the completeness or not of such sets of Wigner functions. By contrast, better recent reviews on noncommutative soliton (D-brane) theory, such as [hep-th/0102076], have subsequently directly utilized the CUZ contribution described here, so the gap in the literature has been effectively closed. By virtue of the generating functions, the contribution evaluates matrix elements and star-exponentials for simple systems (indexed discretely and continuously) efficiently. It then applies this picture to produce surprising results for the Liouville Hamiltonian (exponential interaction), which bear promise for solitons in the tachyonic sector of string theory. Several mathematical results are also provided as bonus byproducts of this investigation, including the star-composition laws for the generating functions introduced, connections to coherent state representations, and the deformation quantization mechanics of CBH identities.

(C. Zachos)

III. ACCELERATOR RESEARCH AND DEVELOPMENT

III.A. ARGONNE WAKEFIELD ACCELERATOR PROGRAM

III.A.1 Facility Status and Upgrade

A new 8 capacitor and inductor pack was added to the existing PFN modulator. After careful tuning and conditioning, we have extended the RF pulse length from current 4 μs to 6 μs. This would enable us to operate the new AWA photo-injector at the designed power level. Also a new laser trombone was installed, this laser trombone can produce a much better quality witness beam because its straightness.

The new drive gun was successfully brazed at SLAC. Experiences working with SLAC were excellent. The surprising fact was that the gun resonant frequency did not change after brazing, thus no further tuning needed. The vacuum has reached to 2×10^{-9} torr without baking; thus 10^{-10} torr can be obtained with high temperature baking. This can be attributed to the careful engineering and fabrication process used by us. This gun is currently installed in the AWA tunnel and ready for conditioning.

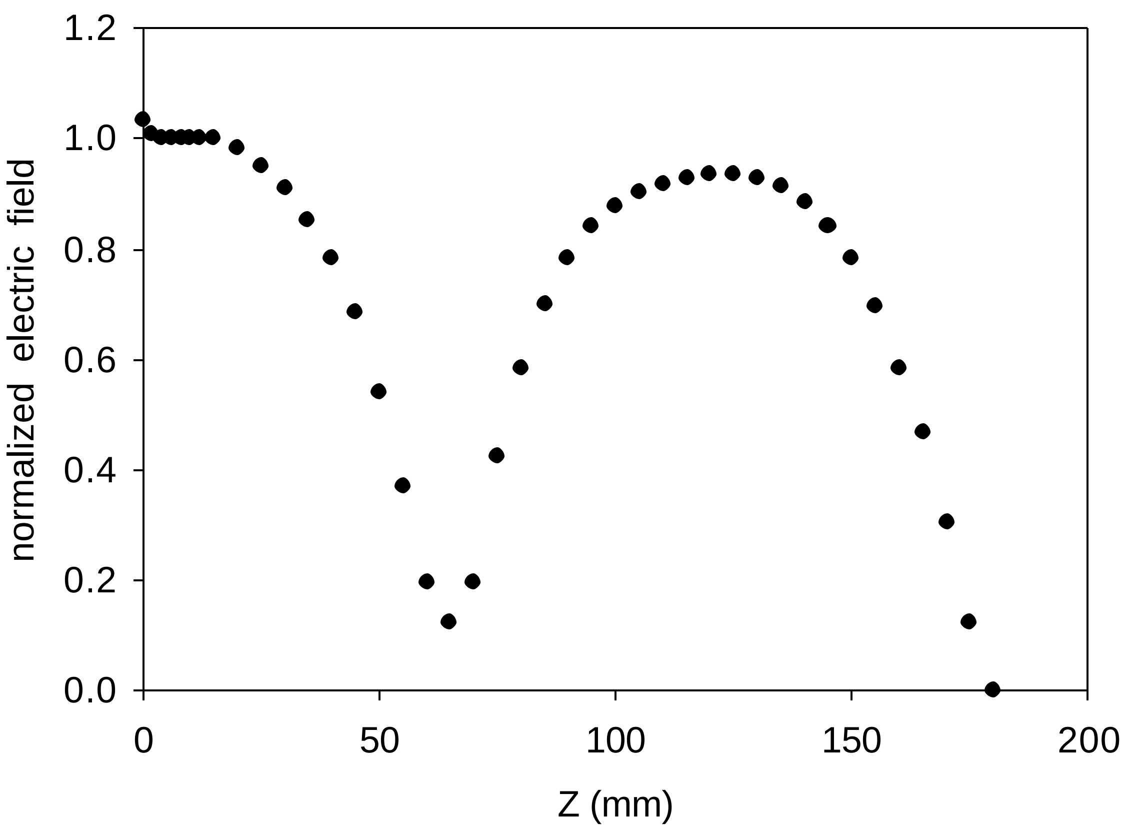

Figure 1. Bead pull measurement result after the gun was brazed. It shows field balance of 1% between cells achieved.

III.A.2 Experimental Program

a. Two-beam Acceleration Experiment

We have showed that two-beam acceleration experiment was successfully demonstrated in the last report. During this period, we have mapped details of the wakefield in stage II tube. The result is shown in Figure 2.

