ANL-HEP-TR-98-30

HIGH ENERGY PHYSICS DIVISION SEMIANNUAL REPORT OF RESEARCH ACTIVITIES

July 1, 1997 – December 31, 1997

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

Members: J. Norem
R. Rezmer
C. Schuur
R. Wagner

July 1998

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Abstract

This report describes the research conducted in the High Energy Physics Division of Argonne National Laboratory during the period July 1, 1997 - December 31, 1997. Topics covered here include experimental and theoretical particle physics, advanced accelerator physics, detector development, and experimental facilities research. Lists of Division publications and colloquia are included.

I. EXPERIMENTAL RESEARCH PROGRAM

I.A. EXPERIMENTS WITH DATA

I.A.1 Medium Energy Physics Polarization Program

During the period July-December 1997 work continued on AGS experiments E913 and E914, which use the Crystal Ball (CB) Spectrometer. Much of this work focused on early stages of the analysis of data taken during the successful first run of the Crystal Ball at the AGS, which had ended in May 1997. These efforts were carried out by H. Spinka and C. Allgower in close collaboration with a group from Valparaiso University, which consisted of D. Koetke, R. Manweiler, D. Grosnick, S. Stanislaus, and students J. Alyea and A. Gibson. Included in this research were ongoing studies of crystal gain calibration in the CB, the neutron response of the Crystal Ball, development of a software package for on-line and off-line viewing of hit patterns of events in the crystals of the CB (called the single event display), investigation of effects observed in the data by using the single event display, extensive efforts to cleanly identify events from kaons in the incident beam, and preliminary analysis of the data for the $\pi^- p \rightarrow \pi^\circ n$ reaction. Talks on some of these topics were presented by members of the Valparaiso group at the Whistler, BC meeting of the APS Division of Nuclear Physics in October. In addition, several collaboration-internal reports (available from the CB web page), called CB reports, were written to document these efforts. Two of these were published as Argonne technical reports ANL-HEP-TR-97-86 and ANL-HEP-TR-97-87. There are plans underway to publish some of the work on the neutron response of the CB as an article in Nuclear Instruments and Methods. In August, H. Spinka attended the CB collaboration meeting at BNL, for which he wrote the minutes and published them as a CB report. On December 1st, C. Allgower was sent on permanent site transfer to BNL, where he joined the effort to upgrade and improve the hardware of the CB experiments in preparation for three months of running at the BNL AGS to take place in summer and fall of 1998. In November, the AGS Program Advisory committee approved a letter of intent for measuring Ke4 decays with the Crystal Ball as part of the already-approved experiment E927. The spokesmen for the Ke4 letter of intent were J. Comfort of Arizona State University and C. Allgower.

In August, C. Allgower completed his Ph.D. at Arizona State University, and published his dissertation on the results of Saclay experiment E225 (see Argonne technical report ANL-HEP-TR-97-71), thus successfully ending a four-year period of work for the group as an ANL graduate student. As of September 1st he continued working for the group, now as a Postdoctoral Fellow. He began to take a more active role in the other projects of the group, such as the Crystal Ball experiment and the high energy work at BNL. However, effort by H. Spinka and C. Allgower on the publication of the Saclay results continued. An instrumentation article describing measurements with the Saclay polarized ion source was published (NIM A399, 171

(1997)). Another paper describing Saclay pp elastic scattering analyzing power data taken prior to 1992 was also published (Z. Phys. C76, 465 (1997)). Another paper was accepted for publication ("Angular Dependence of pp Spin Correlation and Rescattering Observables Between 1.80 and 2.10 GeV"), and two others are nearing completion. Several other papers remain to be written.

The analysis of data from Lampf experiment E1178 on pion-proton charge exchange polarization measurements was nearly completed this period. The results are reported in the Ph.D. thesis of Carole Gaulard of Arizona State University, and were collected using the Neutral Meson Spectrometer in the LEP channel at Lampf. The data are shown in Figure 1, along with a phase shift analysis prediction of R. Arndt, et al. They will be helpful to determine the pion-nucleon phase shifts at low energies, and to derive the chiral symmetry breaking sigma term due to nonzero quark masses in the nucleon.

(H. Spinka)

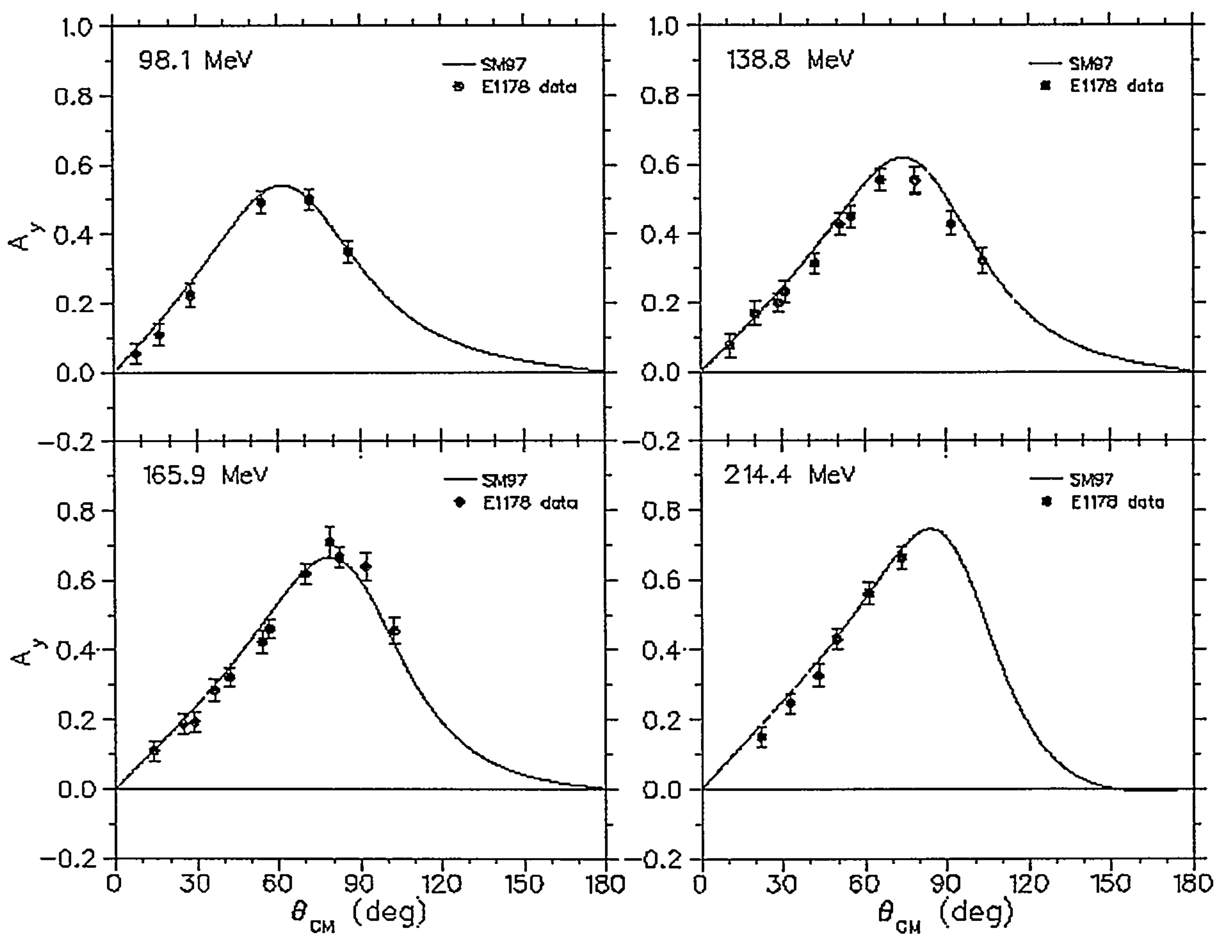

Fig 1. Pion-proton charge exchange polarization data from Lampf experiment E1178. The solid lines are phase shift predictions of R. Arndt, et al.

I.A.2. Collider Detector at Fermilab

a. Physics Results

Bob Blair and Steve Kuhlmann are working with several students on QCD related photon analyses. A student has been recruited to work on the inclusive photon analysis for the 94-95 data. Bob, working with students at the University of Chicago, is helping to bring the photon pair exotics searches to publication. Steve is leading a collaboration studying dijet mass issues, most profitably QCD motivated jet definition changes, in order to improve dijet mass resolution for searching for Higgs decay to b bbar with the TeV33 luminosity upgrade.

Tom LeCompte got his search for flavor changing neutral currents in top decay through the referee procedures and scheduled for PRL. Larry Nodulman was chief internal reviewer for a letter on the overall cross section for top, which managed to get submitted with some quantification of the compatibility of the leptonic and hadronic rates, despite some controversy on b tagging systematics.

Randy Keup produced code which used the material map as found by Barry Wicklund with photon conversions to produce dE/dx track corrections. This code is generally useful but targeted specifically at tracking calibrations for the W mass using the ψ and Υ masses. Adam Hardman has directed his effort to using the transverse mass tail in the muon W sample to determine the W width. Bob Wagner continues as co-convener of electroweak physics and continues working with the group studying radiactive W and Z events.

In b physics, Barry Wicklund has been working with Fumi Ukegawa on improved charged and neutral B meson lifetime measurements using inclusive semileptonic decays. Karen Byrum has become a consulting expert on issues of electron trigger efficiency. Barry and Larry Nodulman are serving as internal reviewers for a CP study using same side tagging of $B^0 / \overline{B}^0 \rightarrow \psi K^0_s$. And Barry has finally agreed to become co-convener for b physics.

b. Summary of Tevatron Run 2 Preparation

Tom LeCompte continues as co-project manager for CDF muon upgrades, working with various groups on new chambers and scintillators for the extended muon coverage.

Bob Wagner and Randy Keup are working on putting calorimeter software into the new Run 2 framework which is C++ based but allows FORTRAN code to be used.

Run 2 preparation work on readout electronics and the tracking chamber replacement is covered in the I.C. Detector Development section.

· (L. Nodulman)

I.A.3. Non-Accelerator Physics at Soudan

a. Physics Results

During the first half of 1997 Soudan physicists continued the analysis effort on the identification and characterization of atmospheric neutrino interaction events. Significant progress was made on the search for nucleon decay, in particular for the supersymmetric favored decay mode, $p \to \nu K^+$. We searched for such events using two different decay modes of the K meson, $K^+ \to \mu^+ \nu_\mu$ and $K^+ \to \pi^+ \pi^0$, and then combined the two limits with and without background subtraction.

a.1. Search for the Decay $p \to \nu K^+$, $K^+ \to \mu^+ \nu_\mu$

To choose the selection criteria and determine efficiencies we generated a large sample of $K^+ \to \mu^+ \nu_\mu$ Monte Carlo events from proton decay. Features of the typical Monte Carlo event shown in Figure 1 include a highly ionizing K^+ which (usually) comes to rest, and emits a 236 MeV/c μ^+. The μ^+ has an average range of 42 cm in the Soudan 2 detector. At the end of its range, the dE/dx of the muon is rising. The μ^+ comes to rest and decays into an e^+, which gives an average of 3 hits.

The results of the analysis for the proton decay simulation, the neutrino simulation, the data, and the shield-tagged rock background are given in Table 1. The simulated events are generated in the entire mass of the Soudan 2 detector. Efficiencies within the fiducial mass are calculated by dividing the fraction of events which pass a set of cuts by the ratio of the fiducial mass to the total mass (0.79).

The Monte Carlo events were first subjected to a simulated trigger, which 81 events failed. Both Monte Carlo and data events were processed through a filter program which applied containment criteria, reducing cosmic ray muons by a factor of more than 10^3. One-hundred fourteen (114) MC events, essentially all with hits outside the containment volume, were rejected. The remaining events were then scanned by physicists to remove the remaining non-contained events, mostly events starting or ending on module boundaries. At this stage, 204 $p \to \nu K^+, K^+ \to \mu^+ \nu_\mu$ events remained, compared with 367 data events without shield hits, 1008 shield-tagged rock events, and 1923 events from the atmospheric neutrino Monte Carlo. The data corresponds to 3.56 fiducial kiloton-years of exposure, compared to 20.24 kiloton-years for the atmospheric neutrino MC.

The required topology is two charged tracks with a common vertex. Events in which both tracks appear to be protons based on ionization and straightness are not included. These topology features were exhibited by 95 of the remaining 204 events from the MC. We also require that the K^+ candidate which is usually the shorter track, has a length less than 50 cm. The muon track length distributions for all four event samples at this stage of the analysis are shown in Figure 2. The range of muons from the K decay is peaked at 43 cm whereas the background distributions are relatively flat. The muon range was therefore required to lie between 29 and 58 cm. Our final cut requires a visible muon decay electron having two or more hits. This requirement discriminates strongly against neutrino induced background, since the predominant background is $\nu n \to \mu^- p$ and in our iron detector most μ^- are absorbed rather than decay after stopping.

After all cuts, our efficiency for accepting $p \to \nu K^+, K^+ \to \mu^+ \nu_\mu$ events in the fiducial volume is 14%. Two atmospheric ν Monte Carlo events pass all of the cuts and represent an expected background of 0.21 events, taking into account that we found the atmospheric neutrino flavor ratio (ν_μ / ν_e) to be only 0.61 of the expected value. The rock event background in the zero shield hit sample is calculated to be 0.19 events. This was found based on the penetration depth analysis mentioned above, which found background in the track data equal to 9.5% of the shield-tagged track sample.

As shown in Table 1, one event in the data survives our cuts.

a.2 $K^+ \to \pi^+\pi^o$ Analysis

We searched for the mode $p \to \nu K^+, K^+ \to \pi^+\pi^o$ by selecting events with a short heavily ionizing track (K^+candidate), one other track and two showers. These features are illustrated in the Monte Carlo event shown in Figure 3. The short highly ionizing track is the K^+ before it decays. A π^o is reconstructed from the two showers and the K^+ from the π^o and the second track, assumed to be a π^+. At these low energies the two γ's from the π^o are usually identifiable. The K^+ mass is required to be in the range 100 MeV/c^2 $< m_{K^+} <$ 660 MeV/c^2. The $\pi^+$and π^o momenta are required to be in the ranges 80 MeV/c $< p_{\pi^+} <$ 400 MeV/c and 40 MeV/c $< p_{\pi^o} <$ 390 MeV/c. The invariant mass of the two shower systems is required to be in the range 10 MeV/c^2 $< m_{2\gamma} <$ 290 MeV/c^2. The resulting detection efficiency for this mode is 26%.

Event Selection	PDK MC	ν MC	Rock	Data
MC decays in total detector	493			
Triggered detector	412			
Containment filter	298			
Scanned as Contained	204	1923	1008	367
Topology	95	345	61	30
K range requirement	95	286	54	27
Muon range requirement	88	62	21	1
Visible muon decay	55	2	2	1
Exposure corrected background		0.21	0.19	

Table 1. Numbers of MC and data candidate events for $p \to \nu K^+$, $K^+ \to \mu^+\nu_\mu$ which survive the triggering, containment, topology, and kinematic cuts of this analysis. Events are generated in the full detector, while efficiencies in Table 3 are quoted for the fiducial volume.

The effects of these cuts on the proton decay simulation are shown in Table 2. No data events pass these cuts. The background from atmospheric neutrino interactions is estimated to be 1.05 events based upon our MC simulated ν events. The background is from ν_e charged current and ν_μ neutral current interactions, so the suppression factor of 0.62 is not used here.

The estimated background contribution from rock events is 0.09 events, based on the one rock event which passed our cuts.

Event Selection	PDK MC	ν MC	Rock	Data
MC decays in total detector	493			
Triggered detector	442			
Containment filter	317			
Scanned as Contained	229			
Topology	106	18	3	5
K range requirement	106	15	3	4
K mass requirement	106	11	3	1
π^+ momentum cut	103	7	2	0
π^o momentum cut	103	6	1	0
π^o mass cut	101	6	1	0
Exposure corrected background		1.05	0.09	

Table 2. Numbers of MC and data candidate events for $p \rightarrow \nu K^+$, $K^+ \rightarrow \pi^+\pi^o$ which survive the triggering, containment, topology, and kinematic cuts of this analysis.

We have combined the limits for the proton decay mode $p \rightarrow \nu K^+$ using both decay modes. We observe one candidate event for $K^+ \rightarrow \mu^+\nu_\mu$ and zero candidates for $K^+ \rightarrow \pi^+\pi^o$; the estimated backgrounds are 0.40 events and 1.14 events respectively. Our combined lower lifetime limit at 90% CL is 4.3 X 10^{31} years. Our limit with background subtraction is 4.6 X 10^{31} years.

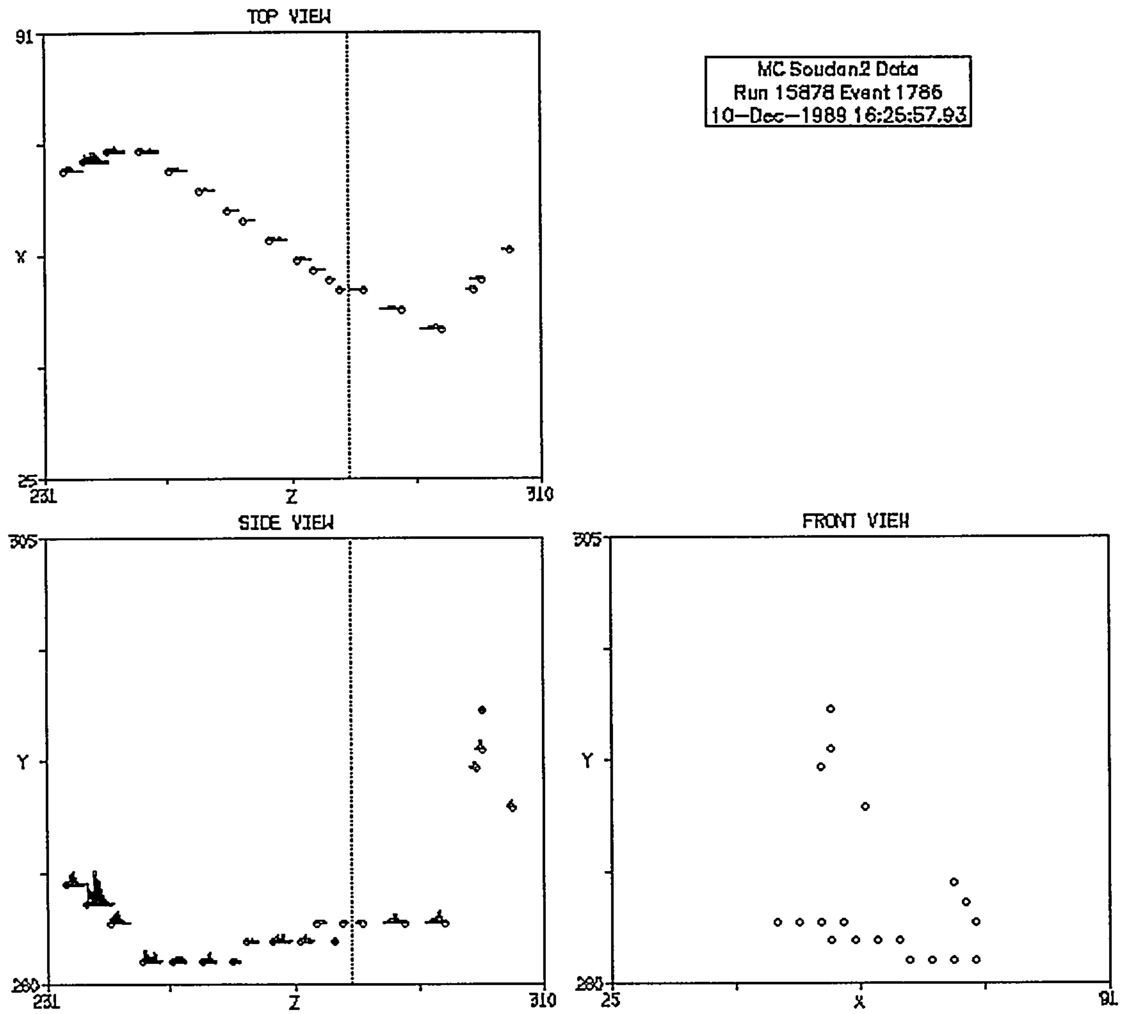

Fig. 1. Monte Carlo event of $p \to \nu K^+$. The three projected views are shown. The xz/yz views correspond to the anode/time and cathode/time views. The xy view is based on matching anode and cathode hits using their time and pulse shape. For each hit, the pulse area is proportional to the recorded energy loss. The K^+ is the short heavily ionizing track on the left/left/right of the xz/yz/xy plot. Three hits from the e^+ decay of the μ^+ appear at the right/right/top. Scales are in cm.

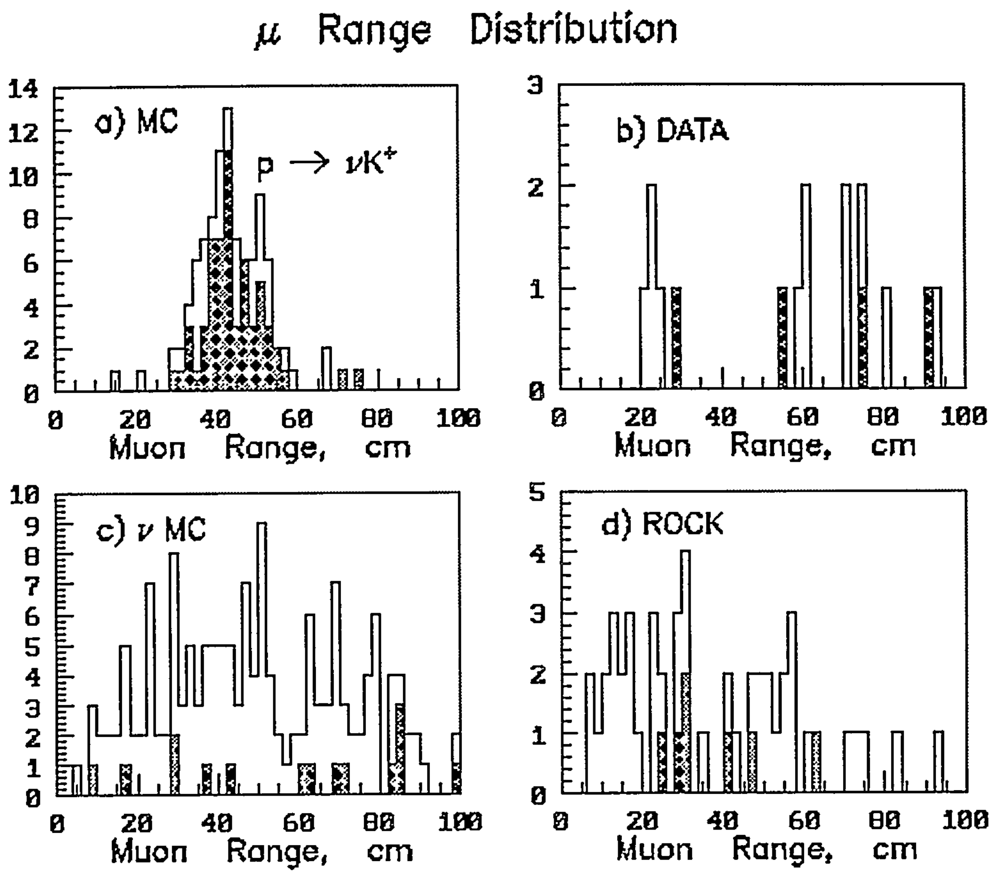

Fig. 2. Muon range distributions (before the muon decay cuts are imposed) for (a) 236 MeV/c μ's from the $p \rightarrow \nu K^{+}$ Monte Carlo simulation, (b) the data, (c) the atmospheric neutrino Monte Carlo, and (d) the shield-tagged rock background. The numbers of events (including overflows) are the same as in the row labeled "*K* range requirement" of Table 1. The shaded events pass the muon decay cut.

