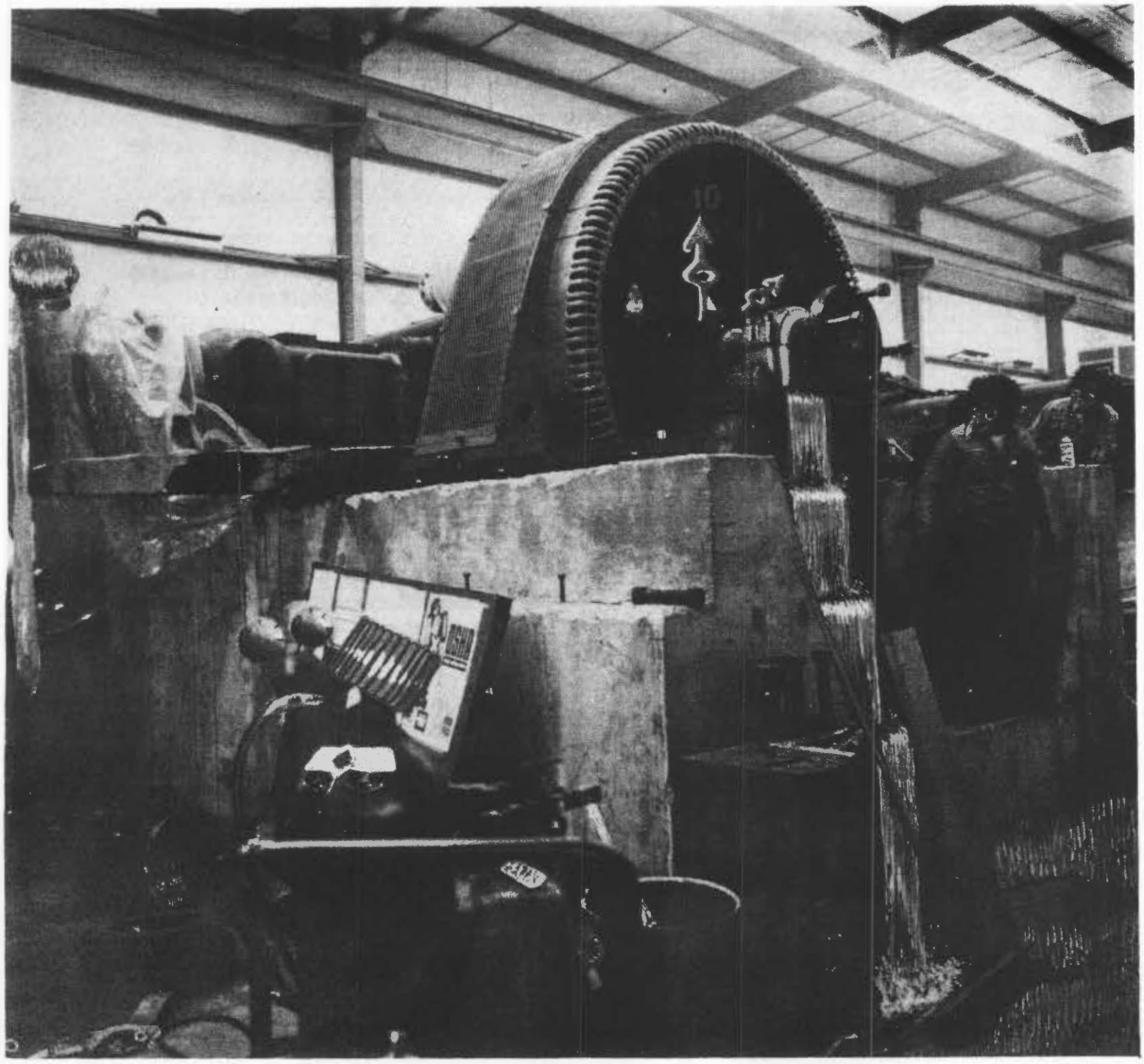
fermilab report

Fermi National Accelerator Laboratory Monthly Report

March 1978



CONTENTS MARCH 1978

POSITIVE RESULTS WITH NEGATIVE HYDROGEN IONS

Very encouraging results were obtained in initial trials of H^- charge-exchange injection into the Booster during the coal-strike shutdown. H^- beam was first injected on February 24th and a new Booster intensity record of 3.46×10^{13} protons per Main-Ring cycle, significantly above the previous record 3.06×10^{13}, was attained eight days later. The new record was reached while injecting 15 turns of 24 mA H^- beam, corresponding to 8×10^{13} protons per Main-Ring cycle. A full report will appear in next month's Fermilab Report.