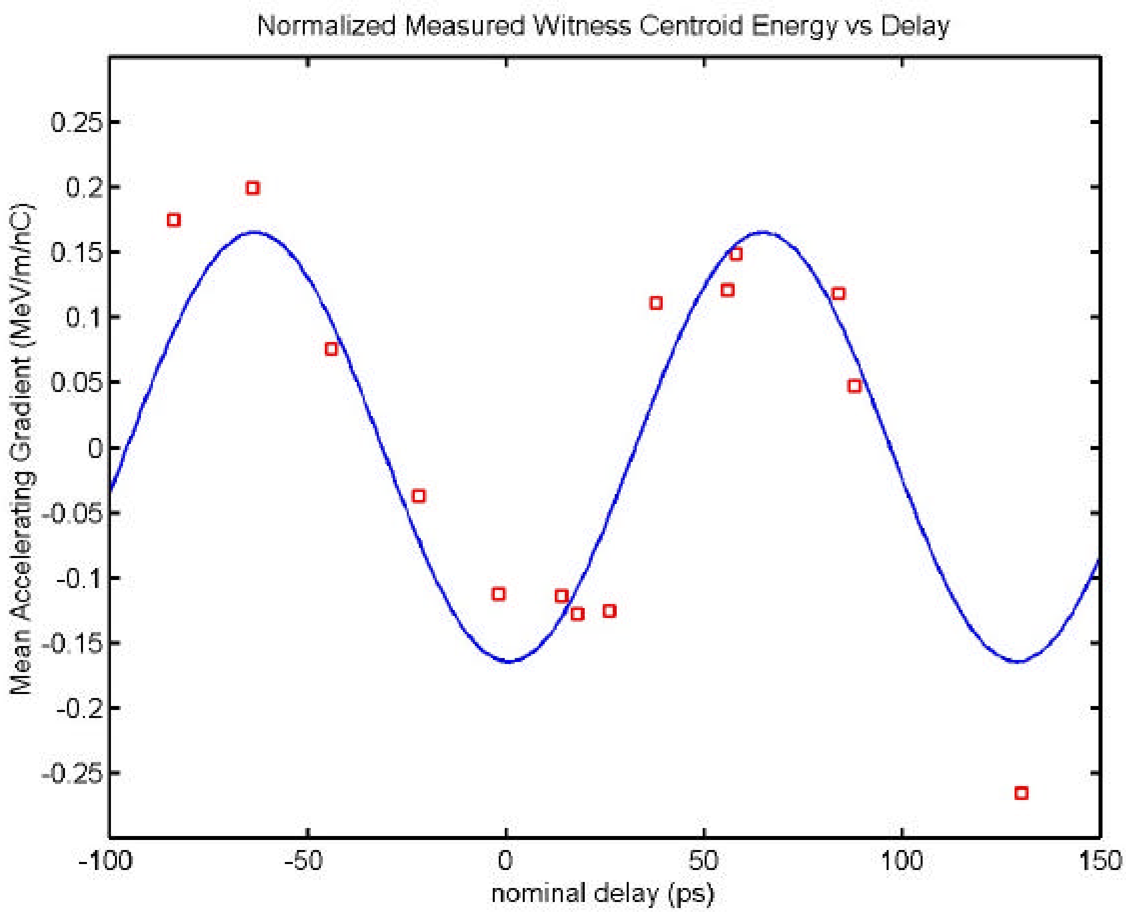

Figure 2. Detailed wakefield measurement in stage 2 of the two-beam acceleration experiment. The centroid energy of the witness beam changes vs. time delay of the drive beam. It shows periodical behavior. The dots are data and solid line is prediction. The data showed good agreement with predictions.

b. Theoretical Accelerator Physics

We explored a new type of acceleration structure: Hybrid dielectric/iris loaded accelerator. The structure has distinguished advantage over pure iris loaded structure: maximum acceleration field is on axis instead of on irises. In pure iris loaded structure, the peak field on iris can be 3 times higher than acceleration field on axis, therefore producing severe arcing that degrades the accelerator performance.

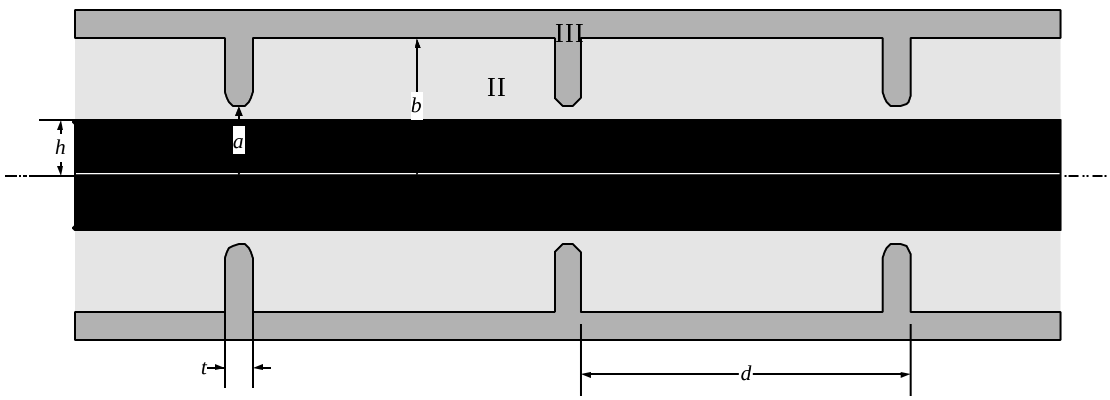

Figure 3. Hybrid dielectric/iris loaded structure.

Details of the property comparison for x-band (11.424 GHz) structure is shown in the following table.