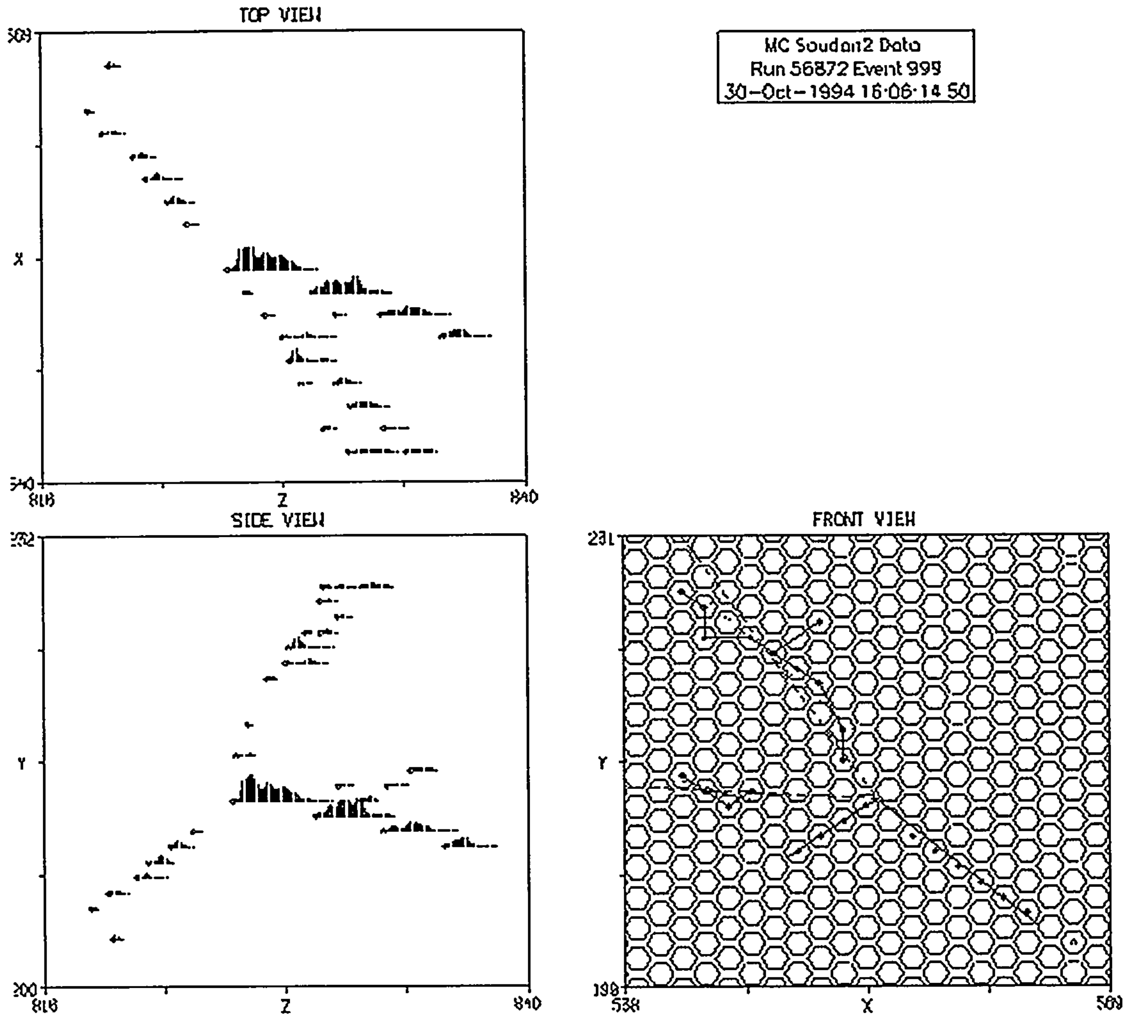

Fig. 3. Monte Carlo event of $p \rightarrow \nu K^+$; $K^+ \rightarrow \pi^+\pi^0$. The K^+ track of four heavily ionizing hits, ranges and decays at rest, yielding a pion track and two showers from the K^+ endpoint. The showers are the π^0 remnants; they appear in directions opposite to the pion track and are overlapping in the xz view. The xy view also shows the results of our track and shower fits. Scales are in cm.

b. Experimental Apparatus, Operation and Maintenance

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

c. Planning Activities

The Soudan group plans to run the detector for nucleon decay, atmospheric neutrino and other cosmic ray studies until an exposure of 5.0 kt-year fiducial volume is achieved. After that, the Soudan detector will become an integral part of the MINOS long-baseline neutrino oscillation experiment. The progress on that project is described elsewhere in this report.

(M. Goodman)

I.A.4. ZEUS Detector at HERA

a. Physics Results

Seven papers were published in this period and seven more manuscripts were submitted for publication.

i) Measurement of the Proton Structure Function F_2 *and* $\sigma_{tot}^{\gamma^* p}$ *at low* Q^2 *and very low x at HERA*

In previous studies, ZEUS and H1 have shown that for $Q^2 \geq 1.5$ GeV^2 and $x << 10^{-2}$, the proton structure function F_2 rises rapidly as x decreases, in agreement with models based on perturbative QCD. In 1995 ZEUS installed a small electromagnetic sampling calorimeter in the rear direction and close to the beam pipe to enhance the acceptance for very low x and low Q^2 inelastic neutral current scattering. In this paper we presented a measurement of $F_2(x)$ and $\sigma_{tot}^{\gamma^* p}(W^2)$, see Fig. 1, for $0.11 \leq Q^2 \leq 0.65$GeV^2 and $2\times10^{-6} \leq x \leq 10^{-5}$, covering the region between deep inelastic scattering and photoproduction at very low x and large W. In combination with data from E665 for $x \geq 10^{-3}$, $F_2(x)$ exhibits a modest rise with decreasing x in this region of low Q^2. With increasing Q^2, the rise becomes gradually more rapid, as can be seen from previously published HERA data for $Q^2 \geq 1.5$GeV^2. The predictions of Donnachie and Landshoff (DL) based on Regge theory are able to qualitatively describe the data for Q^2 below ~ 1 GeV^2, but fail to reproduce the steep rise observed at larger values of Q^2. Conversely, the predictions of Glück, Reya, and Vogt (GRV) based on the DGLAP evolution adequately describe the data for $Q^2 \geq 1.5$ GeV^2.

ii) D Production in Deep Inelastic Scattering at HERA*

This paper present measurements of $D^{*\pm}$ production in deep inelastic scattering using the decay channel $D^{*\pm} \rightarrow (D^0 \rightarrow K^-\pi^+)\pi^+$ (+ c.c.). In the kinematic region 5 < Q^2 <

100 GeV^2 and y < 0.7, the integrated $D^{*\pm}$ cross section for $1.3 < p_T(D^*) < 9.0$ GeV/c and $|\eta(D^*)| < 1.5$ is $\sigma_{p_t,\eta} = 5.3 \pm 1.0(\text{stat.}) \pm 0.8(\text{syst.})$nb. The corresponding prediction from analytical next-to-leading order (NLO) QCD is about one standard deviation smaller, $\sigma_{p_t,\eta} = 4.15$ nb. We have used QCD calculations to extrapolate the $D^{*\pm}$ cross section measured in the restricted $p_T(D^*), \eta(D^*)$ region to the full region and estimated the integrated charm cross section and the charm contribution $F_2^{cc}(x, Q^2)$, see Fig. 2, to the proton structure function $F_2(x, Q^2)$. When compared to fixed target measurements (performed at large x) F_2^{cc} is found to rise steeply as x decreases. This rise is described by NLO QCD calculations when using a gluon density consistent with that extracted from scaling violations in the proton structure function $F_2(x, Q^2)$ measured at HERA.

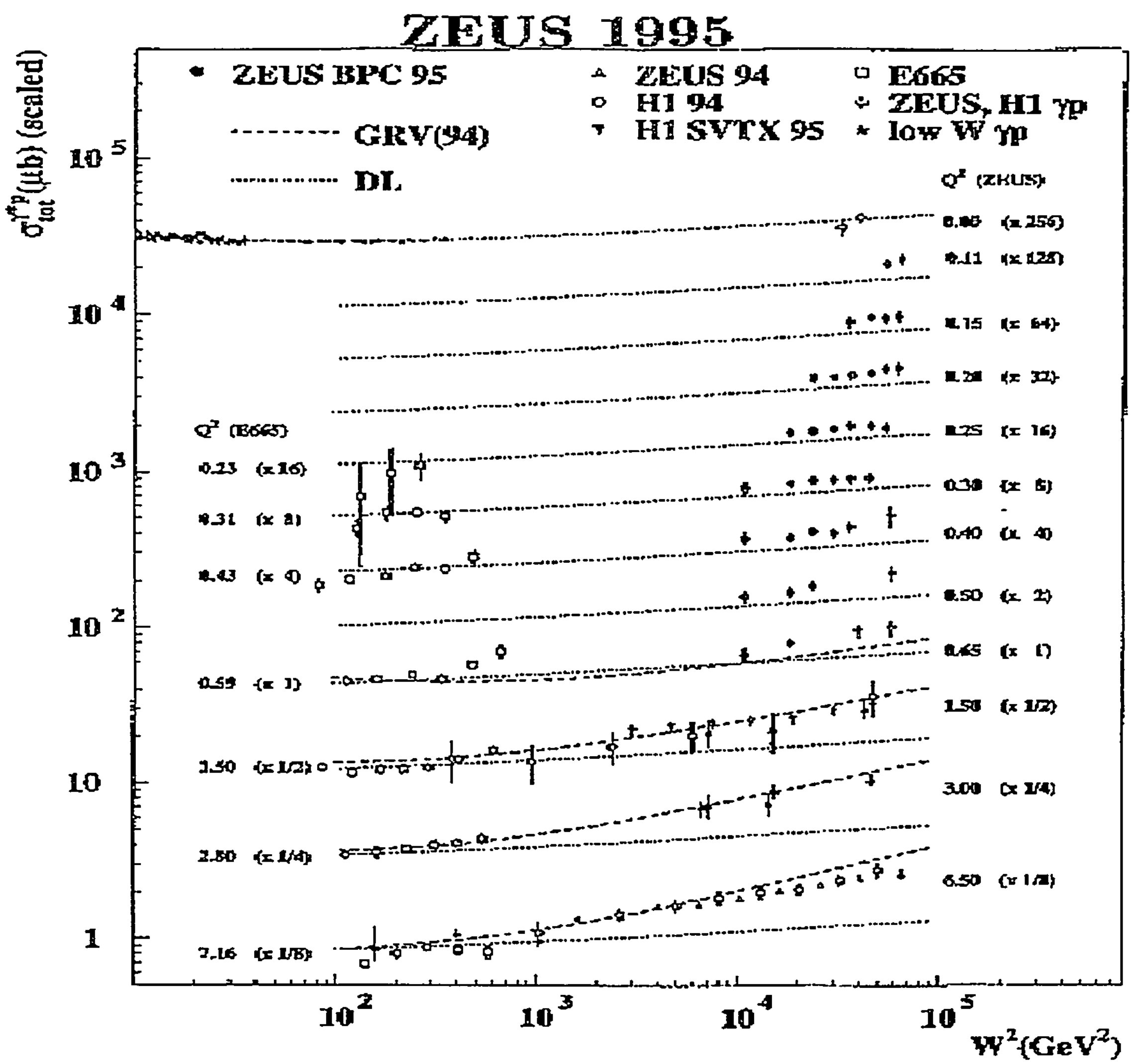

Fig. 1. The total virtual photon-proton cross section $\sigma_{tot}^{\gamma^* p}$ as a function of W^2. The data from this analysis, previous 1994 ZEUS analysis, H1, and E665 are shown. The total cross-sections for real photon-proton scattering from ZEUS, H1, and at low W are also shown. The prediction soft DL and GRV (see text) are indicated by the dotted and dashed curve, respectively.

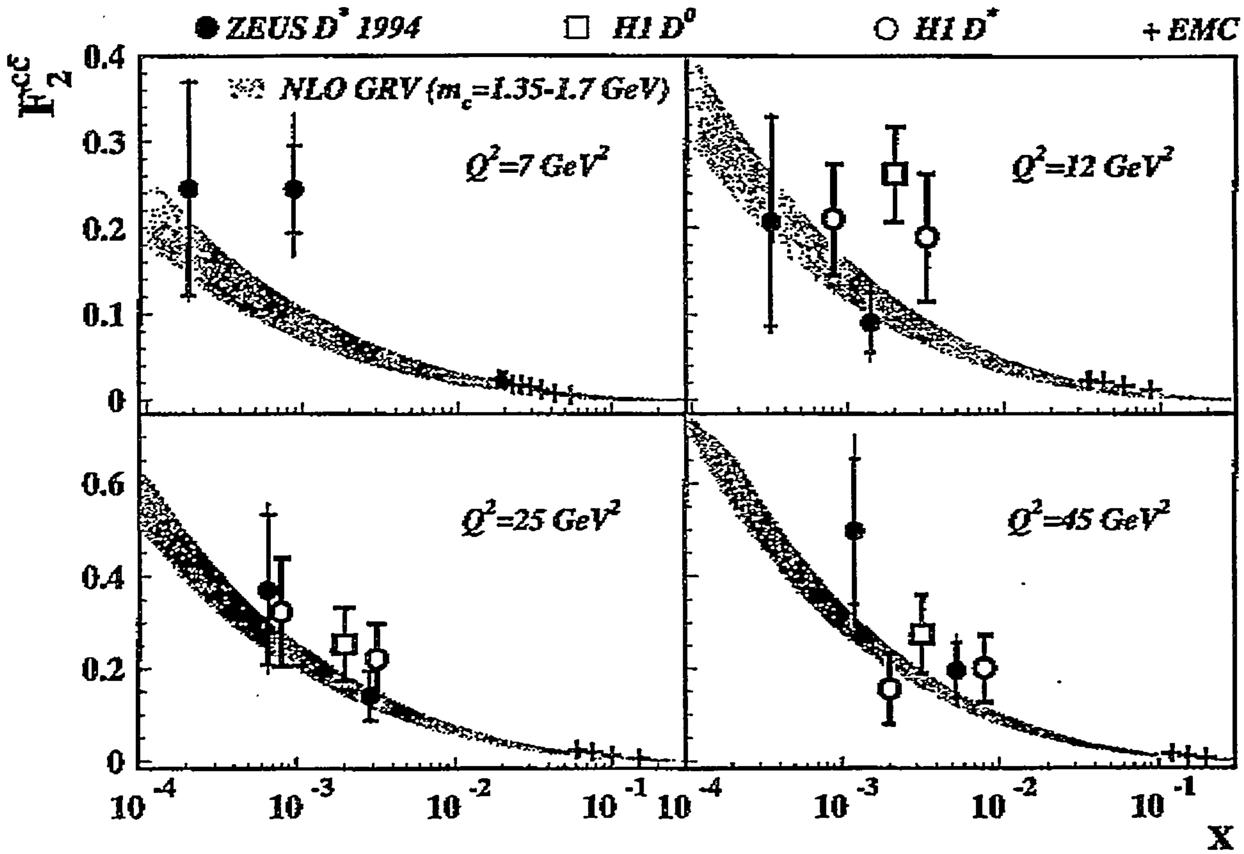

Fig. 2 The charm contributions , $F_2^{c\bar{c}}(x,Q^2)$, to the proton structure function $F_2(x,Q^2)$ as derived from inclusive D^* (ZEUS and H1) and D^0 (H1) and EMC in comparison with the NLO QCD predictions based on GRV parton distributions using different charm quark masses.

iii) Observation of Scaling Violations in Fragmentation Functions at HERA

The observation of scaling violations in structure functions measured in deep inelastic scattering helped establish QCD as the theory of strong interactions and led to measurements of the strong coupling constant, α_s. Similar scaling violations are predicted in the fragmentation functions, which represent the probability for a parton to fragment into a particular hadron carrying a fraction x_p of the parton's momentum. Fragmentation functions incorporate long distance, non-perturbative physics of the hadronization process in which the observed hadrons are formed from initial partons and, like structure functions, cannot be calculated in pQCD, but can be evolved from a starting distribution at a defined energy scale. Figure 3 shows the inclusive charged particle distribution, $1/\sigma_{tot} d\sigma/dx_p$ in the current fragmentation region of the Breit frame compared to NLO calculations. The latter combines a full NLO matrix element with the MRSA' parton densities and NLO fragmentation functions derived by Binnewies et al. from fits to e^+e^- data. The data and the calculations are in good agreement, supporting the idea of universality of quark fragmentation in e^+e^- and deep inelastic scattering.

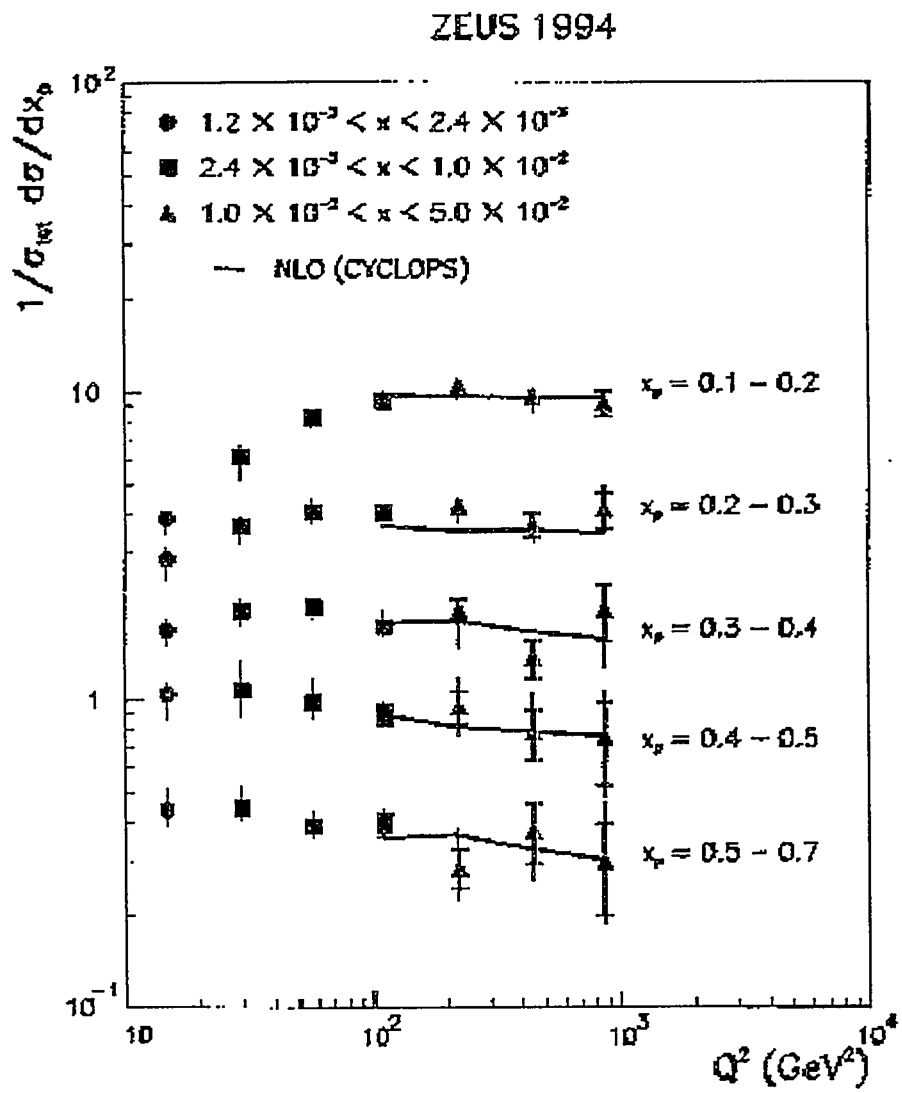

Fig. 3. The inclusive charged particle distribution, $1/\sigma_{tot} d\sigma / dx_p$ in the current fragmentation region of the Breit frame compared to NLO calculations.

iv) A Search for Excited Fermions in e^+p *Collisions at HERA*

The existence of excited leptons or quarks would provide clear evidence for fermion substructure. At HERA, single excited electrons and quarks could be produced by t-channel γ/Z^0 boson exchange and excited neutrinos could be produced by t-channel W boson exchange. In this paper we reported on a search for heavy excited states of electrons, neutrinos, and quarks using the combined 1994 and 1995 data sets. No evidence of a signal was found in any of eight distinct topologies. Limits on the production cross section times branching ratio and on the characteristic couplings, f/Λ, are derived for masses up to 250 GeV. For the particular choice $f/\Lambda = 1/M_{f^*}$, we exclude at the 95% confidence level excited electrons with masses M_{f^*} between 30 and 200 GeV, excited electron neutrinos with masses between 40 and 96 GeV, and quarks excited electroweakly with masses between 40 and 169 GeV.

v) Observation of Isolated High-E_T Photons in Photoproduction at HERA

Events containing an isolated prompt photon with high transverse energy, together with a balancing jet, have been observed for the first time in photoproduction at HERA. The fraction of the incoming photon energy participating in the production of the prompt photon and the jet, x_γ, shows a strong peak near unity, see Fig. 4. This is in agreement with expectations based on

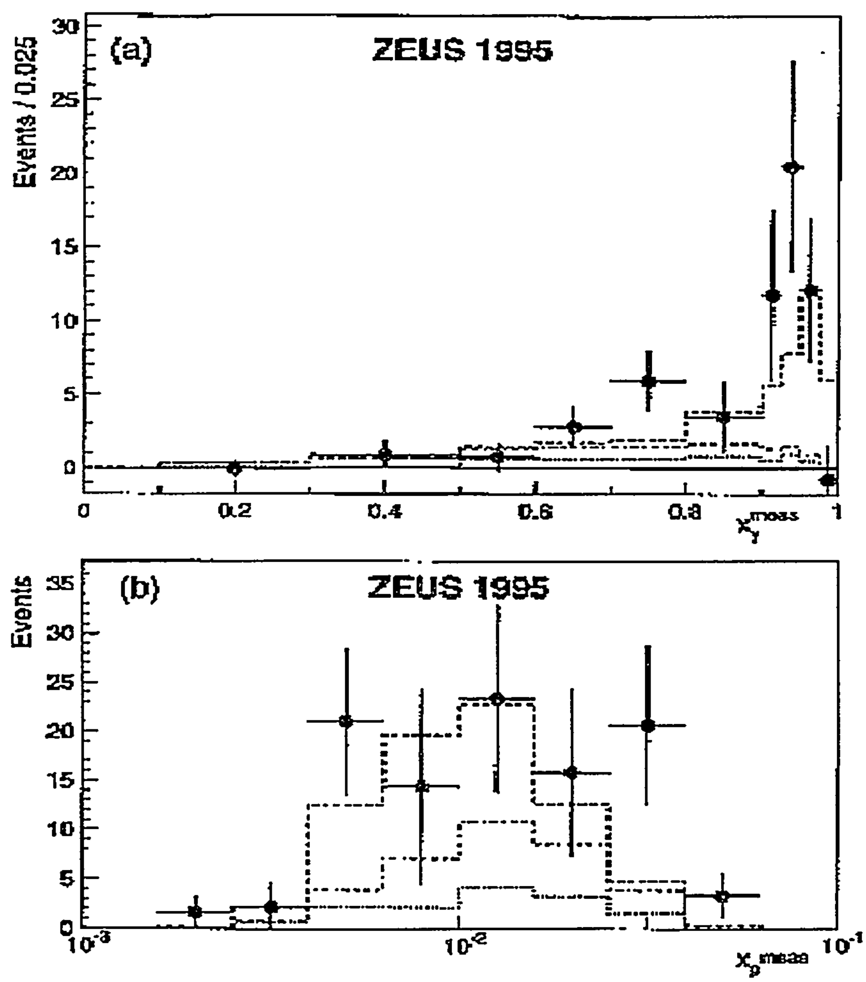

Fig. 4. a) Distribution in x_γ^{OBS} of prompt photon events after background subtraction. Points = data; dotted histogram = MC radiactive contribution; dashed-dotted = radiative + resolved; dashed = radiative + resolved + direct.

b) Distribution in x_p^{OBS} with data and histograms as in a).

LO QCD Monte Carlo programs. In the transverse energy and pseudorapidity range $5 \leq E_T^\gamma < 10$ GeV, $-0.7 \leq \eta^\gamma < 0.8$, $E_T^{jet} \geq 5$ GeV, and $-1.5 \leq \eta^{jet} \leq 1.8$, with $x_\gamma^{OBS} > 0.8$, the measured cross section is $15.3 \pm 3.8 \pm 1.8$ pb, in good agreement with recent NLO calculations.

iv) Measurement of Inelastic J/ψ Photoproduction at HERA

In this paper we presented a measurement of the inelastic J/ψ photoproduction cross section obtained by studying the reaction $e^+p \rightarrow e^+J/\psi X$. The J/ψ has been identified using both leptonic decay channels and was selected within the range $0.4 < z < 0.9$ ($0.5 < z < 0.9$) for the muon (electron) decay mode, where z is the fraction of the photon energy carried by the J/ψ in the proton rest frame. Figure 5 shows the differential cross section dσ/dz for $p_t(J/\psi) > 1$ GeV and $50 \leq W \leq 180$GeV compared to NLO calculations. Agreement in both shape and normalization is found within errors. Recently, there has been theoretical activity attempting to solve the discrepancy between the J/ψ production cross section measurements in hadronic reactions and the colour-singlet model by invoking additional colour-octet contributions. A specific leading order calculation of J/ψ production at HERA has been carried out using values of the non-perturbative colour-octet terms determined from a fit to CDF data. These calculations predict a cross section for HERA rising with z, which is not seen in our data.