A soft drink to celebrate installation of the first magnet in the Cooling Ring enclosure. Kneeling in front are Don Breyne and Tom Larson. Standing are (left to right) Max Palmer, Joe Otavka, Terry Svedja, Frank Krzich, Bill Carl, Al McDonald, Jeff Gannon, George Chadwick, Fred Mills, and Nathan Sands.

(Photo by Fermilab Photo Unit)

MANUSCRIPTS AND NOTES PREPARED FROM JANUARY 8, 1978, TO MARCH 10, 1978

Copies of preprints with Fermilab publication numbers can be obtained from the Publications Office or Theoretical Physics Department, 3rd floor east, Central Laboratory. Copies of some articles listed are on the reference shelf in the Fermilab Library.

Experimental Physics

K. W. Chen and A. Van Ginneken (Experiment #26)	Origin of Muon-Induced Dimuons and Scale Violations at Small x (FERMILAB-Pub-78/25-EXP; submitted to Phys. Rev. Lett.)
J. Bell et al. (Experiment #45)	Diffractive Production of Vector Mesons in High Energy Neutrino Interactions (FERMILAB-Pub-78/24-EXP; submitted to Phys. Rev. Lett.)
J. P. Berge et al. (Experiment #45)	Inclusive Neutral Strange Particle Production from High Energy νp Charged-Current Interactions (FERMILAB-Pub-78/26-EXP; submitted to Phys. Rev. D)
J. E. Brau (Experiment #'s 154/299)	Inclusive and Semi-Inclusive Charge Structure in Pion-Proton Multiparticle Production Reactions at 150 GeV/c (MIT Ph. D. Thesis, January, 1978)
G. C. Fox (Experiment #'s 236, 260, and 395)	Recent Experimental Results on High Transverse Momentum Scattering from Fermilab (Invited talk presented at the Argonne APS Meeting, October 6-8, 1977)
G. Donaldson et al. (Experiment #268)	Angular Dependence of High Transverse Momentum Inclusive π^0 Production in $\pi^{\pm}p$ and pp Interactions (Submitted to Phys. Lett. B)
G. J. Donaldson et al. (Experiment 268)	Inclusive η Production at Large Transverse Momenta
M. D. Corcoran et al. (Experiment #313)	Polarization in p-p Elastic Scattering at High Energies
K. Moriyasu et al. (Experiment #338)	Multiplicity Distributions and Double-Scattering Effects in π^-d Interactions at 360 GeV/c
W. R. Francis (Experiment #398)	Scaling Parameters in Deep Inelastic Muon Scattering (Invited talk presented at the Argonne APS Meeting, October 6-8, 1977)

R. T. Edwards et al. (Experiment #415)	Forward Inclusive Production Spectrum of K_S, Λ^o, $\overline{\Lambda}^o$, and n in the Collision of 200 GeV/c π^-, K^-, $\overline{p}$ and p on Be (Submitted to Phys. Rev.)
D. A. Garelick et al. (Experiment #439)	Confirmation of an Enhancement in the $\mu^+\mu^-$ Mass Spectrum at 9.5 GeV (Received in January 1978; submitted to Phys. Rev. Lett.)
R. J. Fisk et al. (Experiment #494)	Correlations Between Two Hadrons at Large Transverse Momenta (FERMILAB-Pub-78/15-EXP; submitted to Phys. Rev. Lett.)

Theoretical Physics

B. W. Lee and R. E. Shrock	An SU(3)$\otimes$U(1) Theory of Weak and Electromagnetic Interactions (FERMILAB-Pub-77/48-THY; submitted to Phys. Rev.)
C. H. Albright et al.	Heavy-Lepton Interpretation of Multimuon Events Produced in Neutrino and Antineutrino Beams [FERMILAB-Pub-77/91-THY; Phys. Rev. D16, 3182 (1977)]
W. A. Bardeen et al.	Mass Generation in a Normal-Product Formulation [FERMILAB-Pub-77/94-THY; Phys. Lett. 72B, 231 (1977)]
M. B. Einhorn and R. Savit	Topological Excitations in the Abelian Higgs Model (FERMILAB-Pub-77/97-THY; submitted to Phys. Rev.)
H. D. I. Abarbanel and J. Bartels	Questions of Quark Confinement and Ambiguities in Coulomb Gauge of Yang-Mills Fields (FERMILAB-Pub-77/104-THY; submitted to Nucl. Phys.)
C. Quigg and J. L. Rosner	Semiclassical Sum Rules (FERMILAB-Pub-77/106-THY; submitted to Phys. Rev.)
H. B. Thacker et al.	Inverse Scattering Problem for Quarkonium Systems I. One-Dimensional Formalism and Methodology (FERMILAB-Pub-77/108-THY; submitted to Phys. Rev.)
H. B. Thacker et al.	Inverse Scattering Problem for Quarkonium Systems II. Applications to ψ and Υ Families (FERMILAB-Pub-77/109-THY; submitted to Phys. Rev.)