TABLE 1. 11.424GHz pure iris-loaded traveling-wave structure

a (mm)	*b* (mm)	*t* (mm)	*d (mm)*	E_s/E_a	*r* (MW/m)	*Q*	*r/Q* (W/m)	v_g (*c*)
5.6021	11.1254	1.0	8.7535	2.4	75.6	7251	10343	0.088

TABLE 2. 11.424GHz hybrid dielectric-iris-loaded traveling-wave structure (e=6, *t*=1.0 mm)

a (mm)	*b* (mm)	*h* (mm)	*d (mm)*	E_s/E_a	*r* (MW/m)	*Q*	*r/Q* (W/m)	v_g (*c*)
5.5	6.923	4.0	8.7535	1.1	38.0	4506.0	8433.2	0.089
4.0	5.361	2.0	8.7535	1.01	66.8	4899.0	13635.4	0.087

(W. Gai)

III.B. MUON COLLIDER R&D

III.B.1 Muon Collider and Neutrino Source

a. Modeling

Emittance exchange is a major goal of the Muon cooling simulation effort and a promising option has been identified. A major limitation of Muon cooling simulations so far is that while the bunch can be cooled in the transverse direction, it is difficult to maintain the longitudinal emittance, e_L and it has not been possible to reduce e_L from the initial value in any of the cooling simulations done so far. Following a workshop at BNL the "Gentle Bend" geometry was identified as having some potential advantages. Unlike the SFOFO geometry or some more complex geometries, this system uses a very simple magnetic structure, a homogeneous "single flip" solenoid bent with a radius of about 10 m, to provide a dispersion of on the order of 0.2 m. Incorporating realistic constraints requires alternating wedge and bend sections of about 6 m long, a length set by the synchrotron oscillations, which tend to mix the particle energies. The bends seem to work best when they go in opposite directions. Steve Kahn of BNL helped simulate a number of different options.

One problem that was encountered was the somewhat ambiguous definition of emittance, in a fully six dimensional environment with correlations. The correlations can, in principle, be removed by such techniques as equal and opposite bends, and careful placement of wedges.. The size of the correlations, however, can be comparable to the changes in the longitudinal emittance.

Using a combination of dispersion and wedges, the longitudinal emittance has been shown to be lowered by as much as 30% in a single wedge assembly. The dispersion generated by this method is comparable to other, more complicated, geometries and the coil system should be a small perturbation on the "single flip" geometry, which is the simplest option being studied. Thus this method seems to show considerable promise. More detailed simulations will follow, incorporating longer beamlines, which can study both the gross features of emittance exchange and the complications of correlations.

III.B.2 Muon Cooling Experiment

Measurement of Muon beams in an environment, which contains high gradient rf cavities, is being studied by a large number of people. A workshop was held at IIT organized by ANL (Norem) and IIT (Solomey) to identify the techniques that could be used for bunched beam cooling experiments. At the present time single particle measurements are not being considered because of ANL measurements which showed the large dark current and x-ray flux produced in this environment. A number of methods were identified and an experimental program is being set up to test them with realistic rf and a 5 T magnet in Lab G of Fermilab. This work has been delayed by Run II at Fermilab, but should begin in May or June.

(J. Norem)

IV. PUBLICATIONS

IV.A. BOOKS, JOURNALS, AND CONFERENCE PROCEEDINGS

A Comparison of Spin Observable Predictions for RHIC
G. P. Ramsey
RIKEN Rev. **28**, 86-89 (2000).

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M. C. Goodman (*The Soudan 2 Collaboration*)
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Canonical-Covariant Wigner Function in Polar Form
T. Hakioglu
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Constraints on the Gluon Density from Lepton Pair Production
E. L. Berger and M. Klasen
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Direct Measurement of the *W* Boson Width in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.8 TeV
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G. Chalmers and J. Erdmenger
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E. L. Berger, S. E. Kuhlmann, *et al*.
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D. Wall (*The Soudan 2 Collaboration*)

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Search for the Charged Higgs Boson in the Decays of Top Quark Pairs in the et and mt Channels at $\sqrt{s} = 1.8$ TeV

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M. Derrick

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D. E. Kaplan, G. D. Kribs, and M. Schmaltz

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S. Kuhlmann

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A. R. White

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J. B. Kogut and D. K. Sinclair

Phys. Lett. **B492**, 228-232 (2000).

IV.B. MAJOR ARTICLES SUBMITTED FOR PUBLICATION

A Feasibility Study of a Neutrino Source Based on a Muon Storage Ring

D. Ayres, M. Goodman, A. Hassanein, T. Joffe-Minor, D. Krakauer, J.H. Norem, C.B. Reed, P. Schoessow, D. Smith, R. Talaga, J. Thron, L.C. Teng, C. Wagner, and C.X. Wang (T. Anderson, *et al*.)
ANL-HEP-PR-01-31

$b \rightarrow sg$ and Supersymmetry with Large tan b

M. Carena, D. Garcia, U. Nierste, and C.E.M. Wagner

Phys. Lett. B
ANL-HEP-PR-00-104

Canonical-Covariant Wigner Function in Polar Form

T. Hakioglu

J. Opt. Soc. A
ANL-HEP-PR-00-095

Compatibility of Various Approaches to Heavy-Quark Fragmentation
G. T. Bodwin and B. W. Harris
Phys. Rev. D
ANL-HEP-PR-00-093

CP-Violating MSSM Higgs Bosons in the Light of LEP 2
M. Carena, J. Ellis, A. Pilaftsis, and C.E.M. Wagner
Phys. Letts. B
ANL-HEP-PR-00-099

Direct Probes of R-Parity-Violating Supersymmetric Couplings Via Single-Top-Squark Production
E. L. Berger, B. W. Harris, and Z. Sullivan
Phys. Rev. D
ANL-HEP-PR-00-062

Elliptic Flow in Au + Au Collisions at $\sqrt{S_{NN}}$ = 130 TeV
K.H. Ackermann, *et al.* (*The STAR Collaboration*)
Phys. Rev. Lett.
ANL-HEP-PR-00-105

Do Electroweak Precision Data and Higgs-Mass Constraints Rule out a Scalar Bottom Quark with Mass of *O*(5 GeV)?
M. Carena, S. Heinemeyer, C.E.M. Wagner, and G. Weiglein
Phys. Rev. Letts.
ANL-HEP-PR-00-087

