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Medium-Energy Physics Program

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Compiled by

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GLOSSARY OF TERMS USED IN THIS REPORT

ADC – Analog Digital Converter
ADS – Analog Data System
ASCII – American Standard Code for Information Interchange
CCF – LASL Central Computer Facility
CCT – Color Character Terminal
CCR – Computer Control Room
CCTV – Closed Circuit Television
CIU – Console-Interface Unit
CPU – Central Processing Unit
CRT – Cathode Ray Tube
C-W – Cockcroft-Walton
DACT – Data-Acquisition and Control Terminal
DPM – Digital Panel Meter
DVM – Digital Volt Meter
EFB – Effective Field Boundary
EPA – Electron-Prototype Accelerator
ETL – Equipment Test Laboratory
FET – Field-Effect Transistor
fh – Filament Hours
FWSS – Fast-Wire-Scanner System
hfs – Hyperfine Structure
hvh – High-Voltage Hours
IC – Integrated Circuit
ICR – Injector Control Room
IDS – Information Display System
IEC – International Electrotechnical Commission
IFA – Interface Amplifier
I/O – Input/Output
ISIC – Insertable-Strip Ion Chambers
IVR – Induction Volt Regulator
LAM – Look-at-Me Interrupt
LAMPF – Clinton P. Anderson Meson Physics Facility
LCF – Localized Current Fields
LED – Light-Emitting Diode
LEEP – LAMPF Electronics and Equipment Pool
LET – Linear-Energy Transfer
MBD – Microprogrammed Branch Driver
m.i. – Mineral Insulated
MIG – Metal Inert Gas
MSSC – Multistrip Scintillation Chamber
MTBF – Mean Time Between Failures
MWPC – Multiwire Proportional Chamber
NCL – Nuclear Chemistry Laboratory
NIM – Nuclear Instrumentation Module
NMR – Nuclear Magnetic Resonance
pc – Printed Circuit
PHA – Pulse-Height Analyzer
PLI – Procedural Language Interface
RBE – Relative Biological Effectiveness
RGB – Red-Green-Blue
RICE – Remote Information and Control Equipment (remote data terminal
RIU – RICE Interface Unit
SCC – Serial Crate Controller
SCR – Silicon Control Rectifier
SSD – Serial System Driver
SY – Switchyard
TDC – Time-to-Digital Converter
TDI – Temperature Difference Integrator
TIG – Tungsten Inert Gas
TOF – Time of Flight
TR – Transition Region

Experimental Area

Primary beam lines in experimental area:
- Line A – Main Beam Line
- Line B – Nuclear Chemistry Facility
- Line C – High-Resolution Proton Spectrometer
- Line D – Weapons Neutron Research Facility

Experimental beams:
- Beam Area A:
  - BSA – Beam Stop A
  - EPICS – Energetic Pion Channel and Spectrometers
  - LEP – Low-Energy Pion Channel
  - Neutrino A
  - P^3 – High-Energy Pion Channel
  - RADIP – Radiation Damage and Isotope Production
  - SMC – Stopped Muon Channel
  - TA-1 – Target A-1
  - TA-2 – Target A-2
  - TTA – Thin Target Area
- Beam Area B (Room BR):
  - AB – Neutrons
  - AB – Nuclear Chemistry
  - EPB – External Proton Beam
- Beam Area C:
  - CCH – Area C Control and Counting House
  - HRS – High-Resolution Proton Spectrometer

QUARTERLY REPORT ON THE MEDIUM-ENERGY PHYSICS PROGRAM

FOR THE PERIOD ENDING OCTOBER 31, 1975

I. SUMMARY

Engineering Support

Approximately one-third of the group's effort was directed to work in Experimental Area A. In addition to fabricating harps, current monitors, collimators, beam pipes, target boxes, and other hardware, most of the group technicians spent part of the quarter in the experimental areas on assignment to other groups.

The entire 805-MHz rf system was turned on early in the quarter. More maintenance work than usual had to be performed because of problems which were aggravated by the shutdown. Fifteen modulators were repaired and five 1.25-MW klystrons required repair or reprocessing. One klystron was rebuilt and three more were restored to operating condition by external repairs or reprocessing.

The slow-kicker was operated in the switchyard with beam to Line D. The fast-kicker modulator has been operated into a dummy load at 8000 A, 12-μs pulses at rates up to 50 Hz.

Work is continuing on the Biomedical Beam Line. Several components were tested and simulated remote-handling operations were performed to facilitate the actual remote handling which will be done in the future.

Accelerator Support

Activities for the quarter were centered around the completion of modifications to power supplies and shunt regulators, checkout of new systems installed during the shutdown, and support of the accelerator during operation. Work was also continued on the 201-MHz test stand at ETL.

Experience with accelerator operation since the shutdown has shown a significant improvement in beam availability. The availability has improved from something near 60% before the shutdown to near 80% at present (at low-intensity operation). Most of this improvement can be attributed to improvements in the 201-MHz rf systems, specifically, the tanks, rf windows, and amplifier chains.

The 201-MHz test stand at ETL is nearing completion and should be finished by the end of November. The craft work is 90% complete at this time; work required of MP staff is progressing, although this activity has low priority compared to accelerator support.

The tank-to-tank phase-monitoring system, installed during the shutdown, has worked well and has been effective in isolating accelerator problems during operation. This system is presently installed only on the first 12 modules and is still undergoing evaluation. When the evaluation is complete, a decision will be made as to whether to install the system in the remainder of the accelerator.

Accelerator Systems Development

Analysis of the field distribution in the 201-MHz linac continued with data reduction on the bead-pull measurements, error estimation, and use of the PARMILA code to build an accurate model and to design experiments for testing the validity of the model.

Experiments were completed on the character of the horizontal beam oscillations, 100-MeV emittance, transverse matching, and acceptance at 750 keV. A data base of all linac alignment information was prepared.

Stability studies included development of software, monitoring of both long- and short-term data for all modules, and measurements of beam sensitivity and the sensitivity of the Δt measurement to off-resonance conditions in the accelerator.

Data-base development work was concentrated on transferring the Users Group, Inc. data base to System 2000 and continued progress in other areas.

Diagnostic-equipment development included encouraging progress on beam-position monitors and low-momentum phosphors and activity in numerous other areas of instrumentation work.

Code development included a rewrite of PARMILA.

Work on the EPICS particle separator and the Biomed pion range shifter is nearing fruition.

Injector Systems

Both the H^+ and H^- injectors have been on full-time operation since the end of July although, to date, only the H^- injector has been used for production beams. The general operation of both injectors has been excellent, with relatively little unscheduled downtime.

On the H^+ injector, effort has continued to obtain more reliable bouncer operation and to determine optimum control over the transient voltage excursion on the equipment dome during high-current pulsing.

An experiment was carried out to study the effects of injector energy variation on linac beams. The results document the range of the possible effects of injector energy variations and confirm that present stability is not a problem for 100-μA operation.

Work continued on use of the phase-locked 5-kHz oscillator. This circuit has proven to be sensitive to slow-stabilizer tuning and can introduce significant voltage transients on the equipment dome. The present system permits either free-running or phase-locked operation.

The new molybdenum insert in the H^- ion source is still in service and has shown no change in performance during the past three months of operation.

The beam transport lines have functioned at full duty factor operation. The new system of water-cooled apertures now limits the transverse and longitudinal excursions of injector beams that can be transported to the linac.

The modifications to the I-beams in the floor of the polarized ion injector were completed, and construction of the C-W high-voltage power supply was started. Design work on the polarized ion source continues and a test stand for checking polarized source components was set up.

The development effort on a high-current H^- ion source being carried out in collaboration with P-Division is now centered on building a surface ionization source patterned after the Dubnikov design. Work has been carried out at MP-12 to develop a pulser, a high-voltage regulator, and a pulsed valve for this source.

Electronic Instrumentation and Computer Systems

The control computer was operational throughout the quarter for accelerator development and tuneup. A design flaw in the priority-interrupt logic of the computer was identified and corrected.

Work continued on the information-exchange bus which will be the basis for developing the third console. A prototype, CAMAC-based bus controller was tested along with a prototype for the first device to be connected to the bus—a function button panel. Software development and system integration are scheduled for next quarter.

Specifications for a new Master Timer for the facility were prepared and approved.

A prototype of the CAMAC-based Data-Link module incorporating a microprocessor was tested successfully. Software development will continue through next quarter.

Technician training was a major activity. Formal classes dealing with the control computer and its peripherals, the CCR console devices, and the remote data systems were conducted at regular intervals and will continue as required next quarter.

The emphasis of software developments this quarter was on programs to provide better operations support. Numerous programs had to be updated to reflect changes in equipment which occurred during the shutdown. The HRS console was made fully functional as a remote console.

Numerous and significant changes were made to the controls and instrumentation along the primary and secondary beam lines. The Fast-Wire-Scanner System was made operational. Work continued on upgrading the harp system. The control system for EPICS was used successfully in the α-particle test. The controls and instrumentation in the switchyard and Area B were used for beam tests and production runs.

Work continued on the general data-acquisition software package. The nucleus of the package was used successfully in the EPICS α-particle test. Several new features were added subsequently.

Sixteen of twenty-five Event Trigger modules were fabricated, tested, and issued to experimenters. An inexpensive chassis containing fixed-delay cables was designed to augment the existing LEEP stock. Approximately $180k has been committed for additional electronics equipment for LEEP to support the upcoming series of experiments.

Accelerator Operations

Machine startup following the seven-month shutdown began just prior to the start of the quarter and operation continued throughout this report period, for a total of 276 shifts. Of the total, 137 shifts were employed in startup functions, 25 for scheduled maintenance, 59 for facility development experiments, 9 for tuneup for production (research) beams, and 46 for research. Beam availability during research shifts was 77%. Over half of the machine downtime resulting from equipment failures occurred during the first month of the quarter.

Objectives of the startup were to find and fix the numerous faults expected after the extended shutdown and major overhaul, to develop the capability for dual beam operation at 100-μA H^+ and 1-to 3-μA H^-, and to start a limited program of research in Lines B and EPB with H^- beams of a few μA average current. Just over a month was required to move from initial conditioning of 201-MHz tanks to delivery of a production-quality H^- beam to the beam switchyard. Two more weeks were required to achieve simultaneous 100-μA H^+ and 3-μA H^- beams at 800 MeV. The first production run to Line B started just 10 weeks after initial turnon.

Only EPB, Line B, and the Line B nuclear chemistry facility were in operation during this period. Average proton beam currents ranged from 1 to 4 μA, for a total of 505 μA-h.

Linac acceptance was studied for injector energies ranging from 720 to 780 keV. Longitudinal emittance of the H^+ beam was measured at 100 MeV. New emittance, phase-scan, and wire-scan hardware were checked out. Measurements were made to determine the sensitivity and reproducibility of the beam-position monitors under development in the linac. Characteristics of the horizontal transverse-beam oscillation were measured, but efforts to determine the source of the oscillation did not produce definitive results.

Experimental Areas

Plans have been made for a leased facility on the south side of Area A for an experimental area operations office. It will include a remote computer terminal to monitor the major service systems and experimental setups. The staff shop in Area A has been upgraded. The dust problem around Area A has been reduced with the addition of paving in the parking areas.

Modifications of the experimental area cooling-water systems to achieve higher reliability, better monitoring of operating parameters, and remote valving capability are nearly complete. Three pump/heat-exchanger systems for HRS, EPICS, and Area A auxiliary use are being assembled and checked out. A spare heat exchanger is on order for the radioactive water systems.

Support for cryogenic target systems for several experiments continues on a routine basis. Preliminary work is in progress on a tritium system for an upcoming experiment.

First beam in the revised SY was obtained in mid-August. Beam-diagnostic instrumentation was checked out. Production beams for research were delivered through the SY to Lines B and EPB by early October. Multiple beams and large-intensity fluctuations have been occasionally observed in EPB; these troubles appear to be related to H^- beam granularity and transverse instability. Preliminary tests of dual beam simultaneously deflected to Lines X and A-South have been carried out. Encouraging results have been obtained on a 5-min dual beam "heat" run at 800 MeV with current of 100-μA H^+ and 1.5-μA H^-. The magnet-current readout system in the SY was upgraded.