W. A. Bardeen and S.-H. H. Tye	Current Algebra Applied to Properties of the Light Higgs Boson (FERMILAB-Pub-77/110-THY; submitted to Phys. Lett.)
C. H. Albright et al.	A Comparison of Trimuon Production Mechanisms (FERMILAB-Pub-78/14-THY; submitted to Phys. Rev. D)

Cancer Therapy

J. L. Redpath et al.	Dose Fractionation Studies on Mouse Gut and Marrow: An Intercomparison of 6 MeV Photons and Fast Neutrons ($\overline{E}$ = 25 MeV)

General

R. A. Carrigan, Jr.	Compound Quarks as an Explanation for the Apparent Quark Mass Spectrum (FERMILAB-78/13)

Physics Notes

L. C. Teng	Further Parametric Studies of the Accelerator System for Heavy Ion Fusion - Addendum (FN-307A)
L. C. Teng	Effects Limiting Accelerated Beam Intensity in the Largest Proton Synchrotron (FN-308; submitted to the Xth International Conf. on High Energy Accelerators, July 11-17, 1977, Serpukhov, USSR)

DATES TO REMEMBER

April 7-8, 1978	Workshop on Channeling at High Energies (for further details contact R. A. Carrigan).
April 14, 1978	Meson Lab Workshop.
May 5, 1978	Fermilab Users Organization Annual Meeting.
May 5, 1978	Deadline for receipt of all new proposals and other written materials to be considered at the summer meeting of the Program Advisory Committee.
May 18-19, 1978	Proposal Presentation Meeting.
June 17-23, 1978	Summer meeting of the Fermilab Program Advisory Committee.

CHARM PRODUCTION BY NEUTRINOS

Charles Baltay
Columbia University

The production of charmed particles by neutrinos has been observed in the Fermilab 15-ft bubble chamber by a Columbia University-Brookhaven National Laboratory collaboration (Fermilab Experiment #53A). The charmed particles were observed both via their semileptonic decays, as, for example, the reaction $\nu_\mu + Ne \rightarrow \mu^- + D + \ldots$, $D \rightarrow K + e^+ + \nu + \ldots$, as well as their hadronic decays, such as the reaction $\nu_\mu + Ne \rightarrow \mu^- + D + \ldots$, $D \rightarrow K^o + \pi^+ + \pi^-$.

The experiment used the horn-focused wideband neutrino beam, with 1.0×10^{13} 400-GeV protons hitting the target per pulse. The 15-ft chamber was filled with a heavy neon-hydrogen mix (64% neon, 36% hydrogen by volume). The 40-cm radiation length and 125-cm nuclear interaction length of this mixture allows good identification of the particles produced in the neutrino interactions. Electrons are identified by radiation (bremsstrahlung) followed by conversion of the radiated photon into e^+e^- pairs. Hadrons have a high probability of undergoing a nuclear interaction and muons are recognized as tracks that leave the chamber without interacting. The 30-kG magnetic field of the chamber allows the measurement of the sign of the charge and the momentum of the particles. Strange particles can be detected via their decays, such as $K^o \rightarrow \pi^+ + \pi^-$ or $\Lambda^o \rightarrow p + \pi^-$ (vees). So far, about 150,000 photographs have been taken for this experiment with, on the average, one neutrino interaction per picture.