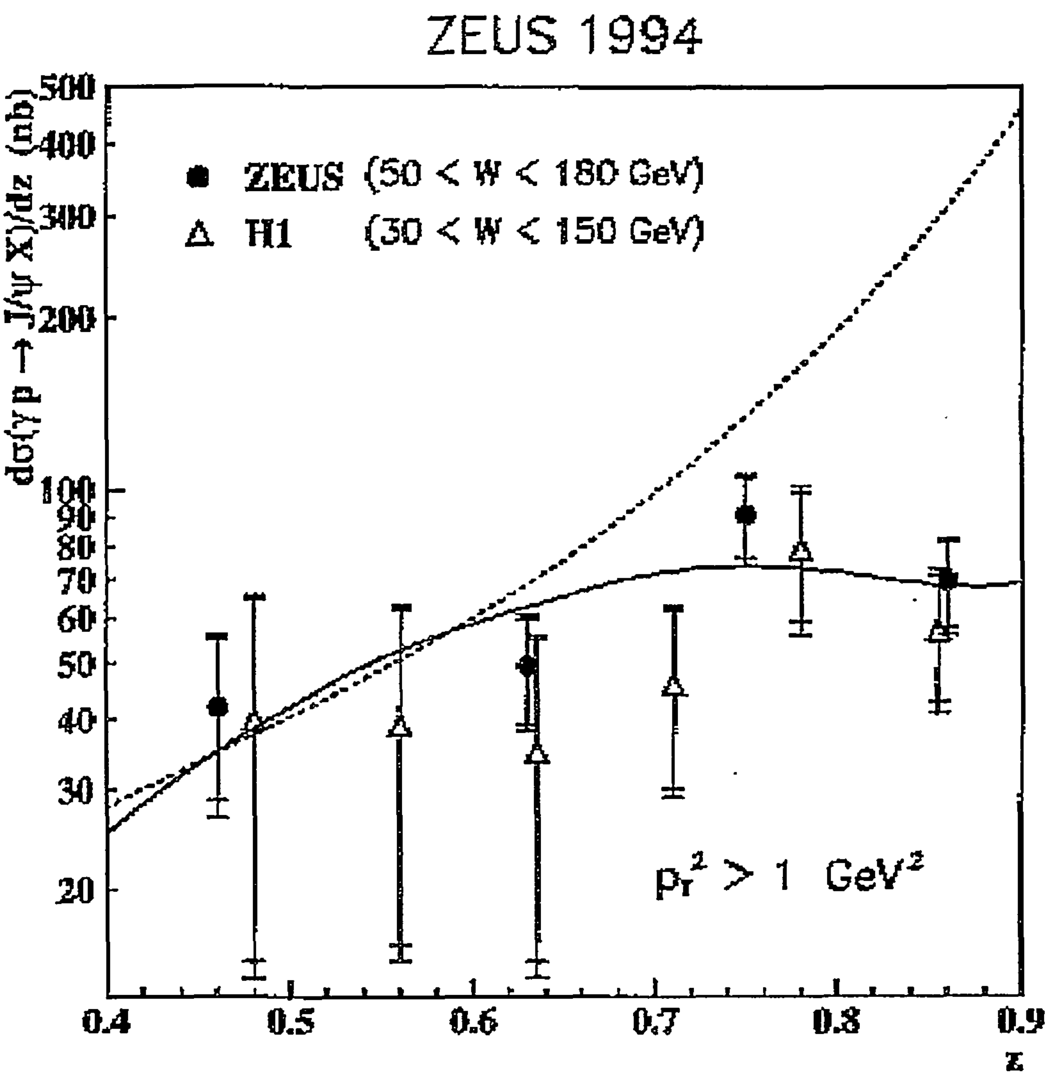

Fig. 5. Differential cross section dσ/dz for the inelastic J/ψ sample for $p_T > 1\,GeV$ and $50 \leq W \leq 180$ GeV. Data from ZEUS and H1 are shown. The predictions of NLO QCD with the GRV structure function are shown as a solid line. The predictions from the colour-octet calculation are shown as a dashed line.

vii) Study of Photon Dissociation in Diffractive Photoproduction at HERA

Diffractive dissociation of quasi-real photons at a photon-proton center of mass energy $W \approx 200\,GeV$ was studied. The process under consideration is $\gamma p \rightarrow XN$, where X is the diffractively dissociated photon system of M_X and N is either a proton or a nucleonic system with mass $M_N < 2$ GeV. The cross section for this process in the interval $3 < M_X < 24$ GeV relative to the total photoproduction cross section was measured to be $\sigma_D^{partial} / \sigma_{tot} = (6.2 \pm 0.2 \pm 1.4)\%$. After extrapolation to the mass interval $m_\varphi^2 < M_X^2, 0.05W^2$ and correction for proton dissociation, the fraction of the total cross section attributed to single diffractive proton dissociation is found to be $\sigma_D / \sigma_{tot} = (13.3 \pm 0.5 \pm 3.6)\%$. This value is consistent with those obtained from other measurements at HERA and with measurements of diffractive proton dissociation in $p\bar{p}$ interactions at c.m. energies $\sqrt{s} = 546\,\text{GeV}$ and 1.8 TeV at the Tevatron.

b. HERA and ZEUS Operations

After a short shutdown over the end-of-the-year holidays, the 1997 HERA running period had a successful start providing useful luminosity already by February. At the end of the run, the machine had delivered 36.4 pb^{-1} which is about twice the delivered luminosity of the 1996 running period. Due to the observation of an excess of events at high Q^2 and x, the interest in an extended low energy run to explore the possibility of measuring the longitudinal structure function F_L had vanished.

The machine shutdown period started in the beginning of November. The ZEUS collaboration will take advantage of the fact that the shutdown will be relatively long to install new components into the detector.

1) The installation of the Barrel Presampler will be completed with the insertion of all 32 scintillator cassettes. With the completion of the Barrel Presampler, the entire high resolution calorimeter will be covered with preshower detectors.

2) The Forward Plug Calorimeter will be installed to extend the calorimeter coverage in the very forward region. This new calorimeter also requires the installation of a new beam pipe with a significantly reduced diameter.

3) The installation of the Forward Hadron-Electron Separator (FHES) will be completed this shutdown. The FHES will provide a powerful tool to identify the scattered electrons of very high Q^2 events and to identify prompt photons in the forward region.

4) The Forward Neutron Calorimeter will be equipped with a position sensitive detector. This addition will result in a better understanding of the geometrical acceptance and, thus, to the reduction of systematic errors.

The following improvements will be performed to the machine:

1) Installation of NEG pumps along the entire electron beam line. These new pumps are necessary for obtaining long beam lifetimes with electrons.

2) Installation of additional RF stations. Currently, the plan is to keep the electron energy at 27.5 GeV. The new RF stations will provide more stability to the electron ring.

3) Replacement of the proton ring power supplies. The new power supplies are expected to be more reliable.

4) Several minor improvements, such as an additional electron kicker system and a new HERA control system.

(J. Repond)

I.A.5. BNL AGS Experiment to Overcome Intrinsic Resonances

The goal of the E-880 experiment is to provide polarized proton acceleration in the AGS through all depolarizing imperfection resonances and intrinsic spin resonances by utilizing a partial snake and an RF dipole. Earlier we reported successful performance of the partial snake.

In this period, an attempt was made to overcome intrinsic resonances using an RF dipole.

In E-880, full spin flip of a polarized proton beam, without emittance growth, was observed at:
$G\gamma = 12 + \nu_z$ or 9.8 GeV and $36 - \nu_z$ or 13.3 GeV $(\nu_z \approx 8.70,$ vertical betatron tune$)$ by adiabatically exciting a vertical coherent betatron oscillation using the single RF dipole magnet.

At the injection energy into RHIC, the beam polarization was about 40% at 21.7 GeV. In the next E-880 run, the usage of the RF dipole will be optimized so that we will achieve higher beam polarization.

(A. Yokosawa)

I.A.6. Polarized Beam Experiments for a RHIC Polarimeter

As reported earlier, installation and testing of the E-925 experiment was completed last June. This was a useful run as data were collected and analyzed for detector efficiencies.

In November 1997, we measured asymmetries in the inclusive reaction $pC \rightarrow \pi^{\pm} + X$ using the 22 GeV extracted polarized proton beam from the AGS. The beam polarization was about 35%. The preliminary results as shown in Figure 1 indicate a nice resemblance to the Fermilab 200-GeV data where π^{+} and π^{-} show a mirror symmetry with respect to x_F at $p_T >$ 0.7 GeV/c in $pp \rightarrow \pi^{\pm} + X$. Figure 2 shows zero asymmetry in the reaction $pC \rightarrow p + X$ and this is in sharp contrast to the $\pi^{\pm}$ production.

The above results render the technique, with a carbon target, a useful tool for a relative RHIC Polarimeter. The negative pion asymmetry is of particular interest, as it eliminates the need for Cerenkov counters and particle identification in the high-intensity RHIC environment.

Data analysis will continue to identify any weak spots in the apparatus and improve the trigger system. Work has started on building a liquid hydrogen target for the experiment, $pp \rightarrow \pi^{\pm} + X$.

(A. Yokosawa)

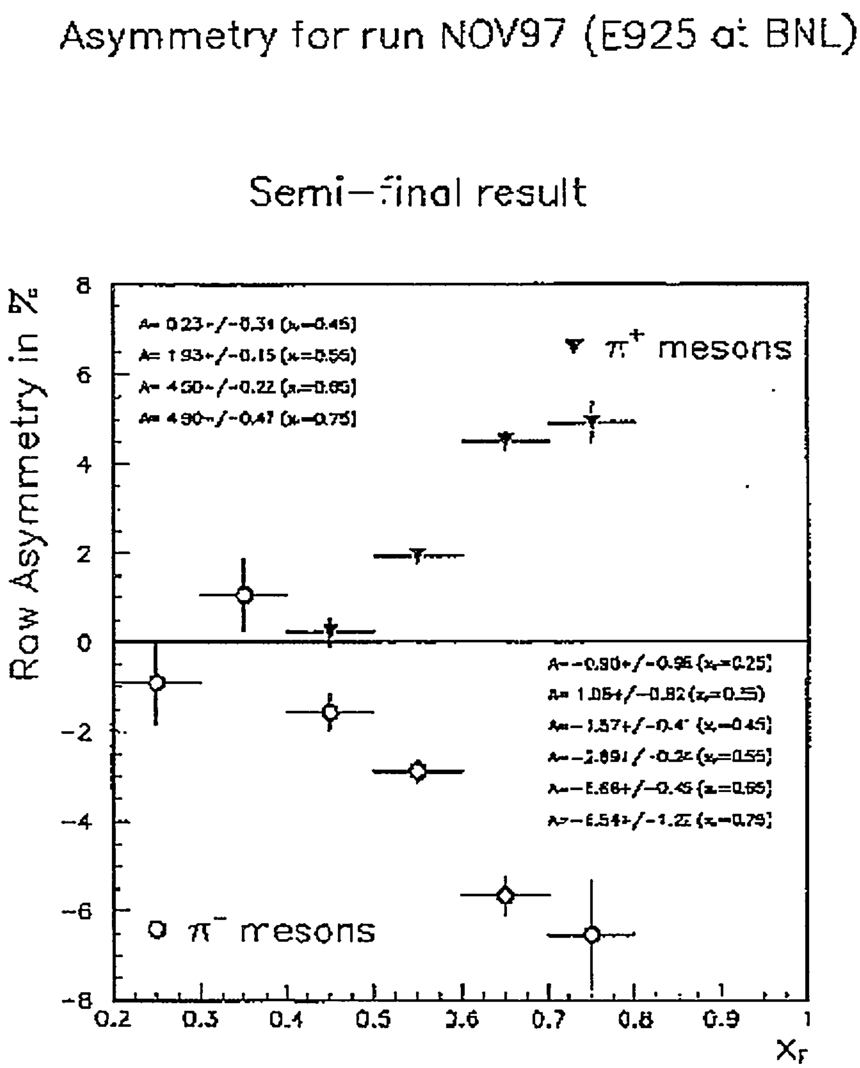

Fig. 1 Indicates a nice resemblance to the Fermilab 200-GeV data where π^+ and π^- show a mirror symmetry with respect to x_F at $p_T > 0.7$ GeV/c in $pp \rightarrow \pi^{\pm} + X$.

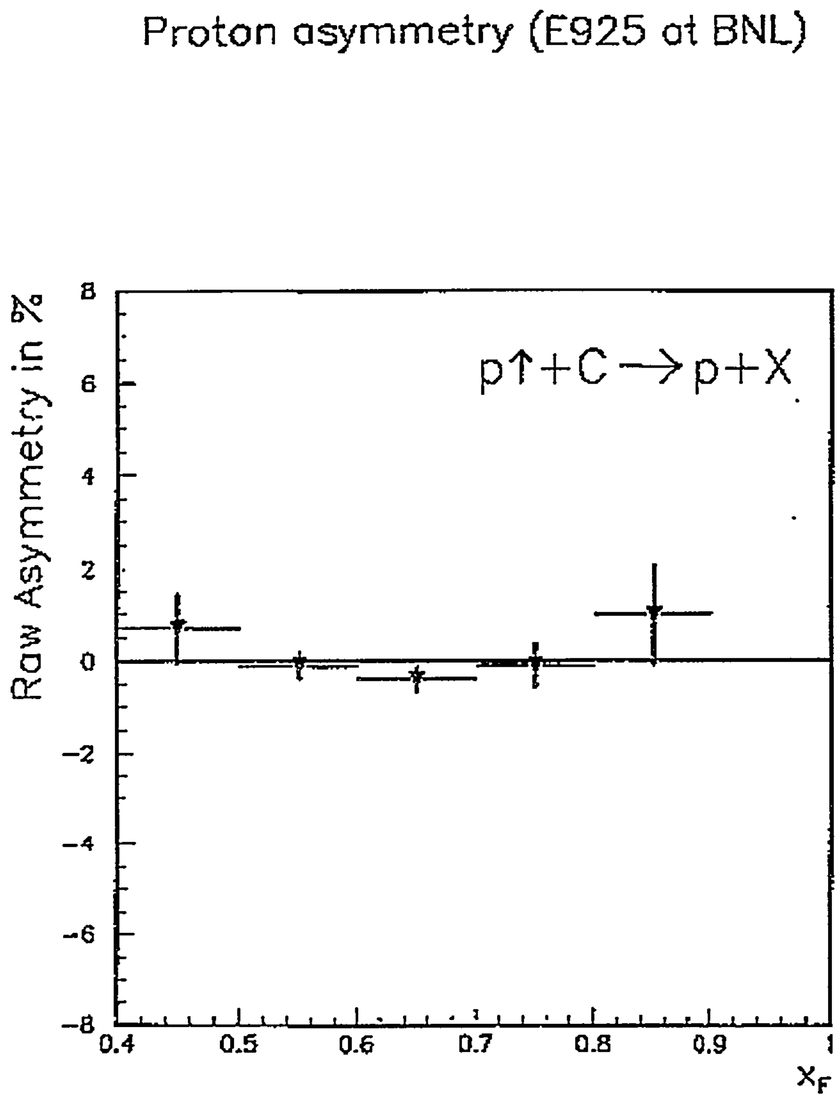

Fig. 2 Shows zero asymmetry in the reaction $pC \rightarrow p + X$ and this is in sharp contrast to the $\pi^{\pm}$ production.

I.B EXPERIMENTS IN PLANNING OR CONSTRUCTION

I.B.1 STAR Detector for RHIC

During this period most of the support rails for the EMC were installed in the STAR megnet. Argonne designed the installation fixtures for the installation of the rail supports, and the Argonne engineer made several trips to BNL to supervise the installation.

The anticipated Construction Readiness Review was delayed until sometime in calendar 1998. Argonne personnel were very active in work on better cost and effort estimates, and refinements of construction drawings for this review.

Argonne also developed a Memorandum of Understanding for work on the EMC project. In this MOU Argonne had continuing responsibility for all aspects of installation, including designing all fixtures and doing the installation tests of a real module in a simulated magnet. Argonne was the Lead institution in EMC electronics. It was anticipated that the second module assembly line would begin at Argonne as soon as the EMC funding profile allowed, which was expected in FY 2000. This MOU, developed with input from the EMC management and the collaboration, has yet to be reviewed and approved by EMC management.

Argonne did further studies on the proposed a pre-converter as a cost and physics-effective alternative to depth segmentation.

Related to Spin Physics in STAR that would involve the calorimeter, Argonne was very involved in work on Specifying the Scaler requirements in a way that would be compatible with the peculiar way of implementing the equivalent of scalers in STAR.

T. LeCompte of ANL was named overall STAR Analysis Coordinator.

The limited funding during this period was primarily for design and construction of rail installation fixtures.

(D. Underwood)

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

The MINOS long baseline experiment is designed to search for neutrino oscillations in the region of $\sin^2(2\theta)$ and Δm^2 parameter space which is suggested by the atmospheric neutrino flavor ratio anomaly. This effect, which was initially seen in the Kamiokande and IMB water Cerenkov detectors, was confirmed in early 1997 by the Soudan 2 and SuperKamiokande experiments. Over the past three years the MINOS Collaboration has conducted an extensive R&D program aimed at optimizing the design of the experiment, particularly focused on the choice of active detector technology and the steel plane thickness. This phase of the experiment concluded in late September 1997, with the choice of extruded plastic scintillator strips as the active detector technology and of 1-inch thick steel as the longitudinal granularity.

One input to the choice of major detector parameters was the development of detailed cost estimates for the MINOS near and far detectors, and an evaluation of these estimates in light of funding guidelines from Fermilab. A new aspect of these guidelines is the requirement that the detector costs include a 40% "scope contingency" allowance, which might be used for an upgrade of the baseline detector after more is known about neutrino oscillation physics in a few years time. Although the cost estimates for all of the active detector technologies and steel plane thickness' under consideration were about the same, the reduced funds available for the initial baseline detector made it necessary to decrease the design mass of the far detector from 10 kilotons to 8 kilotons. Following these choices of major detector parameters, the collaboration focused its effort on optimizing as many of the design details as possible during the final three months of 1997. This process will culminate in the spring of 1998 with the submission of the MINOS Detector Technical Design Report and its evaluation by a DOE "Lehman" review committee.

Prior to the collaboration's choice of plastic scintillator for MINOS detectors, the Argonne group had concentrated its effort on the development of the competing Aluminum Proportional Tube (APT) technology. This work culminated in the late summer of 1997 with calibration of a prototype APT calorimeter in a Fermilab test beam. The group also constructed and tested a number of full size (8 m long) APT chambers and cathode strips. The results of these studies showed the performance of APTs to be excellent, as discussed later in this report.

In parallel with the APT prototype tests, Argonne physicists and engineers also made important contributions to the development of plastic scintillator extrusion technology. The group worked with Quick Plastics (the company which produced the APT plastic sleeves) on the development of coextruded plastic scintillator strips. The 1 cm by 4 cm by 8 m long strips are enveloped by a layer of white reflective (TiO_2 loaded) plastic to increase light collection efficiency. Coextrusion of the reflective coating is less expensive than wrapping the strips with reflective material during assembly, and also provides mechanical protection for the strips. Each strip also has an extruded groove along the center of one of the 4 cm sides to accommodate the wavelength shifting fiber. Detailed tests of the first prototype strips, conducted at Argonne, looked very promising and were an important factor in the collaboration's choice of extruded plastic scintillator for MINOS.

Other MINOS developments and accomplishments in during the second half of 1997 included:

1) Work continued on the evaluation of the sensitivity of MINOS to oscillations with very low Δm^2 (~0.001 eV^2). This included studies of low energy neutrino beam possibilities with the NuMI facility, and was considered in the choice of 1-inch thick steel planes for the baseline detector design.

2) A baseline design for the MINOS near detector was chosen. It will be a 6-meter wide octagon structure consisting of 280 1-inch thick magnetized steel planes. The neutrino beam will be centered halfway between the central coil hole and one edge of the octagon; only 25% of the upstream part of the near detector will be

instrumented because of the small beam size. The full area of every fourth plane in the downstream muon spectrometer section will be instrumented.

3) Argonne physicists and engineers worked closely with the Oxford and Rutherford groups to define the parameters of the baseline electronics design. The basic features of the design were agreed to at a collaboration meeting at Rutherford in November, allowing work on detailed design and cost estimates to begin.

4) The Argonne group designed a test facility for full size scintillator “modules” in Building 366. Modules are panels of 16 to 24 4-cm wide scintillator strips which are packaged for easy handling and shipping. The group began the construction of a test facility for automated mapping of the response of modules with a rapidly moving radiactive source. Argonne physicists also developed a technique for radiactive source calibration of modules after installation in the detector; this was later chosen for the baseline detector design.

5) The Argonne group continued work on the design of installation procedures for the MINOS far detector at Soudan. The group prepared engineering drawings and cost estimates for scintillator detector module mounting and the routing of fiber optics cables between the modules and the photodetectors.

6) The State of Minnesota Legislature passed a $3M bond issue to pay for a large fraction of the excavation of the new MINOS cavern in the Soudan mine.

(D. Ayres)

I.B.3 ATLAS Detector Research and Development

a. Overview of ANL LHC Related R&D Programs

The ATLAS TileCal group realized two important milestones in the second half of 1997. First of all, the extended barrel prototype module, in conjunction with a second prototype module constructed in Europe, was tested using high energy particle beams at CERN in the late summer and fall. The second milestone in fact represents the first construction milestone for the project. An internal Production Readiness Review of the TileCal mechanics was held at CERN in November, following which the mechanical components were approved for construction (with the procurement of absorber steel in Europe commencing late in 1997). In addition, we completed an extensive review of costs and the basis of estimate for all tasks at the lowest WBS level, in preparation for the baseline review of US ATLAS scheduled for February 98. This was all cross-checked and properly put into the US ATLAS tracking system (an ACCESS database) along with an associated schedule and funding plan.

(J. Proudfoot)

I.B.4 ATLAS Calorimeter Development

a. Hadron TileCal Calorimeter

With the completion of the construction of the prototype module, the work in the mechanical area has been directed toward a small number of specific issues comprising: structural analysis of the Tile Calorimeter and its connections and the effect of the supports of the liquid argon cryostat; the girder design and analysis of stresses in the welded part of the structure; installation questions and, in particular, issues surrounding the installation of the cryostat on the partially assembled Tile Calorimeter. In addition, with the expectation of approval and funding for construction, we have begun planning these activities and performing necessary work to fully define and optimize fabrication and assembly procedures.

b. Structural Design and Analysis

The three areas in which design, and where necessary, analysis, has been carried out are in the inner support of the endcap cryostat, the TileCal support girder and in the integration of the installation and support for the endcap cryostat. In addition to the Production Readiness Review, the TileCal group conducted an internal review following the experience of the prototype construction. These are discussed in turn.

b.1 Finite Element Analysis of Endcap Cryostat Supports

A 3-dimensional, finite element analysis was done on the extended barrel structure to which the load from the cryostat was applied. The purpose of this analysis was to gain an understanding of the forces that would result between modules when the extended barrel is fully assembled.

Half of an extended barrel was modeled. Symmetric boundary conditions were applied at the bottom of the extended barrel at the 6 o'clock position. It was assumed that the extended barrel was open at the top, at 12 o'clock. Submodules were modeled using solid elements and plate elements were used from the front plate. The girder was modeled using thick plate elements. The girder to submodule connection was modeled using beam elements to model the 12 mm bolts making this connection.

The cryostat group had proposed moving the support for the front cryostat feet back to the second submodule on the Extended Barrel. Two analyses were performed to compare supporting the front cryostat load of 37 metric tons on the first submodule or on the second submodule as proposed by the cryostat group. In both cases, the back cryostat load of 87 metric tons was supported on an external "donut" support. Figure 1 shows the Z location of the proposed location of the cryostat feet and the external support.

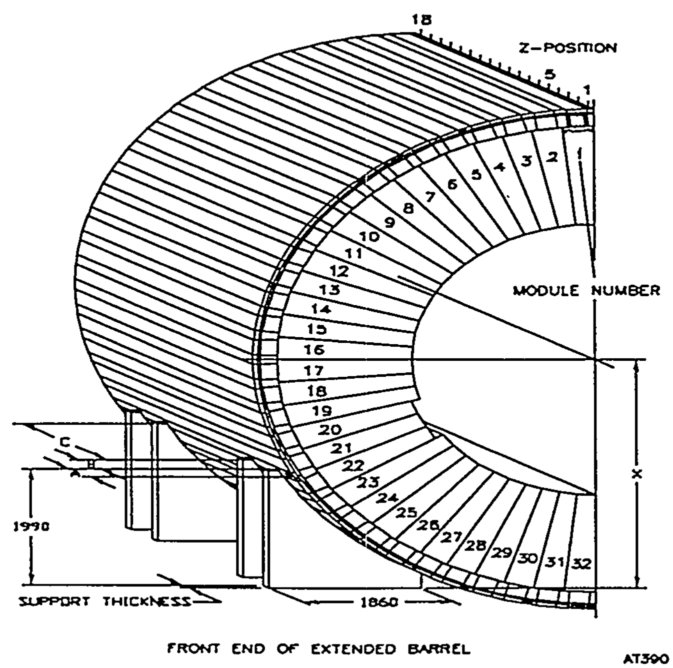

Fig. 1. Extended barrel support saddle concept used in finite element analysis model.

The main concern of this analysis was the deflection of the support points for the end-cap cryostat. If this deflection is large then interference may occur between the Extended Barrel calorimeter structure and the end-cap cryostat.

Table 1 - Deflection of Cryostat Support

	Horizontal Deflection (mm)		*Vertical Deflection (mm)*		*Axial Deflection (mm)*	
	1st Submodule	2nd Submodule	1st Submodule	2nd Submodule	1st Submodule	2nd Submodule
Front Support	0.7	0.6	-1.2	-1.1	-0.7	0.6
Back Support	0.4	0.4	-0.7	-0.8	-0.4	-0.4

The deflections of the cryostat support points when the cryostat is supported at the front either on the first submodule or the second submodule, are compared in Table 1. This analysis shows that the move of the front cryostat feet back in Z to the second submodule has little affect on the deflection of the support points for the end-cap cryostat.

The bearing and radial forces between modules were also analyzed in this analysis. The results showed that the movement of the cryostat support points further back in Z had no significant impact on either the magnitude or the uniformity of the distribution in Z of the forces between the modules.

(V. Guarino)

b.2 Design and Analysis of TileCal Girder

The girder at the back of each module plays an important structural role in the assembly of the Tile Calorimeter barrel. It is important therefore, to clearly understand the welds within it. In order to do this, a 2-dimensional finite element model was constructed of the girder cross-section similar to a model used earlier at CERN to analyze the girder. This model is shown in Fig. 2. Plain strain elements were used that had a thickness of 1mm.

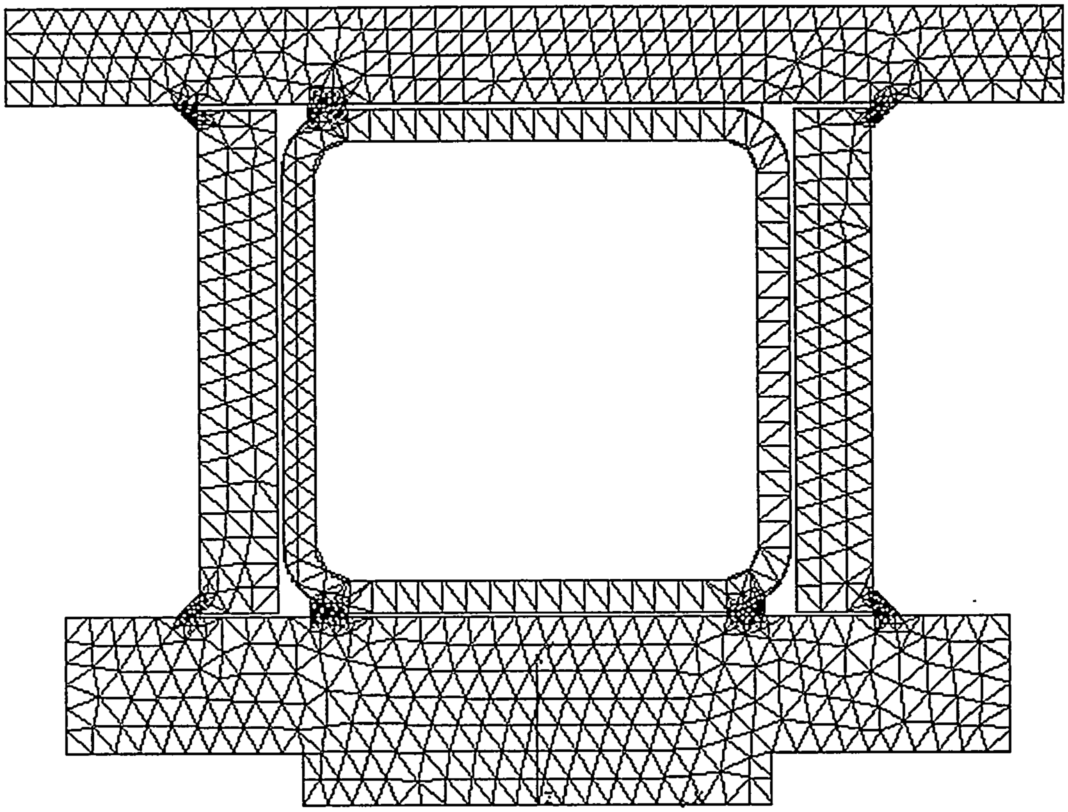

Fig. 2. Finite element model of girder.