Wire-scanner performance has been improved by the adoption of a continuous-scan option, new amplifiers, new programming, and better signal-to-noise characteristics, but the faster drive system had to be dropped because of marginal performance. Tests of clearing fields on scanners were positive for ribbons, but no effect was obtained for round wires.

All harp card assemblies for Area A have been completed; a successful beam test was carried out in the SY. The radiation-hardened cable assemblies for these harps are complete and ready for installation.

Two-position air-operated actuators for phosphor insertion have been developed. Beam tests of various radiation-hardened phosphors were made. The results showed that chromium-doped Al_2O_3 was best.

Three new curtain strippers installed in Lines A and B appear to work well.

Procedures for tuning the SY and Lines X, B, and EPB have been written. Programs for determining beam-phase-space parameters from standard beam measurements are being developed.

Installation of the vacuum-system components of the main beam has been a major effort during this quarter. There are still a number of missing components, including the target box at target cell A-2. Vacuum-checking of the installed components is in progress and several major portions of the beam line are already leak-tight.

The P^3, SMC, and LEP secondary beam lines are nearly ready for high-intensity operation. These three beam lines have been completely reassembled and have been checked out, including their magnet systems. Beam-line shielding has been completed on the P^3 and the SMC lines, and is being installed on the LEP line. Rebuilding of the experimental caves and construction of the new SMC-East cave area are in the planning stage.

Minor improvements have been made on Lines B and EPB. Some shielding deficiencies have been corrected and proton beams up to 6 μA can now be delivered safely to Area B. Both Lines B and EPB have been in routine research use since early October.

Preliminary testing of the prototype cryostat for the polarized proton target has been completed. All essential components are in preparation or under development except the target head. Progress is slow at the present level of effort.

Entirely new pion-production target systems have been built for use on the main beam line at target cells A-1 and A-2.

Purchase negotiations are in progress for the acquisition of new servomanipulators for remote handling of main beam-line and beam-stop components. Mockup operations are being carried out with the Monitor remote-handling system.

Design work for all bulk shielding in Area A is essentially complete. Four of the six steel boxes for the Merrimac doors have been assembled and are ready for filling. Portions of the water-cooled shielding at A-1, A-2, and A-5 have been installed. Shielding closures for the SY have been completed.

Over 400 work activities in the Area A high-intensity modification program were completed during the quarter. There are about 380 tasks remaining to be completed before Area A is ready for high-intensity beam. It is projected that the earliest turn-on date for Area A is mid-January 1976.

Large-Spectrometer Systems

EPICS

The EPICS channel was put into operation, and an alpha-particle test of the resolution was performed. This test indicated that the resolution of the channel is very close to the design resolution. All mechanical units functioned well during the test. The separator also worked, but since closed-loop control of the high voltage was not available, it was difficult to make a definitive test. Because the effort to commission the EPICS channel required all available manpower, little or no progress was made on construction of the EPICS spectrometer.

HRS

During this period, magnetic measurements were completed on the first spectrometer dipole and the magnet has undergone final preparations for rigging into the spectrometer frame. Final measurements are now in progress on the second spectrometer dipole. The specific measurement results obtained for HS-BM-01 during this quarter include shimming the "uniform" field region to give an integral field uniformity which is good to $\pm 3 \times 10^{-5}$ from 4-14 kG over a transverse region of ± 25 cm about the optic axis. In addition, higher order curvatures in the effective field boundary through fourth order were obtained which were consistent with design to $\leq \pm 0.1$-mm peak-to-peak at entrance and exit of the magnet over the same transverse region (± 25 cm). This particular magnet has since undergone a number of other operations including the addition of rigging and alignment fixtures, movement into its proper location for rigging, and vacuum testing. It is now ready for installation into the frame—an operation which will begin not later than the last week in November.

Related work includes a number of similar items on HS-BM-02 as well as the fabrication of a multipole magnet which goes between these two dipoles. The pump and heat-exchanger package for the spectrometer system has been fabricated and installed in the area. The first spectrometer power supply has been installed in the B/C equipment building and interfaced to the computer. It has been run from CCH using HS-BM-02.

We have successfully operated the first remote console to CCR during this quarter, using it to turn on and cycle Line C magnets. We have finalized the design of the spectrometer particle-identification system as well as built and tested the various scintillation and Cerenkov detectors. A remotely controllable, CAMAC driven, 16-channel delay box has been laid out and is being fabricated for the particle-identification system. The Q-program for data acquisition is running on our RSX operating system and we have taken cosmic-ray spectra from these detectors in preparation for subsequent beam-line tests using the pencil beam.

High-precision transductors for current monitoring on the beam-line power supplies have been installed and are being calibrated. The taut-wire monitoring system has been installed on the beam line, upstream of the Line C shield wall. This line has undergone final alignment and is currently under vacuum and ready to accept beam while being operated from CCH.

Research

During the quarter, results of analysis of data from ten experiments were received. Most of these experiments were LAMPF-user collaborations, and some were users solely. The results of the pion-nucleus total-cross-section work were accompanied by some interesting theory featuring an improved treatment of the Coulomb interaction.

A novel time-pickoff detector was successfully developed and tested. It shows very high time resolution. It will be used for precise TOF measurements as part of a new experiment to detect nuclear fragments from proton-induced nuclear spallation reactions.

New experiments run during the quarter were based perforce on the EPB line and on Line B. They included a search for "direct" electron production, a preliminary study of proton-induced nuclear breakup, a study of np charge-exchange reactions, and several nuclear chemistry experiments.

Some effort by research personnel went into checkout and installation of protective monitoring devices in Area A, notably a beam-on-target ion chamber and several secondary emission multiplier devices for collimator-watching.

Nuclear Chemistry

This is the first report on the development of the LAMPF nuclear chemistry facilities. During the Great Shutdown the array of available α, β, and γ radiation counting and nuclear spectroscopy equipment in the nuclear chemistry laboratory was reorganized in three counting rooms for more efficient utilization. The hardware of the data-acquisition system, developed around a DEC PDP-11/40 computer interfaced to a CAMAC branch highway and crates, was brought to operational status. It has been set up to handle the data output from the variety of radiation counters and pulse-height analyzers. The general data-acquisition program, "Q," has been incorporated into the system, but the system is only partially operational because of the limited software written to date.

A number of programs of general usefulness to researchers on activation experiments have been assembled, modified, or written for execution on the large CCF computers.

Two stainless-steel containment boxes have been acquired for use in the Area A nuclear chemistry hot cell. The one box will be open and for use for dry operations only, while the other will be completely closed and for use for wet chemical operations remotely carried out on highly radioactive targets.

Under development for several years, the pneumatically operated "rabbit" system, designed to transport a target to an irradiation station and then return it to the experimenter, is nearing phase-one completion. The last major component of the system, namely the control console, was recently installed adjacent to the nuclear chemistry hot cell. Proton irradiations in Line B and neutron irradiations at the A-6 beam stop will be the initial targeting capabilities of the system.

A new member has been added to Group T-5 to provide direct theoretical support to the nuclear chemistry program. The initial support effort has been concentrated on a detailed study of the BNL-developed VEGAS intranuclear cascade code with the objective of developing significant improvements.

Practical Applications of LAMPF

During this period, emphasis at the Biomedical Facility was placed on preparing systems and apparatus for beam turn-on. Completed tasks include revisions to the magnet current-control system, computer interfacing of the three-dimensional dosimetry scanner, improved shielding in the vicinity of the Biomed entrance triplet, and the design of logic circuitry for pulsing the high voltage on MWPC and LET ion chambers (to allow data acquisition during periodic low-intensity beam pulses). Channel-tuning studies have incorporated new effective lengths of the quadrupoles determined from *in situ* field measurements. Work continued on developing computer codes for on-line acquisition and analysis of dosimetry and microdosimetry data. Microdosimetry equipment has been rebuilt and tested and will be transported to the Univ. of California at Davis for neutron dosimetry experiments in December. A code, eventually to be used in treatment planning, has been developed which calculates the three-dimensional dose distribution in a water phantom due to realistic negative pion beams. The code uses input data from MWPCs and determines the doses due to pion ionization loss, pion star products, and beam contaminants. Calculated dose distributions are in good agreement with experimental observations.

Design and construction of a portable temperature controller for localized current-field tumor therapy have been completed. Documentation on the instrumentation will be available soon. Several malignant animal tumors were treated this period.

Some development work was initiated on aerators for practical applications. Ion linacs which operate at high frequencies and low injector energies and which utilize novel focusing methods are being studied.

Management

The proceedings have been distributed of the recent Santa Fe and Los Alamos Conference on High-Energy Physics and Nuclear Structure, which was edited by members of LASL with help from Stony

Brook and the National Research Council of Canada. Coming out as it did in less than four months after the meeting ended, the prompt publication of the volume is a tribute to the efforts of the authors, editors, and the A.I.P. publishing staff.

Total operating costs to date for FY-76 exceeded the budget forecast by $50k, or approximately 0.1%. About 69% of the fiscal-year capital equipment allocation has been obligated or costed. The average number of full-time-equivalent employees chargeable to medium-energy-physics funding is 355, one more than forecast.

Close control of the radiological safety aspects of work on the accelerator and in the experimental areas continued. Individual exposures as well as total man-rem exposures were kept to an acceptable level. A procedure was prepared which specifies methods for control and disposal of solid, liquid, and gaseous radioactive waste. The overall status of electrical safety was investigated by members of the Electrical Safety Committee. Safety reviews of experiments continued and became more formalized. A new safety review form is being used to evaluate safety aspects of each experiment. All experiments are now required to have an on-site safety representative. Of the 29 accidents reported this quarter, none caused any significant loss of time from work.

Leases have been obtained for 11 Los Alamos Medical Center efficiency apartments and two 2-bedroom apartments for subleasing to LAMPF users. These apartments will be assigned to users on a priority basis, according to the scheduling of experiments. Six of the Medical Center apartments will revert to the Univ. of New Mexico Cancer and Treatment Center for scheduling as soon as patient treatments at the Biomedical Facility begin.

In addition to visitors on conducted tours, 248 "casual" visitors, from 12 foreign countries, were received at MP Division. There were 250 visitors at LAMPF to participate in the research programs, with 191 visitors received and 131 checked out during this report period.

Work continued this quarter in preparation for the ninth meeting of the LAMPF Users Group, Inc., at which the annual election of officers to the Board of Directors will be held. As of September, the LAMPF Users Group, Inc. comprised 1042 members from 242 institutions in the U.S. and 71 foreign institutions.

The next meeting of the Program Advisory Committee will be held at LAMPF on January 16-18, 1976, at which time 27 new proposals for beam time will be considered.

Publications

"High-Energy Physics and Nuclear Structure—1975" (Santa Fe and Los Alamos, AIP Conf. Proc. No. 26, Editors: D. E. Nagle, A. S. Goldhaber, C. K. Hargrove, R. L. Burman, and B. G. Storms (New York, 1975).

J. F. Dicello, H. I. Amols, T. F. Lane, A. S. Lundy, J. D. Doss, H. B. Knowles, and J. E. Barnes, "Dosimetry for Pion Beams at LAMPF," Rad. Res. **62**, 562 (1975).

H. B. Knowles, "An Envelope Equation in the Dispersive Plane of a Bending Magnet," Particle Accel. **6**, 193-200 (1975).

K. Tanabe, "Photon Propagation in Nuclear Matter and the Correction to the Theoretical Nuclear Charge Density," Phys. Rev. C **12**, 1346-1353 (1975).

M. D. Cooper and R. A. Eisenstein, "FITPI: Modifications to the Optical Model Program PIRK for Parameter Searches and Total Cross Sections," Los Alamos Scientific Laboratory report LA-5929-MS (April 1975).

D. E. Nagle, "Parity Nonconservation in Two-Nucleon Systems," Proc. American Inst. of Physics High-Energy Physics and Nuclear Structure Conf. (Santa Fe and Los Alamos, New Mexico, 1975), No. 26, pp. 497-503.

R. L. Burman, "Low Energy Pion-Nucleon and Pion-Deuteron Interactions," Proc. American Inst. of Physics High-Energy Physics and Nuclear Structure Conf. (Santa Fe and Los Alamos, New Mexico, 1975), No. 26, pp. 41-54.

Papers Prepared for Publication: Papers Submitted at Conferences

J. D. Knight, C. J. Orth, M. E. Schillaci, R. A. Naumann, H. Daniel, K. Springer, and H. B. Knowles, "Chemical Effects in Negative Muon Capture in Some Ionic and Covalent Solids and Ionic Aqueous Solutions," submitted to Phys. Rev. A.