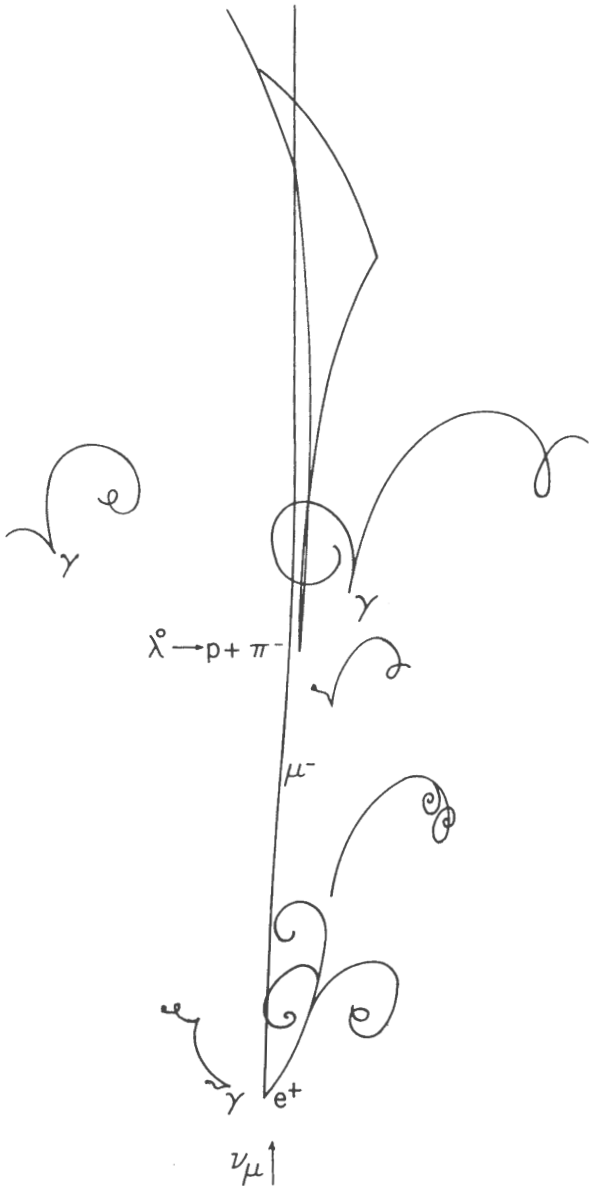
The signature for semileptonic charm decays is the production of a μ^- and an e^+ (dilepton events). A total of 164 $\mu^- e^+$ events have been observed in the experiment so far (from about two thirds of the available pictures). One of the most striking features of charm is a dominant decay into strange particles, as postulated in the Glashow-Iliopoulos-Maiani (GIM) model. In this experiment, the 164 $\mu^- e^+$ events were accompanied by 33 neutral strange particle decays (vees). In the normal charged-current neutrino interactions, 164 events would be expected to have approximately 10 vees; the observation of 33 vees demonstrates that the $\mu^- e^+$ events are significantly correlated with strange particles. Dilepton events have also been observed in the $\mu^- \mu^+$ channel in counter experiments at both Fermilab and the CERN SPS. It is the correlation with strange particles seen in the bubble chamber that identifies the source of the dilepton events in neutrino interactions as semileptonic decay of charmed particles. Correcting the 33 vees for branching ratios, detection efficiencies, and charged strange particles, we infer that between 1 and $1\text{-}\frac{1}{2}$ strange particles are produced per $\mu^- e^+$ event, in good agreement with the prediction of the GIM model. The 33 vees contain 23 K_S^o decays and 10 Λ decays, indicating that both charmed meson and charmed baryon production are being observed. The rate of the $\mu^- e^+$ events is $(0.5 \pm 0.15)\%$ of all charged-current neutrino interactions, from which the total charm production is estimated to be 5 to 10%, again in good agreement with the expectations of the GIM model.

The signature for the hadronic decays of charmed particles in this experiment is the production of a μ^- accompanied by a neutral strange particle decay (vee). A sample of 1800 events with a μ^- and a visible

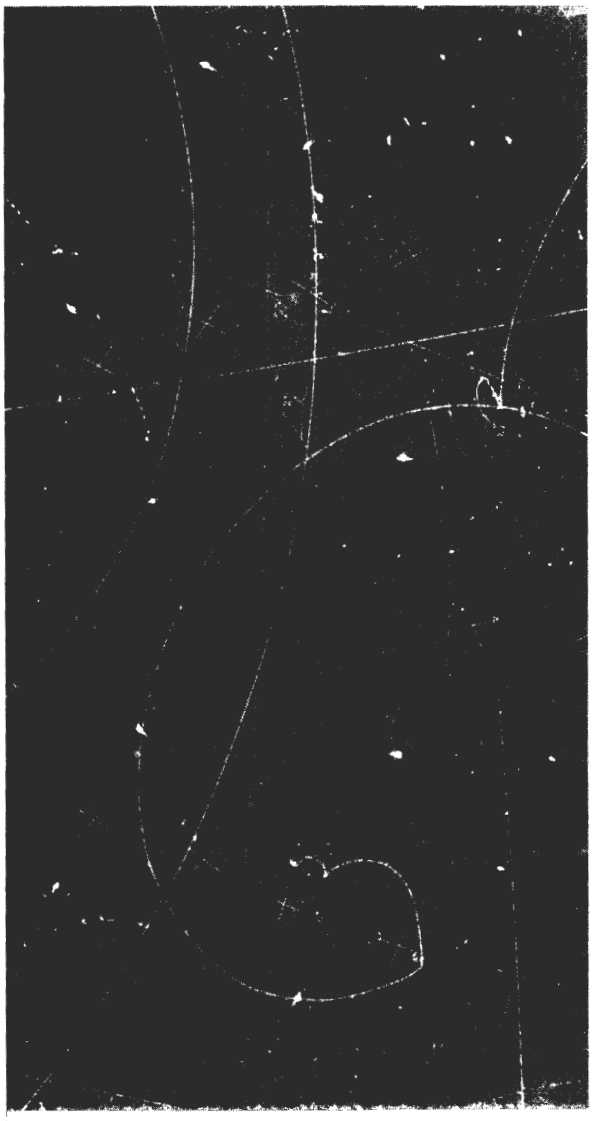
$K_S^O \to \pi^+ + \pi^-$ decay have been used for a search for the lightest charmed meson, the D. The $K_S^O + \pi^+ + \pi^-$ mass distribution in the reaction $\nu_\mu + Ne \to \mu^- + K_S^O + \pi^+ + \pi^- + \ldots$ shows a peak corresponding to the decay $D^O \to K_S^O + \pi^+ + \pi^-$, with a D^O mass of 1850 ± 15 MeV. The peak has about 60 events above background, with a statistical significance of over 4 standard deviations, and has a width consistent with the mass resolution of the experiment.