Experimental Puzzles in Heavy Flavor Decays Anomalously High *h'* Appearance in Charmless Strange *B* Decays – Flavor SU(3) Breaking in Charm Decays
H. J. Lipkin
Phys. Letts.
ANL-HEP-PR-00-100

Gaugino-Assisted Anomaly Mediation
D. E. Kaplan and G. D. Kribs
JHEP
ANL-HEP-PR-00-090

Generating All Wigner Functions
T. Curtright, T. Uematsu, and C. Zachos
J. Math. Phys.
ANL-HEP-PR-00-115

Global Conformal Anomaly in *N*=2 String
G. Chalmers and W. Siegel
Phys. Rev. D
ANL-HEP-PR-00-086

Introductory Calculus from the Viewpoint of Non-Standard Analysis-Derivative of Sine and Cosine

J. L. Uretsky

SIAM Review, Section 4

ANL-HEP-PR-00-107

Low Energy Supersymmetry and the Tevatron Bottom-Quark Cross Section

E. L. Berger, B. W. Harris, D. E. Kaplan, Z. Sullivan, T.M.P. Tait, and C.E.M. Wagner

Phys. Rev. Letts.

ANL-HEP-PR-00-116

Measurement of the Two-Jet Differential Cross Section in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1800 GeV

R. E. Blair, K. L. Byrum, E. Kovacs, S. E. Kuhlmann, T. LeCompte, L. Nodulman, J. Proudfoot, R. Thurman-Keup, R. G. Wagner, A. B. Wicklund (*The CDF Collaboration*)

Phys. Rev. D

ANL-HEP-PR-00-138

Measurement of the *W* Boson Mass with the Collider Detector at Fermilab

R. Blair, K. Byrum, E. Kovacs, S. Kuhlmann, T. LeCompte, L. Nodulman, J. Proudfoot, R. Thurman-Keup, R. Wagner, A. Wicklund (*The CDF Collaboration*)

Phys. Rev. D

ANL-HEP-PR-00-88

Moduli Spaces and Scattering of Supersymmetric Monopoles

G. Chalmers

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ANL-HEP-PR-00-096

N=2 Quantum String Scattering

G. Chalmers, O. Lechtenfeld, and B. Niemeyer

Nucl. Phys. B

ANL-HEP-PR-00-061

Non-Linear Canonical Transformations in Weyl Quantization

T. Hakioglu

Phys. Rev. D

ANL-HEP-PR-00-119

On the Finiteness of $N = 8$ Quantum Supergravity

G. Chalmers

Phys. Rev. Letts.

ANL-HEP-PR-00-083

Production of X_{c1} and X_{c2} in $p\overline{p}$ Collisions at $\sqrt{s}$ = 1.8 TeV

R. E. Blair, K. L. Byrum, E. Kovacs, S. E. Kuhlmann, T. LeCompte, L. Nodulman, J. Proudfoot, R. Thurman-Keup, R. G. Wagner, A. B. Wicklund (*The CDF Collaboration*)

Phys. Rev. Letts.

ANL-HEP-PR-00-130

Search for Neutral Supersymmetric Higgs Bosons in $p\overline{p}$ Collisions at $\sqrt{s}$ =1.8 TeV

R. E. Blair, K. L. Byrum, E. Kovacs, S. E. Kuhlmann, T. LeCompte, L. Nodulman, J. Proudfoot, R. Thurman-Keup, R. G. Wagner, A. B. Wicklund (*The CDF Collaboration*)

Phys. Rev. Letts.

ANL-HEP-PR-00-114

Search for the Supersymmetric Partner of the Top-Quark in $p\overline{p}$ Collisions at $\sqrt{s}$ = 1.8 TeV

R. E. Blair, K. L. Byrum, S. E. Kuhlmann, T. LeCompte, L. Nodulman, J. Proudfoot, R. Thurman-Keup, R. G. Wagner, A. B. Wicklund (*The CDF Collaboration*)

Phys. Rev. D

ANL-HEP-PR-00-131

Supersymmetric CP-violating Currents and Electroweak Baryogenesis

M. Carena, J. M. Moreno, M. Quiros, M. Seco, and C.E.M. Wagner

Nucl. Phys. B

ANL-HEP-PR-00-101

Systematics of Large Axial Vector Meson Production in Heavy Flavor Weak Decays

H. J. Lipkin

Nucl. Phys. B

ANL-HEP-PR-00-126

Variable Flavor Number Schemes Versus Fixed Order Perturbation Theory for Charm Quark Electroproduction

A. Chuvakin, J. Smith, and B. W. Harris

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ANL-HEP-PR-00-113

Viable Ultraviolet-Insensitive Supersymmetry Breaking

N. Arkani-Hamed, D. E. Kaplan, H. Murayama, and Y. Nomura

JHEP

ANL-HEP-PR-00-135

W Boson Physics at Hadron Colliders

R. M. Thurman-Keup

Rev. Mod. Phys.