T. M. Putnam, "The Clinton P. Anderson Meson Physics Facility and its Operational Safety Program," to be presented at the Health Phys. Soc. Ninth Midyear Topic Symposium on Operational Health Physics, Feb. 9-12, 1976, Denver, Colorado. (Proceedings to be published.)

R. L. Hutson, J. J. Reidy, K. Springer, H. Daniel, H. B. Knowles, "Tissue Chemical Analysis with Muonic X Rays," to be presented at the Radiological Soc. of North America; submitted to Radiology.

J. F. Dicello, "Dosimetry of Pion Beams," presented at Intern. Particle Radiation Therapy Workshop, Key Biscayne, Florida, Oct. 1-3, 1975. (To be published in Proceedings.)

E. A. Knapp, "Physical Properties of Charged Particle Beams for Use in Radiotherapy," ibid.

M. Leon, "Hadronic Atoms and Ticklish Nuclei: The E2 Nuclear Resonance Effect," submitted to Nucl. Phys.

H. I. Amols, J. F. Dicello, T. F. Lane, G. W. Pfeufer, J. A. Helland, and H. B. Knowles, "Microdosimetry of Negative Pions at LAMPF," submitted to Radiology.

R. L. Burman, R. Fulton, and M. Jakobson, "Design of the LAMPF Low-Energy Pion Channel," submitted to Nucl. Instrum. Methods.

M. D. Cooper and M. B. Johnson, "Integrated Pion-Nucleus Cross Sections," submitted to Nucl. Phys. A.

LAMPF Experimental Program Reports and Publications

(Parasite experiment) C. J. Orth, W. R. Daniels, and B. J. Dropesky, "Identification of ^{236}Th," submitted to Phys. Rev. C.

(Exp. 2) M. D. Cooper, D. C. Hagerman, R. P. Redwine, H. O. Meyer, M. J. Jakobson, R. H. Jeppeson, I. Halpern, L. D. Knutson, R. E. Marrs, G. R. Burleson, K. F. Johnson, and J. R. Calarco, "$\pi^{\pm}$ - ^{4}He Total Cross Sections from 50-100 MeV," prepared for the Conf. of the Amer. Phys. Soc. (Washington, D.C., April 28-May 1, 1975); submitted to Bull. Am. Phys. Soc.

(Exp. 2) G. R. Burleson, K. P. Johnson, J. Calarco, M. Cooper, D. C. Hagerman, H. O. Meyer, R. P. Redwine, I. Halpern, L. Knutson, R. Marrs, J. M. Jakobson, and R. H. Jepperson, "Measurements of $\pi^{\pm}$ Nucleus Total Cross Sections at Energies Below 20 MeV," prepared for the Intern. Conf. on High Energy Physics and Nuclear Structure (Santa Fe, NM, June 9-14, 1975). Phys. Soc.

(Exp. 2) G. Rinker, "Analysis of Muonic-Atom Isomer Shifts in ^{209}Bi and ^{207}Pf," Phys. Rev. C4, 2150 (1975) (thesis).

(Exp. 7) J. P. Davidson, E. B. Shera, L. K. Wagner, and R. M. Steffen, "Muonic X-Rays from the Transition Nuclei ^{194,195,196}Pt," prepared for the Conf. of the Amer. Phys. Soc. (Washington, D.C., April 28-May 1, 1975); submitted to the Bull. Am. Phys. Soc.

(Exp. 7/163) G. Rinker and J. B. Mann, "Comment on the Validity of the Slater Approximation in Electron Screening in Exotic Atoms," Phys. Rev. A11, 385 (1975).

(Exp. 26) L. R. Veeser, G. J. Russell, E. D. Arthur, P. A. Seeger, W. F. Sommer, D. M. Drake, R. G. Fluharty, and R. F. Bentley, "Spectrum and Shielding Measurements and Calculations of Neutrons Produced by 800-MeV Protons," presented at the Conf. of Nuclear Cross Sections and Tech., (Washington, DC, March 1975); to be published in the Proc.

(Exp. 27/125) J. Simmons, "Some Topics Concerning N-N and N-D Experiments at Medium Energy," Proc. of the VI Intern. Conf. on High-Energy Physics and Nuclear Structure, (Santa Fe, New Mexico, June 9-14, 1975).

(Exp. 37) T. W. Crane, D. E. Casperson, V. W. Hughes, P. A. Souder, R. D. Stambaugh, P. A. Thompson, H. F. Kaspar, H. W. Reist, H. Orth, G. zu Putlitz, and A. B. Denison, "Precision Measurements of $1S_{1/2}$ Muonium Hyperfine Structure Interval $\Delta\nu$: I. Experimental Method," prepared for the Conf. of the Amer. Phys. Soc. (Washington, D.C., April 28-May 1, 1975); submitted to the Bull. Am. Phys. Soc. and Phys. Rev.

(Exp. 37) T. W. Crane, D. E. Casperson, V. W. Hughes, P. A. Souder, R. D. Stambaugh, P. A. Thompson, H. F. Kaspar, H. W. Reist, H. Orth, G. zu Putlitz, and A. B. Denison, "Precision Measurement of $1S_{1/2}$ Muonium Hyperfine Structure Interval $\Delta\nu$: II. Results," ibid.

(Exp. 50) H. W. Baer, J. A. Bisterlich, S. Cooper, K. M. Crowe, J. P. Perroud, R. H. Sherman, F. T. Shively, and P. Trüoel, "Photon Spectrum in Pion Capture on Tritium," submitted for presentation at the VI Intern. Conf. on High-Energy Physics and Nuclear Structure, Santa Fe, NM, June 9-14, 1975.

(Exp. 56) C. W. Bjork, P. J. Riley, B. E. Bonner, J. E. Simmons, K. D. Williamson, Jr., D. W. Werren, H. C. Bryant, C. G. Cassapakis, S. Cohen, B. D. Dieterle, C. P. Leavitt, D. M. Wolfe, M. L. Evans, G. Glass, J. C. Hiebert, M. Jain, and L. C. Northcliffe, "Neutron Spectra from Proton Bombardment of Deuterium at 647 and 800 MeV," prepared for the Intern. Conf. on Few Body Problems in Nuclear and Particle Physics, Laval Univ., (Quebec, August 27-31, 1974).

(Exp. 56) B. E. Bonner, J. E. Simmons, K. D. Williamson, Jr., D. W. Werren, H. C. Bryant, C. G. Cassapakis, S. Cohen, B. D. Dieterle, D. M. Wolfe, M. L. Evans, G. Glass, J. C. Hiebert, M. Jain, L. C. Northclife, C. W. Bjork, and P. J. Riley, "Measurement of the 0° Neutron Spectrum from the Reaction $p + p \rightarrow n + p + \pi^+$ at $T_p = 764$ MeV," ibid.

(Exp. 56) G. Glass, M. L. Evans, M. Jain, L. C. Northcliffe, C. G. Cassapakis, C. W. Bjork, P. J. Riley, B. E. Bonner, and J. E. Simmons, "Neutron Production at 0° from the Reaction $pp \rightarrow np\pi^+$ at the Medium Energies," submitted for presentation at the VI Intern. Conf. on High-Energy Physics and Nuclear Structure, Santa Fe, NM, June 9-14, 1975.

(Exps. 67 & 119) B. J. Dropesky, G. W. Butler, C. J. Orth, R. A. Williams, G. Friedlander, M. A. Yates, and S. Kaufman, "Excitation Functions for the $^{12}C(\pi\pm,\pi N)^{11}C$ Region of the (3,3) Resonance," submitted to Phys. Rev. Lett.

(Exps. 67 & 119) N. P. Jacob, S. S. Markowitz, R. R. Silbar, and M. M. Sternheim, "Neutron Knockout by Pion$^{\pm}$ on ^{14}N, ^{16}O, and ^{19}F," Bull. Am. Phys. Soc. **20**, 663 (1975).

(Exp. 81) J. Hudomalj-Gabitzsch, J. Witten, N. Gabitzsch, G. Mutchler, J. Clement, T. Williams, G. Phillips, E. Hungerford, L. Y. Lee, B. Hayes, M. Warneke, and J. Allred, "Pion Production by 800-MeV Protons in the Reaction $^1H(p,\pi^+,p)N$," Bull. Am. Phys. Soc. **20**, 554 (1975).

(Exp. 81) T. M. Williams, T. R. Witten, M. Furic, D. Mann, J. Gabitzsch, G. Mutchler, J. Clement, R. Felder, G. C. Phillips, B. Mayes, E. Hungerford, L. Lee, M. Warneke, and J. Allred, "Quasi-Free Scattering in p=d Break-up Reactions at 800 and 600 MeV," Bull. Am. Phys. Soc. **20** 554 (1975).

(Exp. 84) Clark Goodman, "Neutron Energy Flux and Dosage in the LAMPF π^- Biomedical Channel," Los Alamos Scientific Laboratory report LA-5746-MS (October 1974).

(Exps. 86 & 79) A. M. Zebelman, A. M. Poskanzer, J. D. Bowman, R. G. Sextro, and V. E. Viola, Jr., "Fragments from Uranium Irradiated by 2.1 GeV/Nucleon Deuterons and Alpha Particles," Lawrence Berkeley Laboratory report LBL-3427; submitted to Phys. Rev. C.

(Exp. 96) J. S. Frank, R. H. Heffner, K. A. Klare, R. E. Mischke, D. E. Nagle, and D. C. Moir, "The Elastic Scattering of Low Energy Pions on Protons," submitted for presentation at the VI Intern. Conf. on High-Energy Physics and Nuclear Structure, Santa Fe, NM, June 9-14, 1975.

(Exp. 99) C. A. Bordner, P. A. M. Gram, W. Hassenzahl, H. H. Howard, F. T. Shively, T. R. King, A. T. Oyer, and G. A. Rebka, "The Elastic Scattering of Positive Pions by Carbon at 147 MeV," submitted for presentation at the VI Intern. Conf. on High-Energy Physics and Nuclear Structure, Santa Fe, NM, June 9-14, 1975.

(Exp. 100) R. L. Hutson, "*In Vivo* Tissue Analysis Using Mu-Mesic X Rays," Los Alamos Scientific Laboratory report LA-5867-MS (February 1975).

(Exp. 105) R. G. Helmer, R. C. Greenwood, R. J. Gehrke, and C. W. Reich, "Gamma-Ray Studies of the Decay of ^{128}Ba and ^{128}Cs," Bull. Am. Phys. Soc. **19**, 1029 (1974).

(Exp. 105) M. E. Bunker, J. W. Starner, B. J. Dropesky, W. R. Daniels, and B. S. Neilson, "The $^{158}Er \rightarrow {}^{158}Ho$ Decay Scheme and Q_B Value," Bull. Am. Phys. Soc. **20**, 625 (1975).

(Exp. 106/210) P. M. Grant, B. R. Erdal, and H. A. O'Brien, Jr., "A ^{82}Sr-^{82}Rb Isotope Generator for Use in Nuclear Medicine," J. Nucl. Medicine **16**, 300-304 (1975).

(Exp. 111) J. C. Hill, K. H. Wang, and R. F. Petry, "Production of Neutron-Rich Nuclides Using High-Energy Neutrons at LAMPF," Bull. Am. Phys. Soc. **19**, 1027 (1974).

(Exp. 111) R. F. Petry, K. H. Wang, and J. C. Hill, "Study of the ^{200}Pt - ^{200}Au Decay Chain at LAMPF," Bull. Am. Phys. Soc. **19**, 1019 (1974).

(Exp. 119) M. M. Sternheim and R. R. Silbar, "Effects of Nucleon Charge Exchange on the $(\pi,\pi n)$ Puzzle," submitted to Phys. Rev. Letters.

(Exp. 125) L. C. Northcliffe, M. L. Evans, G. Glass, J. C. Hiebert, M. Jain, H. C. Bryant, C. G. Cassapakis, S. Cohen, B. D. Dieterle, D. M. Wolfe, B. E. Bonner, J. E. Simmons, D. W. Werren, C. W. Bjork, and P. J. Riley, "Precision Measurement of n-p Charge Exchange Cross Section at 640 MeV," prepared for the Intern. Conf. on Few Body Problems in Nuclear and Particle Physics, Laval Univ., (Quebec, August 27-31, 1974).