A search for the hadronic decays of charmed baryons into final states such as $\Lambda^O\pi^+$ and $\Lambda^O\pi^+\pi^+\pi^-$ is in progress using a sample of approximately 1400 events with a μ^-, a Λ^O, and pions.

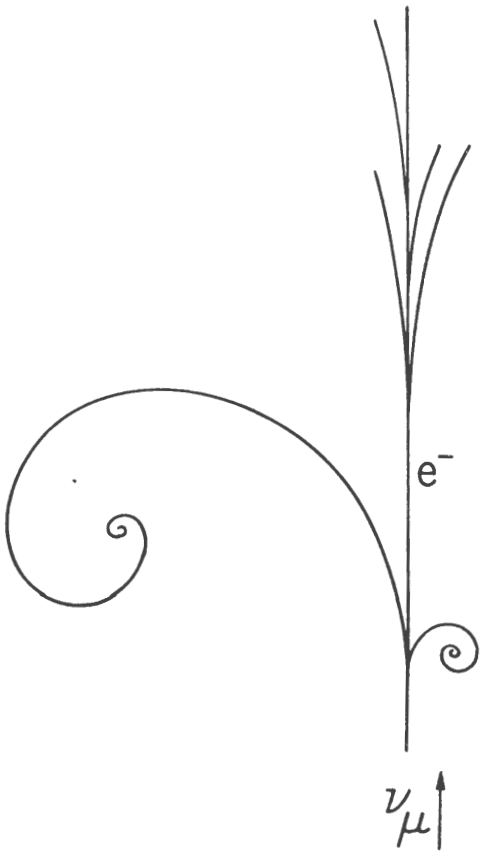
The experiment has also observed three examples of the very rare process $\nu_\mu + e^- \to \nu_\mu + e^-$. These events are very clean; the backgrounds in this experiment are negligible. The experiment should eventually yield 10 to 20 such events.



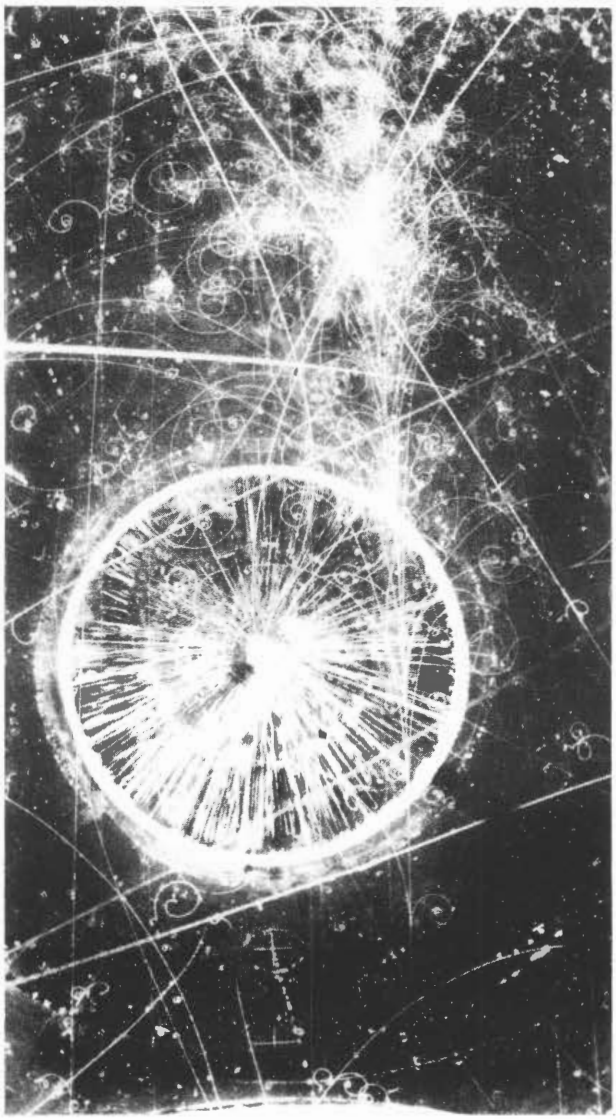
A tracing of the event on the right.