ANL-HEP-PR-00-112

IV.C. PAPERS OR ABSTRACTS SUBMITTED TO CONFERENCES

A_N for Inclusive $p^{\pm}$ Production at 21.6 GeV/c from C and LH_2

H. Spinka, C. Allgower, T. Kasprzyk, K. Krueger, D. Underwood, A. Yokosawa (ANL), *et al*.

The 14th International Spin Physics Symposiumn (SPIN 2000) Osaka, Japan, October 16-21, 2000, accepted.
ANL-HEP-CP-00-129

A Survey of Star Product Geometry

C. Zachos

NATO Advanced Research Workshop: *Integrable Hierarchies and Modern Physical Theories* (UIC 2000), Chicago, IL, July 2000.
ANL-HEP-CP-00-085

Commissioning of RHIC p-Carbon CNI Polarimeter

H. Huang, *et al*.

Spin 2000 - 14th International Spin Physics Symposium, Osaka, Japan, October 16-21, 2000.
ANL-HEP-CP-00-136

Constraints on the Proton's Gluon Density from Lepton-Pair Production

E. L. Berger and M. Klasen

XXXth International Conference on High Energy Physics (ICHEP 2000), Osaka, Japan, July 27 – August 2, 2000.
ANL-HEP-CP-00-098

Experimental Demonstration of Dielectric Structure Based Two Beam Acceleration

W. Gai, M. E. Conde, R. Konecny, J. G. Power, P. Schoessow, X. Sun, and P. Zou

9th Advanced Accelerator Concepts Workshop (AAC), Santa Fe, NM, June 10-16, 2000, accepted.
ANL-HEP-CP-00-125

Experimental Measurements of Wakefields in a Multimode, Dielectric Structure Driven by a Train of Electron Bunches

J. G. Power, M. E. Conde, W. Gai, A. Kanareyken, R. Konecny, and P. Schoessow

9th Advanced Accelerator Concepts Workshop (AAC), Santa Fe, NM, June 10-16, 2000, accepted.
ANL-HEP-CP-00-103

Fully Differential QCD Corrections to Single Top Quark Final States

B. W. Harris, E. Laenen, L. Phaf, Z. Sullivan, and S. Weinzierl

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S. Magill and S. Chekanov
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ANL-HEP-CP-00-134

Next-to-Leading Order SUSY-QCD Calculation of Associated Production of Gauginos and Gluinos
E. L. Berger, T.M.P. Tait, and M. Klasen
XXXth International Conference on High Energy Physics (ICHEP 2000), Osaka, Japan, July 27 – August 2, 2000.
ANL-HEP-CP-00-097

Prompt (Direct) Photon Production at Colliders
S. R. Magill
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ANL-HEP-CP-00-132

QCD/Two-Photon Physics - Summary Report
S. R. Magill
Linear Collider Workshop 2000, Batavia, IL, October 24-28, 2000.
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M. Carena, J. S. Conway, H. E. Haber, J. D. Hobbs, B. W. Harris, S. Kuhlmann, Z. Sullivan, T.M.P. Tait, C.E.M. Wagner, *et al*.
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ANL-HEP-CP-00-118

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R. Brock, *et al.*

Workshop on QCD and Weak Boson Physics in Run 2, Batavia, IL, March - November, 2000.
ANL-HEP-CP-00-123

Summary Report: Working Group 5 on "Electron Beam-Driven Plasma and Structure Based Acceleration Concepts"
M.E. Conde and T. Katsouleas
9th Advanced Accelerator Concepts Workshop (AAC), Santa Fe, NM, June 10-16, 2000.
ANL-HEP-CP-00-111

Supersymmetry Searches at the Tevatron
T. J. LeCompte
Spin 2000 - 14th International Spin Physics Symposium, Osaka, Japan, October 16-21, 2000.
ANL-HEP-CP-00-137

The Anomaly and Reggeon Field Theory in QCD
A. R. White
High Energy Physics International Euroconference in Quantum ChromoDynamics (QCD 00), Montpellier, France, July 6-13, 2000.
ANL-HEP-CP-00-092

Transformer Ratio Enhancement Using a Ramped Bunch Train in a Collinear Wakefield Accelerator
J. G. Power, W. Gai, and A. Kanareykin
9th Advanced Accelerator Concepts Workshop (AAC), Santa Fe, NM, June 10-16, 2000, accepted.
ANL-HEP-CP-00-102

Two-Colour QCD at Finite Fundamental Quark-Number Density and Related Theories
S. J. Hands, J. B. Kogut, S. E. Morrison, and D. K. Sinclair
18th International Symposium on Lattice Field Theory (LATTICE 2000), Bangalore, India, August 17-22, 2000.
ANL-HEP-CP-00-110

V.D. TECHNICAL REPORTS AND NOTES

CDF Notes:

CDF-5389
Shower Maximum Timing Issues
G. Drake, S. Kuhlmann, and J. Proudfoot

CDF-5404
List of `Banks' in the Run II PAD Format
R. Culbertson, H. Frisch, P. Murat, S. Rolli, D. Saltzberg, P. Savard, R. Snider, P. Tamburello, R. G. Wagner, A. Yagil

CDF-5416
Last Results on the Jet Energy Resolution using Calorimeter, Tracking, and Shower Max Information
A. Bocci, S. Kuhlmann, S. Lami, and G. Latino

CDF-5423
SUSY Searches at the Tevatron
T. LeCompte (for CDF)

CDF-5424
Muon Trigger Bits for the Commissioning Run
E. James, A. Varganov, T. LeCompte, M. Shochet, D. Saltzberg, B. Badgett, J. Lewis, P. Wilson, M. Schmitt, T. Liss, K. Pitts, G. Pauletta, and D. Carlsmith

CDF-5433
Yet Another Study of Electrons in Superjet Events
R. G. Wagner

CDF-5439
Determination of the QCD Jet -> Fake Photon Background in the Run 1 V+gamma Data Samples
D. Benjamin, L. Christofek, D. Errede, S. Errede, K. Hara, M. Lindgren, T. Muller, D. Neuberger, H. Sato, M. Shimojima, and R. G. Wagner