As a first check of this model, it was run using the same force and boundary conditions as used by the CERN engineer. The results obtained were in agreement with this earlier calculation and showed that the maximum stress in the welds reached 200 N/mm^2.

Since 200 N/mm^2 stress is approaching the material yield stress of 235 N/mm^2, two questions have been considered: a) what modifications to the design could allow a significant reduction in the maximum welds stresses; b) how should our design be evaluated in terms of European welding norms.

As a way of reducing this stress, the design was modified to include an additional bar to the model with a width of 12 mm and a thickness of 0.04mm, as shown in Fig. 3. Plain stress elements were also used to model this bar. In this design, the maximum stress in welds was calculated to be 153 N/mm^2. Increasing the thickness of this bar to 0.1mm reduced the maximum stress further to 138 N/mm^2. To represent this equivalent cross-section, a bar of this thickness in the actual girder would be approximately 30mm wide in Z and located on every submodule. The use of such a bar would be a cheap and simple way to significantly reduce the maximum weld stresses in the girder. However, for it to be feasible, this solution must be consistent with the requirements for fiber routing, the locations of the PMT holes and the mount bolts. These issues remain to be studied.

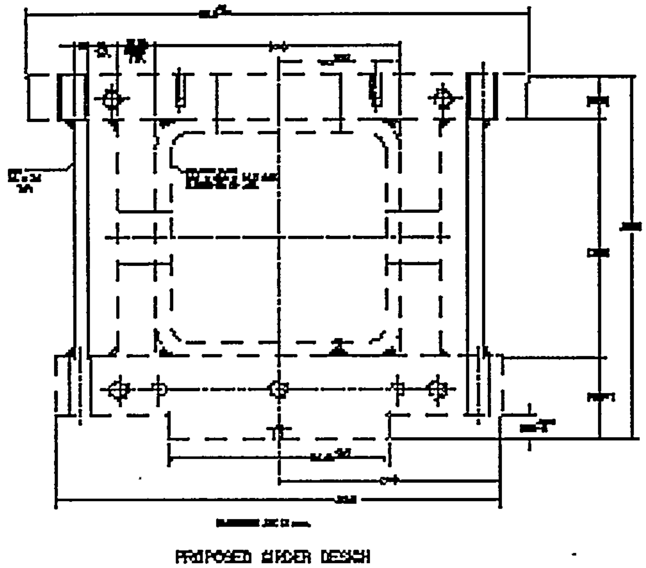

Fig. 3. Proposed modification to girder design to include reinforcing bars.

As a first point it was recognized that, according to European norms, fillet welds as shown on our present design are not allowed. Instead, penetration butt welds are recommended and the design has been modified accordingly. A second aspect of the European norms is that stress concentrations in welds need not be considered except under fatigue loading conditions. The average weld stress is considerably lower than the maximum stress (38 N/mm^2). Therefore, it is also an option for the Tile Calorimeter group to decide that our present design (with the change in type of welds) is acceptable and that no further modifications are required to reduce the stresses in the welds. This issue will be decided at the first engineering meeting in 1998.

(V. Guarino)

b.3 Design of the Cryostat Support Base

ANL is responsible for the design of the support base, mounted or indeed part of the TileCal structure, on which cryostat foot sits. To be more precise, at the present time this encompasses only the inner Z supports.

The general layout is shown in Figure 4. From this it can be seen that we have included a jacking system as part of the design. This is because the Argonne group strongly feels that it will be necessary to adjust the height of the cryostat independently of the position of the Tile Calorimeter once fully assembled, in order to meet the position envelope required for the installation of the beam pipe. The jacks were initially conceived as standard commercially available single cylinder hydraulic jacks. However, subsequent to discussions at CERN, when it became clear that material properties of the aluminum cryostat feet were quite important, these were changed to dual cylinder and custom design systems.

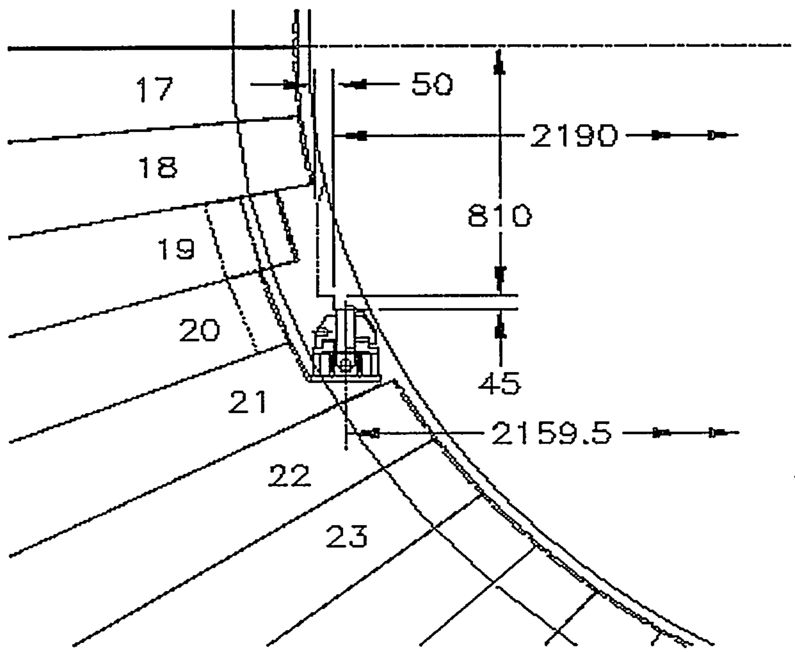

Fig. 4. General layout of inner cryostat support and jacking system.

In addition, as part of the work in developing the conceptual design for the support base for the cryostat, it was deemed useful to construct a full scale model of the area. A full scale plywood model of this region, covering about 45 degrees in azimuth, was built. This will be used to directly evaluate access scenarios as the conceptual design for this interface region is developed. Eventually this basic design may also be adapted for use at the outer Z supports (for example the jacks may be omitted in this case).

b.4 Mechanical Design Re-Evaluation

With the completion of the prototype construction in which one full scale barrel module and two full scale extended barrel modules were built, the TileCal group reviewed the overall design of the calorimeter to determine if it fully met our goals. Therefore, in September and again in late October the basic design was re-evaluated by the core group of engineers and physicists (including one engineer and one physicist from Argonne).

The most significant issue which was considered was the specification of the azimuthal gap between modules. After much discussion on the tolerances for the individual elements contributing to the full tolerance envelope it was agreed to modify this to 1.5mm and to realize this increased gap by reducing the thickness of the magnetic shielding plate on the outer radius of the girder by a corresponding amount. Two other critical design issues were also revisited: the strength of the welds connecting the mounting bars to the submodules and the strength of the girder itself (and especially a re-evaluation with respect to the maximum expected stresses). Mechanical tests were done at CERN following a test plan developed at Argonne, which demonstrated that the welds connecting the mounting bars were sufficiently strong (in fact these tests indicated that the limiting element would be the mounting bolts and not the welds). However, it was appreciated by all that this result is only valid in the case that there is no additional stress put on the welds during mounting to the girder (as would be the case if the gap were not shimmed properly) and that great care must be taken to define the procedures used to control this. The second important issue was the design of the girder (as well as that of the special girders needed in the vicinity of the supports, where the stresses are the greatest). There was basic agreement that the design as shown at present required some modification (for example the type of welds must be changed to meet engineering codes). In addition, it was recognized that the connecting plates previously thought to be straightforward pieces, were reaching the limits of what could be achieved in terms of the number of pins and bolts. No final design has yet been realized and, in fact, the TileCal group is still re-evaluating the conditions under which the maximum loads may be realized. Work in this area is expected to continue into the summer of 1998.

The remaining issues addressed were primarily areas in which minor changes to the design could realize significant cost reductions. For example, the connecting weld bars were redesigned to conform to a stock precision bar size, and the design of the spring pins was changed at the request of a potential vendor. Finally, the number of access holes in the girder was reduced by a factor of two (and indeed we are still considering whether it is essential to have these access holes at all, except for a single hole at the center of the barrel girder.)

(V. Guarino and J. Proudfoot)

c. Construction Preparations

Starting in late summer, work was begun in Building 366 at Argonne to prepare the area for the construction of submodules and modules, with a provision being made for a clean area in which instrumentation could be carried out. A building layout for the area to be used for construction of the ATLAS calorimeter modules is shown in Figure 5. It should be noted that this layout also takes into account the needs of other (present and future) projects in the Division expecting to use this area. Most of the work required to clean out existing stored materials and surplus equipment has been completed. Work on the individual areas (for example to install the gantry rail system and roll-up door in the submodule stacking building) will take place in 1998.

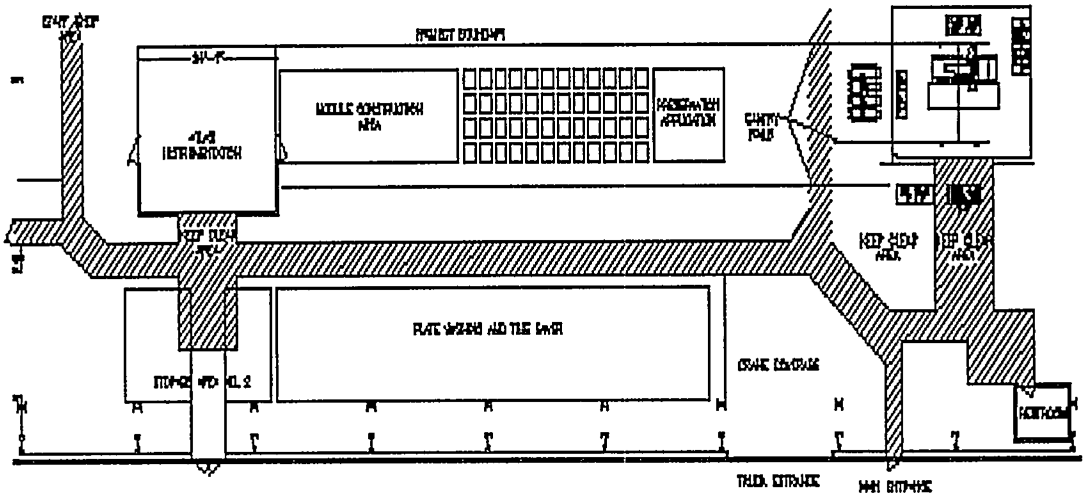

Fig. 5. General layout of Atlas construction area in Building 366.

Preparation of the plates for gluing ("Timesaver") has long been recognized as an area in which some cost reduction might be realizable. Tests were carried out at the vendor using a wet process which was claimed to be capable of simultaneously removing all oil and grease from the plate surface and roughening it in preparation for gluing. These were very successful and glue shear strength measurements made subsequently at Argonne gave a maximum glue shear strength of 10 N/mm^2. This is close to the maximum glue strength given by the manufacturer and significantly better than had been achieved previously, which was already sufficient for our design. In addition, the rate at which the plates were processed indicated that all plates for a single submodule could be processed in less than about three hours using a two-person crew. This is very cost effective, and we are therefore proposing to purchase such a machine for each submodule construction site. As a side benefit, this approach also facilitates building layout. One remaining issue is the noise level of the machine during operation. This is about 90 dB and some work will be done in 1998 to understand how best to alleviate this on the work force at each stacking location (each of which has its own special problems associated with high noise levels).

A third task accomplished as part of preparation for construction in the US was preparation of draft specification documents for some of the key components: the 5mm absorber sheets, master plate stamping, the girder and a specification for welding of submodule bars. These will be discussed and reviewed by the TileCal collaboration in early 1998 and will form the basis for the procurement and construction documents.

Finally, Argonne is also contributing the master plate die built as part of the prototype program towards a test of stamping master plates for the barrel modules at a European plant. The die was shipped to CERN in late summer and to their selected stamping plant in November. An initial stamping test of 10 plates was carried out in late November and indicated that the basic operation could be successful. There is some concern regarding early die wear and this will be evaluated further in 1998. In addition, one minor dimension on the stamped plate is out of specification. This is agreed to represent a deviation in the die and a variance will be noted on the construction drawing.

(J. Proudfoot)

d. Test Beam Program

d.1. Running Periods

The second half of 1997 saw two periods of data taking in the H8 testbeam at CERN. Both of the extended barrels, that constructed at Argonne and that constructed at Barcelona, were mounted contiguously in ϕ on the scanning table, with the old 1m modules sandwiching them and acting as transverse shower catchers. The Argonne module was equipped with front-end electronics which satisfied the dynamic range by incorporating compressor circuitry, while the Barcelona module included both compressors and bi-gain circuitry. Argonne personnel were involved in the setup and data taking in August, as well as the final data taking in October.

Based on these data periods, several critical items resulted in a main focus of activity throughout the collaboration:

- The choice of bi-gain over compressor electronics,
- The profile crosstalk problem,
- The anomalous decrease of the ^{137}Cs signal,
- Light yield.

A noticeable improvement in the response of the detector was shown with the bi-gain channels. Only after many man-months of massaging calibration constants did the compressor channels become close to functional. It was shown that the bi-gain channel gave superior response in terms of linearity, noise and resolution. Therefore, the collaboration has decided to discard the compressor circuits and entirely implement the Tile Calorimeter with bi-gain electronics.

During setup it was noticed that the profiles fixing the waveshifting fibers to the tiles were not completely opaque. Light from one depth section was thus able to crosstalk to other sections of the calorimeter. This problem was evident in the linearity and resolution of the detector. Argonne personnel assisted in the software fixes for the crosstalk problem.

As part of the stability monitor, the source scan showed an anomalously high decline as seen in Figure 6. After correcting for the decay of the ^{137}Cs source, the average decline of ^{137}Cs current was about 1% per month. This problem is not yet understood.

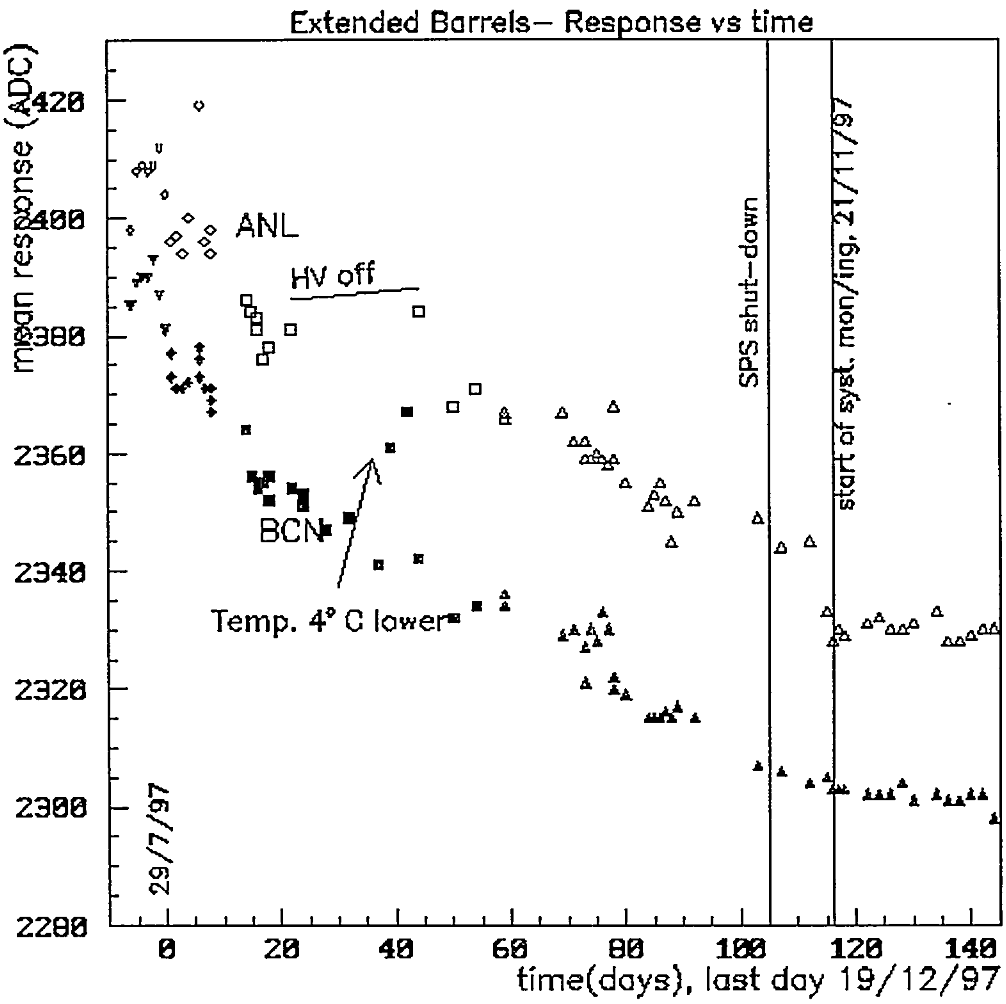

Fig. 6. The module-average ^{137}Cs raw source current as a function of time for both the Argonne (ANL) and Barcelona (BCN) modules. Shown on the figure are places where standard running is interrupted, such as HV off, or front-end electronics temperature changes.

d.2. Analysis

Previously, the best light yield obtained from Tile Calorimeter modules was around 64 photoelectrons GeV. Data from the current running period evaluated by Argonne personnel suggest a much lower yield ranging anywhere between 20-40 pe/GeV. The methods of extracting the light yield utilized both laser and electron data. The light yield calculated using the laser incorporated an Argonne analysis of the response of different cells to electrons, from which the calibration constant was found to be 0.73 pC/GeV.

Following up on the study of the anomalous decrease in Cs signal, Argonne members looked at the stability to pulsed signals using the laser data. It was found that indeed a downward trend existed, however with a magnitude about 4 times worse than the Cs decrease. Furthermore, it was found that time structure seen with the laser was not evident in the Cs data. These data and other observations helped better clarify possible sources of the anomaly.

Finally, in preparation for an LHCC review in January, 1998, a study of the high energy tails of the detectors was pursued. Figure 7 shows the number of pion events ≥ where is obtained from a gaussian fit to the total energy. Most all of the events ≥ 5 were found to be either multiple beam particles or, in fact, pions that shower electromagnetically. In one or two cases was it found that the events at unusually high responses looked very reasonable. This effect is possibly due to the miscalibration of the compressor circuit at very high charges. These events are under study.

(R. Stanek)

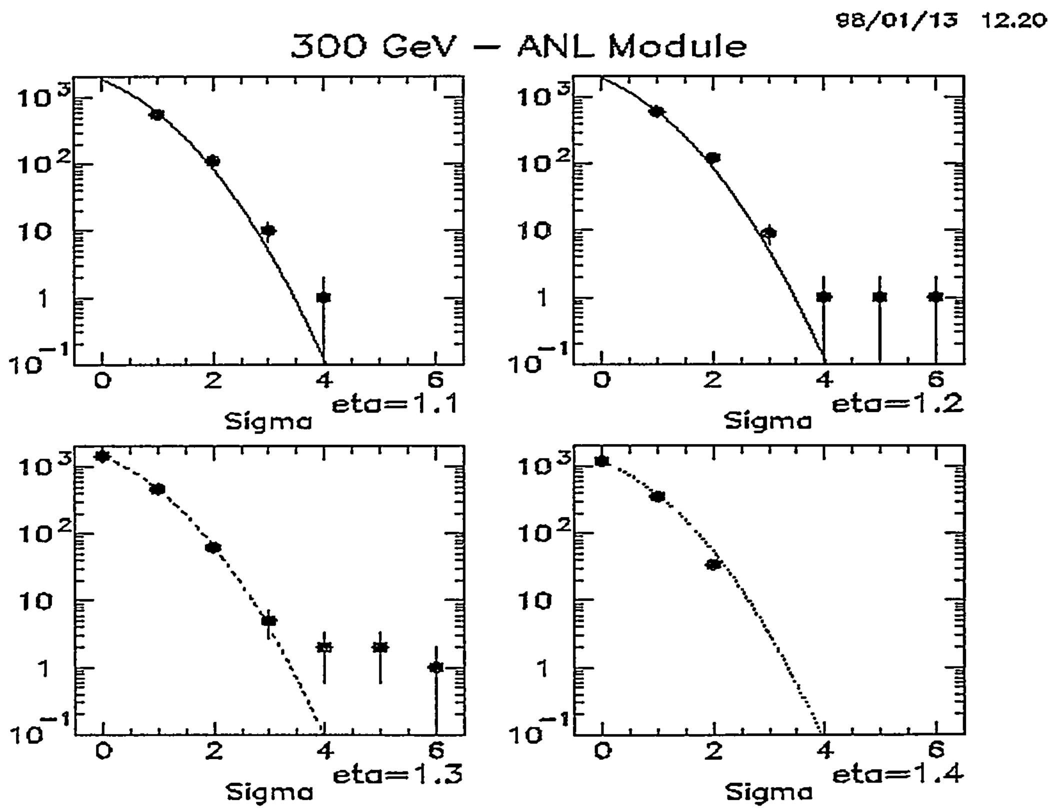

Fig. 7. The number of events above for given incident of the pion beam. is found from a gaussian fit to the total energy of all modules. The curve in the figure is the number of events expected from a gaussian.

C. DETECTOR DEVELOPMENT

I.C.1 CDF Detector Projects

a. CDF Detector and DAQ Electronics Development

John Dawson's VME digital readout board for shower maximum and related detectors ("SMXR") was prototyped and testing of the prototype was begun, and the basic scheme seems fine. Gary Drake continues to assist with the development of the SMQIE shower max digitizer ASICs as that design continues iteration. He is developing "SQUID" daughter boards for mounting the SMQIEs, and digital prototypes for system tests have been made. SQUID prototypes for the current version of SMQIEs are being developed for Karen Byrum and Steve Kuhlmann to use in test stand evaluations. Karen, working with John Dawson, is developing a receiver for the level 2 trigger system to accept the information from SMXR, negotiating with the Michigan level 2 people. Bob Blair, Steve Kuhlmann and John Dawson are working to make sure the interface for photon/electron trigger isolation hardware is adequate, and to get approval to make the relevant boards. Jimmy Proudfoot has directed his database related effort toward specifics for calorimeter calibrations, and he has recruited Jim Schlereth to make the electronics test stand software he will be developing usable in the actual on-line environment.

b. CDF Central Tracker Chamber

Randy Keup and Larry Nodulman, working with Vic Guarino and Emil Petereit, proposed a design for production tooling for inserting wire planes and field sheets into the new CDF central tracker "COT." Randy has also worked with David Kazhins at Fermilab, stringing the COT prototype and using it to solve various problems in electrostatic and gravitational deflections for the field sheets and wire planes.

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

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

(L. Nodulman)

I.C.2 ZEUS Detector Upgrade

a. Barrel Presampler (BPRE)

The last half of 1997 saw the completion of construction and testing of the remaining 26 BPRE modules and PMT Housings. Also during this period, at DESY, the calorimeter readout was finally modified successfully to include the data from the 6 BPRE modules installed in ZEUS. In all, a total of 1.1 pb^{-1} of data was taken with the 6 BPRE modules read out.

Construction continued in the last half of 1997, with all BPRE modules completed by mid December. Most of the modules and PMT Housings were shipped before the end of December, arriving at DESY the first week of January 1998. The last shipment of modules left ANL the first week of January, arriving at DESY by the middle of January. In early December, the 6 BPRE modules installed at DESY were removed for installation of the LED system. This was done and the modules were prepared for re-installation in ZEUS in 1998. During this period, the remainder of the PMT bases were received, completing procurement of all parts and equipment for the BPRE.

At the beginning of this period, development of the testing procedure was finalized. All BPRE modules were tested before leaving ANL with a source scan, LED pulse, and cosmic rays. The procedure was defined as follows:

- first, the module was source scanned, iterating the scanning procedure while adjusting the HV per channel such that each channel's response was the same as all others. This procedure was used to determine the operating HV for each channel. Figure 1 shows the final source scan result for a BPRE module.

- second, the LED was pulsed at several attenuation settings to measure each channel's response in numbers of photoelectrons. Figure 2 shows the LED response for several BPRE channels.

- thirdly, a cosmic ray run was done overnight to determine the response to mips for each channel. Figure 3 shows the mip response of some channels from the cosmic ray test.

Readout for the cosmic ray run was available for 2 modules worth of channels, so normally 2 modules were stacked up for the tests. The testing procedure, as described above, required one day per module. From these tests, a database of results was made up for each BPRE channel. In this way, the PMT gain was determined for each channel prior to installation at ZEUS. These gains will be used to determine the initial HV setting for each BPRE channel after installation. The final BPRE calibration will be determined from the ep data itself, requiring about 1 pb^{-1} of data to complete the calibration.