A neutrino interaction interpreted to be $\nu_{\mu} + Ne \rightarrow \mu^{-} + e^{+} + \Lambda^{o} + \pi^{o}$'s.



A tracing of the event on the right.



An example of the very rare process $\nu_\mu + e^- \rightarrow \nu_\mu + e^-$. The e^- has a momentum ~ 30 GeV and an angle of 4 ± 7 milliradians with respect to the incident ν_μ direction.

MARCH 9-10 MEETING OF THE FERMILAB PROGRAM ADVISORY COMMITTEE

E. L. Goldwasser

One of the first orders of business at the March meeting of the PAC was to announce a change in the name of the Committee. In the distant past, the Laboratory sometimes asked the advice of a committee which was called the "Physics Advisory Committee" in addition to that of the Program Advisory Committee. The deliberations of the Program Advisory Committee were originally focused entirely upon experimental proposals submitted for implementation in the relatively short range. The Physics Advisory Committee was asked for advice regarding the long-range plans of the Laboratory.

The Physics Advisory Committee has been inactive; its last series of meetings occurred in 1973. Since that time, the Laboratory has tended, more and more, to discuss matters of medium- to long-range planning with the Program Advisory Committee. Members of the Program Advisory Committee have expressed their interest in becoming more involved in some of those long-range questions. In recognition of the Laboratory's intention to bring such matters increasingly to the attention of the Program Advisory Committee and to welcome gratuitous advice on such matters from the Program Advisory Committee, it was decided to change the name of the Committee to "Physics Advisory Committee." Fortunately this sweeping change still leaves the Committee's abbreviated title "PAC," so the resulting confusion should not be unmanageable.

At the March meeting the results and recommendations of three prior subcommittee meetings were given final consideration. The first of those meetings had been a review of the neutrino program in the 15-ft bubble chamber. The second had been a review of new proposals for an upgraded 30-in. bubble chamber hybrid spectrometer system. The third of the meetings had been the regular Proposal Presentation Meeting held in February.

Following the meeting of the PAC in November 1977, it was announced that a test would be made, this spring, with plates in the 15-ft chamber and with a hydrogen fill. If that engineering test is successful and if physics analysis of the pictures is not compromised by the presence of the plates, the deuterium runs which have long been planned for the chamber will be made with a set of plates installed in the downstream section of the chamber. As a result of discussions at the March PAC meeting, two major experiments were approved to run in that configuration. The approvals we have given provide for the taking of 350,000 pictures with neutrinos and 150,000 pictures with antineutrinos.

After further consideration of the past deliberations on the 30-in. bubble chamber hybrid spectrometer program it was decided to proceed with an upgrading of that hybrid spectrometer system which will provide it with three new major downstream detectors. One of them is a large "ISIS" type system, now called "CRISIS." That system will play a role in the identification of secondary particles through the measurement of the relativistic rise in ionization density. A second downstream detector which will be

available for future runs is a large segmented Cerenkov counter which will also be used for downstream particle identification. It will be used primarily in an antiproton bombardment which is now approved for one of the two major groups that are building the new downstream detectors. A third detector is a large downstream gamma-ray detector which can be used in place of the Cerenkov counter. A 15-week run has been approved for one of the two consortia with emphasis on π^+ and π^- bombardments. A 10-week bombardment has been approved for the second group, with emphasis on the antiproton bombardment. In total, the Laboratory expects that about two million pictures will be taken with the 30-in. hybrid spectrometer system during the next running period now planned for late 1979.

Another familiar old problem received considerable attention at the recent meeting of the PAC. That problem has to do with a possible beam-dump experiment in the Neutrino Area. Five years ago an approved beam-dump experiment was given up by the experimenters involved, in favor of extending another approved run in a normal neutrino beam. At that time, the Laboratory encouraged all experimenters with suitable detectors in the neutrino beam to get together to plan the best possible beam-dump run, using a clean beam and the maximum available useful detector mass. Although a proposal was invited at that time, none was received until preliminary reports of a beam-dump run at CERN were forthcoming.

The first formal proposal for a similar run at Fermilab was received late in January 1978. That proposal was presented at the Proposal Presentation Meeting in February and further discussed at the full PAC meeting

in March. As a result of those discussions it was decided not to approve the proposal at this time.

The only point in extending the CERN investigation at Fermilab would be if a significant new contribution could be made which might lead to a better understanding of the phenomena which have been observed at CERN. Such a contribution might be of a qualitative nature, such as the investigation of observed event rates as a function of production angle or, such as the performance of the experiment in a substantially cleaner incident beam configuration. Alternatively, a new contribution could be made by improving the existing data in a quantitative fashion by increasing, perhaps by an order of magnitude, the number of events that have been observed. The amount of effort and beam time required to perform such an experiment would be quite substantial. It could not be done without serious interferences with our present program. The suggestion that a beam-dump experiment should be run in the near future was rejected on those grounds. One minor problem is that the beam dump which is now available in the neutrino beam line is made of aluminum. The signal to background would be less favorable than that obtained at CERN in the recent experiment there that was carried out with a copper beam dump.