CDF-5446
Event 65085-273167 High-Mass Z+gamma Candidate
D. Benjamin, L. Christofek, D. Errede, S. Errede, K. Hara, M. Lindgren, T. Muller, D. Neuberger, H. Sato, M. Shimojima, and R. G. Wagner

CDF-5456
Electron Identification for Run II: Algorithms
R. G. Wagner

CDF-5462
A Sample Composition of The Run1b Photon + Muon
K. Kurino, S. Kuhlmann

CDF-5483
Summary of Proposals for B Physics Triggers in Run II
M. Paulini and B. Wicklund (*for The B Physics Group*)

CDF-5507
Studies of Jet Energy Resolution
S. Lami, A. Bocci, S. Kuhlmann, and G. Latino

CDF-5510
Behavior of Central Detectors Using SMQIEs in the Commisioning Run
K. Byrum, G. Drake, S. Kuhlmann, M. Lindgren, J. Proudfoot, L. Nodulman

CDF-5518
Proposal to Add Timing Information Into the Readout of the Central and Plug Electromagnetic Calorimeters
D. Toback, T. Kamon, S. Lee, S. Krutelyov, C. Battle, H. Frisch, P. Onyisi, C. Grosso-Pilcher, R.G. Wagner, and M. Cordelli

CDF-5519
Proposal to replace the Central Preshower Detector and Central Crack Chambers with an Integrated Scintillator Detector
R. Blair, J. Huston, S. Kuhlmann, L. Nodulman, A. Rostovtsev, and A. B. Wicklund

NuMI Notes:

NuMI-L-704 J. Grudzinski
"A Position Against the Need for Alner Bars in Minos Module Installation"
December 12, 2000

NuMI-L-680 Maury Goodman, Sanjib Mishra, *et al*.
"A description of the THESEUS proposal"
December 2000

NuMI-L-679 G. Bock, J. Cobb, M. Diwan, H. Gallagher, M. Goodman, K. Heller, P. Litchfield, T. Mann, S. Mishra, A. Para, G. Pearce, D. Petyt, G. Rameika, and L. Wai
"Report of the THESEUS Working Group (Version 3.3)"
November 28, 2000

NuMI-678 The Fermilab NuMI Project Staff and The MINOS Collaboration
"Summary of the NuMI Project"
November 20, 2000

NuMI-B-665
"Final Report of the MINOS Beam Monitoring Advisory Group (MIBMAG)"
August 10, 2000

Wakefield Notes:

WF-200
"6 MeV X-Band On-Axis Standing Wave Linear Accelerator"
Xiang Sun
October 12, 2000

WF-201
"Calculation of AWA Drive Beam Parameters at Low Charge"
Xiang Sun
October 25, 2000

ZEUS Notes:

00-039

"Jet Energy Corrections with the ZEUS Barrel Preshower Detector"

S. Magill and S. Chekanov

January 11, 2000

00-041

"Detector Position Review: 1997, 1998"

R. Yoshida

November 22, 2000

V. COLLOQUIA AND CONFERENCE TALKS

Edmond L. Berger

Predictions for Associated Production of a Gaugino and a Gluino at Hadron in SUSY-QCD at Next-to-Leading Order

Department of Physics, Michigan State University, East Lansing, September 26, 2000.

Next-to-Leading Order SUSY-QCD Predictions for Associated Production of a Gaugino and a Gluino

University of Chicago Program Review, HEP, Argonne, IL, September 18, 2000.

Predictions for Associated Production of a Gaugino and a Gluino at Hadron Colliders in SUSY-QCD at NLO

5th International Symposium on Radiative Corrections (RADCOR 2000), Carmel, CA, September 13, 2000.

Next-to-Leading Order SUSY-QCD Predictions for the Associated Production of Supersymmetric States at Hadron Colliders

Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China, August 18, 2000.

Predictions from Next-to-Leading Order Perturbative QCD for the Production of Supersymmetric States at Hadron Colliders

University of Science and Technology of China, Hefei, China, August 12, 2000.

Lepton-Pair Production – A New Method to Constrain the Proton's Gluon Density in Spin-Averaged and Spin-Dependent Reactions

Institute of Theoretical Physics, Academia Sinica, Beijing, China, August 10, 2000.

Next-to-Leading Order SUSY-QCD Predictions for the Associated Production of Supersymmetric States at Hadron Colliders

Institute of Theoretical Physics, Academia Sinica, Beijing, China, August 7, 2000.

Predictions from Next-to-Leadng Order QCD for the Production of Supersymmetric States at Hadron Colliders

China National Summer School for Graduate Students on Particle and Nuclear Physics, Beijing University, China, August 4, 2000.

Next-to-Leading Order SUSY-QCD Calculation of Associated Production of Gauginos and Gluinos

XXXth International Conference on High Energy Physics, Osaka, Japan, July 27, 2000.

Constraints on the Proton's Gluon Density from Lepton-Pair Production

XXXth International Conference on High Energy Physics, Osaka, Japan, July 27, 2000.

Geoffrey T. Bodwin

Resummation of Large QCD Corrections to Quarkonium Decay Rates
Department of Physics, Beijing University, Beijing, China, November 10, 2000.

Resummation of Large QCD Corrections to Quarkonium Decay Rates
Institute of Theoretical Physics, Beijing, China, November 7, 2000.

Gordon Chalmers

Quantization of N=2 Strings and Selfdual Field Theories
Department of Physics, Ohio State University, Columbus, OH, October 18, 2000.

Dual Expansions of Gauge Theories via *IIB* Superstring and the Holographic Correspondence
Department of Physics, Purdue University, West Lafayette, IN, October 17, 2000.

Quantization of N=2 Strings and Selfdual Field Theories
Department of Physics, ITP, SUNY, Stony Brook, NY, September 20, 2000.