(Exp. 137B) J. D. Bowman, C. M. Hoffman, C. Hwang, R. E. Mischke, D. E. Nagle, J. M. Potter, D. M. Alde, P. G. Debrunner, H. Frauenfelder, L. B. Sorensen, H. L. Anderson, and R. Talaga, "Limit on Parity Violation in P-Nucleus Scattering at 6 GeV/C," Phys. Rev. Lett. **34**, 1184 (1975).

(Exp. 137B) J. D. Bowman, "Parity Nonconservation in P-P and P-Nucleus Scattering," presented at Symposium on Interaction Studies in Nuclei, Mainz, Feb. 17-20, 1975 (Proc. to be published); also presented at the Gordon Conf., Colby, NH, June 21, 1975.

(Exp. 137B) D. E. Nagle, "Parity Violation in p-p and p-Be Reactions," to be published in Neutrino '75 Proceedings, Balaton, Hungary, Fifth Intern. Conf. on Neutrino Science, June 16-21, 1975.

(Exp. 142) W. K. Hensley, J. R. Huizenga, D. G. Perry, J. C. Browne, and C. Kalbach, "Muon Lifetime Measurements in the Actinide Elements," prepared for the Conf. of the Amer. Phys. Soc. (Washington, D.C., April 28-May 1, 1975); submitted to the Bull. Am. Phys. Soc.

(Exp. 143) M. M. Kligerman, C. O. Sternhagen, F. Dobrowolski, H. T. Davis, E. Barnes, T. F. Lane, J. N. Bradbury, E. A. Knapp, and D. F. Petersen, "Initial Comparative Response of Metastatic Superficial Nodules and Surrounding and Underlying Normal Tissue to Peak Pions and X-Rays," prepared for the American Radium Soc. Mtg. (San Juan, Puerto Rico, May 4-9, 1975); to be published in Radiology.

(Exp. 143) J. F. Dicello, H. I. Amols, T. F. Lane, A. S. Lundy, J. D. Doss, H. G. Knowles, and J. E. Barnes, "Dosimetry for Pion Beams at LAMPF," Proc. 23rd Radiation Research Soc. Conf. (May 11-12, 1975); to be published in Radiation Research.

(Exp. 143) H. Amols, J. F. Dicello, and T. F. Lane, "Microdosimetry of Negative Pions," prepared for the Fifth Symposium of Microdosimetry (Italy, September 22-26, 1975); submitted for publication in Radiology.

(Exp. 143) L. S. Gomez, D. M. Smith, and J. F. Dicello, "Effects of Negative Pions on Testes Weight Loss and Spermatogenic Stem-Cell Renewal in Mice," to be presented at the 23rd Ann. Mtg. of the Radiation Research Society, Miami Beach, FL, (May 11-15, 1975); submitted to Radiation Research for publication.

(Exp. 143) P. W. Todd, J. Dicello, G. West, C. Shonk, M. M. Kligerman, and M. R. Raju, "Survival of Cultured Mammalian Cells Irradiated at Various Depths in the LAMPF Negative Pion Therapy Beam," Los Alamos Scientific Laboratory report LA-6049-MS (September 1975).

(Exp. 147) D. G. Perry, D. W. Barr, J. S. Gilmore, D. J. Dudziak, M. L. Simmons, G. J. Russell, P. A. Seeger, M. J. Fluss, R. Heinrich, and V. A. Ryan, "Neutrons from a High Energy Proton Beam Stop," Proc. First Topical Mtg. on Technology of Controlled Nucl. Fusion (San Diego, CA, April 16-18, 1974), Vol. I, p. 333.

(Exp. 151) H. B. Knowles, G. E. Tripard, and F. H. Ruddy, "Plastic Tract Detectors as Negative Pion Macro- and Micro- Dosimeters," to be presented at the 17th Ann. Mtg. of the American Assoc. of Physicists in Medicine, San Antonio, TX, (Aug. 3-7, 1975); to be published in the Proc..

(Exp. 153) J. F. Amann, P. D. Barnes, M. Doss, S. A. Dytman, R. A. Eisenstein, J. Penkrot, and A. Thompson, "Studies of Charged Particle Emission in Reactions Induced by 220 and 50-MeV Plus-Pions," submitted to Bull. Am. Phys. Soc. and Phys. Rev.

(Exp. 161) E. L. Haines, I. D. Hutcheon, and J. R. Weiss, "Fission Track Record of Apennine Front Kreep Basalts," submitted to Lunar Science VI (1975).

(Exp. 163) E. B. Shera, G. A. Rinker, Jr., M. J. Bennett, R. B. Perkins, E. T. Ritter, H. D. Wohlfahrt, G. Fricke, L. K. Wagner, P. Kleinheinz, R. K. Sheline, R. M. Steffen, and J. W. Negele, "Muonic Isotope Shifts in the Even Fe Nuclei," Phys. Rev. Lett. **34**, 535 (1975).

(Exp. 163) G. Rinker and J. W. Negele, "Deformed Hartree-Fock Description of the Fe, Ni, and Zn Isotopes," Proc. of the VI Intern. Conf. on High-Energy Physics and Nucl. Structure, Santa Fe, New Mexico, June 9-14, 1975.

(Exp. 163) G. Rinker and L. Wilets, "New Limits on the Difference Between the Muon- and Electron-Nuclear Interactions," Phys. Rev. D7, 2629 (1973).

(Exp. 166) R. J. Powers, F. Boehm, P. Vogel, A. Zehnder, T. King, A. R. Kunselman, P. Roberson, P. Martin, G. H. Miller, R. E. Welsh, and D. A. Jenkins, "A Precise Determination of E2 and E4 Moments in ^{165}Ho from Muonic X Rays," Calif. Inst. of Technology report CALT-63-218 (January 1975); Phys. Rev. Letters **34** No. 8, 492 (February 24, 1975).

(Exp. 180) R. A. Eisenstein, J. Amann, P. D. Barnes, M. Doss, S. A. Dytman, J. A. Penkrot, and A. C. Thompson, "Elastic Scattering of 50-MeV π^- and ^{12}C," prepared for the Conf. of the Amer. Phys. Soc. (Washington, D.C., April 28-May 1, 1975); submitted to the Bull. Am. Phys. Soc.

(Exp. 206) R. O. Mueller, V. W. Hughes, H. Rosenthal, and C. S. Wu, "Collision Quenching of the Metastable 2S State of Muonic Hydrogen and the Muonic Helium Ion," submitted to Phys. Rev. A.

Stopped Muon Channel

G. Rinker and L. Wilets, "High-Order Vacuum Polarization in Exotic Atoms," Proc. of the VI Intern. Conf. on High-Energy Physics and Nuclear Structure, (Santa Fe, New Mexico, June 9-14, 1975).

G. Rinker and L. Wilets, "Estimate of the $(Z\alpha)^2\alpha^2$ Vacuum Polarization Term in Muonic Lead," Phys. Rev. Lett. **34**, 339 (1975).

G. Rinker and K. W. Ford, "Comparison of Muonic-Atom and Electronic X Ray Isotope Shifts in Lead," Phys. Rev. C**9**, 2444 (1974).

G. Rinker and L. Wilets, "Vacuum Polarization in High-Z, Finite-Size Nuclei," Phys. Rev. Lett. **31**, 1559 (1973).

G. Rinker and K. W. Ford, "Analysis of Muonic-Atom X Rays in the Lead Isotopes," Phys. Rev. C**7**, 1206 (1973).

G. Rinker and M. Rich, "Some Implications of a Recent Test of Muonic-Atom Theory," Phys. Rev. Lett. **28**, 640 (1972).

G. Rinker and L. Wilets, "Vacuum Polarization in Strong, Realistic Electric Fields," Phys. Rev. **A12**, 748 (1975).

II. ENGINEERING SUPPORT

LAMPF Accelerator

Accelerator Support

Spare components for four TR bending magnets are being reworked or fabricated. Four half-coils have been reworked and one has been potted in epoxy resin. Several design modifications for the beam-pipe assembly have been completed.

Parts for eight spare linear actuators have been received. The subassemblies for these units are now being furnace-brazed and welded at the ETL.

There was a total of 110 fabrication activities, of which 49 were H_2 furnace-braze heats, TIG welding and leak-checking of the Area A collimators, beam pipe, and target components. Experimental support accounted for 42 fabrication activities, and the balance were for klystron rebuilding and Line D field-clamp assembly modifications.

During the 201-MHz linac renovation, chromel-alumel thermocouples were installed in the upstream drift-tube bellows of each tank to monitor the bellows temperature while the machine is in operation. Measured temperature rises above system ambient (29°C) at full peak power and 8.4% rf duty factor ranged from 24°C (Tank 1) to 72°C (Tank 4), and are deemed satisfactorily low.

805-MHz RF System

The VA-862A klystrons have accumulated over 540 000 fh with seven failures, and the L-5120s have accumulated 100 000 fh with six failures. One klystron of each type failed in this quarter. Ninteen of the sixty VA-862As were found to have a Kovar component in their output-window cooling passages. The Kovar part is subject to rust, and three have developed water-system leaks to date. The leaks were repaired and these klystrons are again operational. It is probable that the corrosion is more pronounced when the klystrons are stored, rather than when the klystrons are in operation. As such, all klystron water passages are now thoroughly dried before the klystrons are stored. This should minimize future corrosion. A fiber glass-epoxied band has been used to repair the leaks, and the same technique will be applied to the remaining klystrons which have Kovar exposed to the water system. An order for 10 more VA-862A klystrons has been placed with the vendor.

The LPT-44 modulator triodes have now accumulated over 629 000 fh. An additional 25 LPT-44s have been ordered. In this quarter, 23 modulator triodes were removed from service due to high interpulse current and will be reprocessed as required.

Fifteen modulators required maintenance this quarter. Two klystrons with small vacuum leaks were reprocessed and will be installed on the accelerator. Klystrons with minor vacuum leaks are pumped by the electron beam and will, therefore, have a better vacuum and longer life if placed in operation rather than in storage.

Klystron Repair Facility

An L-5120 Klystron, S/N 2020R1, was successfully repaired in this period, and another L-5120, S/N 2014, is now in the bakeout oven. Five klystrons have been successfully rebuilt at LASL and have accumulated more than 15 000 fh, with no failures. Of these, four are presently installed on the accelerator.

A cleaning facility and deionized water system have been designed for the klystron-rebuilding activities. Orders have been written for heated stainless-steel tanks, a deionized water unit, an in-line water heater, a chemical hood, and a water-purity meter. A work-station plan was devised to facilitate parts flow at the ETL and to make parts-handling safer. Several klystron stands were rebuilt to conform to this plan. A welder and rotary welding table were installed in the klystron room so that all rebuilding operations (with the exception of brazing) are done in a single room.

There are currently five klystrons in various stages of the repair cycle, with a sixth klystron being tested to see if it is serviceable.

201-MHz Klystron

An electrical design for a 3-MW, 201-MHz klystron has been made. An output cavity and coax-to-waveguide transducer were designed and tested on a quarter-scale model. The preliminary mechanical design for this klystron has been started, and many design details have been decided upon. Detailed cost estimates on the savings in power, tube replacement, and maintenance are being made to determine the cost effectiveness of the klystron system.

Experimental Lines

Area A

Most of the group technicians spent at least part of this period in Area A, on assignment to other groups, in support of the shutdown activities, and their efforts are reported elsewhere. The major beam-line components, target boxes, harp boxes, magnets, collimators, and beam pipe are now ~50% installed and aligned. The A-5 target box was measured and marked with external targets. All of the carbon-wire harps required in Area A were fabricated early in the quarter and are ready for installation.

The design of the Cell A-1 target-mechanism shield plugs has been started and is ~25% complete. The special crane-mounted pallet lifter to handle these plugs is now on hand.

Biomedical Beam Line

Approximately 8800 kg of lead shielding was added to the quadrupole triplet magnet to simplify the task of close-packed shield in the front end of the beam line. Two rad-hard jumpers were relocated to permit optimum shielding on top of the triplet.

Slit 1 and its stepper drivers were assembled (Fig. II-1) and delivered to the Biomed area for interfacing with the computer. The assembly of Slit 2 has commenced.