An extension was approved for the HPWF experiment (Neutrino #310) which has been operating in Laboratory C in the Neutrino Area since the earliest neutrino observations were made at Fermilab. The contributions of the HPWF collaboration to the physics output of the Laboratory have been stimulating, and it is with a combined sense of satisfaction and regret that

the recently approved extension is identified as the run which will write finis to the work done by that group using the present Lab C detector.

Two of the interesting and controversial phenomena which have recently received the attention of that group have been the "high-y anomaly" and the production of multimuons in neutrino interactions. The newly approved run will use a major portion of the present detector, during the planned bombardment of the deuterium filled 15-ft bubble chamber, with a neutrino and anti-neutrino beam formed by the double horn focusing system. It is hoped that these data could be useful in resolving some of the controversy and uncertainties which surround the two phenomena in question.

Another major decision reached affecting the Neutrino Laboratory program is the approval for installation and initial running of a flash chamber detector proposed in P-594, which should be useful for the study of neutral current events. An approval for running during 1979 has been granted to that experiment. The apparatus will probably be developed in a modular fashion, running initially in the space immediately upstream of the liquid calorimeter of E-310.

One new proposal for a jet experiment, using a hadron calorimeter, was considered at the March meeting, but final consideration was deferred. It was noted that there are several similar live or embryonic proposals and it was felt that an occasion should be arranged, before the June PAC meeting, when the status and promise of jet physics could be reviewed and when all of the remaining proposals could be considered together.

NOTES AND ANNOUNCEMENTS

FERMILAB SUMMER PROGRAM. . .

Fermilab staff members are being invited to propose assignments for participants in the 1978 Summer Program for Minority Students. Approximately 20 students are brought to Fermilab to work on technical assignments under the direct supervision of Fermilab scientists and engineers. Interested people should contact the Summer Program Committee Chairman, Ernest Malamud.

RESEARCH ACTIVITIES DURING FEBRUARY 1978

James MacLachlan

The accelerator operated from February 3 to February 22 at 400 GeV with a 1.25-sec flattop. There were 333.2 hours of beam for high-energy physics out of the 452 hours scheduled during this period; 1.6×10^{18} protons were accelerated at an average intensity of 1.5×10^{13} per pulse and an average repetition rate of 11.9 seconds. For a week starting February 8 a 30-40 msec spill of about 3×10^{12} p/pulse was provided for further tests of the νe scattering experiment Neutrino #253. There has been at least a respite in the recent rash of failures of Main-Ring pulsed power transformers; the last two failures were February 3 and February 8.

In the middle of the month the Laboratory was notified by the Department of Energy of its intention to suspend operations to conserve power during the coal strike. Over a week of uncertainty followed during which the Laboratory appealed for a reconsideration. However, a notice of indefinite suspension was received February 22 during a two-day maintenance and development period. The Laboratory continued in a standby state for the rest of the month with activities limited to low energy accelerator studies and those maintenance and development projects which could be finished or interrupted on one-day notice so that high-energy physics running could resume quickly in the event of favorable action on the continuing appeal.

Among the accelerator activities during the suspension were the running in of the H^- injection into the Booster and the installation of three rebuilt Main-Ring pulse power transformers. In addition, two transformers

were moved from less critical positions to replace failed transformers so that the Main Ring's capability for < 9 sec cycling has been restored.

Muon #203A running in the N1 beam downstream of the cyclotron spectrometer was the top priority on the experimental program in February, and the experiment received an average of 10^{13} p/pulse. The μ/p ratio averaged $\gtrsim 2\times10^{-7}$. During some brief periods of higher intensity the experimenters discovered that they suffered some significant loss of drift-chamber efficiency in the hottest part of the beam. Partial blockage of the cooling circuits in the large-aperture quads in Enclosure 103 made it impossible to move the beam focus far enough upstream to spread the beam at the position of the critical drift chamber. Several remedies were tried. The installation of a 4Q120 quadrupole at the upstream end of the Muon Lab proved inadequate. Toward the end of the month it was found that it was possible to ramp the quads to the desired 1200 A, even though they are not laminated, by ramping only from 500 A, rather than from zero current. In this mode the experimenters achieved about a fourfold increase in beam size with little loss in yield and apparently were able to run with satisfactory efficiency up to something like 4×10^{6} μ/sec.