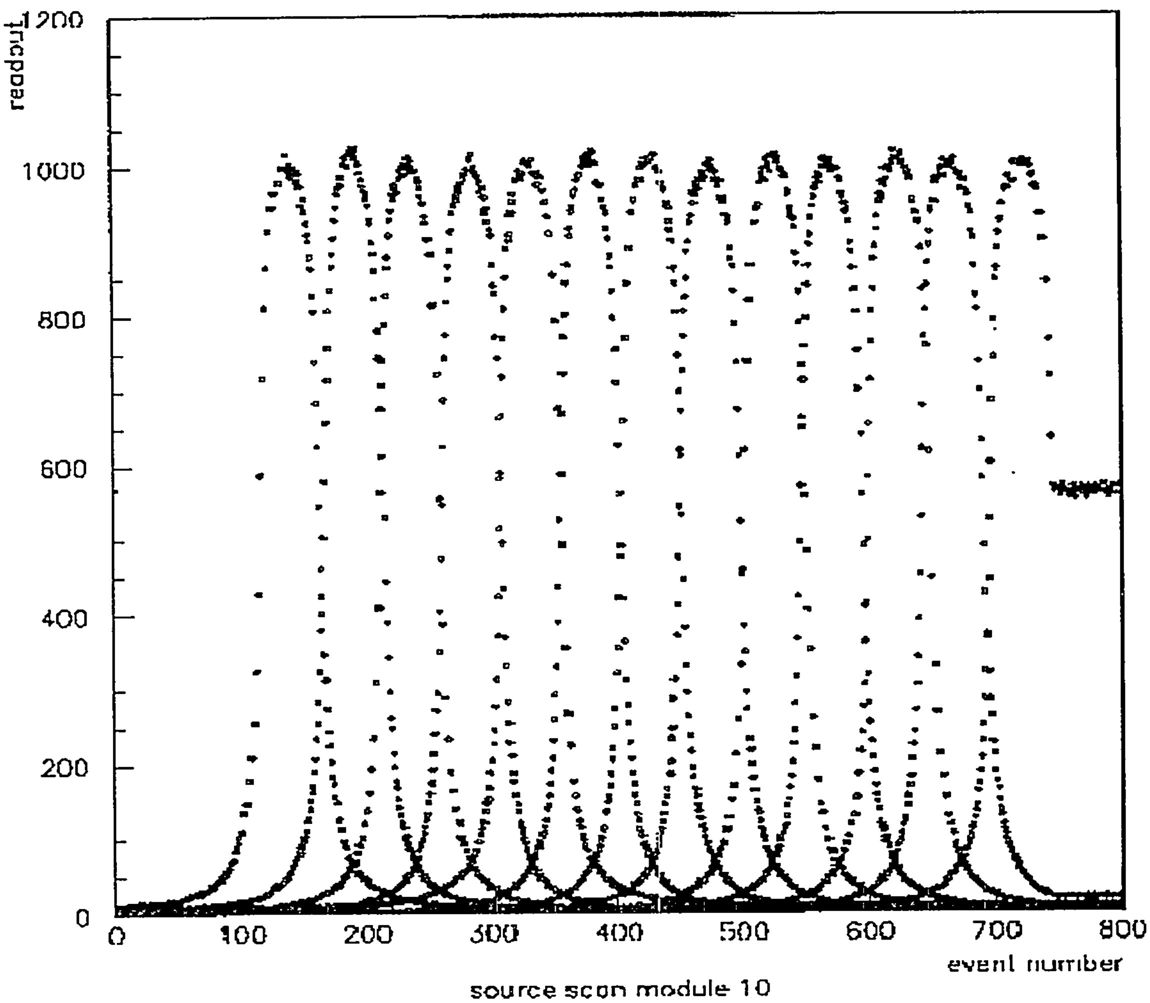

Fig. 1. Final source scan response of BPRE module 10.

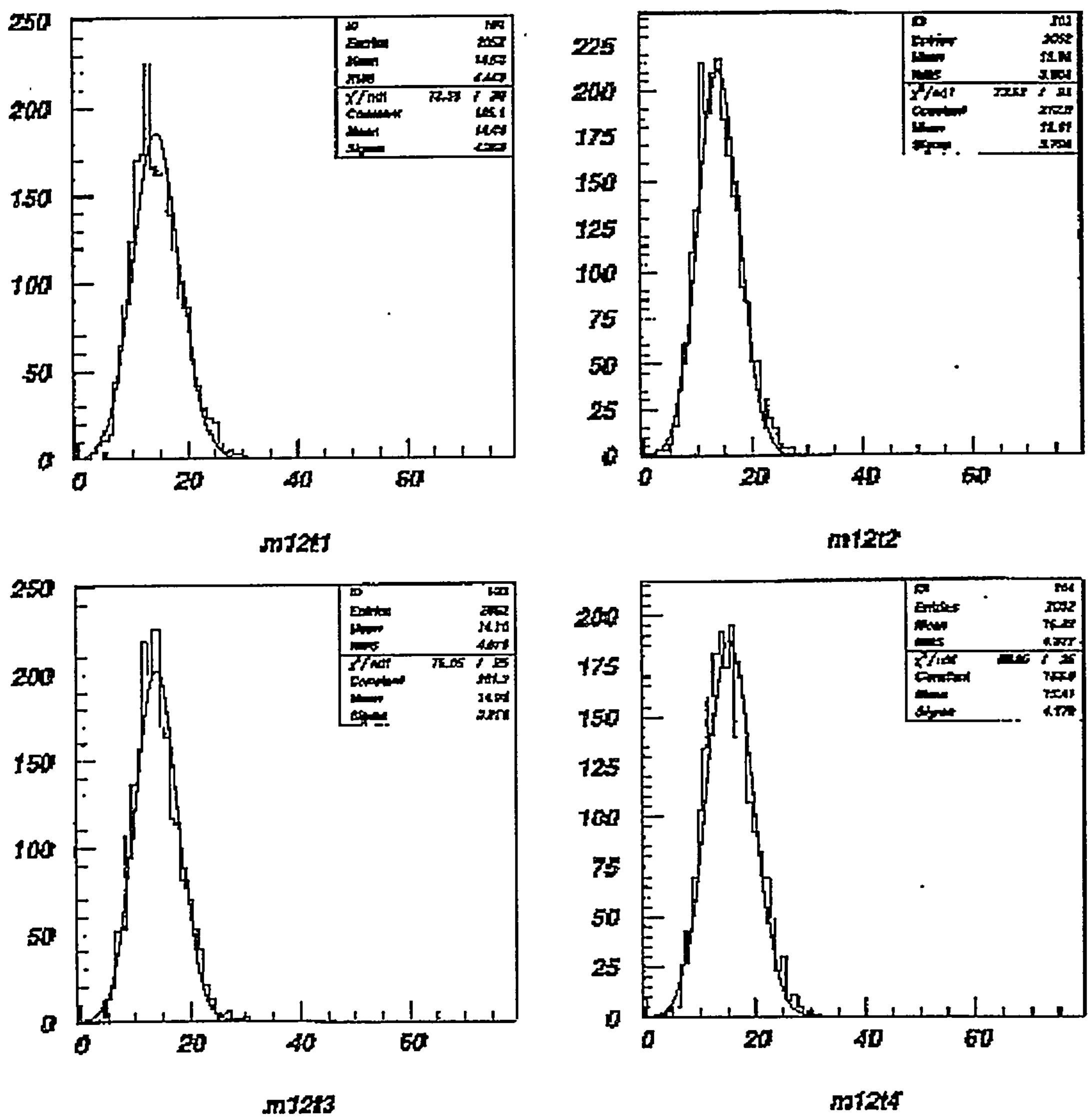

Fig. 2. LED signals from 4 channels of BPRE module 12.

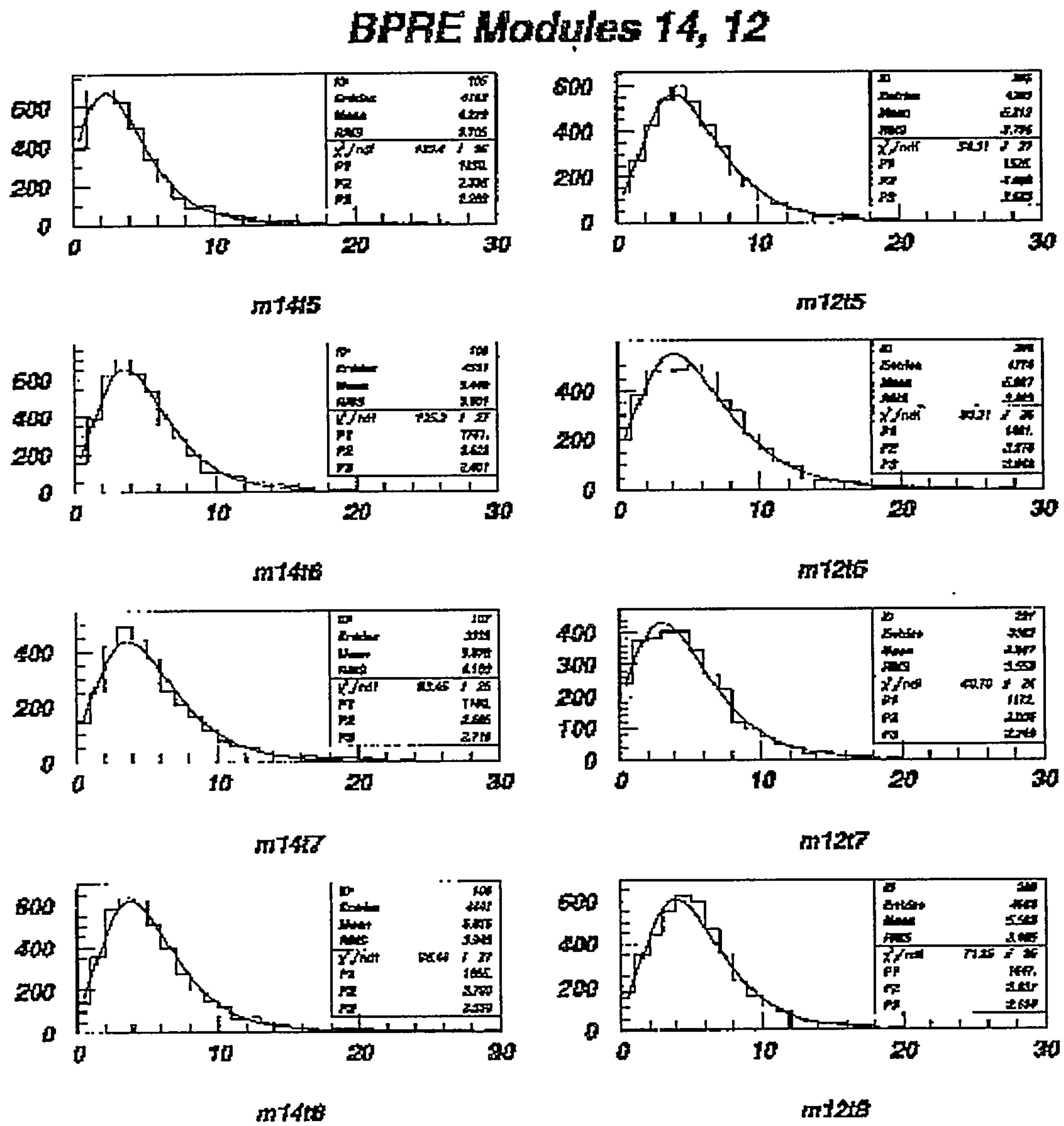

Fig. 3. MIP response from cosmic rays for 4 channels each from modules 14 and 15.

A new version of the calorimeter readout, which included the 6 BPRE modules, was completed in October 1997. For approximately the last week of the 1997 running period, the BPRE was included in ZEUS data-taking. In all, about 1.1 pb^{-1} of data was obtained with the BPRE included. By looking at all the data, it could be determined that there was a definite correlation between signals in the BPRE channels and the BCAL towers immediately above them. In fact, a miscabling in one BPRE module was found by scanning the correlation plot. Figures 4 and 5 show the response of the BPRE to electrons and hadrons. Figure 4 shows the response of all particles (dominated by hadrons) compared to a Landau function fit around the peak of the distribution. Multi-mip signals are seen as an excess in the tails of the distribution. Figure 5 shows the BPRE response to scattered positrons in the data. The curve is a Landau function, again showing a multi-mip excess in the tail of the distribution. By comparing the means and RMS values of Figures 4 and 5, it can be seen that positrons exhibit more evidence of showering than hadrons. In the future, with these signals from the full BPRE, positrons and hadrons in the tails of the distributions will be corrected for energy loss using parameterizations determined in test beams and by Monte Carlo methods.

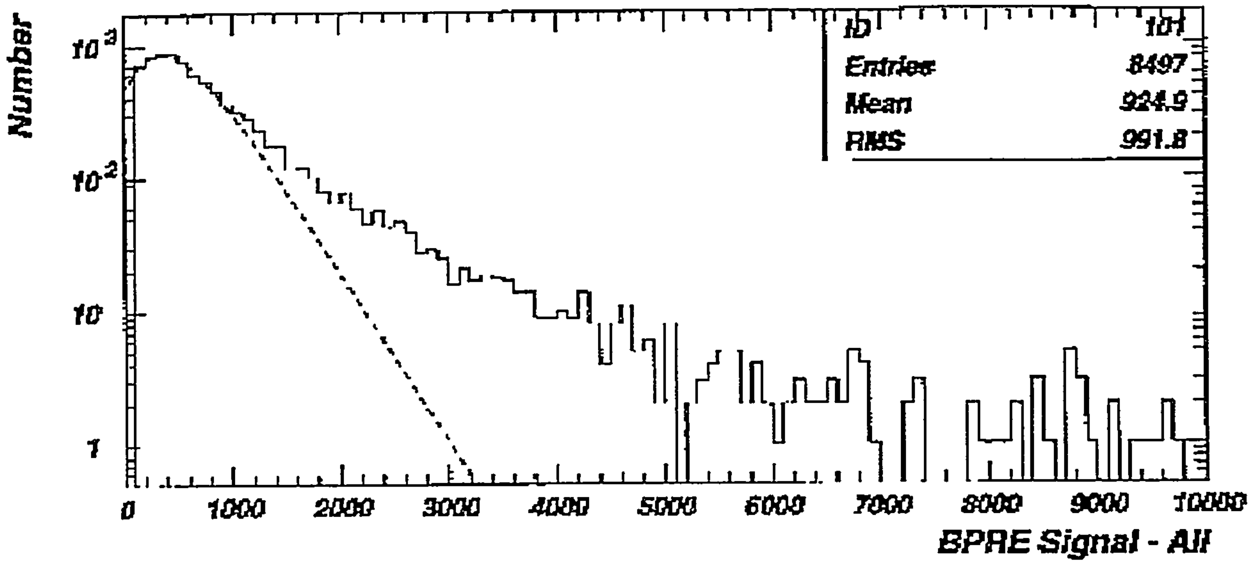

Fig. 4. BPRE signal from ZEUS data - all charged particles.

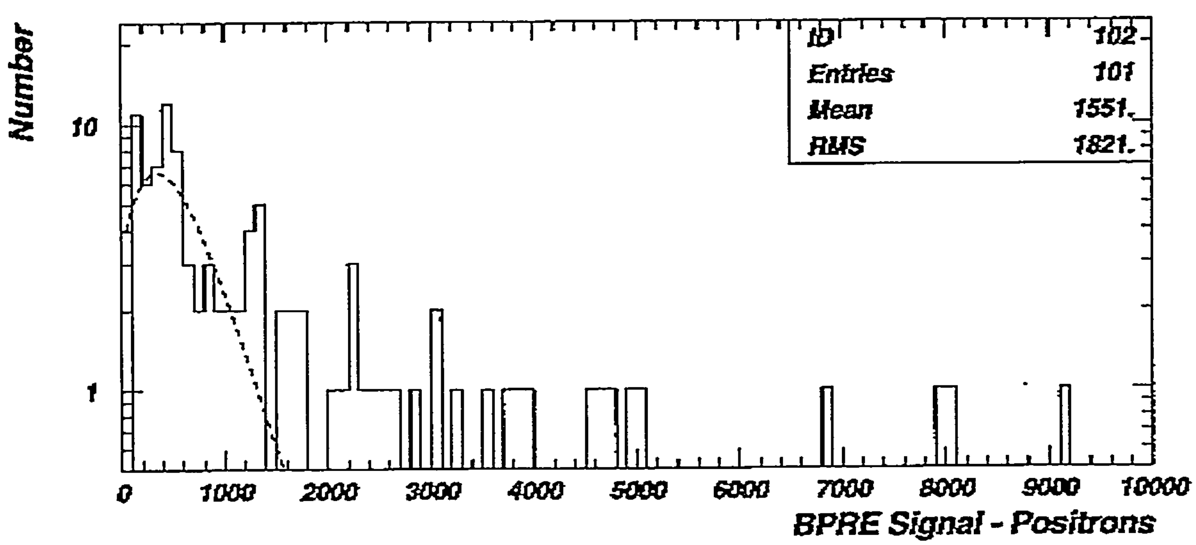

Fig. 5. BPRE signal from scattered positron candidates in 1.1 pb^{-1} of ZEUS data.

(S. Magill)

I.C.3 ATLAS Trigger Development

The trigger for the LHC ATLAS experiment will use a novel approach to reducing the amount of data used in making trigger decisions. It uses the regions defined by early hardware processing (done by a fast level 1 trigger) to guide what data is used at the next level for the decision. This next level, level 2, is expected to be done using data only from the regions of interest, ROI's, defined by the level 1 trigger. The information about these ROI's has to be collected from the level 1 system and passed to other parts of the ATLAS trigger. Argonne and Michigan State Universtiy are collaborating to provide the hardware and software that will acheive this. This system is called the Supervisor, ROI builder (SRB).

The ATLAS trigger architecture is currently being decided on. During the end of 1997 the ATLAS level 2 group has evaluated data from two test runs of small scale systems and decided to proceed with a very simple trigger system. This system will involve a single network switch connecting all the processors used to make the level 2 decisions and the readout buffers (ROB's) used to store event data. This is the simplest and most flexible architecture possible. Tests had been done of several architectures wirh small numbers of processors and buffer emulators. These tests indicate that individual components of the system perform in a way that allows for an adaquatly affordable system to be built. Larger scale tests are being planned to truly demonstrate this. The next set of tests will involve setting up a sixteen node system (some nodes emulating processors and some emulating ROB's) in the US.

The level 2 trigger will involve many coupled computers that have to communicate and perform coordinated tasks. The software for this requires a high level of coordination between the different systems. In order to get started on this the ATLAS group has begun to pull together a team of software specialists to make a reference system where all the subtasks that the trigger and the systems it depends on will be represented. This will act as a starting point for an overall software system within which the SRB software will begin to take shape. Argonne has begun on the software system design for the SRB within this framework.

(R. Blair)

I.C.4 MINOS Detector Development

During the summer of 1997 the Argonne MINOS group focused its effort on the study of a prototype Aluminum Proportional Tube (APT) calorimeter in a test beam at Fermilab, and on the construction and evaluation of full size (8 meter long) APT chambers and strip planes at Argonne. The construction of APT chambers and their use in the prototype calorimeter was described in detail in the previous two Semiannual Reports.

The APT calorimeter tests were performed in two stages using the same "hanging file" steel plane structure. The first stage used the electromagnetic configuration, consisting of nine planes, each with three APT's and orthogonal cathode strip planes. The second stage used the hadron calorimeter configuration, with 25 planes of six APT's each (without strip planes). The same steel plane structure, consisting of 25 1.5-inch thick steel planes, each 1 meter by 1 meter, was used for both stages. The hadron calorimeter configuration used a total of 150 1-meter long APT's, which required a major fabrication effort. One third of the chambers were assembled at Tufts and the remainder at Argonne (with substantial help from the Dubna group). Argonne physicists and engineers designed, fabricated and installed the 1200 channels of front-end and ADC interface electronics needed for the test beam measurements.

The Fermilab test beam used for these studies had a wide (5%) momentum spread and contained no particle identification other than that provided by the calorimeter itself. The positron beam was relatively free of hadron contamination, and muon-electron identification using simple topology cuts was very effective. The hadron beam consisted of a mixture of positrons, pions and muons. The large positron contamination was eliminated by using a lead preradiator and topology cuts in the first few calorimeter planes. Muon data were used to measure the uniformity of APT response. The channel to channel variation of muon pulse heights had an rms spread of about 7%, which was substantially better than our design goal.

The electromagnetic energy resolution at each beam energy was obtained by fitting the anode-wire charge spectrum to a Gaussian. The $40\%/\sqrt{E}$ dependence obtained agrees well with expectations; the 6.7% constant term in the resolution energy dependence is due to the large momentum spread in the beam.

Figure 1 shows the energy resolutions obtained for hadrons (pions) by fitting charge spectra to Gaussians; rms fits and analysis of hit count distributions gave similar results. The excellent $71\%/\sqrt{E}$ energy dependence is apparently due to the high degree of compensation which occurs for APTs with 1.5-inch thick steel planes. The electron/hadron response ratio varied from 1.3 at low energies to 1.1 at higher energies. Figure 2 compares our results with those obtained from other gas calorimeters.

Six full-length (8 meter), 8-channel APT chambers were built and tested at Argonne, along with an array of 24 2-cm wide, 8-m long cathode strips. The chambers used wire supports at 50 cm intervals along their lengths (identical supports were used to center the anode wires at the ends of the 1-m chambers built for the APT prototype calorimeter). The signal size was measured at a number of locations along the wires and strips using a movable cosmic ray telescope. No attenuation effects were observed for either wires or strips. Figure 3 is a photograph of the test setup.

Following the decision of the MINOS Collaboration to use extruded plastic scintillator strips instead of APTs, the Argonne group turned its attention to a number of scintillator development activities. The most important of these is to continue work with commercial vendors to optimize the light yield of extruded polystyrene scintillator strips. Industrial partners include the APT extrusion vendor, Quick Plastics, which also produced very promising scintillator strips prior to the technology decision.

Additional Argonne scintillator R&D tasks include the development of an automated radioactive source scanner for mapping the response of scintillator strip modules (arrays of 16 to 24 strips in a light-tight, fireproof enclosure), and of a radioactive source calibration technique which can be used to compare the responses of scintillator modules at the fabrication facilities with their responses after installation in the near or far detectors. Other tasks included the engineering and prototyping of specific fabrication and installation techniques and the design of a packaging and shipping system for completed scintillator modules. The most immediate goal of this work is to provide engineering designs and cost estimates for detector fabrication and installation for the MINOS Detector Technical Design Report. This Report is to be submitted to Fermilab in the spring of 1998 and will be the subject of a DOE Lehman Review later in the year.

(D. Ayres)

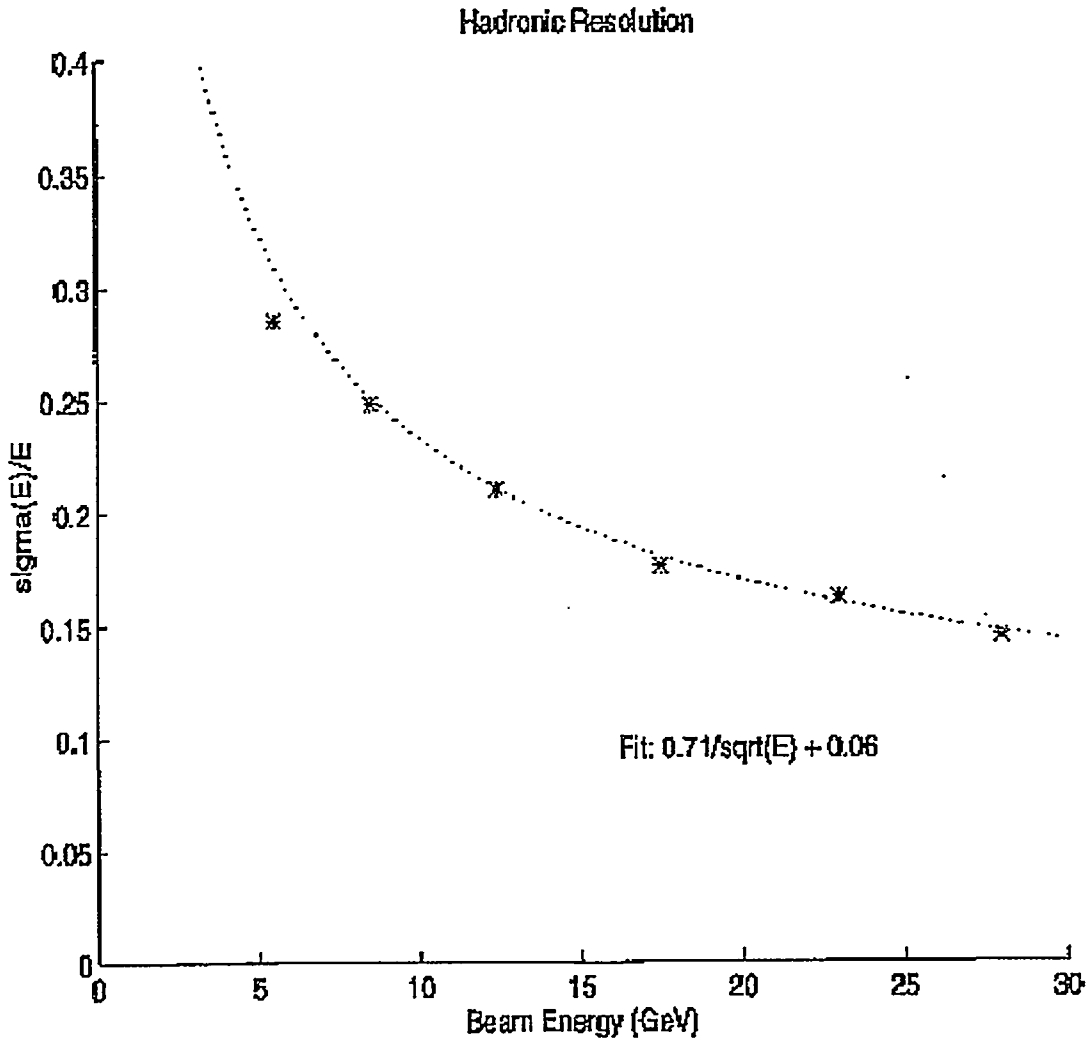

Fig. 1. Hadron energy resolution obtained from the MINOS APT prototype calorimeter. The large constant term is caused by the 5% spread in beam energy.