Dual Expansions of Supersymmetric Gauge Theory Via *IIB* Superstring Theory and *S*-Duality 2000 Meeting of the Division of Particles and Fields of the American Physical Society (DPF 2000)
Columbus, OH, August 9-12, 2000.

Brian Harris

Theory Summary for Strong Interaction Session
Thinkshop2: Top-Quark Physics for Run II, Batavia, IL, November 12, 2000.

Status of Single-Top-Quark Theory
Thinkshop2: Top-Quark Physics for Run II, Batavia, IL, November 11, 2000.

b-Quark Cross Section at the Tevatron: A NEW Approach
CTEQ Meeting, Argonne, IL, October 23, 2000.

Progress Report on NLO QCD Corrections to Single Top Production at Hadron Colliders 2000 Meeting of the Division of Particles and Fields of the American Physical Society (DPF 2000)
Columbus, OH, August 9-12, 2000.

David Kaplan

Gaugino-Assisted Anomaly Mediation
SLAC, Stanford, CA, November 15, 2000.

Supersymmetry Breaking and a Small Extra Dimension
LBNL, Berkeley, CA, November 13, 2000.

Supersymmetry Breaking and a Small Extra Dimension
Weizmann Institute, Rehovot, Israel, October 26, 2000.

Gaugino Mediated Supersymmetry Breaking
Workshop on Physics at the Weak Scale and Beyond, Aspen, CO, August/ September XX, 2000.

Gaugino Mediated Supersymmetry Breaking
Beyond Four Dimensions Conference, Trieste, Italy, July 3, 2000.

Eve Kovacs

Jet Physics at CDF
Department of Physics, Beijing University, Beijing, China, November 10, 2000.

Jet Physics at CDF
Institute of Theoretical Physics, Beijing, China, November 9, 2000.

Steve Kuhlmann

Large X-Parton Distributions
Invited talk at Workshop on Nucleon Structure in High x-Bjorken Region (HiX2000), Philadelphia, PA, March 30 - April 1 2000. *(Not previously reported.)*

Harry J. Lipkin

The Parton Model and the Mossbauer Effect – From Crystals with Synchrotron Radiation to Heavy Quarks
University of Toronto, Canada, November 2, 2000.

The Parton Model and the Mossbauer Effect – From Crystals with Synchrotron Radiation to Heavy Quarks
Brookhaven National Laboratory, Upton, NY, October 31, 2000.

Experimental Puzzles in B and D Decays
ANL-HEP Division Lunch Seminar, Argonne, IL, August 29, 2000.

Maury Goodman

Highlights and Lowlights from Neutrino 2000
ANL-HEP Division Lunch Seminar, Argonne, IL, July 25, 2000.

Steve Magill

Jet Energy Corrections with the ZEUS Barrel Preshower Detector
IX International Conference on Particle Physics, Annecy, October 9-14, 2000.

John Power

Wakefield Acceleration and the Transformer Ratio at the Argonne Wakefield Accelerator
ANL Beams and Applications Seminar, Argonne, IL, September 1, 2000.

Gordon P. Ramsey

The Shape and Experimental Tests of the Q^2-Invariant Polarized Gluon Asymmetry
Spin Physics Symposium (SPIN 2000), Osaka, Japan, 16-21 October 2000.

Donald K. Sinclair

Two-Color QCD at Finite Fundamental Quark Number Density and Related Theories
XVIII International Symposium on Lattice Field Theory (LATTICE 2000), Bangalore, India, August 16-22, 2000.

Hal Spinka

A_N for Inclusive $p^{\pm}$ Production at 21.6 GeV from C and LH_2
The 14th International Spin Physics Symposium, Osaka, Japan, October 2000.

Zack Sullivan

Direct Probes of R-parity Violation at the Tevatron
CDF SUSY Workshop, Batavia, IL, December 1, 2000.

An Introduction to Top Quarks and the Weak Interaction
Thinkshop 2: *Review of the Discussion Groups*, Batavia IL, November 12, 2000.

A Theoretical Overview of Top Quarks and the Weak Interaction
Thinkshop 2: *Weak Interactions of the Top Quark*, Batavia IL, November 11, 2000.

Timothy Tait

Flavor and Supersymmetry Breaking from a Small Extra Dimension
Brookhaven National Laboratory, Upton, NY, December 6, 2000.

Carlos Wagner

Higgs Physics and Electroweak Baryogenesis in the MSSM
Department of Physics, University of Alabama, Tuscaloosa, AL, November 17, 2000.

Electroweak Baryogenesis in the MSSM
5th International Symposium on Radiative Corrections (RADCOR/2000), Carmel, California, September 13, 2000.

Supersymmetry and Electroweak Baryogenesis
IX Mexican School on Particles and Fields, Metepec, Puebla, Mexico, August 9-19, 2000.

Light Sbottoms and Electroweak Precision Measurements
Summer Workshop entitled "Physics at the Weak Scale and Beyond," Aspen, CO, August 21-September 8, 2000.

Light Sbottoms and Electroweak Precision Measurements
2000 Meeting of the Division of Particles and Fields of the American Physical Society (DPF 2000), Columbus, Ohio, August 12, 2000.

Electroweak Baryogenesis in the MSSM
2000 Meeting of the Division of Particles and Fields of the American Physical Society (DPF 2000), Columbus, Ohio, August 10, 2000.

Alan R. White

The Anomaly and Reggeon Field Theory in QCD
High Energy Physics International Euroconference in Quantum ChromoDynamics (QCD 00), Montpellier, France, July 6-13, 2000.

Cosmas Zachos

Star Product Geometry
University of Florida, Gainesville, FL, October 20, 2000.