Multi-Muon #439 running in the Meson Area's M2 line was off during the first half of the month while repairs were made on two coils for their magnetized beam dump and further improvements were made in the M2 shielding. Additional steel shielding was added under the mezzanine during the power pause with the hope of permitting secondary intensity $\gtrsim 10^{11}$ p/pulse during day as well as night and weekend running. Inclusive K_S^o #383 was the

top-priority experiment in the Meson Area after the first week of running because it became clear that the ~ 3×10^{12} p/pulse intensity required for finishing its program in a reasonable time was a problem for the switchyard. The work done in response to their increased priority made it possible to provide > 3×10^{12} p/pulse most of the time and allowed E-383 to complete the 125-GeV portion of their program before the power pause.

The good news in the Proton Area is the lack of specific information to report. Both Photoproduction #87A in Proton-East and Di-Lepton #288 in Proton-Central used most of the available beam for routine data-taking. Improvements in their trigger allowed E-87A to raise their primary beam rate from 3×10^{11} to 7×10^{11} p/pulse during the month. Running in the Internal Target Area was almost mostly routine, and p-N Scattering #522 which ran for the entire period made good progress in steady data-taking.

FACILITY UTILIZATION SUMMARY--FEBRUARY 1978

I. Summary of Accelerator Operations

			Hours	
A. Accelerator use for physics research				
Accelerator physics research			16.0	
High energy physics research			333.2	
Research during other use			-	
		Subtotal		349.2
B. Other activities				
Accelerator setup and tuning to experimental areas			5.8	
Program interruption	Scheduled	74.0		
	Ad hoc*	124.0	198.0	
Unscheduled interruption			119.0	
		Subtotal		322.9
C. Unmanned time				-
				672.0

II. Summaries of High Energy Physics Research Use

	# of Expts.	Hours	Results
A. Counter experiments	14	2328.0	-
B. Bubble chamber experiments	-	-	-
C. Emulsion experiments	-	-	-
D. Special target experiments	1	-	1 target exposed
E. Test experiments	1	79.9	e^- calorimeter calib.
F. Engineering studies and tests	(1)	184.6	N3 yield studies
G. Other beam use			
	16	2592.5	

III. Number of Protons Accelerated and Delivered @ 400 GeV ($\times 10^{18}$)

A. Beam accelerated in Main Ring				1.63
B. Beam delivered to experimental areas				
Meson Area			0.19	
Neutrino Area				
	Slow Spill	1.04		
	Fast Spill	0.14		
Proton Area			0.10	1.47

*Suspension of program for power conservation

BEAM UTILIZATION BY

	Beam	Hours
MESON AREA		
Multiparticle #110 A	M6W	258.6
Hadron Dissociation #272	M1E	231.8
Inclusive K_S^O #383	M4	208.5
Multimuon #439	M2	161.8
NEUTRINO AREA		
Muon #203A/391	N1	247.9
Neutrino #253	N0	99.1
Neutrino #310	N0	1.5
Neutrino #356 Calib.	N5	69.2
Muon #448 Tests	N1	273.6
Nuclear Fragments #466	N0	-
PROTON AREA		
Photoproduction #87A	P1	262.4
Di-Lepton #288	PC	275.0
P #519 Tests	PW	79.9
INTERNAL TARGET AREA		
p-N Scattering #552	C0	292.6
Hours for Experiments		2407.9
Engineering tests (N3 yield meas.)		184.6
TOTAL HOURS FOR HIGH ENERGY PHYSICS		2592.5

EXPERIMENT -- FEBRUARY 1978

Activities

tuneup & data: -100 and -175 GeV on LH_2 target looking at 12 exclusive channel triggers with emphasis on the $\pi\pi n$ channel

tuneup: 50 and 100 GeV e^- calibration of liquid argon calorimeter, drift-chamber tests, counter timing, trigger studies, etc.

data: 125 GeV/c K^- on an LH_2 target to look for $K^- + p \rightarrow K_s^o + X$ in a pair spectrometer

data: $\sim 10^{11}$ p/pulse into a magnetized beam dump using di-μ and multi-μ triggers

data: deep inelastic μ scattering, multi-μ production, etc. with 225 GeV μ^+ into a distributed target calorimeter

test: test of μ background at 400-GeV proton energy using a 30 msec spill

data: single-μ and multi-μ data with an iron-scintillator calorimeter and toroidal μ spectrometer

tests: calibration of the target calorimeter with hadrons and muons

setup: trigger tests, etc.

data: three-week bombardment of an uranium foil by the N0 primary proton beam

data: photoproduction of high mass hadron states using the broadband photon beam

data: high mass di-μ data in a high rate configuration

test: electron beam calibration of multi-cell calorimeter

data: pp scattering at beam energies of 20-400 GeV at $t = -1$ to -3 using an H_2 jet target and proton recoil spectrometer