Helium-pressure decay, window-burst pressure, and flange cooling-water flow tests on the helium chamber for the initial triplet magnet (RT-QM-01, -02 and -03) were completed. Halo shields and the helium chamber, including mounting brackets, remote disconnects, and copper plumbing, were then installed in this magnet. Plumbing for the magnet core cooling was then modified to allow mounting of additional alignment fixtures.

A simulated remote-handling operation of this magnet was performed, using a mockup and the Monitor manipulator system. The first slit assembly was removed and replaced on the magnet. The downstream helium window was removed and replaced on the chamber (Figs. II-2, II-3).

In the course of these simulated remote-handling operations, several minor problems became apparent, and slight modifications in the equipment were made to facilitate future remote operations. It was determined that a general-purpose lifting system is required in the congested areas where there is insufficient working space for the standard crane hook. A modified hook is being designed for this purpose.

An alignment check of the positions of all of the biomed magnets was performed. The first two magnets were realigned and the others were found to be in their proper positions.

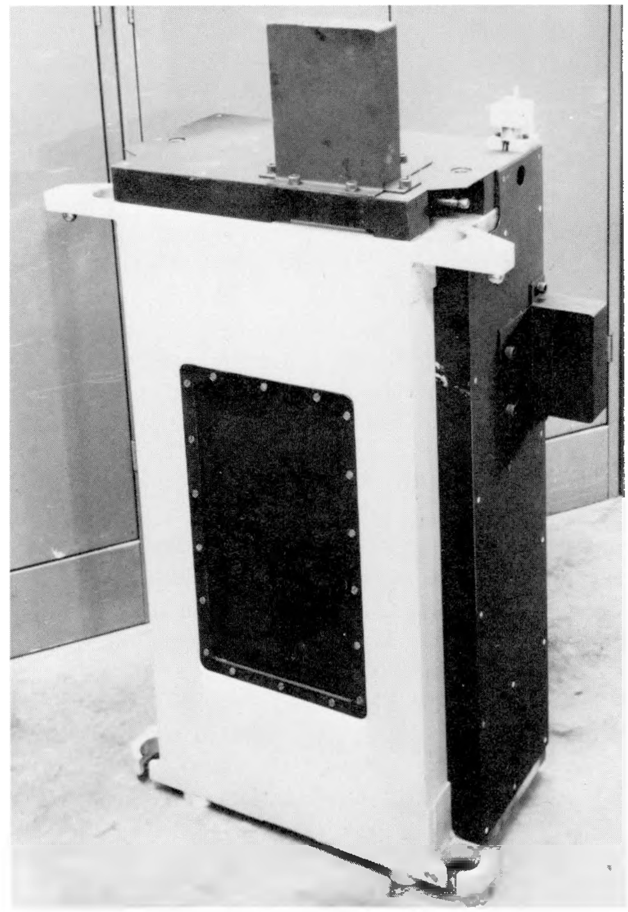

Fig. II-1.
Biomed Slit No. 1.

Energetic Pion Channel and Spectrometer

The design of shielded trucks for lifting and moving the EPICS separator shield plug was completed, and fabrication of these trucks has begun. The track system for this plug was modified to allow the plug to be set down anywhere along its travel to permit removal of the trucks from under the plug.

A complete alignment check of the EPICS components through IP-BM-04 was completed. The last magnet had to be repositioned. The EPICS alpha-source assembly was aligned and marked so it can be properly positioned for testing in the beam line.

Weapons Neutron Research Facility—Line D

Eight of the WNR-tunnel quad magnets have been processed through the tooling dock and received alignment fixturing. All the waterfall bending magnets were realigned. Four additional magnets were installed and aligned in the waterfall area. The locations of the quadrupole support structures and alignment monuments were established in the tunnel.

The slow-kicker magnet system was used to send beam into the first Line D beam stop. The system can send either one beam pulse out of 120, or half the beam pulses to Line D while the remaining pulses go to Line A. The fast-kicker system has been assembled and operated at currents of up to 8000 A at 12-μs pulse widths into a surrogate fast-kicker magnet. The system has been tested satisfactorily at pulse rates up to 50 Hz. The actual kicker magnet should be available early in the quarter for further testing and tuning of the system. The development of the packaging of the system for installation in the switchyard is continuing.

Other Beam-Line Support

Alignment work was performed on Line B, on a large HRS magnet, and on the framework of the HRS spectrometer magnets.

Instrumentation

All of the remaining harp planes were wound and assembled early in the quarter. Storage boxes were designed and built to safely store and transport these delicate assemblies. One complete assembly was tested in the switchyard and performed well.

Seven beam-line phosphor and TV systems were installed in B and EPB as an interim measure. Parts for the final phosphor systems are being fabricated, and the assembly of nine detectors has started.

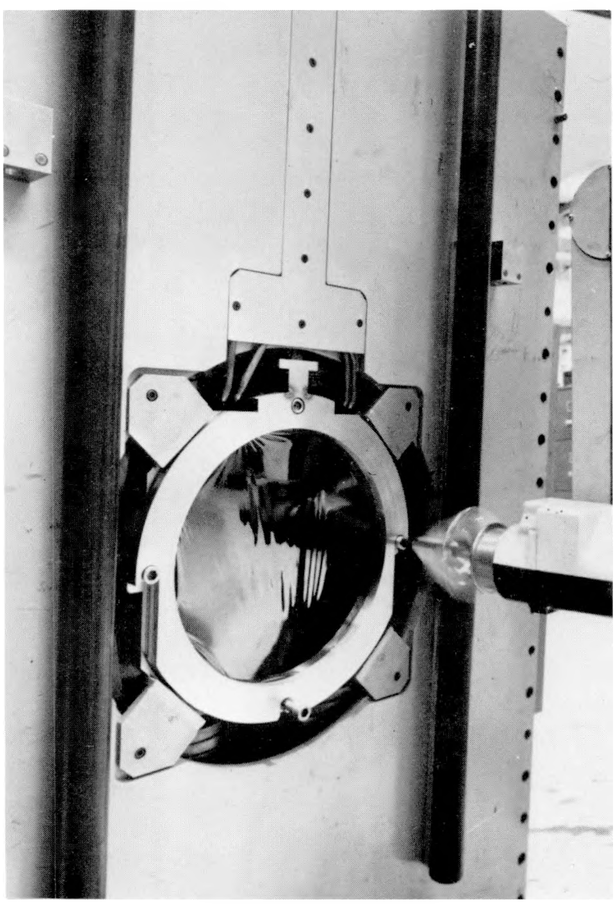

Fig. II-2.
Removal and replacement of the downstream window of the Biomedical beam line by remote handling.

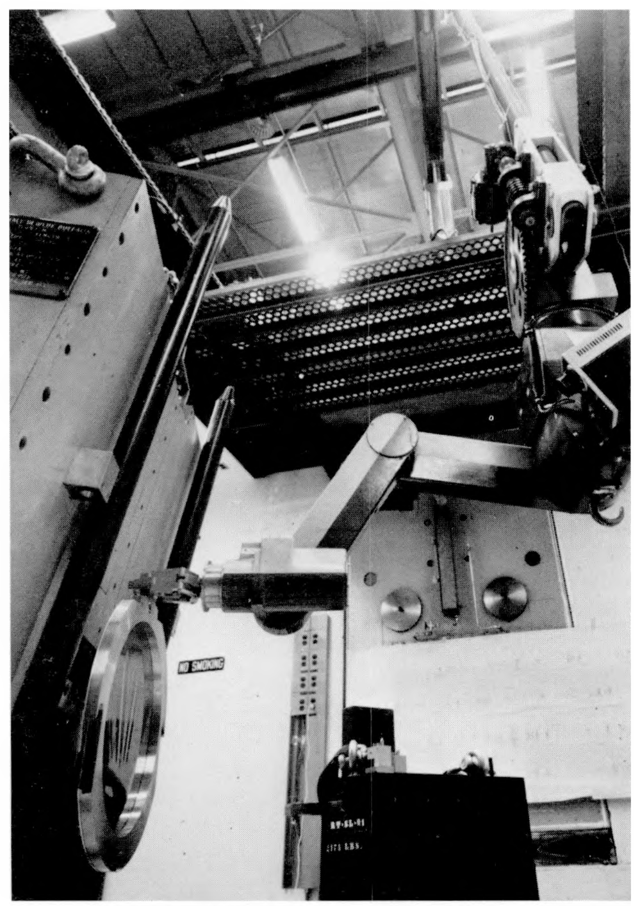

Fig. II-3.
Simulated remote-handling operations in the Biomedical beam line.

All of the Class I current monitors for Area A were built and tested. Rad-hard fiber glass cables for all the Area A current monitors and secondary-emission monitors were also built.

The design and fabrication of the hardware associated with the RM-16 Neutron Monitor System has been completed; 25 of these units are on hand and will be installed throughout the experimental area during the next quarter.

A preliminary design and cost estimate has been made for a low-momentum detector which will be used in the switchyard.

Electron Prototype Accelerator

Frequency measurements of all tank sections were completed, and some cells were retuned to provide the best average resonant frequency. The longer lead-time items for the accelerator structures (special seals, cooling pads, assembly studs, etc.) are on order or were received. Rebuilding activities of the accelerator structures were curtailed in order to provide additional manpower to complete the experimental areas during the shutdown.

The transformers for the 1.25-MW modulator were designed and cores have been ordered for the modulator.

Experiment Support

A temporary repair of the original coils of the Ames "C" magnet has been started to permit some of the earlier experiments (80/90) to proceed. A permanent solution has been designed, but cannot be implemented because of budgetary constraints. The fabrication of a target-chamber rotation pedestal is now 80% complete.

The vacuum chambers and associated equipment have been designed and purchased for Exp. 179. The scattering chamber has been installed and the magnet chamber is 90% complete. The support structure is being fabricated. Additional high-voltage plates and ceramic insulators have been fabricated for the detector assemblies.

The coils for the Bicentennial spectrometer magnet (Exp. 29/64) have been received and final assembly will commence as manpower becomes available. The main structure of the magnet stand is 90% complete and delivery is expected early next quarter. The remainder of the stand is being built at LASL. All packaged parts are on hand.

The scintillators on three sides of the counter assembly for Exp. 31 have been installed on their stands.

The mechanical assembly of the lift mechanism for the cryogenics target chamber for Exp. 2 is complete. The limit switches for the remote-control system are being installed.

The new aluminum mirrors for the large-aperture Cerenkov chamber for Exp. 130 have been completed and mounted. This chamber is now completely assembled, pressure-tested, and ready for the user.

Activities lists and experimental-arrangement drawings have been distributed for Exps. 42, 90, 176, 179, 192, and 193.

III. ACCELERATOR SUPPORT

201-MHz RF System

An average of 2018 h was accumulated on each of the 201.25-MHz rf stands during the quarter.

During this report period, four teardowns of the 7835 amplifiers were necessary. One teardown was for a fingerstock failure in the input section of the amplifier. Another was for a combined failure of the filament spring contacts and a fingerstock failure in the input section. The third teardown was for a filament-spring-contact failure, and the fourth for an apparent tube failure. The 7835 failed with ~4400 h of filament time. It is now at the test stand awaiting a gas check and will be returned to RCA for a "test, cut, and analysis" in the future. The failure closely approximated a previous failure that was caused by silver plating on the anode ceramic that caused flashover inside the tube.

One new and one rebuilt 7835 were received during the quarter. Negotiations have been renewed between Fermilab and Omini-Wave relative to developing a second 7835-rebuild source.

Problems with the cooling water for the rf tubes have become increasingly apparent during the quarter. These problems appear to be due to precipitates from water forming at certain critical points in the rf system, causing high current leakage, and a bad electrical contact in the case of the filament-spring contacts on the 7835. Some stopgap remedial actions have been taken but the problems still exist, and may be getting worse. A preventive maintenance program of cleaning water courses in tubes is being generated to preclude actual tube failures due to these problems.

The test piece of Belden-8871 high-voltage cable in module 1 has 2500 hvh on it and shows no evidence of failure. A rash of failures of this cable and its termination design were attributed to initial assembly problems. The 8871 cable shows the same susceptibility to corona damage as the RG218 cable. Since the 8871 is more delicate than the RG218, another terminating design for the RG218 will be tried in the future.

All of the 3500-mm Rexolite vacuum barriers on the drift-tube tanks have logged over 2200 h of running time with no failures.

The loss, in one day, of three epoxy-encapsulated transformers prompted an effort to design an oil transformer to replace at least one type of the remaining three types of epoxy transformers.