A Survey of Star Product Geometry
NATO Advanced Research Workshop: *Integrable Hierarchies and Modern Physical Theories* (UIC 2000), Chicago, IL, July 25, 2000.

VI. HIGH ENERGY PHYSICS COMMUNITY ACTIVITIES

David Ayres

Deputy Spokesperson, MINOS Collaboration.

Edmond Berger

Adjunct Professor of Physics, Michigan State University, East Lansing, MI, 1997-present.

Member, CTEQ Collaboration.

Member, High Energy and Nuclear Physics Advisory Committee, Brookhaven National Laboratory, 1995-2001.

Consultant, Department of Energy Review of the High Energy Physics Program at the Stanford Linear Accelerator Center, April 3-5, 2001.

Organizing Committee, Theory Institute 2001: From Supersymmetry to Extra Dimensions, Argonne, IL, June 17-29, 2001.

Scientific Program Organizing Committee, Fourth Rencontres du Vietnam, Physics at Extreme Energies, Hanoi, July, 2000.

Scientific Advisory Committee, Frontiers in Contemporary Physics-II, Vanderbilt University, March 5-10, 2001.

Scientific Program Organizing Committee, XXXVIth Rencontres de Moriond, QCD and High Energy Hadronic Interactions, France, March, 2001.

International Advisory Committee, 9th International Conference on Hadron Spectroscopy (HADRON2001), Protvino, Russia, August 25 - September 1, 2001.

Organizing Committee, 8th Conference on the Intersections of Particle and Nuclear Physics (CIPANP 2003), New York, May, 2003.

Gordon Chalmers

Organizing Committee, Theory Institute 2001: From Supersymmetry to Extra Dimensions, Argonne, IL, June17-29, 2001.

Wei Gai

Member, Scientific and Organizing Committee, Advanced Acceleration Concepts Workshop 2000.

Maury Goodman

Member, Particle Data Group.

Co-Chairman, MINOS Working Group on Theseus.

Brian Harris

Convener, Thinkshop 2 session entitled *Strong Interactions*, FNAL, Batavia, IL, November 11-20, 2000.

Organizing Committee, Theory Institute 2001: From Supersymmetry to Extra Dimensions, Argonne, IL, June 17-29, 2001.

David Kaplan

Organizing Committee, Theory Institute 2001: From Supersymmetry to Extra Dimensions, Argonne, IL, June 17-29, 2001.

Edward May

Member, ESnet Steering Committee.

Lawrence Nodulman

Member, Fermilab Users Organization Executive Committee.

James Norem

Member, Muon Collider Group Technical Committee.

Lawrence Price

Chair, ESnet Steering Committee.

Hal Spinka

Co-Spokesperson, the Brookhaven experiment E953 (Crystal Ball).

Zack Sullivan

Organizing Committee, Theory Institute 2001: From Supersymmetry to Extra Dimensions, June 17-29, 2001.

Convener, Thinkshop 2 session entitled *Weak Interactions of the Top Quark*, FNAL, Batavia, IL, November 10-12, 2000.

Tim Tait

Organizing Committee, Theory Institute 2001: From Supersymmetry to Extra Dimensions, Argonne, IL, June 17-29, 2001.

Carlos Wagner

Organizing Committee, Theory Institute 2001: From Supersymmetry to Extra Dimensions, Argonne, IL, June 17-29, 2001.

Cosmas Zachos

Member, Scientific Committee for the NATO Advanced Research Workshop: *Integrable Hierarchies and Modern Physical Theories* (UIC 2000), Chicago, IL, July 22-26, 2000; Chairman of the AM session of July 24, 2000.

VII. HEP DIVISION RESEARCH PERSONNEL

Administration

Price, L.
Hill, D.

Accelerator Physicists

Conde, M.
Gai, W.
Norem, J.
Power, J.
Schoessow, P.

Experimental Physicists

Ayres, D.
Blair, R.
Byrum, K.
Chekanov, S.
Derrick, M.
Fields, T.
Goodman, M.
Joffe-Minor, T.
Krakauer, D.
Kuhlmann, S.
LeCompte, T.
Magill, S.
May, E.
Musgrave, B.
Nodulman, L.
Pellegrino, A.
Proudfoot, J.
Repond, J.
Reyna, D.
Spinka, H.
Stanek, R.
Talaga, R.
Thron, J.
Thurman-Keup, R.
Underwood, D.
Wagner, R.
Wicklund, A.
Yokosawa, A.
Yoshida, R.

Theoretical Physicists

Berger, E.
Bodwin, G.
Chalmers, G.
Harris, B.
Kaplan, D.
Sinclair, D.
Sullivan, Z.
Tait, T.
Wagner, C.
White, A.
Zachos, C.

Engineers, Computer Scientists, Applied Scientists

Dawson, J.
Drake, G.
Grudzinski, J.
Guarino, V.
Haberichter, W.
Hill, N.
Kovacs, E.
Mouser, C.
Schlereth, J.

Technical Support Staff

Ambats, I.
Anderson, S.
Caird, A.
Cox, G.
Cundiff, T.
Franchini, F.
Jankowski, D.
Kasprzyk, T.
Kocenko, L.
Konecny, R.
Matijas, Z.
Nephew, T.
Reed, L.
Rezmer, R.
Rice, J.
Skrzecz, F.
Wood, K.

Laboratory Graduate Participants

Bell, W.
Breitweg, J.
Green, R.
Wolf, S.
Zou, P.

Visiting Scientists

Kovacs, E. (Theory)
Krueger, K. (STAR)
Lipkin, H. (Theory)
Ramsey, G. (Theory)
Sun, X. (AWA)
Uretsky, J. (Theory)
Xiao, L. (AWA)