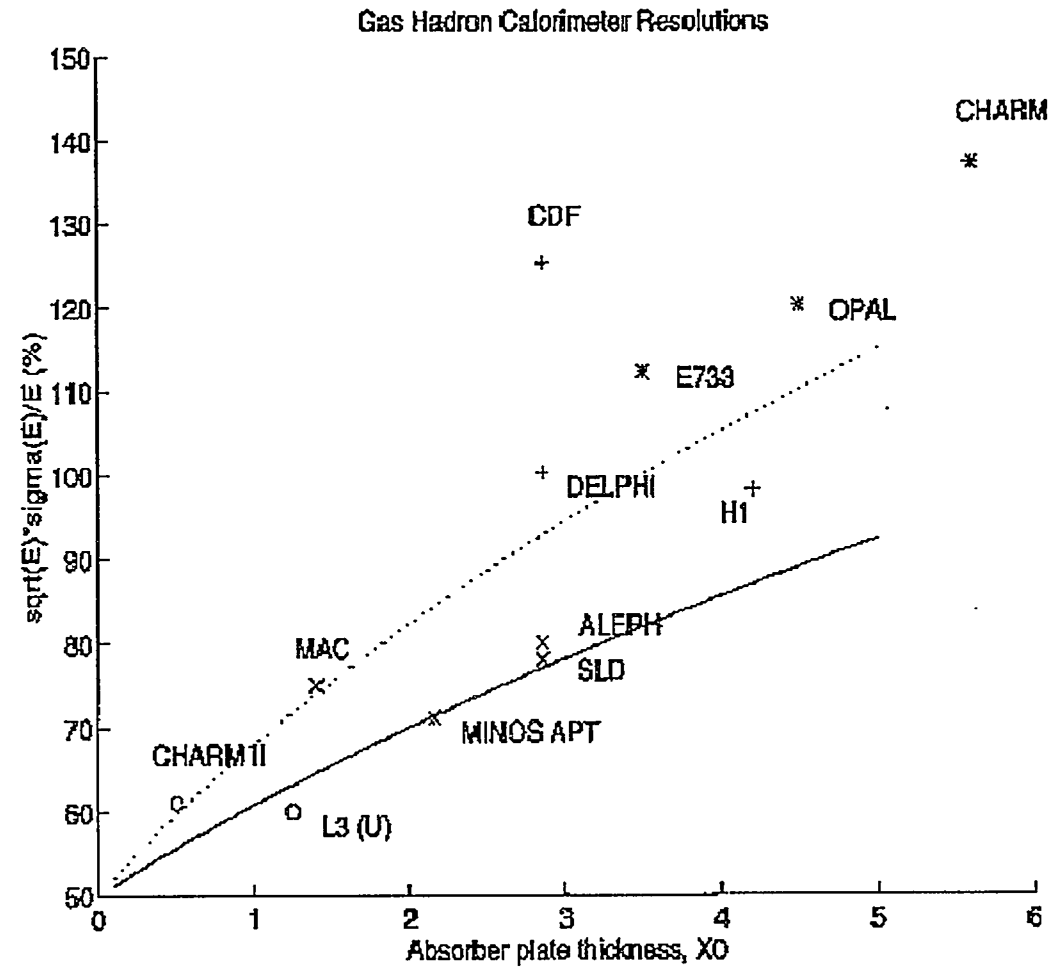

Fig. 2. Comparison of the hadron energy resolution of the MINOS APT calorimeter with results from other gas detectors. The resolution is plotted as a function of absorber plate thickness in radiation lengths. The curves are the result of parametrizations of the expected absorber-thickness dependence of the energy resolution.

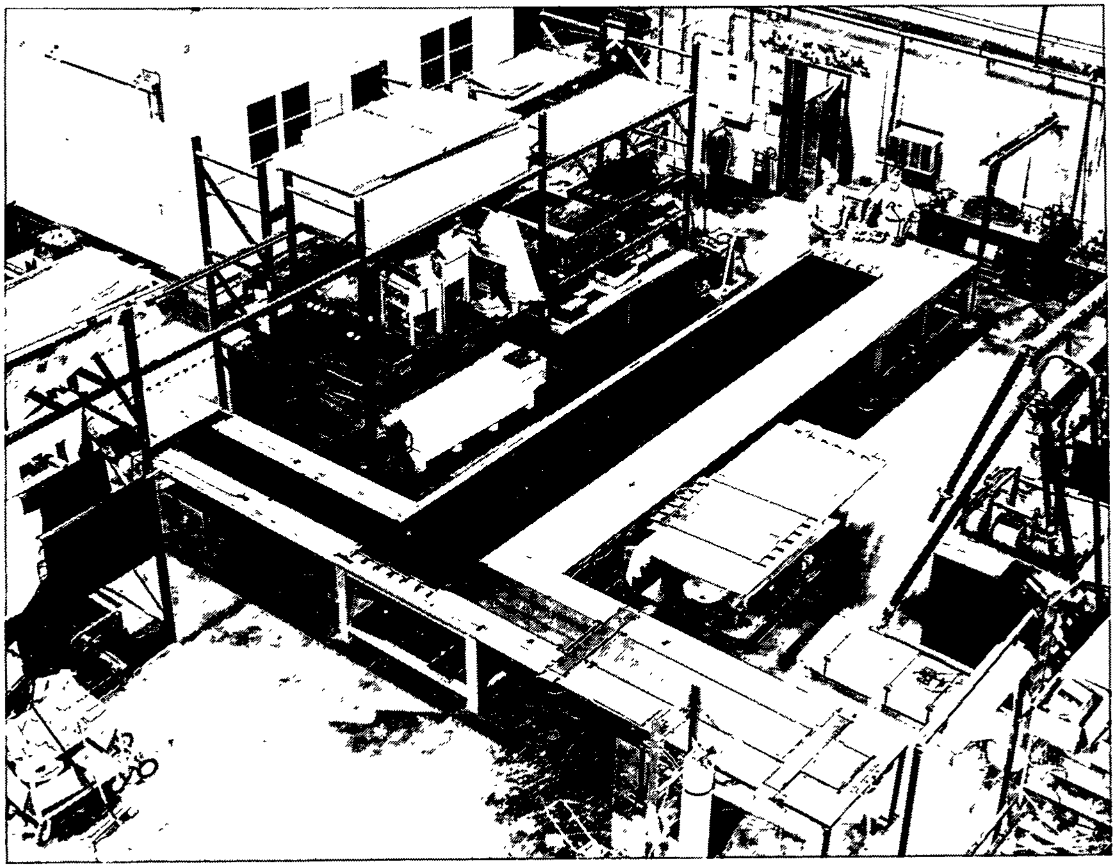

Fig. 3. Photograph of the setup used to test 8-m APT chambers and cathode strips in Building 366. The readout ends of the six APT chambers (with extruded black PVC gas envelopes) are at the top right corner of the photo. The readout end of the 24-strip array (covered with black PVC spacer material) is at the lower right corner. Since the arrays of strips and chambers crossed at only one strip location, three 1-m long APT chambers were used to measure strip response at other positions. The top of the sheet-aluminum Faraday cage was removed for this photograph. (A 1 m by 1 m plane of APTs and cathode strips, similar to that used in the prototype calorimeter, is also visible at the lower right.)

I.C.5 Electronics Support Group

ZEUS: The ZEUS experiment at DESY has been taking data for several years. The trigger electronics that we built in the past for the experiment have been working well, and we have not had significant problems or repairs over the last year.

There were two new projects for ZEUS this last year. One was the development of a multi-channel LED pulser for pulsing phototubes associated with the calorimeters, to be used for calibration and diagnostics. Another project was the development of a system for providing digitally-controlled reference voltages for the Cockcroft-Walton phototube bases. This project involved the design of a new interface board for the phototubes bases, and also the re-production of a digitally-controlled DAC board, designed previously by our group, for providing the reference voltages.

CDF: We are presently involved with the development of front end electronics for the Shower Max Detector of the CDF Upgrade at Fermilab. We have overall responsibility for the electronics engineering of that system, and it is a major project for our group. Among other responsibilities, the position involves the coordination of the design engineering and system integration, over a group of 5 engineers, 5 physicists, 1 programmer, and 4 technicians.

Besides oversight, we are directly responsible for a number of specific subprojects, including the specification and testing of the front end ASIC (Application Specific Integrated Circuit); the design, testing, and production of the front end daughter boards; specification and evaluation of front end crates and power supplies; and the design and production of a VME-based readout board, called the SMXR. The latter project is a sophisticated data processor, which receives digitized data in floating-point form from the front end electronics at the rate of 300 MByte/Sec, linearizes the data with the use of look-up tables, adds together up to four words as sampled in time to reconstruct a long signal, 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 system is designed for dead-timeless operation, so there is simultaneous processing of digitized data with the acquisition of analog signals from the 132 nS interaction rate from proton-antiproton collisions. Noise is very important in this system, as the detectors have high sensitivity to environmental noise, so we are heavily involved with the specification and evaluation of digital links and grounding of other detector subsystems.

We are presently in the late stages of prototype development, and expect to do small system tests by the spring of 1998. We expect to begin production of ~100 SMXR boards by fall, 1998, with the production of ~5000 front end daughter boards by spring, 1999. The full system should be installed by spring, 2000.

In addition to the Shower Max electronics, we are also involved with two other projects for the CDF Upgrade. We are designing and building electronics to trigger on isolated photons, called ISOPICK. This board works with the Cluster Finder, which identifies a group of hit channels in a detector region that might contain an "interesting" event. The isolation trigger performs algorithms on channels around this "cluster seed" to look for events arising from isolated photons. The ISOPICK sends the result of the algorithms to the second level trigger, as part of the Level 2 trigger decision.

Another project is the interface of the Shower Max system with the second level trigger, called RECES. This board works in conjunction with both the Cluster Finder and the Central Tracking Detector. It requires an event from a cluster seed to also have a signal pointing from the Tracking Detector into the Central Shower Max Detector. This is used to differentiate events with electrons from other background events, such as hadronic showers or events with pions. The RECES trigger will reduce the backgrounds by 50%, while retaining 90% of the electron sample.

Both the RECES and ISOPICK are currently being designed. Testing will occur by fall, 1998, with production in 1999.

STAR: This last year, we began active involvement with STAR, the Polarized Beam Experiment at Brookhaven, and have been participating in the specification of the front end electronics, the trigger, and the data acquisition system. We anticipate having sole responsibility for building the front end electronics for the Shower Max detector, which contains ~36000 channels. We also anticipate having joint responsibility for building the Data Collector and the Level 0 Trigger Processor, shared with Michigan State University. Important milestones include a test beam run at Brookhaven in October, 1998, and the startup of the STAR experiment in Fall, 1999. It is desirable to have prototype electronics for the test beam. It is likely that not all of the electronics will be built by the startup date of the experiment, and we anticipate that production and installation will continue into 2000.

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 the Level 2 Trigger Supervisor, and the Region of Interest (ROI) Builder. The system assembles data from the first level trigger describing where data from an "interesting event" can be found, requests buffers to pass the data to available Level 2 processors, and communicates to the buffer when to pass the data to the event builder if the event is selected.

In 1996, we built the first Trigger Supervisor, which is the hardware router for distributing event data coming from the first level trigger system, to one of several Level 2 processors. Originally, there were three different architectures proposed for the Level 2 System, each of which used different philosophies and technologies in their implementations.. The Supervisor was designed to support all three architectures. In 1997, a series of studies called the Demonstrator Program was initiated to study the relative merits and efficiencies of the architectures. We provided both hardware and software support for this series of studies.

The Demonstrator Program was completed at the end of 1997. The result was that two of the three architectures seem viable (although one of the two performed somewhat better than the other), and it was concluded that more study is needed. A new program, called the Pilot Project, was organized as the next step in the development of the system. It will use a larger network, and also try to implement the ROI Builder, the interface from the first level trigger. The function of the ROI Builder is to receive a list of addresses from the Level 1 Trigger, identifying where the event data from the "Region of Interest," can be found. The ROI Builder collects the data, and makes it available to the Trigger Supervisor for distribution to Level 2 processor.

The Pilot Program began in January 1998, and will be the focus of effort throughout the year. We expect to support the activities of the program by providing both hardware Supervisors, and also software support, in building up the larger network. We also anticipate building the first ROI Builder prototype. As part of this effort, we will build a small system here in the United States. By the end of 1998, we expect to transport the system to Saclay, to merge with their system an create a larger network. By the summer of 1999, the system will move to CERN for further testing. It is anticipated that the result of this phase of development will lead to a full specification of the architecture of the Level 2 Trigger System, including the Supervisor and the ROI Builder. We expect that ANL and MSU will have joint responsibility in building these pieces of hardware for the final system.

MINOS: This last year, we began active involvement with MINOS, the Neutrino Oscillation Experiment at the Soudan mine. During 1997, we participated in several workshops to specify the operation and performance of the detector and electronics. The collaboration chose solid scintillator as the detector type, but the photodetector has yet to be selected. The choice of photodetectors has been narrowed to Hamamatsu 16 channel multi-anode phototubes, or DEP Hybrid Photodiodes (HPDs.) There is a preference for using HPDs, due to better channel-to-channel uniformity and lower per-channel cost. The collaboration will to postpone the decision on the photodetector for a time, to allow the HPDs to become more mature.

The system has special requirements, in that an experimental goal is to measure single photoelectron signals. Thus, noise sensitivity and photodetector dark current errors are important. These parameters are a strong function of the type of photodetector and the associated electronics. It is anticipated that a period of front end R&D will occur through 1998 and into 1999, probably as separate efforts for each of the photodetector types. We anticipate being involved in some of the R&D work for the front end electronics. A decision on the choice of photodetector, along with the associated electronics, is anticipated by mid-1999.

Longer term, we anticipate being involved with some of the production of electronics for the experiment. The United Kingdom is contributing a significant amount of engineering and money for production, but production costs are cheaper in the United States. Argonne may play a role in the overseeing the production of circuit boards, and in testing the electronics before installation at Soudan. Production could start in 2000. The scope of this work is not yet known.

(G. Drake)

II. THEORETICAL PHYSICS PROGRAM

II.A. THEORY

II.A.1 All-Orders Calculation of Cross Sections for the Production of Top Quarks and of States Predicted in Supersymmetry Models

As reported previously, Edmond Berger and Harry Contopanagos (Electrical Engineering Department, UCLA) have developed and published an original formalism for summation of the contributions of initial-state soft-gluon radiation to all orders of perturbation theory in quantum chromodynamics (QCD). The first application of their method was to improve the theoretical reliability of predictions for the total cross section of top-antitop pairs at hadron collider energies. The extension of their method to the production of pairs of squarks and gluinos at hadron collider energies accounts for an important fraction of their research efforts during the past year. The matrix elements for squark and gluino production are significantly more intricate than those for top quark production. They hope to publish their findings shortly.

Berger was invited to present a review of methods of soft-gluon resummation at the Symposium on QCD Corrections and New Physics, Hiroshima, Japan, in October, 1997. His review appears as Argonne report ANL-HEP-CP-98-03 and will be published in the Proceedings of the Symposium. Berger also spoke about his and Contopanagos' method and the differences with other approaches, at Kyoto University in Japan in October.

(Edmond L. Berger)

II.A.2 Production of Pairs of Photons in Hadronic Reactions

The production of a pair of prompt photons in hadronic reactions at fixed-target and collider energies is of interest as a means for probing the dynamics of strong interactions. The process is important also in searches for new phenomena, notably the Higgs boson. Edmond Berger and Stephen Mrenna, in collaboration with C. Balazs and C.-P. Yuan (Michigan State University) undertook a detailed investigation of the production rate and kinematic distributions of isolated photon pairs. Their results appear in Argonne report ANL-HEP-PR-97-84, since published in Physical Review D57, 6934 - 6947 (1998). This calculation incorporates the full content of the next-to-leading order contributions from the quark-antiquark and quark-gluon initial-state subprocesses, supplemented by resummation of contributions to these subprocesses from initial-state radiation of soft gluons to all orders in the strong coupling strength. The computation also includes essential contributions from the gluon-gluon box diagram and long-distance fragmentation contributions from fragmentation of final state quarks into photons. Resummation plays a significant role in the calculation, particularly in the description of the behavior of the transverse momentum distribution of the pair of photons, as distinct from that of the photons individually. The resummation is also necessary for a reliable prediction of kinematic distributions that depend on correlations between the momenta of the two photons. In the paper, results of the calculation are compared with data from the two Fermilab collider collaborations, CDF and D0. The agreement is good in both absolute normalization and shapes of various distributions.

(Edmond L. Berger)

II.A.3 Renormalon Ambiguities in Heavy-Quarkonium Decays

In Quantum Chromodynamics (QCD), it is often useful to describe physical processes involving more than one distance scale by making use of a factorization formalism. In such a formalism, a physical observable is written as a sum of products of short-distance coefficients with long-distance operator matrix elements. The short-distance coefficients may be calculated as a perturbative series in the strong coupling constant a_s, evaluated at the short-distance scale. The operator matrix elements are usually nonperturbative in nature and may be fixed by comparison of physical quantities with experimental values or through nonperturbative methods, such as lattice QCD.

The conventional wisdom is that the perturbation expansions for the short-distance coefficients in QCD factorization formulae are, at best, asymptotic series, exhibiting factorial growth at large orders. In recent years, considerable attention has been paid to a model for the large-order behavior of the QCD perturbation series. In this model, which is exact in the large N_f limit, one considers the perturbation series that is obtained by including all numbers of vacuum-polarization corrections to the gluon propagator in a one-loop contribution. In this model, the breakdown of the perturbation expansion is signaled by the appearance of the Landau pole in the gluon propagator.

A useful tool for summing asymptotic series is the Borel transform. If the Borel transform of a series is nonsingular along the positive real axis and falls sufficiently fast at infinity, then the inverse transform is well-defined and yields an expression whose asymptotic expansion agrees with the original series. In the case of the large-N_f QCD model, the Borel transform has poles, known as renormalons, some of which lie on the positive real axis. The renormalons on the positive real axis make the inverse Borel transform ill-defined: There are ambiguities, which arise from the various ways in which one can define the contour of integration near the poles. In many applications of factorization formulae, such ambiguities are significant, since they are of the same nominal size as power-suppressed corrections to the physical observables.

Recently, Geoffrey Bodwin and Yu-Qi Chen (Ohio State) investigated the renormalon ambiguities in the expressions for S-wave heavy-quarkonium decay rates in the Nonrelativistic QCD (NRQCD) factorization formalism. They argued that, when one uses a hard-cutoff factorization scheme, renormalon ambiguities do not appear in the short-distance coefficients. The reason for this is that a hard cutoff prevents loop integrations from entering the region of small loop momentum, where the running coupling blows up. Therefore, the ambiguities that appear in the dimensionally-regulated ($\overline{MS}$) short-distance coefficients must be an artifact of the factorization scheme. Furthermore, since, the physical decay rates are unambiguous, any ambiguities in the short-distance coefficients must be canceled by ambiguities in the operator matrix elements.

Bodwin and Chen computed the leading ambiguities in the dimensionally-regulated NRQCD matrix elements. To obtain the ambiguities, it is necessary only to compute the change in the matrix elements in going from a hard-cutoff UV-regularization scheme to dimensional regularization. Hence, the computation is short-distance (perturbative) in nature. The results of Bodwin and Chen can be compared with a computation of the renormalon ambiguities in the short-distance coefficients that was carried out by Eric Braaten (Ohio State) and Chen. The combined results demonstrate that the renormalon ambiguities do, indeed, cancel in the expressions for the decay rates.

This work supports, and demonstrates through a detailed example, a principle that has been the object of some controversy in recent years. The principle is that the factorial growth in the perturbation series for the dimensionally-regulated short-distance coefficients is cured order-by-order in perturbation theory by a corresponding behavior in the dimensionally-regulated operator matrix elements. In applying factorization formulae at the level of power-suppressed corrections, it is crucial to have such control over the factorial growth of the perturbation series and, hence, over the corresponding ambiguities. A paper describing this work (ANL-HEP-PR-98-29) is in progress.

(Geoffrey T. Bodwin)

II.A.4 Confinement and the Supercritical Pomeron in QCD

For a long time, Alan White has proposed identifying a "supercritical phase" of Reggeon Field Theory with a semi-perturbative picture of the QCD Pomeron. The suggestion is that, in the supercritical phase, the "Pomeron is a single (reggeized) gluon in a soft gluon background". A major new paper (hep-ph/9712466, ANL-HEP-PR-97-95) provides a transverse momentum cut-off, confining, solution of QCD that is equivalent to a detailed derivation of this connection between RFT and the QCD Pomeron.

There are important experimental properties of the Pomeron that are not present in perturbation theory. In particular, in small momentum transfer processes the Pomeron is (approximately) a Regge pole, while in large Q^2 deep-inelastic scattering recent HERA data shows that it looks remarkably like a single gluon. In White's work these non-perturbative properties of the Pomeron are closely related to the well-known non-perturbative physics of confinement and chiral symmetry breaking - which are also an outcome of the solution.

The framework for the analysis is multi-regge theory. Beginning with the multi-regge behavior of massive quark and gluon amplitudes, reggeon unitarity is used to derive a reggeon diagram description of a wide class of multi-regge amplitudes, including those describing the formation and scattering of bound-state Regge poles. When quark and gluon masses are taken to zero, a logarithmic divergence is produced by helicity-flip reggeon interactions containing the infra-red quark triangle anomaly. With the gauge symmetry partially broken, this divergence selects the bound states and amplitudes of a confining theory. Both the Pomeron and hadrons have an anomalous color parity wee-parton component. For the Pomeron the wee-parton component determines that it carries negative color charge parity and that the leading singularity is an isolated Regge pole.

(Alan R. White)

II.A.5 Parton Evolution in Diffractive Deep Inelastic Scattering and Prompt Photon Plus Charm Production in $p\bar{p}$ Collisions

Continuing previous work where diffractive scattering at HERA had been investigated in the framework of perturbative QCD, the effect of parton evolution was studied in more detail. The initial quark-antiquark pair which emerges from the dissociating virtual photon undergoes an evolution in the course of which a bunch of additional quarks and gluons is generated. The initial "parton distribution of the Pomeron" is associated with first order Feynman diagrams containing a quark or a gluon in the final state. Multiple parton emission is included by evaluating higher order diagrams to leading log(Q^2)-accuracy. This procedure is similar to ordinary leading order parton evolution inside hadrons and leads to an improved prediction for the parton distribution of the Pomeron. The resulting shape of these distributions can be tested with recent data from H1 and ZEUS.

In collaboration with Stephane Keller (Fermilab), the possibility of determining the bottom contents of the proton was discussed. The means by which such a measurement can be realized is prompt photon production associated with bottom. The major task is to isolate and enhance the contribution arising from the QCD-Compton process where a bottom quark absorbs a gluon and emits a photon by imposing a set of appropriate cuts. The event rate for this process depends very much on the ability of tagging B-mesons. The B-tagging efficiency for both experiments at the Tevatron will be significantly improved for the future runs. Together with an increase in luminosity, the event rate is expected to be high enough for a first estimate on the fraction of bottom in the proton.

Final results on both projects are expected to be published in the near future.

(M. Wüsthoff)

II.A.6 Time-Independent Wigner Functions

Wigner's phase-space distribution function furnishes the basis for Moyal's deformation quantization alternative to the more conventional Hilbert space and path integral quantizations. Quantum Mechanics (and Field Theory) can thus be formulated through mere c-number functions, which, however, compose through a fundamental, nonlocal, "star-product". With D. Fairlie (U. of Durham) and T. Curtright (U. of Miami), C. Zachos has analyzed and understood the functional ("star") eigenvalue equations (discovered by Fairlie) which control these distributions and their consequent projective orthogonality properties: [ANL-HEP-PR-97-93, hep-th/9711183, "Phys. Rev. D, in press"]

The corresponding Darboux ("supersymmetric") isospectral potential recursions for these functions were worked out in detail, as well as their canonical transformations, i.e. transformations preserving phase-space volume. These features and systematic solutions of the "star-genvalue" equations are then illustrated explicitly through simple solvable potentials: the harmonic oscillator, the linear potential, the Pöschl-Teller potential, and the Liouville potential. The worked examples can then facilitate applications. The abstract structure of these star products is linked to the celebrated large N limit of M-theory.

(C. Zachos)

II.B. COMPUTATIONAL PHYSICS (LATTICE GAUGE THEORY)

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

We continued our studies of lattice QCD with staggered quarks with a fermion action designed to reduce the flavour symmetry violations associated with this way of transcribing fermions to the lattice. Our previous investigations on a small lattice ($8^3 \times 32$) were extended to a more serious study on a larger lattice ($16^3 \times 32$) confirming the fact that this type of action reduces the flavour symmetry violations by $\approx$65-75% in the chiral limit over the standard action, and $\approx$25-30% over and improved action developed by the MILC collaboration (Figure 1).

For some time we have been simulating lattice QCD with an irrelevant chiral 4-fermion interaction which has enabled us to work in the chiral (zero quark mass) limit, important for studying the properties of the finite temperature (deconfining/chiral) phase transition. Our initial studies with 2 light quark flavours (u and d quarks) on $8^3 \times 4$ and $12^2 \times 24 \times 4$ lattices showed first order rather than the expected second order transition. New simulations on the same size lattices, but with weaker 4-fermion coupling, and simulations on $12^3 \times 6$ and $18^3 \times 6$ lattices show evidence for the expected second order transition. It remains to be seen if we can achieve our goal of calculating the critical exponents at this transition.