A great deal of progress was made by crafts personnel on the 201-MHz test stand. The work is expected to be finished within the next two weeks. The test stand will be available for 7835 gas checks and pumping early next quarter; it should be ready for rf by the first of the year.

805-MHz RF System

A large portion of time this quarter was spent on maintenance work and periodic inspections. A "fail-safe" capacitor room cooling system has been installed in Sector H and will be evaluated until the next major shutdown. The drawing of system-wiring diagrams, as an aid to troubleshooting, is 70% complete.

The test of RG218 high-voltage cable has been completed. Plastoid Co. cable showed the greatest life under the 40-kV ac breakdown test. The Belden-8871 high-voltage cable under life test at ETL has 6190 hvh and 4799-h drawing current.

The responsibility for the Δt maintenance was assumed by the 805 rf section during October. Currently, the prints are being updated and components are being identified.

Low-Level RF System

Two 8501 tubes, both with less than 2000 h, failed in the source room during this quarter. An investigation of past 8501 failures indicated that tube life varied from 1200 to 7000 h, and the usual mode of failure was a grid-to-cathode short. Closer examination of the available failed tubes revealed hairline cracks in the ceramic between plate and screen. Temperature measurements of the ceramic will be made. If this is a heating problem, a modification of the air-flow system will be required. The problem is under discussion with RCA.

A spare air compressor was added to the master drive-line system. This compressor will be valved on-line automatically if the main compressor faults.

Installation of 201-MHz timing signals, in those experimental areas where requested, has been completed.

Phase-and-Amplitude Control System

The phase-and-amplitude section personnel continued their support of normal accelerator operations by routine repair of phase-and-amplitude components. Since phase-subsystem problems are becoming increasingly common, we have instituted a more thorough system of repair for these units. New drive assemblies have been purchased and are being installed in every unit returned for repair, which should reduce sticking and hysteresis problems. The installation of an additional attenuator in several systems has resulted in improved linearity, and this modification is being included wherever necessary.

Support has also been given to the building of the new H^+ buncher. Three new 201-MHz fast-phase shifters have been built and checked out. One of these phase shifters will be used in the new buncher. A new buncher-interrupt panel, which is identical to the one presently operating in the main buncher, has been built for the H^+ buncher. An additional panel has also been built for the H^- buncher.

The reference-line temperature-controller interlock system has been in operation for three months without any failures. It has therefore been assigned a unit number and is now under the same configuration control as other units in the accelerator. A spare panel and spare PC cards have also been fabricated and are available.

Efforts have been made to monitor the phase relationships between the 201- and 805-MHz reference line by installing a monitor system in the source room. Modifications to improve the stability of the electronics in the phase-monitor system should aid in the correlation studies which are in progress.

Power Supplies

The modification program on existing power supply systems and the installation of new power supply and by-pass shunt systems have been the major activities of the power supply section.

Modification and installation were completed on one Acme and five Ling power supplies on the EPICS line. Work is now complete on EPICS power supplies; all units have been tested and one is operational.

Five Acme power supplies on the P^3 line, and one Acme and one Ling power supply on the SMC line, have been modified and tested. Modification is complete on all Line B and Line C power supplies that drive bending magnets, except the LC-BM-03 magnet. Two Acme power supplies on LEP bending magnets, and two Ling power supplies on target cell 1A, have been modified but have not been checked out. Modifications to 10 Acme power supplies in the Line C twister section have also been made. Two of these units have yet to be checked out.

Two Christie power supplies, four E/M power supplies, and eighteen Transrex power supplies have been installed in Line D.

Three Transrex power supplies were installed and checked out in the SMC. These units replace two troublesome dual-Acme power supplies and one Magnetics air-cooled power supply. With the installation of the three new units, the complete rearrangement of the SMC power supplies is well under way. The planned changeover to the LAMPF standard regulator system in the dual-Acme power supplies is being prototyped on one of the removed dual-Acme units.

The design of the ground-fault detectors has been modified for a second time. The detectors will now operate if there is a ground that produces high fault currents and will not self-destruct when subjected to a fault current. The lower current trip point is ~0.8A, which is only slightly higher than that of the first design modification.

The by-pass shunt system for EPICS bending magnets BM-01-04 has been completed. NMR measurements at full field show that more by-pass current capability is needed than was originally requested and for which the by-pass shunts were designed. A fixed by-pass resistor and a lower-value collector resistor have been installed to increase the current capability, but it has not yet been checked. The new by-pass shunt system for the Line A, Line X magnets is being preassembled in new racks and is 75% complete.

Beam Diagnostics

The activities of the beam-diagnostics section during the last quarter have been essentially in three areas: 1) routine maintenance and repair of beam-diagnostics equipment, 2) organization and maintenance activities and procurement of spare equipment, and 3) testing, development, and fabrication of beam-diagnostics equipment.

Linear actuators with mechanical problems (bent shaft, worn bearings, etc.) were repaired, all 805 wire-scanner amplifier modules were checked out and recalibrated, linear-actuator driver modules were repaired, and minor repairs were made to the emittance chassis.

The procurement of spare parts was continued. The stocking of the equipment cages with spares, drawings, and tools was also continued during the quarter.

Testing, development, and fabrication activities during this quarter included the following:

1. The new absorber/collector devices installed during the Great Shutdown did not operate properly. Extensive testing showed that the problem was associated with the collectors. New collectors were installed on all devices.

2. The wire scanners in module 5 are being tested at this time to determine the reason for apparent differences in signal amplitude between the scanners.
3. A new control chassis for the 121-MeV absorber/collector device was fabricated and installed.
4. New harp boards (ceramic boards with carbon wire) were fabricated during the quarter. They will be installed and tested during the next quarter.
5. The rest (10) of the bias supplies for biasing the devices were fabricated and installed.
6. New control cables for the devices in the transition region were fabricated and installed.
7. A water-cooled collector for emittance station No. 2 was assembled.
8. The design of an ac connector bracket for the device-control bins was completed. Fabrication and installation of the brackets on all control bins will begin during the next quarter.
9. The design of a new sample-and-hold system using the fast-wire-scanner amplifier was initiated during the quarter. Tests are being conducted at this time on the signal wiring system associated with the sample-and-hold system.
10. An improved transient-suppression circuit was installed in all ten 805 wire-scanner driver modules.

Vacuum Systems

General

With the exception of Areas A and B, vacuum support for the accelerator was moderate and fell into the routine maintenance category. A few defective ion pumps on the 805 vacuum were replaced; a few modules were let up for beam-diagnostic-device maintenance; two valves had to be worked on; and several leaks were found and repaired.

Area A

Time was available for moderate to heavy support of the reassembly work going on in Area A this report period. The support consisted mostly of fabrication and leak-checking of components both on site and in vendor shops.

Area B

The vacuum section rendered considerable support to Exps. 192, 179, 176, 42, and 241 in installation work, modification and relocation of the hydrogen vent system, modification to the nuclear chemistry cave vacuum system, and installation of several pieces of diagnostic equipment.

Mechanical Support

Despite low priority and continued delays, work has been progressing on the two new 4664 cavities. Two cabinets for the tubes and cavities have been completed; the 4664 cavities were fabricated, but require modifications.

Modifications have been made to help eliminate air from the A-01 cooling system for modules 1-4. Air vents have been installed, and a new procedure for turn-on is in use. A large, new air separator for the pump room has been ordered and will be installed by ENG-4. It is hoped this will eliminate some of the corrosion problems in the 7835 and 4616 amplifier systems.

Support for MP-10 has increased this quarter and will continue into next quarter. A new personnel platform for HRS has been designed and is being fabricated at LASL. Various special components for the HRS cooling system have been procured, or designed and fabricated.

Spares for beam-diagnostics equipment are being fabricated in LASL branch shops. This has been another low-priority item and consequently does not show the progress desired.

IV. ACCELERATOR SYSTEMS DEVELOPMENT

Beam Dynamics

201-MHz-Linac Field Distribution

Continued progress was made in the various aspects of achieving an understanding of the 201-MHz-linac field distribution. The first problem involved removing base-line effects from the bead-pull field-distribution measurement data. This reduction is complicated by the fact that a simple point-by-point subtraction of the base-line signature from the measured data is not possible. Unfortunately, the amount of offset required for a good match varies with time during the duration of the measurement (the string speed had variations during the field or signature measurements). An analysis program was developed which performs the signature matching and correction on a peak-by-peak basis with a minimum of interaction by the program user. The program also corrects for long-term base-line drift before making peak-height and integrated-field estimates. These reduction steps were completed for the end-cell adjustment data.

The next step was to estimate the remaining errors in the data and remove them if possible. Extensive analysis was made of the effect introduced by the bead size; it now apears that the effect is ≤1% for the bead sizes (up to 0.5-cm diam) used. It was also shown, at least for the central cells in the first tank, that the field shape is not a function of tank-field tilt, bead size, or tuning-slug position; i.e., the shape remains symmetric. This suggests that the axial-field integral could be inferred from the peak axial field, assuming the bead is on axis. This would be an advantage since the signal-to-noise ratio of the measurement is highest at the peak. Therefore, theoretical fields were generated using the LALA code. At this point, unresolved difficulties with both the experimental and the LALA results leave discrepancies of about 5% between the two methods, with somewhat better agreement between the relative fields.

Finally, PARMILA calculations were made to investigate the effects of end-cell perturbations and field-distribution errors on the beam dynamics through the first tank. A number of experiments were modeled to define a set of measurements which, when performed on the actual linac, would verify the model. These experiments will involve measuring various characteristics of the phase-energy longitudinal-phase space, such as amplitude cut-offs and phase widths, at various field tilts and injection energies. When the model is verified, then a tuning-optimization scheme for the 201-MHz linac can be pursued.

Some preliminary experiments were completed, which measured the acceptance of Tank 1 for the existing field distribution and determined the necessary buncher settings and other calibration factors.

201-MHz-Linac Horizontal Oscillations

Measurements were made using the prototype beam-position monitors to determine the character of the small (<4 mm) transverse beam oscillations observed primarily in the horizontal plane in the beam after passage through the 201-MHz linac. The basic character is that of an amplitude-modulated sine wave with a carrier frequency of 10.0-10.5 Hz. There is also some frequency modulation. There is a characteristic amplitude modulation at frequencies in the 0.5- to 2.0-Hz range, and larger amplitude modulations at 0.5 to 1.5 min per cycle. It is suspected that even slower patterns may be present since the effects are more noticeable on some days than on others. The relative phasing of the H^+ and H^- oscillations was observed at several points between 100 and 211 MeV. There was a tendency toward maintaining a phase relationship, but a different one at each location and with considerable scatter. The phasing changes rapidly within ±45°, and occasionally slips 90° or 180°. This situation is not conducive to good control with a single magnet, although some net improvement might be possible. Further investigation will be made when position monitors are available at the 40- and 70-MeV locations in the 201-MHz linac.

100-MeV Emittance

An estimate of the longitudinal emittance at 100 MeV was made using a 1.6-mA peak-current H^+ beam. The procedure involved measuring the phase spread of the beam at the entrance to the 805-MHz linac as a function of bucket-rotator amplitude. The phase spread was measured by scanning the beam across the left edge of the acceptance bucket of modules 5 and 6 and measuring the amount of accelerated beam on the collector following module 6.

The emittance estimate was made by fitting the phase spreads (resulting from different bucket-rotator amplitudes) to ellipse parameters representing the beam at the exit of the 201-MHz linac. Some resultant emittance ellipses are shown in Fig. IV-1. These emittance contours were obtained by fitting the phase spreads containing 50, 80, 90, and 95% of

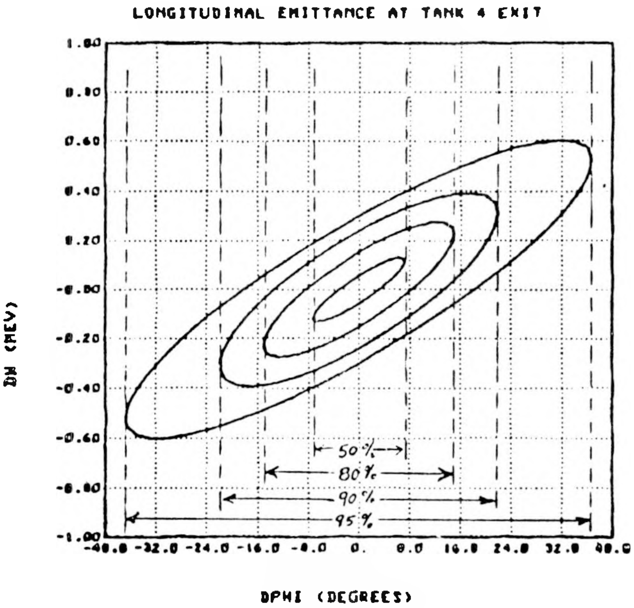

Fig. IV-1.
Estimated emittance ellipses obtained by fitting the phase spreads containing 50, 80, 90, and 95% of the beam.

the beam. The ellipses themselves do not contain these percentages of the beam, but have the same phase spread (or energy spread) as the specified percentages.