We have just started studies of lattice QCD with a new method for lattice fermions, that has recently attracted much attention—domain-wall fermions. Here fermions (quarks) live on the 4-dimensional boundaries of a 5-dimensional lattice. Such fermions have the advantage that, in contrast with staggered and Wilson fermions, they have exact chiral flavour symmetry (in the limit as the 5th dimension becomes infinite). After looking at the hadron spectrum on small lattices, we have just started to investigate their use for studying the Atiyah-Singer index theorem and the related problem of the difference between flavour singlet and flavour non-singlet scalar and pseudo-scalar meson propagators for high temperature lattice QCD, and the role played by instantons in the high temperature phase.

The above calculations are being performed on the CRAY C90 and on the CRAY T3E at NERSC. Small lattice calculations continue to be performed on our group's workstations and PC.

(D. K. Sinclair and J.-F. Lagaë)

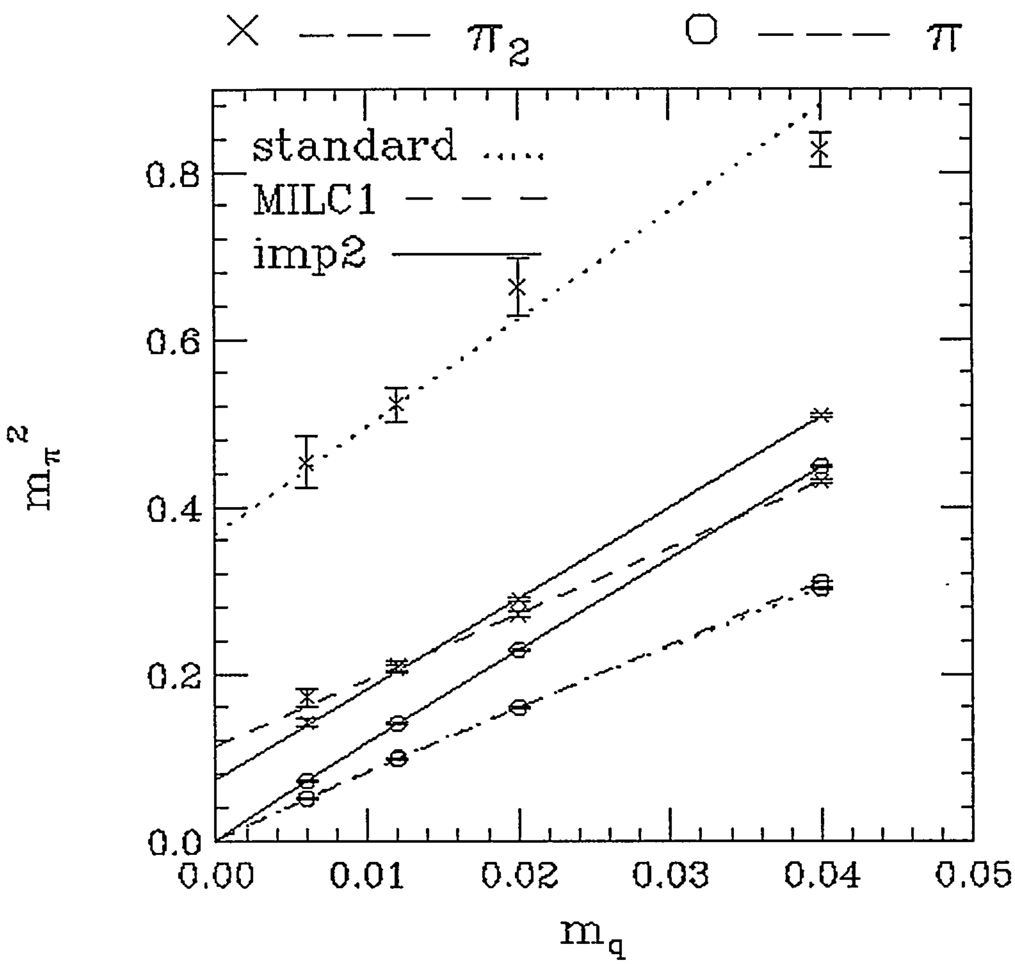

Fig. 1. Goldstone and non-Goldstone pion masses as functions of the quark mass for our improved action (imp2) compared with the standard action (standard) and the MILC action (MILC1).

III. ACCELERATOR RESEARCH AND DEVELOPMENT

III.A. ARGONNE WAKEFIELD ACCELERATOR PROGRAM

III.A.1 AWA Facility Status/Experiments and New Ideas

a. Machine Physics

The major part of the AWA program during this reporting period was devoted to drive linac performance optimization studies preparatory to the next round of plasma wakefield and dielectric structure experiments. Particular attention was paid to careful monitoring of beam conditions as a function of cavity rf and laser injection phases. Systematic studies of the effects of solenoid currents on transmission and bunch length were also performed. The end result of these measurements was the development of a new drive linac tuning procedure, in which the energy, charge, and bunch length are optimized in order. The new procedure permits more rapid tuning of the drive beam for experiments.

Some interesting experiments to study the effects of beam propagation in the drive linac were performed by windowing the laser pulse to make a narrow vertical rectangular spot on the photocathode rather than the usual circular spot, and observing how the initially vertical electron spot profile transformed as a function of linac parameters. Further analysis of this data is expected to shed light on the still unexplained "rosette" asymmetry in the drive beam profile which is observed under certain conditions.

b. Dielectric Structures

Experiments began on rf power generation in dielectric structures, where the wakefield of the beam is coupled out to a calibrated detector diode using a rectangular waveguide with optimized coupling determined from network analyzer measurements. This represents significant progress towards the demonstration of the dielectric wakefield transformer, since the device tested is essentially the drive stage of the transformer.

For these measurements a 7.8 GHz structure was used. The Figure shows measured rf power vs beam charge in the structure. The expected quadratic dependence of power on charge is observed (solid line). The scatter in the data points is due to shot to shot bunch length fluctuations.

Power levels in excess of 3 MW were attained with a 10 ns rf pulse length. Also of interest is that no dielectric charging was evident despite considerable beam interception during tuning, and no observable change in dielectric properties due to radiation damage was observed. In general the data agrees well with predictions and validates the techniques used for bench measurements.

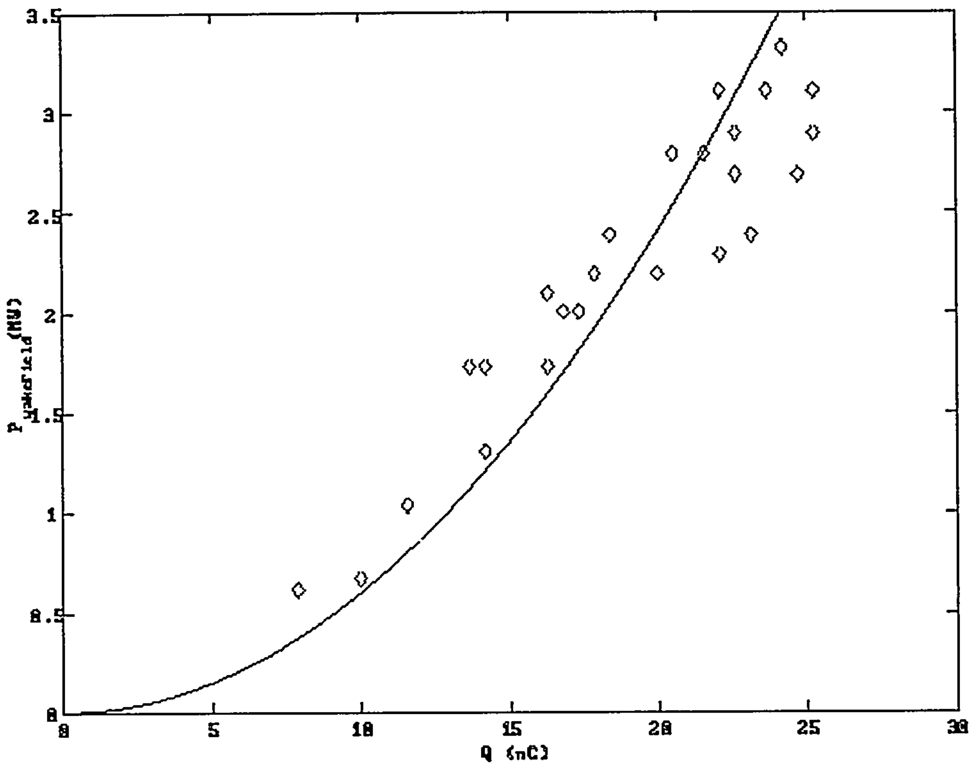

Fig. 1. Measured rf power vs beam charge in a 7.8 GHz dielectric structure.

III.B. MUON COLLIDER R&D

III.B.1 Proton Bunching Experiment at the Brookhaven AGS

One of the primary problems in developing a design for the muon collider has been the requirement that the proton bunch length on target must be very short to minimize the longitudinal emittence of the produced pions and muons and to optimize the separation of the polarization states. Experiment E-932 was run at the AGS in June 97 with the goal of determining how narrow a bunch could be produced below transition with high current bunches of comparable emittence to that expected in the proton driver for the muon collider.

Analysis of the data from the AGS experiment has shown that bunches of 2 ns can be produced in that machine with longitudinal emittence of 1.5 eV-sec. Since the AGS rf system is about 3 MHz at transition this would correspond to 1 ns bunches in a proton driver with the present design rf frequency of 6-7 MHz.

While the bunch charge was quite high, it was only about one tenth that expected in the proton driver, so it was impossible to look at space charge effects during bunching. It may be possible to test this aspect of the bunching at the KEK 12 GeV proton synchrotron where the transition jump system first lowers, than returns the transition energy to the initial starting point. This permits a larger bunch rotation frequency at the end which would minimize space charge effects. Modeling of this option is proceeding both at KEK and Fermilab.

III.B.2 Cooling Muons for the Muon Collider

Both muon colliders and very high power neutrino beams will be possible when it becomes possible to reduce the transverse and longitudinal emittence of muon beams using ionization cooling. Two efforts are described here:

1) Design of solenoidal magnet systems which minimize the emittence growth of muons during the longitudinal to transverse emittence exchange process, and

2) a complete cooling algorithm using algebraic approximations for the many physical effects.

Since the muons are produced in solenoids, it seems desirable to examine the limitations of solenoidal optics for the longitudinal to transverse exchange module when bent solenoids are used to provide the beam dispersion. Initial studies have shown that there is considerable anomalous emittence growth if the transition from straight to curved is sudden, but this emittence growth can be minimized if the transition can take place adiabatically, over one or more Larmor lengths. Calculations are underway to examine the tradeoffs between the cost of a long system and the emittence growth from a short one. In addition, it has been noted that wedge absorbers should be distributed along the beam direction, either over one Larmor length for small momentum bites, or adiabatically distributed over more than one Larmor length for large momentum bites.

An effort is underway to develop a complete cooling scenario, starting at descriptions of transverse cooling and emittence exchange modules which have been Monte Carloed, and extending upstream to the production target and downstream to the Li lens used for final cooling. This is proceeding.

(J. Norem)

IV. DIVISIONAL COMPUTING ACTIVITIES

IV.A. GRAND CHALLENGE APPLICATIONS (GCA)

IV.A.1 Data Access for High Energy and Nuclear Physics R&D

Two physicists (L. Price and E. May) and a computer scientist (D. Malon) from DIS division continued to work on the "Grand Challenge Application on HENP Data" project. This is a DOE/ER MICS, HENP-HEP, HENP-NP supported R&D project to provide develop tools to allow High Energy and Nuclear Physicists to analyze and manage the massive amounts of data which will be generated by next generation of experiments. In addition to its direct impact on the success of High Energy and Nuclear Physics experiments this work will also have impact on other governmental and commercial enterprises faced with massive amounts of data. Laboratory and University collaborating partners are LBNL, ANL, BNL, FSU, UCLA, U Tenn., and Yale.

During this interval we worked in the following areas:

- We attended three collaboration and workshop meetings at BNL & LBNL. An architectural model for the GCA/HENP data access and storage system was completed. See Figure 1.

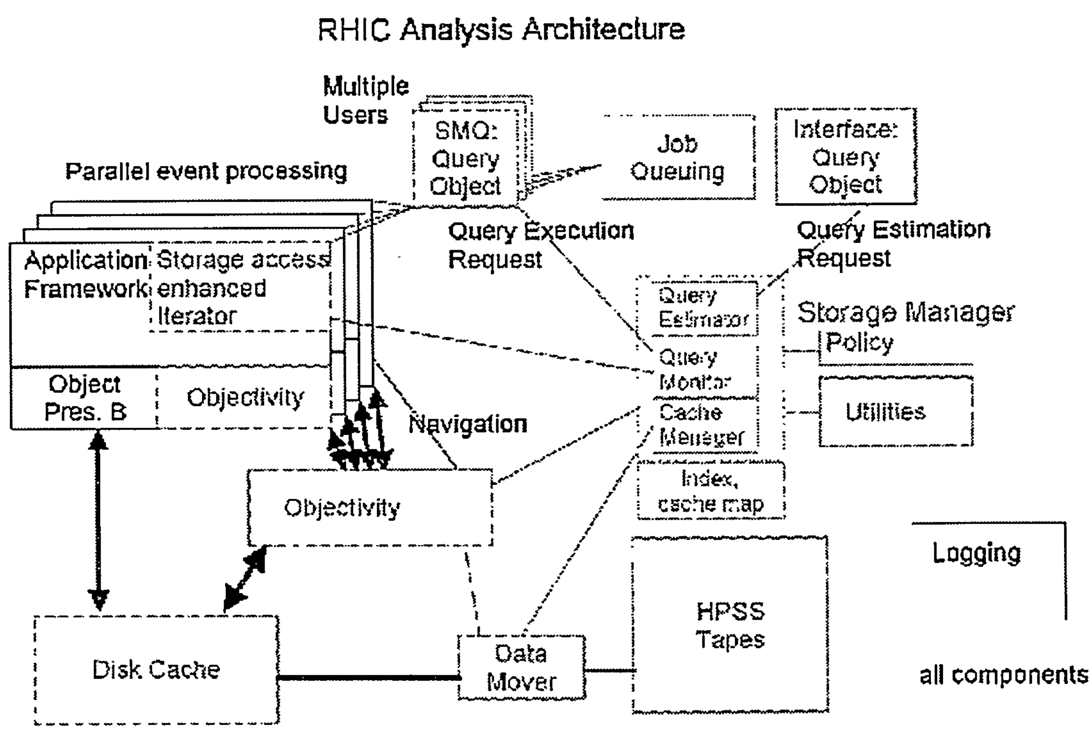

Fig. 1. Drawing of architectural model for the GCA/HENP data access and storage system.

The focus of our design, implementation and testing will be on the object oriented data model, object orient database (Objectivity), parallelization and "order optimized iterator" components. Testing and evaluation of the Objectivity version 5 beta was done, including the building and using small databases of NA49 and Atlas simulation data. The collaboration agreed to participate in the RHIC Mock Data Challenge at BNL using the GCA/HENP data access and storage system to store and analyze STAR and PHENIX simulation data. This will be an important milestone for both the GCA/HENP group and the RHIC computing center.

- A visit to CERN was made to work with the RD45 and Atlas Database groups.

- A paper was written and accepted for presentation at the VLDB'97 Conference, "Critical Database Technologies for High Energy Physics."

(Ed May)

V. PUBLICATIONS (1997-2)

V.A. JOURNAL PUBLICATIONS, CONFERENCE PROCEEDINGS, BOOKS

"A Theoretical Overview on Single Hard Diffraction"
M. Wüsthoff
Proceedings of the XIth Symposium on Hadron Collider Physics, edited by D. Bisello, G. Busetto, and L. Stanco (World Scientific, Singapore, 1997) pp. 600-611

"B Physics at CDF"
A. B. Wicklund
Proceedings of the b 20 Symposium "Twenty Beautiful Years of Bottom Physics," (1997), edited by R. A. Burnstein, *et al.* (AIP, Woodbury, 1998) p. 251

"Breakdown of Conventional Factorization for Isolated Photon Cross Sections"
E. L. Berger, X.-F. Guo, and J.-W. Ziu
Proceedings of the 14th International Conference on Particles and Nuclei (PANIC '96), edited by C. E. Carlson and J. J. Domingo (World Scientific, Singapore, 1997) pp. 641-643

"Constraints on ΔG from Prompt Photon Plus Jet Production at HERA-$\vec{N}$"
L. E. Gordon
Phys. Lett. B406, pp. 184-192 (1997)

"Critical Database Technologies for High Energy Physics"
D. M. Malon and E. N. May
Proceedings of the 23rd International Conference on Very Large Databases (VLDB '97) edited by M. Jarke, M. Carey, K. R. Dittrich, F. Lochovsky, P. Loucopoulos, and M. A. Jeusfeld (Morgan Kaufmann Publishers, Inc., San Francisco, CA, 1997) p. 580

"Discovering a Light Mass Higgs Boson at the Tevatron Collider"
S. Mrenna
Perspectives in Higgs Physics II, edited by G. L. Kane (World Scientific, Singapore, 1997) pp. 131-147

"Double Parton Scattering in $\bar{p}p$ Collisions at $\sqrt{s} = 1.8$ TeV"
L. Nodulman, R. Blair, R. Thurman-Keup, S. Kuhlmann, T. LeCompte, J. Proudfoot, R. Wagner, A. B. Wicklund, and the CDF Collaboration
Phys. Rev. D56, 3811 (1997)

"Electromagnetic Wakefields and Beam Stability in Slab-Symmetric Dielectric Structures"
P. Schoessow
Phys. Rev. E56 (6), 7204 (1997)

"Excess Cross-Sections at the Electroweak Scale in the Sextet Quark 'Standard Model' "

A. R. White

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"First Observation of the All-Hadronic Decays of $t\bar{t}$ Pairs"

R. Blair, K. Byrum, R. Thurman-Keup, S. Kuhlmann, T. LeCompte, L. Nodulman, J. Proudfoot R. Wagner, A. B. Wicklund (ANL) and the CDF Collaboration

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"Higher Twist in Diffractive Dissociation"

J. Bartels and M. Wüsthoff

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"Isolated Photons at Hadron Colliders at $O(a a_s^2)$ (I): Spin Averaged Case"

L. E. Gordon

Nucl. Phys. B501, pp. 175-196 (1997)

"Isolated Photons at Hadron Colliders at $O(a a_s^2)$ (II): Spin Dependent Case"

L. E. Gordon

Nucl. Phys. B501, pp. 197-206 (1997)

"Isolated Prompt Photon Production"

E. L. Berger, X. Guo, and J. Qiu

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"Isolated Prompt Photon Production at HERA"

L. E. Gordon and W. Vogelsang

Proceedings of the International Workshop on Deep Inelastic Scattering and Related Phenomena (Dis'96), edited by D. G. Agostini and A. Nigro (World Scientific, 1997) pp. 278-282

"J/ψ and $\psi(2S)$ Production in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV"

R. Wagner, R. Blair, K. Byrum, R. Thurman-Keup, S. Kuhlmann, T. LeCompte, L. Nodulman, J. Proudfoot, A. B. Wicklund (ANL), and the CDF Collaboration

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"Large Rapidity Gap Events in DIS"

M. Wüsthoff

Proceedings of the Fifth International Workshop on Deep Inelastic Scattering and QCD (DIS '97), edited by J. O. Repond and D. Krakauer (AIP, New York, 1997) pp. 494-498

"Limits on Quark-Lepton Compositeness Scales from Dileptons Produced in 1.8 TeV $p\bar{p}$ Collisions"

R. Wagner, R. Blair, K. Byrum, R. Thurman-Keup, S. Kuhlmann, T. LeCompte, L. Nodulman, J. Proudfoot, A. B. Wicklund (ANL), and the CDF Collaboration

Phys. Rev. Lett. 79, 2198 (1997)

"Measurement of Diffractive Dijet Production at the Fermilab Tevatron"

R. Blair, K. Byrum, R. Thurman-Keup, S. Kuhlmann, T. LeCompte, L. Nodulman, J. Proudfoot R. Wagner, A. B. Wicklund (ANL) and the CDF Collaboration

Phys. Rev. Lett. 79, 2636 (1997)

"Measurement of Double Parton Scattering in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.8 TeV"

R. Wagner, R. Blair, K. Byrum, R. Thurman-Keup, S. Kuhlmann, T. LeCompte, L. Nodulman, J. Proudfoot, A. B. Wicklund (ANL), and the CDF Collaboration

Phys. Rev. Lett. 79, 584 (1997)

"Measurement of Elastic J/ψ Photoproduction at HERA"

M. Derrick, J. Breitweg, D. Krakauer, S. Magill, D. Mikunas, B. Musgrave, J. Repond, R. Stanek, R. L. Talaga, R. Yoshida, H. Zhang (ANL) and the ZEUS Collaboration

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"Measurement of the Proton Structure Function F_2 and $\sigma_{tot}\gamma^* p$ at Low Q^2 and Very Low x at HERA"

ZEUS Collaboration, J.Breitweg *et al.*

Phys. Lett. B407, 432 (1997)

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ZEUS Collaboration, J.Breitweg *et al.*

Phys. Lett. B413, 201 (1997)

"Observation of Scaling Violations in Scaled Momentum at HERA"

ZEUS Collaboration, J.Breitweg *et al.*

Phys. Lett. B414, 428 (1997)

"Pentaquark Phenomenology"

H. J. Lipkin

Proceedings of the Sixth Conference on the Intersections of Particle and Nuclear Physics, Vol. 412, edited by T. W. Donnelly (AIP, New York, 1997) pp. 504-509

"Physics Backgrounds to Supersymmetric Signals with Two Photons and Missing Mass at LEP"

S. Mrenna

[http://xxx.lanl.gov/abs/hep-ph/?9705441]

"Physics Results from Polarized DIS"

G. P. Ramsey

Proceedings of the Fifth International Workshop on Deep Inelastic Scattering and QCD (DIS '97), edited by J. O. Repond and D. Krakauer (AIP, New York, 1997) pp. 890-893

"Production of J/ψ Mesons from χ_c Meson Decays in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV"

R. Blair, K. Byrum, R. Thurman-Keup, S. Kuhlmann, T. LeCompte, L. Nodulman, J. Proudfoot R. Wagner, A. B. Wicklund (ANL), and the CDF Collaboration

Phys. Rev. Lett. 79, 578 (1997)

"Properties of Six-Jet Events With Large Six-Jet Mass at the Fermilab Proton-Antiproton Collider"

R. Blair, K. Byrum, R. Thurman-Keup, S. Kuhlmann, T. LeCompte, L. Nodulman, J. Proudfoot, R. Wagner, A. B. Wicklund (ANL), and the CDF Collaboration

Phys Rev. D56, 2532 (1997)

"Sea Quark Matrix Elements and Flavor Singlet Spectroscopy on the Lattice"

J.-F. Lagaë

Quark Confinement and the Hadron Spectrum II, edited by N. Brambilla and G. M. Prosperi (World Scientific, Singapore, 1997) pp. 297-300

"Search for Charged Higgs Boson Decays of the Top Quark using Hadronic Decays of the Tau Lepton"

R. Blair, K. Byrum, R. Thurman-Keup, S. Kuhlmann, T. LeCompte, L. Nodulman, J. Proudfoot R. Wagner, A. B. Wicklund (ANL) and the CDF Collaboration

Phys. Rev. Lett. 79, 357 (1997)

"Search for First Generation Leptoquark Pair Production in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV"

R. Blair, K. Byrum, R. Thurman-Keup, S. Kuhlmann, T. LeCompte, L. Nodulman, J. Proudfoot R. Wagner, A. B. Wicklund (ANL) and the CDF Collaboration

Phys. Rev. Lett. 79, 4327 (1997)

"Search for Gluinos and Squarks at the Fermilab Tevatron Collider"

R. Blair, K. Byrum, R. Thurman-Keup, S. Kuhlmann, T. LeCompte, L. Nodulman, J. Proudfoot, R. Wagner, and A. B. Wicklund (ANL), and the CDF Collaboration

Phys. Rev. D56, 3 R1537 (1997)

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Phys. Rev. Lett. 79, 2192 (1997)

"Search for New Particles Decaying into $b\bar{b}$ and Produced in Association with W Bosons Decaying into $e\nu$ or $\mu\nu$ at the Fermilab Tevatron"

R. Wagner, R. Blair, K. Byrum, R. Thurman-Keup, S. Kuhlmann, T. LeCompte, L. Nodulman, J. Proudfoot, A. B. Wicklund (ANL), and the CDF Collaboration

Phys. Rev. Lett. 79, 3819 (1997)

"Signals of Dynamical Supersymmetry Breaking in a Hidden Sector"

S. Mrenna (ANL) and B. Dobrescu (BU)

"New Directions for High Energy Physics," Proceedings of the 1996 DPF/DPB Summer Study on HEP, edited by D. G. Cassel, L. Trindle Gennari, and R. H. Siemann (SLAC, Menlo Park, CA, 1997) pp. 677-678

"Spin-Dependent Drell-Yan and Double Prompt Photon Production to NLO QCD"

S. Chang, C. Corianò, R. D. Field, and L. E. Gordon

Proceedings of the Fifth International Workshop on Deep Inelastic Scattering and QCD (DIS '97), edited by J. O. Repond and D. Krakauer (AIP, New York, 1997) pp. 844-849

"Study of Elastic ρ^0 Photoproduction at HERA using the ZEUS Leading Proton Spectrometer

M. Derrick, D. Krakauer, S. Magill, D. Mikunas, B. Musgrave, J. R. Okrasinski, J. Repond, R. Stanek, R. L. Talaga, H. Zhang (ANL), and the ZEUS Collaboration

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"Structure Function Subgroup Summary"

A. R. White *et al.*

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"The Hard Gluon Component of the QCD Pomeron"

A. R. White

Proceedings of the Workshop on Quantum Chromodynamics: Collisions, Confinement, and Chaos, edited by H. M. Fried and B. Müller (World Scientific, Singapore, 1997) pp. 283-289

"The $\mu\tau$ and e_τ Decays of Top Quark Pairs Produced in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV"

R. Blair, K. Byrum, R. Thurman-Keup, S. Kuhlmann, T. LeCompte, L. Nodulman, J. Proudfoot R. Wagner, A. B. Wicklund (ANL) and the CDF Collaboration

Phys. Rev. Lett. 79, 3585 (1997)

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A. R. White

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"The Soudan 2 Detector. The Design and Construction of the Tracking Calorimeter Modules"
D. S. Ayres, et al. (ANL), and the Soudan 2 Collaboration
Nuclear Instruments and Methods in Physics Research A376, pp. 36-48 (1996)

"The Soudan 2 Detector. The Operation and Performance of the Tracking Calorimeter Modules"
D. S. Ayres, et al. (ANL), and the Soudan 2 Collaboration
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"Threshold Resummation and the Total Cross Section for Top Quark Production"
E. L. Berger and H. Contopanagos
Proceedings of the Fifth International Workshop on Deep Inelastic Scattering and QCD (DIS '97), edited by J. O. Repond and D. Krakauer (AIP, New York, 1997) pp. 1028-1034

V.B. PAPERS SUBMITTED FOR PUBLICATION

"A Closed Formula for the Riemann Normal Coordinate Expansion"
C. Schubert (ANL), U. Müller, and A. Van de Ven
Classical and Quantum Gravity
ANL-HEP-PR-97-99

"Angular Dependence of pp Spin Correlation and Rescattering Observables Between 1.80 and 2.10 GeV"
C. E. Allgower, D. Grossnick, T. E. Kasprzyk, H. M. Spinka (ANL), *et al.*
Eur. Phys. Journal C
ANL-HEP-PR-98-15

"Confinement and the Supercritical Pomeron in QCD"
A. R. White
Phys. Rev. D
ANL-HEP-PR-97-95

"Diffractive Dijet Cross Sections in Photoproduction at HERA"
M. Derrick, J. Breitweg, D. Krakauer, S. Magill, D. Mikunas, B. Musgrave, J. Repond, R. Stanek, R. L. Talaga, R. Yoshida, H. Zhang (ANL), and the ZEUS Collaboration
Eur. Phys. J.
ANL-HEP-PR-98-40

"Features of Time-Independent Wigner Functions"
T. Curtright, D. Fairlie, and C. Zachos
Phys. Rev. D, in press
ANL-HEP-PR-97-93

"Forward Jet Production in Deep Inelastic Scattering at HERA"
M. Derrick, J. Breitweg, D. Krakauer, S. Magill, D. Mikunas, B. Musgrave, J. Repond, R. Stanek, R. L. Talaga, R. Yoshida, H. Zhang (ANL), and the ZEUS Collaboration
Eur. Phys. Journal B
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"Generation and Acceleration of High Charge Short Electron Bunches"
M. Conde, W. Gai, R. Konecny, X. Li, J. Power, P. Schoessow (ANL) and N. Barov (UCLA)
Phys. Rev. E
ANL-HEP-PR-98-20

"High-E_T Inclusive Jet Cross Sections in Photoproduction at HERA"
M. Derrick, J.Breitweg, D. Krakauer, S. Magill, D. Mikunas, B. Musgrave, J. Repond, R. Stanek, R.L. Talaga, R. Yoshida, and H. Zhang (ANL), and the ZEUS Collaboration
European Journal of Physics
ANL-HEP-PR-98-25

"High Power Radio Frequency Generation by Relativistic Beams in Dielectric Structures"
P. Schoessow, M. E. Conde, W. Gai, R. Konecny, J. Power, and J. Simpson
Submitted to Journal of Applied Physics
ANL-HEP-PR-98-23

"Inclusive Jet Production in γp and $\gamma\gamma$ Processes: Direct and Resolved Photon Cross Sections in Next-To-Leading Order QCD"
M. Klasen (ANL), T. Kleinwort, and G. Kramer
Submitted to Z. Phys. C
ANL-HEP-PR-97-97

"Long-Range Correlations in Deep Inelastic Scattering"
S. V. Chekanov
Submitted to the Eur. Phys. J.
ANL-HEP-PR-98-46

"Measurement of Jet Shapes in High-Q^2 Deep Inelastic Scattering at HERA"
M. Derrick, J. Breitweg, D. Krakauer, S. Magill, D. Mikunas, B. Musgrave, J. Repond, R. Stanek, R. L. Talaga, R. Yoshida, H. Zhang (ANL), and the ZEUS Collaboration
Submitted to Eur. Phys. Journal B
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"Measurement of Jet Shapes in Photoproduction at HERA"
M. Derrick, J. Breitweg, D. Krakauer, S. Magill, D. Mikunas, B. Musgrave, J. Repond, R. Stanek, R. L. Talaga, R. Yoshida, H. Zhang (ANL), and the ZEUS Collaboration
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ANL-HEP-PR-98-37

"Measurement of the Diffractive Structure Function $F_2D(4)$ at HERA"

M. Derrick, J. Breitweg, D. Krakauer, S. Magill, D. Mikunas, B. Musgrave, J. Repond, R. Stanek, R. L. Talaga, R. Yoshida, H. Zhang (ANL), and the ZEUS Collaboration.

Submitted to Eur. Phys. J.
ANL-HEP-PR-98-XX

"Overcoming Intrinsic Spin Resonances with an RF Dipole"

H. Spinka, M. Bai, K. Krueger, D. G. Underwood, A. Yokosawa (ANL), *et al.*

Submitted to Phys. Rev. Lett.
ANL-HEP-PR-98-18

"Propagation of Short Electron Pulses in a Plasma Channel"

M. E. Conde, W. Gai, N. Barov* (ANL), and J. B. Rosenzweig* (*UCLA)

Accepted by Phys. Rev. Lett.
ANL-HEP-PR-98-47

"Properties of Jets in W Boson Events from 1.8 TeV $\bar{p}p$ Collisions"

R. Blair, K. Byrum, R. Thurman-Keup, S. Kuhlmann, T. LeCompte, L. Nodulman, J. Proudfoot, R. Wagner, A.B. Wicklund (ANL), and the CDF Collaboration

Submitted to Phys. Rev. Lett.
ANL-HEP-PR-98-82

"Properties of Photon Plus Two-Jet Events in $\overline{pp}$ Collisions at $\sqrt{s} = 1.8$ TeV"

L. Nodulman, R. Blair, K. Byrum, R. Thurman-Keup, T. LeCompte, J. Proudfoot, R. Wagner, A.B. Wicklund, and the CDF Collaboration

Submitted to Phys. Rev. D
ANL-HEP-PR-98-43

"Searching for Neutrino Oscillations"

M. Goodman

Accepted for publication in the SLAC newsletter, Beam Line, Vol. 28 (2), June 1998
ANL-HEP-PR-98-36

"Search for the Proton Decay Mode $p \to \nu K^+$ in Soudan 2

D. S. Ayres, T. H. Fields, M. C. Goodman, T. Joffe-Minor, W. Leeson, L. E. Price, R. Seidlein, J. L. Thron (ANL) and the Soudan 2 Collaboration

Submitted to Phys. Lett. B
ANL-HEP-PR-98-24

"Study of the Uncertainty of the Gluon Distribution"

S. Kuhlmann, *et al.*

Phys. Rev. D
ANL-HEP-PR-98-09

"The Phenomenology of Single Top Quark Production at the Fermilab Tevatron"
T. Tait and C.-P. Yuan
Phys. Rev. D
ANL-HEP-PR-97-85

"Thermodynamics of Lattice QCD with Chiral 4-Fermion Interactions"
J. B. Kogut, J.-F. Lagaë, and D. K. Sinclair
Phys. Rev. D
ANL-HEP-PR-97-28

"The Search for Supersymmetry at the Tevatron Collider"
S. Mrenna (ANL), *et al.*
Perspectives on Supersymmetry, edited by G. L. Kane (World Scientific, Singapore, 199X)
ANL-HEP-PR-97-98

"Topology, Fermionic Zero Modes and Flavor Singlet Correlators in Finite Temperature QCD"
J. B. Kogut, J.-F. Lagaë, and D. K. Sinclair
Phys. Rev. D
ANL-HEP-PR-97-55

VC. PAPERS OR ABSTRACTS SUBMITTED TO CONFERENCES

"An AGS Experiment to Test Bunching for the Proton Driver of the Muon Collider"
J. Norem (ANL), C. Ankenbrandt (FNAL), *et al.*
Presented at the 4th International Conference on Physics Potential and Development of $\mu^+\mu^-$ Colliders, San Francisco, CA, December 1997
ANL-HEP-CP-98-32

"Critical Database Technologies for High Energy Physics"
D. M. Malon and E. N. May
Presented at the Proceedings of the 23rd VLDB Conference (VLDB '97) Athens, Greece, August 25 - 29, 1997
ANL-HEP-CP-97-45

"e^+e^- and ep Options for the Very Large Hadron Collider"
J. Norem
Presented at the 4th International Conference on Physics Potential and Development of $\mu^+\mu^-$ Colliders, San Francisco, CA, December 1997
ANL-HEP-CP-98-33

"Improving the Staggered Quark Action to Reduce Flavour Symmetry Violations"
J.-F. Lagaë and D. K. Sinclair
Presented by D. Sinclair at the XV International Symposium on Lattice Field Theory (LATTICE '97), Edinburgh, Scotland, July 22-26, 1997
ANL-HEP-CP-98-13

"Photon Scattering in Muon Collisions"
M. Klasen
Presented at the Workshop on Physics at the First Muon Collider, Batavia, IL, November 6 - 9, 1997
ANL-HEP-CP-97-96

"Problems at the Interface Between Heavy Flavor Physics, QCD and Hadron Spectroscopy"
H. J. Lipkin
Presented at the 7th International Conference on Hadron Spectroscopy, Upton, NY, August 25 - 30, 1997
ANL-HEP-CP-97-91

"Problems in Communication Between Heavy Flavor Experiment and Hadron Spectroscopy"
H. J. Lipkin
Presented at the 7th International Conference on Hadron Spectroscopy, Upton, NY, August 25 - 30, 1997
ANL-HEP-CP-97-92

"Results from an Iron-Proportional Tube Calorimeter Prototype"
P. Schoessow, I. Ambats, D. S. Ayres, J. W. Dawson, W. N. Haberichter, N. Hill, R. L. Talaga, and J. L. Thron (ANL), and the MINOS Collaboration
Presented at the VII International Conference on Calorimetry in High Energy Physics, Tucson, AZ, November 9 - 14, 1997
ANL-HEP-CP-98-02

"Threshold Resummation of Soft Gluons in Hadronic Reactions–An Introduction"
E. L. Berger
Presented at the Symposium on QCD Corrections and New Physics, Hiroshima, Japan, October 27 - 29, 1997
ANL-HEP-CP-98-03

"Topology, Fermionic Zero Modes and Flavor Singlet Correlators in Finite Temperature QCD"
J. B. Kogut, J.-F. Lagaë, and D. K. Sinclair
Presented by J.-F. Lagaë at the XV International Symposium on Lattice Field Theory (LATTICE '97), Edinburgh, Scotland, July 22 - 26, 1997
ANL-HEP-CP-97-74

V.D. TECHNICAL REPORTS AND NOTES

"Luminosity MonitorTopics for RHIC Spin and AA, and pA Interactions"
D. Underwood
Technical Report and STAR Note 320
ANL-HEP-TR-97-100

"Neutrons and the Crystal Ball Experiments"
C. Allgower, J. Alyea, R. Manweiler, H. Spinka (ANL), et al.
Technical Report #CB-97-009
ANL-HEP-TR-97-87

CDF Note 4241 "Photons and Diphotons from the Tevatron"
R. Blair (for the CDF Collaboration)

CDF Note 4256 "Timing Information For Central Photons and the ee$\gamma\gamma$ MET Event"
S. Kuhlmann

CDF Note 4259 "Particle Level Study of W$\rightarrow$qqbar and Jet Algorithms"
S. Kuhlmann, D. Costanzo, R. Paoletti, S. Lami

CDF Note 4299 "Recent Electroweak Measurements from the Tevatron"
R. G. Wagner (for the CDF Collaboration)

CDF Note 4351 "dE/dx Correction to Muon Momenta Using Photon Conversions"
R. Thurman-Keup

CDF Note 4354 "Gamma-K*,Psi-K* Trigger for CDF Run II"
A. B. Wicklund

CDF Note 4360 "Study of Charm to Muon Decay Probabilities"
Koichi Kurino, S. Kuhlmann

CDF Note 4421 "CEM Run Dependence for Jets in 1b and 630 Data in 1c"
L. Nodulman

CDF Note 4424 "Et Dependence of the XCES Trigger"
K. Byrum, A.B.Wicklund

CDF Note 4432 "B Physics at CDF"
A. B. Wicklund

NuMI-L-241 Interim Drac Report # 2
L. E. Price

NuMI-L-244 Minutes of the ExCom Meeting at SLAC
M. C. Goodman

NuMI-L-246 Minutes of the Technical Board Meeting at SLAC
D. S. Ayres

NuMI-L-247 Minutes of the MINOS meeting at SLAC
D. S. Ayres

NuMI-L-255 Cost Estimates for the Manufacture of Aluminum Proportional Tubes for MINOS
J. L. Thron

NuMI-L-260 Cost Estimates for the Manufacture of the MINOS APT's
J. L. Thron

NuMI-L-261 MINOS Safety Document
J. L. Thron

NuMI-L-266 Minutes of the MINOS ExCom meeting at Fermilab
M. C. Goodman

NuMI-L-267 Minutes of the April 1997 MINOS Collaboration Meeting
D. S. Ayres

NuMI-L-269 Minutes of the April 1997 MINOS Technical Board Meeting
D. S. Ayres

NuMI-L-270 Transparencies from the April 1997 MINOS Meetings
D. S. Ayres and J. Meier

NuMI-L-274 Minutes of the June 1997 MINOS Executive Committee Meeting
M. C. Goodman

NuMI-L-275 Minutes of the June 1997 MINOS Collaboration Meeting
D. S. Ayres

NuMI-L-277 Minutes of the June 1997 MINOS Technical Board Meeting
D. S. Ayres

NuMI-L-278 Transparencies from the June 1997 MINOS Meeting
D. S. Ayres and J. Meier

NuMI-L-281 The Fermilab Long-Baseline Neutrino Program, July 1997
M. C. Goodman

NuMI-L-286 MINOS Detector R&D Advisory Committee Interim Report #3
L. E. Price

NuMI-L-287	Transparencies from the August 1997 DRAC Meeting D. S. Ayres
NUMI-L-291	Final Report of the August 1998 Drac Committee Meeting L. E. Price
NuMI-L-293	The MINOS detector instrumented with APT's D. S. Ayres
NuMI-L-296	Transparencies of the September 1997 MINOS Meeting D. S. Ayres
NuMI-L-298	Minutes of the September 1997 MINOS Technical Board Meeting D. S. Ayres
NuMI-L-299	Preliminary Specifications for MINOS Test Beam facility R. L. Talaga
PDK 661	Calculating Upper Limits in a Search Experiment T. H. Fields
PDK 662	Minutes of the CEV Meeting, February 12, 1997 R. Seidlein
PDK 663	The Neutrino Flavor Composition of Contained Multiprong Events in Soudan 2 W. R. Leeson, W. A. Mann, D. Wall, T. Kafka, H. Tom
PDK 664	Measurement of the Atmospheric Neutrino Flavor in the First Four CEV Data Sets of Soudan 2 R. Seidlein
PDK 666	Rock Background Correction for the Multiprong Flavor Ratio (ADDENDUM TO PDK-663) W. R. Leeson, T. Mann, D. Wall
PDK 667	Soudan 2 Experiment Quarterly Status Report, January-March 1997 D. S. Ayres
PDK 669	Cosmic Correlations - Part II J. L. Uretsky
PDK 671	Search for AGN Neutrinos with the Soudan 2 Detector M. C. Goodman
PDK 672	Search for Proton Decay in Soudan 2 M. C. Goodman

PDK 673	The Atmospheric Neutrino Flavor Ratio in Soudan 2 M. C. Goodman
PDK 678	Nucleon Decay Final State Effects from Fermi Motion and from INTRANUKE W. R. Leeson
PDK 679	Soudan 2 Experiment Quarterly Status Report April-June, 1997 D. S. Ayres
PDK 680	The Atmospheric Neutrino Flavor Ratio in Soudan 2 M. C. Goodman
PDK 681	Range Measurements in Soudan 2 - Basic Issues T. H. Fields
PDK 682	Muon Ranges from $K^+ \rightarrow \nu\mu^+$ T. H. Fields, W. Leeson
PDK 684	Estimate of Rock Event Background in the Multiprong Sample, October 5, 1997 W. Leeson
PDK 685	Soudan 2 Experiment Quarterly Status Report, July -September 1997 D. S. Ayres
STAR 306	The Case for an EMC Pre-Radiator T. LeCompte
STAR 307	W Production Off Nuclear Targets T. LeCompte
STAR 313	EMC Nonlinearities and their Effects on Physics Analyses T. LeCompte
STAR 316	The Light Outpout Requirements for the EMC T. LeCompte
STAR 320	Luminosity Monitor Topics for RHIC Spin and AA, and pA Interactions D. Underwood

VI. COLLOQUIA AND CONFERENCE TALKS

Edmond L. Berger

"Threshold Resummation of Soft Gluons in Hadronic Reactions–An Introduction"
Presented at the Symposium on QCD Corrections and New Physics, Hiroshima, Japan, October 27, 1997.

"Threshold Resummation of Soft Gluons and the Total Cross Section for Heavy Quark Production at Hadron Colliders"
Presented at Kyoto University, Japan, October 24, 1997.

"Tests of Perturbative Quantum Chromodynamics and the Determination of Spin Dependent Parton Densities in Future Experiments at RHIC"
Presented at Kyoto University, Japan, October 23, 1997.

"Tests of Perturbative Quantum Chromodynamics and the Determination of Spin Dependent Parton Densities in Future Experiments at RHIC"
Invited seminar presented to the Physics Department, Indiana University, Bloomington, IN, October 10, 1997.

Malcolm Derrick

"High EnergyPhysics: The Present State of the Science, the Technology and the Sociology"
Presented at the University of Memphis, October 1997.

"Physics with the ZGS"
Presented at ANL Crosbie Fest, October 1997.

"Recent ZEUS Results on DIS at High Q^2"
Presented at Hadron '97, Brookhaven National Laboratory, Upton, NY, August 25 - 30, 1997.

Wei Gai

"High Current RF Photocathode Gun for Plasma Wakefield Acceleration"
Presented at the 13th Advanced ICFA Beam Dynamics Workshop on Second Generation Plasma Accelerators, Kyoto, Japan, July 1997.

"Wakefield Acceleration"
Presented at the 2nd International OCPA Conference, Taiwan, August 1997.

Michael Klasen

"NLO Photon-Photon and Photon-Proton Scattering"
Presented as a Theoretical Physics Seminar, High Energy Physics Division, ANL, December 22, 1997.

"Photon Scattering in Muon Collisions"
Presented at the Workshop on Physics at the First Muon Collider, Batavia, IL, November 7, 1997.

Jean-Francois Lagaë

"Anatomy of Flavor-Singlet g_A from Lattice Calculation"
Invited talk presented at the 1997 Fall Meeting of the Division of Nuclear Physics, Whistler, B.C., October 8, 1997.

"Topology, Fermionic Zero Modes and Flavor Singlet Correlators in Finite Temperature QCD"
Presented at the XV International Symposium on Lattice Field Theory (LATTICE '97), Edinburgh, Scotland, July 24, 1997.

Tom LeCompte

"The CDF Muon Upgrade"
Invited talk presented at INFN, Trieste, Italy, August 1997.

"Quarkonium Production at the Tevatron"
Invited talk presented at ICT, Lisbon, Portugal, September 1997.

"High pT Physics at STAR"
Invited talk presented at ICT, Lisbon, Portugal, September 1997.

Harry J. Lipkin

"Problems at the Interface Between Heavy Flavor Physics, QCD and Hadron Spectroscopy"
Presented at the 7th International Conference on Hadron Spectroscopy, Upton, NY, August 29, 1997.

"Problems in Communication Between Heavy Flavor Experiment and Hadron Spectroscopy"
Presented at the 7th International Conference on Hadron Spectroscopy, Upton, NY, August 26, 1997.

James Norem

"An AGS Experiment to Test Bunching for the Proton Driver of the Muon Collider"
Presented at the 4th International Conference on the Physics Potential and Development of $\mu^+\mu^-$ Colliders, San Francisco, CA, December 10 - 12, 1997.

Andrea Petrelli

"Higher Order Quarkonium Production and Decays"
Presented as a Theoretical Physics Seminar, High Energy Physics Division, ANL, December 2, 1997.

John G. Power

"Advanced Accelerator R&D in the High Energy Physics Division"
Talk to the HEPAP subpanel at Fermilab, Batavia, IL, August 1997.

Paul V. Schoessow

"Results from an Iron-Proportional Tube Calorimeter Prototype"
Presented at the VII International Conference on Calorimetry in High Energy Physics, Tucson, AZ, November 1997.

Christian Schubert

"Calculation of QED and QCD Scattering Amplitudes in the String-Inspired Formalism. I-V"
Presented as Theoretical Physics *Special Series* Seminars, High Energy Physics Division, ANL, November 24, December 4, 11, 18, & 23, 1997.

"String Theory Methods for Field Theory Calculations"
Invited talk presented to the Department of Applied Math, University of Western Ontario, London, Canada, November 20, 1997.

"Optimized Parameter Integral Representations for Gauge Theory Amplitudes"
Presented as a Theoretical Physics Seminar, High Energy Physics Division, ANL, October 20, 1997.

"String Theory Methods for Field Theory Calculations"
Invited seminar presented to the Department of Physics, University of Michigan, Ann Arbor, October 17, 1997.

Donald K. Sinclair

"Improving the Staggered Quark Action to Reduce Flavour Symmetry Violations"
Presented at the XV International Symposium on Lattice Field Theory (LATTICE '97), Edinburgh, Scotland, July 25, 1997.

Hal Spinka

"A Polarized Antiproton Beam at Intermediate Energies"
Presented at the Workshop on Physics at the First Muon Collider and at the Front End of a Muon, Fermilab, Batavia, IL, November 6 - 9, 1997.

"Baryon Spectroscopy"
Presented at the Workshop on Physics at the First Muon Collider and at the Front End of a Muon, Fermilab, Batavia, IL, November 6 - 9, 1997.

Alan R. White

"Deep-Inelastic Diffraction and the Pomeron as a Single Gluon"
Presented as a Theoretical Physics Seminar, High Energy Physics Division, ANL, October 27, 1997.

"Deep-Inelastic Diffraction and the Pomeron as a Single Gluon"
Invited talk presented at the Workshop Interplay Between Soft and Hard Interactions in Deep-Inelastic Scattering, Heidelberg, Germany, September 29, 1997.

VII. HIGH ENERGY PHYSICS COMMUNITY ACTIVITIES

David S. Ayres

Deputy Spokesperson of the MINOS Collaboration

Edmond L. Berger

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

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

Member, International Advisory Board, Fifth International Symposium on Weak and Electromagnetic Interactions in Nuclei (WIEN '98), Santa Fe, NM, June 14 - 21, 1998.

Member, International Advisory Committee, Seventh International Conference on Hadron Spectroscopy, Brookhaven National Laboratory, Upton, NY, August 24 - 30, 1997.

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

Member, Local Organizing Committee, Workshop on Physics at the First Muon Collider, Fermilab, Batavia, IL, November 6 - 9, 1997.

Member, Scientific Program Committee, XXXIII Recontres de Moriond, "QCD and High Energy Hadronic Interactions," Les Arcs, France, March 1998.

Manoel Conde

Member, High Energy Physics Seminar Committee.

Tom LeCompte

Administrative Positions:

- Project Leader, Muon Upgrade - CDF
- Working Group Convener, High pT Physics - STAR
- Analysis Coordinator, STAR

Ed May

Member, staff of Esnet Steering Committee.

Larry Nodulman

Member, Discussion Panel, Calorimetry at Present and Future Colliders, VII International Conference on Calorimetry in High Energy Physics, Tucson, AZ, November 1997.

Executive Position, CDF Upgrade Coordinator for Central EM Calorimeter.

Larry Price

Chair, Esnet Steering Committee.

Jose Repond

Member, International Advisory Committee, 6th International Workshop on Deep Inelastic Scattering and the QCD.

Hal Spinka

Member, Organizing Committee, Workshop on Hadron Physics in the 21st Century," Washington, D.C., March 1998.

Alan R. White

Adjunct Professor of Physics, Northwestern University, Evanston, IL.

Organizing Committee, 4th Workshop on Small-x and Diffractive Physics, Fermilab, Batavia, IL, September 24 - 27, 1998.

Member, International Advisory Committee, Xth International Symposium on Very High Energy Cosmic Ray Interactions, Gran Sasso, Italy, July 12 - 17, 1998.

Member, International Advisory Committee, International School on High Energy Physics LAFEX/CBPF (LISHEP '98), Rio de Janeiro, Brazil, February 1998.

Carlos Zachos

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

VIII. HEP DIVISION RESEARCH PERSONNEL

Administration

L. Price
D. Hill

Accelerator Physicists

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

Experimental Physicists

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

Theoretical Physicists

E. Berger
G. Bodwin
L. Gordon
M. Klasen
J. -F. Lagaë
S. Mrenna
A. Petrelli
D. Sinclair
A. White
M. Wüsthoff
C. Zachos

Engineers, Computer Scientists, and Applied Scientists

J. Dawson
G. Drake
V. Guarino
W. Haberichter
N. Hill
J. Schlereth
X. Yang

Technical Support Staff

I. Ambats
G. Cox
V. Guarino
D. Jankowski
T. Kasprzyk
C. Keyser
L. Kocenko
R. Konecny
E. Petereit
R. Rezmer
R. Taylor
K. Wood

Laboratory Graduate Participants

C. Allgower
N. Barov
A. Hardman
D. Mikunas
T. Tait
H. Zhang
P. Zou

Visiting Scientists

H. Lipkin (Theory)
X. Li (AWA)
G. Ramsey (Theory)
C. Schubert (Theory)
J. Uretsky (Theory)
T. Wong (AWA)