The estimate obtained for the 1.6-mA H^+ longitudinal emittance has a similar orientation to the H^- emittance measured in December 1974, although the H^+ emittance is smaller than the H^- emittance. Both estimates show converging beams that should be fairly well matched to the acceptance of the 805-MHz linac without using the bucket rotator.

Transverse Matching

Studies were started on achieving a good transverse match for the H^- beam in the transition region and the 805-MHz linac.

Linac Alignment

An alignment data base[1] has been established on disk in the CCR computer which contains the alignment data for all accelerator components which have been measured. So far 866 entries have been made, each entry consisting of the device name, the date when measured, the three-dimensional coordinates in the LAMPF coordinate system, the coordinates of a smooth curve at the same longitudinal point, and the names and positions of the nearest wall and floor monuments. A program has been prepared which allows for additions and corrections and for listings of the data base to be made. The data base is now available for rapid and flexible call-up to aid beam-steering codes. Some of the information has already been incorporated, such as wire-scanner beam-box locations in the wire-scanner plot routines.

Long-Term Stability Development

Software Development and Data Monitoring

The development of software for long-term accelerator-stability analysis is continuing. Several current efforts were in support of the program to better understand module-to-module phase changes, but have potential application in other areas as well. These included a modification of the data-scan program to do some filtering, the incorporation in the scanner of means to save the most recent data on an "endless belt," and the development of a program to plot the difference between current values and last-recorded values of a set of parameters. The "endless-belt" file contains data taken at more frequent intervals than the data recorded for the long-term stability studies; information for the previous hour will be available. A subroutine to extract specified pieces of data from the "endless-belt" file has been written and tested. Figure IV-2 shows a representative format for a data channel from numerous modules plotted from either the "endless-belt" past-hour file or the long-term file.

Figure IV-3 shows a format for displaying many signals for one module from the long-term file, so that cause-and-effect relationships can be studied. The general format is flexible and may be conveniently changed for different investigations.

A table-driven stability-study plotting program developed previously for another application has proved useful in checking out the new beam-position monitors.

Sensitivity to Structure Resonance

A series of measurements were made to obtain data from several 805-MHz modules on the sensitivity of the longitudinal coordinates indicated by the Δt measurement to deviations from structure resonance. Such deviations cause stop-band opening and consequent changes in tank field distributions. The cooling-water control system was

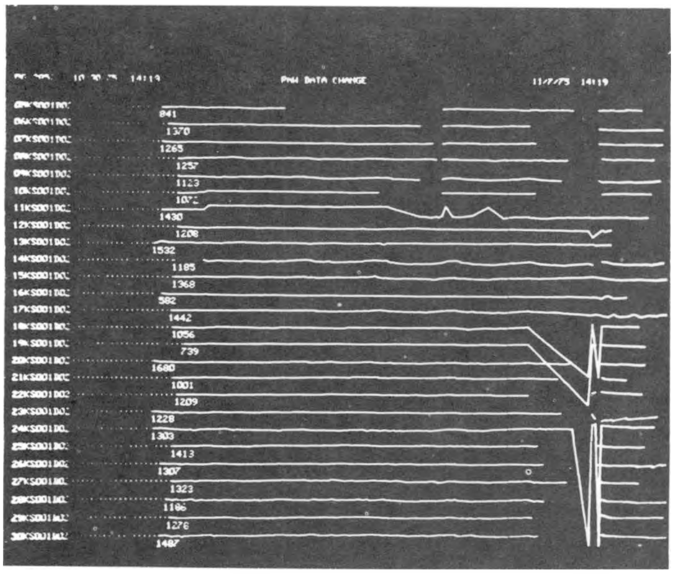

Fig. IV-2.
Display format for similar data from numerous modules, plotted from past-hour "endless-belt" file or long-term stability file.

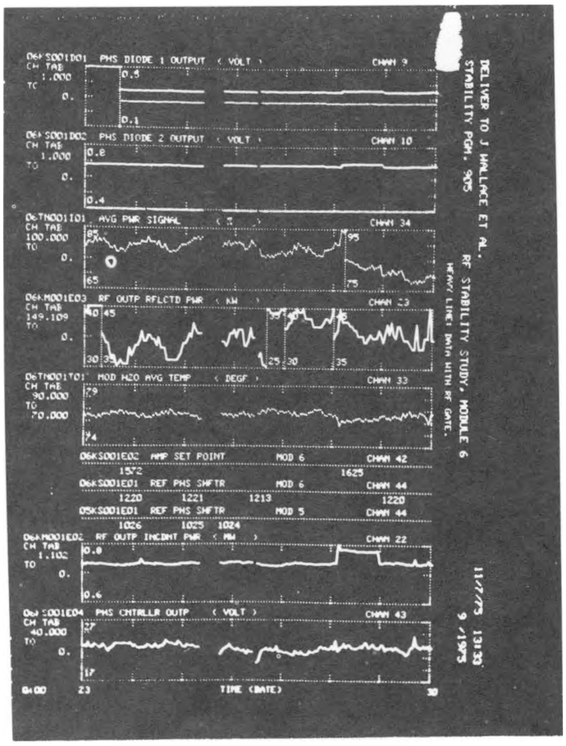

Fig. IV-3.
Display format for many signals from one module, plotted from the long-term stability file.

varied to move the module through resonance. As expected from previous tuning work, modules have individual characteristics and some are quite sensitive. Further analysis is required.

Operations-Support Development

Operations/Maintenance Data Base. Support continued, with no significant development work this quarter.

Experimental-Schedule Data Base. Modifications were made to the features for experiment phase accounting. Special retrievals included a listing of spokesmen and institutes for experiments run to date.

Visitors Center Data Base. Personnel training was completed in the use of the System 2000. Special retrievals included the number of visitors of various types during the quarter, the degree-level of all users currently on-site, and the number of post-doctoral personnel and graduate students on-site during the 1974 production period.

Outside-Contracts Data Base. Programming and training were essentially completed except for one problem which will require the next version of the System 2000 Report Writer scheduled for delivery next quarter. The data base is in production use.

Users Group, Inc. Data Base. A major amount of work was completed in transferring this data base to System 2000. Several retrieval programs were written, and the system was basically operational in time to be of use in preparations for the November Users Group meeting.

Bibliographic Data Base. Work continued, concentrating on the abstracting of progress reports, training, and development of editing procedures.

Diagnostic-Equipment Development

Beam-Position Monitors

The effort to provide beam-position information was accelerated this quarter to determine the best performance achievable with the existing hardware, with a minimum of changes and cost. Investigations also continued on alternate methods.

The performance of the existing hardware continues to be encouraging. Several experiments, using actual beam, verified necessary gain and other calibration constants. Lab testing has clarified some of the tuning interactions and, most important, has indicated a procedure for calibration of the device without the necessity of removing it from the beam line. A simpler circuit also results since the tuned circuits previously installed at the loop-pickup device will not be used. This results in a smaller signal, but less tuning crosstalk and thus easier tuning. The cables leading to the detector electronics are cut to an optimum length. The temperature-control prototypes operated with no failures during the quarter, and stability data showed satisfactory zero-offset behavior. Preparations were made for gathering stability data with rf signals fed to the diodes.

Phase-Scan Hardware

The new phase-scan gear was checked out and it was found that the collector plates were too thin for all but the 5-MeV station. New collector plates were installed, with maximum thickness allowed without extensive remachining. This resulted in collectors which are sufficiently thick to obtain phase-scan data, but still slightly small for stopping the beam completely. The electronic biasing scheme was checked against a "pure battery" bias scheme; no difference was noted.

Wire-Scanner Hardware

Wire-scanner anomalies seen at module 5 have been investigated with little success. The differences in the "effective gains" of the 5-2, 5-3, and 5-4 wire scanners have not been explained. Electronic-gain problems, energy effects, individual wire-scanner peculiarities, and the effect of a harp in the same beam box were investigated. The effect of biasing the wires was also studied. The only usable scheme is to have both wires with the same polarity; otherwise, what happens on one wire affects the other. The benefits of biasing the wire scanners at 100-120 MeV are not sufficiently great to recommend that bias supplies be used.

Linac Harps and Emittance Hardware

An experiment to determine the source of noise on the 201 harps and EM gear was started. It appears that the noise may be due to the total capacitance of all wires connected to the sample-hold chassis. The noise is independent of presence of beam in the linac. Data on the gain ranges desired in the TR were taken.

Bead-Pull Apparatus

A portable and inexpensive control panel which can be used with the NAL microprocessor crate has been designed. The associated software is ~85% complete. This crate will probably be the heart of the new bead-pull hardware.

Steering-Magnet Bandwidth

Bandwidths of the module-3-type and 805-MHz-type steering magnets were measured to see if they might be usable for feedback correction of the horizontal beam oscillation.

Δt Hardware

Extensive rechecks of accuracy were made at the Δt racks, and new tests were made from modules 20, 32, and 44. No errors were found in any measurement $\gtrsim 1.25°$.

New amplifiers were installed in the Δt racks for evaluation. The amplifiers tested very well on the bench, but oscillations developed after about two weeks in the Δt rack. This problem is being investigated.

The rf amplifiers were removed from the fast phase shifters in the Δt system to evaluate Δt performance without them. Operation appears to be satisfactory.

Low-Momentum Phosphor

During recent months, use has been made of the low-momentum phosphors in Lines X and A-South during tune-up. The information from these detectors can identify beam which is not captured in the longitudinal acceptance of the side-coupled linac and modules in which H^- beam is being stripped. The phosphorescent material currently used on this device lacks uniform luminosity and is easily radiation-damaged. A study of six phosphor samples was made to find a more suitable material. A chromium-doped aluminum oxide substrate produces twice the luminosity of the presently used material; no perceptible radiation damage during the test exposures was apparent. This material will be adopted for the low-momentum phosphor, and pending further tests may be adopted for all switchyard-tuning phosphors.

Injector Instrumentation

A new injector bouncer controller was designed and evaluated. Parameters used for control included a proportional signal from the wall-plate capacitor, its integral, and a rate signal from the compensated leg. It was found that a combination of all these signals gave optimum control of the transients. The bouncer output can also be clamped between beam pulses.

A 5-kHz active filter was designed and installed at various places in the injector controller in an attempt to eliminate the extraneous 5-kHz signals.

A 5-kHz oscillator locked to the 201 rf gate and the line frequency was designed, installed, and made operational. It was retuned one time, after adjustments were made in gain and balance of the output tubes, and has worked very well.

Code Development

PARMILA Rewrite

The PARMILA program, the primary code used for studying particle dynamics in the drift-tube linac, has been restructured to make the program more versatile for studying other linac configurations as well as for studying the dynamics of LAMPF. In particular, the linac parameters can now be modified by an external program which in turn can drive the dynamics section of PARMILA. This will facilitate multiparameter search schemes for optimizing beam quality.

Control-Computer Preprocessor

A preprocessor which translates from structured programming control forms to assembly language (or to FORTRAN) for the control computer has been updated. The preprocessor, which runs under KRONOS at the main computer center at LASL, now includes facilities for definition and use of general-program blocks using long identifier names. (Long identifiers are reduced to their acronyms for machine purposes.) The capability of developing programs in top-down sequence with top-level portions in language very near plain English has proved to be a great help in writing special-purpose data scanners and other programs with complex logical structures. In addition, the listings of structured programs with long identifiers provide more complete and understandable documentation than do normal FORTRAN or assembly language listings.

Collaborative Programs

EPICS Beam Separator

The electronic system to drive the EPICS beam separator is now essentially complete and was used to operate the separator during the alpha test that was conducted during this quarter. The separator voltage was set to a level which provided an impulse to the alpha beam 10 times in excess of that given to 300-MeV pions. The crossed magnetic field was therefore also boosted by a factor of 10. Any field perturbations were therefore amplified greatly in the resulting momentum spectrum. No significant disturbance was seen attributable to the separator fields—precisely the effect desired.

Voltage drift during the tests prompted the design and installation of a 0.1% voltage regulator based on an approximation for the Cockcroft-Walton and load of a 2-s time-constant first-order lag. This regulator considerably improves operation of the system. Some difficulty has been experienced with the phase servo that keeps the system on resonance.

Peripheral work on the separator has continued toward complete installation. The rails for removing the unit have been installed and the lifting brackets welded onto the door. Alignment pins have been permanently attached to the box and door to facilitate removal and replacement of the separator unit. The SF_6 pressurization system has been completed and functions properly. The N_2 slow-leak valve and stepping motor have been installed and all gas lines connected. Safety lights and valve circuits were installed.

The system is now ready for more high-voltage testing, with a great deal of interest focusing on the potential benefits of the biasing electrode.

Biomed Pion Range Shifter

The 7460-W hydraulic power supply was completed during this quarter and tested to complete satisfaction. It functions between 400 and 600 psi and automatically cycles through the use of a pressure switch operating off the outlet part of an accumulator. A photo of the unit is shown in Fig. IV-4.

The range shifter itself is now complete and installed in the treatment room. Internal wiring has been finished and an umbilical cord attaches the unit to an electronics rack composed of a dc servocontroller to operate the servovalve, a patch panel, and a homemade analog computer which will be used to close feedback loops. The installation and electronics are shown in Fig. IV-5.

Initial testing has begun on the system using bottled nitrogen. When some operating confidence has been gained and various leaks repaired, hydraulic oil will be used for testing.

The range-shifter and jib-boom assembly is shown in Figs. IV-6-7.

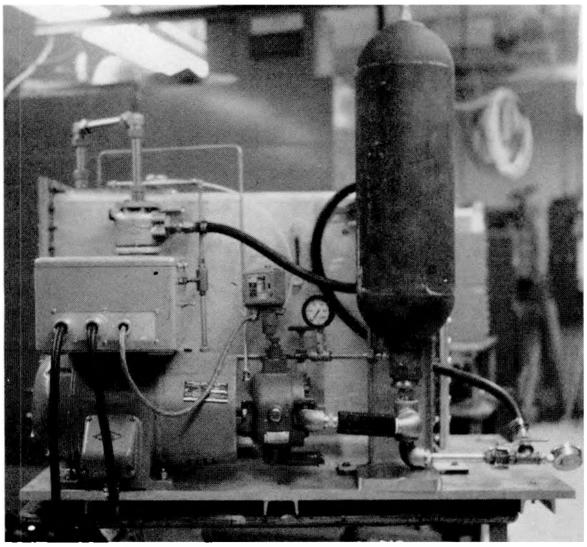

Fig. IV-4.
Hydraulic power supply for biomed pion range shifter.

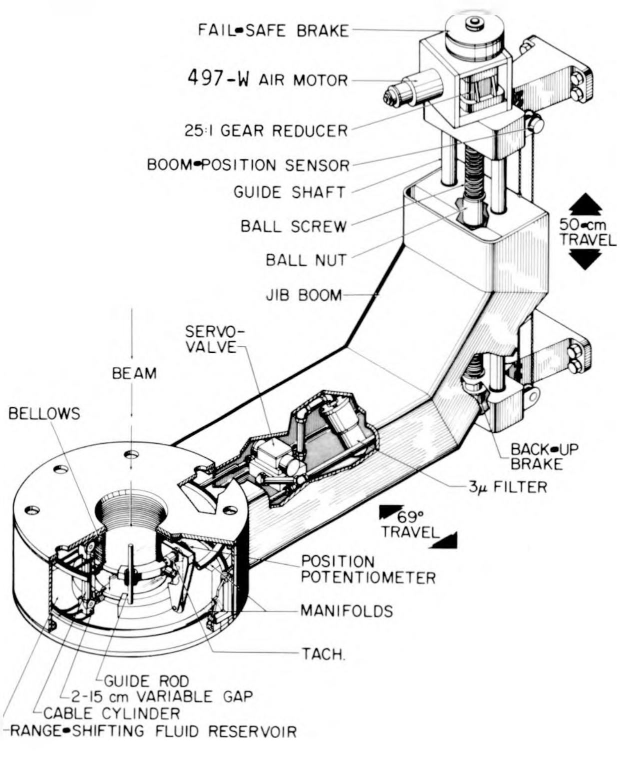

Fig. IV-6.
Biomedical range-shifter and jib-boom drive.

REFERENCE

1. D. Liska, J. Stovall, private communication.

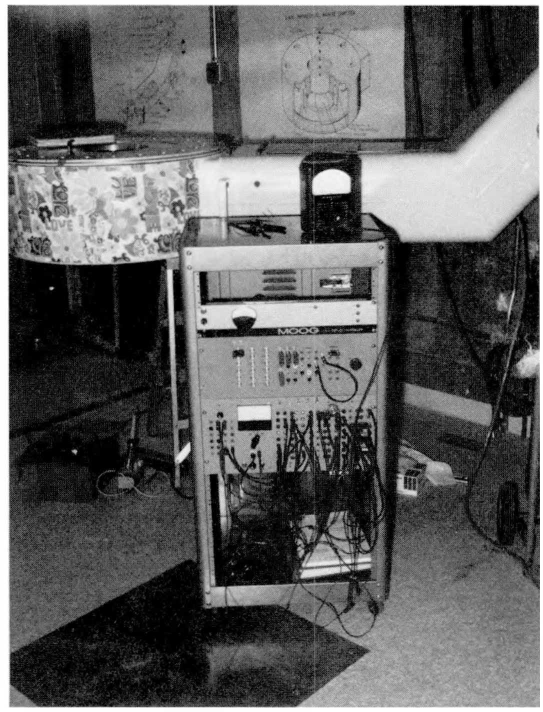

Fig. IV-5.
Assembled range-shifter and jib-boom assembly and associated control electronics.

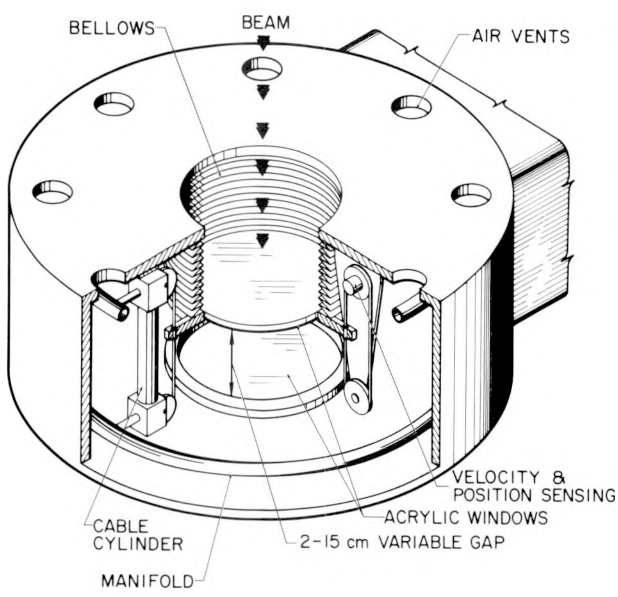

Fig. IV-7.
Functional characteristics of range shifters.

V. INJECTOR SYSTEMS

H^+ Ion Source

During the past quarter, the H^+ ion source system has been used for accelerator-development tests in preparation for on-line operation at the end of this year. Some high duty factor operation has been carried out without difficulty, but most long-term tests to date have still employed low repetition rates.

There are three high-voltage rectifiers that need to be replaced. These rectifiers were shipped at the end of October and will be installed in November, before on-line operation starts.

There have been some problems with component reliability in the new fast-protect channels that have been installed for high-power operation of the H^+ injector. These problems have been resolved. In order to achieve greater reliability, a separate wall-plate capacitor is being installed in the H^+ Faraday cage in order to separate control functions and fast-protect sensing channels. The new wall plate will provide redundancy in sensing faults in injector operation.

The work in providing feedback control systems for the H^+ ion source has continued. Tests have been started using a filament controller which will provide the capability of maintaining a constant filament temperature. A hydrogen pressure controller is now being procured and will be used to maintain constant chamber pressure. Present experience indicates that closed-loop control of filament temperature and chamber pressure together with the existing arc-current damping system should provide required stability of the extracted ion beam under varying duty factor conditions anticipated in LAMPF operations.

H^- Ion Source

The H^- ion source continues to perform well and the necessary production beam for LAMPF operations has been derived from it.

A new anode aperture with a molybdenum insert has been used this past quarter, with no apparent change in ion source performance. An examination of this aperture will be carried out as soon as current operation closes.

Some difficulty from component failure has been encountered in the operation of a slow-protect relay system in the arc-pulse modulator. This relay protection was installed recently to turn off the modulator when crowbars occurred in the beam-pulser power supply and thus prevent damage to the ion source from such faults. A temporary solution with reasonable component lifetime has been found, but further development is still needed.

The computer control problems now appear to be limited to spurious trips at high duty factor operation. Work is still continuing in isolating extraneous ground loops and desensitizing binary command channels.

The tuning of the H^- beam-transport lines was changed in order to provide better transmission through the prebuncher which was added to this beam line during the shutdown. Work is still in progress to complete the installation of the rf systems for this prebuncher.

Polarized Ion Source

The C-W 850-kV power supply and ion source terminal have been received at LASL and assembly of this system is now under way. Modifications to the I-beam floor supports to accept the mounting plate were carried out. The high-voltage ion source terminal is now being erected and installation of the remaining power supply systems has started. Some mechanical damage to the control-system electronics occurred during transit but was not serious.

Mechanical construction and testing of some of the components of the polarized ion source have been resumed. The duoplasmatron is being assembled and will be installed on the old H^- ion source test stand. This test stand is now set up in the new polarized ion source laboratory. This laboratory, which was completed last summer at the same time as the shielded enclosure for the C-W generator, will provide the facility for building and testing the polarized ion source. Work has also started on a newly designed cesium cell which will produce a larger diameter beam of H(2S) atoms. It is anticipated that this cesium cell will be tested on the P-9 polarized ion source before final design of the LAMPF source.

Most of the commercial power supplies for the source are now on hand. Wiring has begun on the duoplasmatron arc-pulser power supply and on the rack wiring for the computer-control interface modules.

The parts for the source gas-control systems (hydrogen and argon) are on hand and the systems are being assembled. Tests of the efficiency of the argon-cryopump system are continuing at the LASL Van de Graaff laboratory using the helium-cycle refrigerator and argon cell which will be installed ultimately in the LAMPF polarized source.

Drawings of the polarized source are now about half completed; the remainder should be finished by the end of the year. At that time, drafting effort will turn to design of the polarized source support systems (vacuum, mechanical housings, etc.) and to the design of Injector C beam-transport line.

Design of the cesium-cell region and the rapid-spin-reversal region of the polarized source has not been finalized. The duoplasmatron/cesium-region design is dependent upon the previously mentioned testing, while the rapid-reversal region planned for use in the parity violation experiment is still undergoing development and testing.

Low-Intensity Beam-Current Monitors

The nonintercepting type of beam monitors used at LAMPF were designed to operate at beam levels greater than a few microamperes. Since the Lamb-shift polarized source for LAMPF will probably initially operate at the hundreds-of-nanoampere level, the present type of beam monitor will not provide a sufficiently accurate measurement of beam current.

To provide measurement capabilities at the lower beam levels, an investigation is being carried out utilizing a modification of the nonintercepting monitor reported by Steiner *et al.*[1] Several versions have been benchtested with encouraging results. Pulsed-current levels down to 20 nA have been measured with an accuracy of 5%.

A testing area is being set up in the H^+-injector beam-transport area for checking the accuracy of this type monitor against that of a total-charge-collecting fast-Faraday cup.

High-Intensity H^- Ion Source Program

Two ion source designs are being pursued by P-11/MP-12 personnel. A surface-emission ion source based on the Dubnikov design is under construction; and a charge-exchange source, based on the Osher design, is now under test. An H^- current of 5-10 mA was obtained in the early operation of this Osher source at 100% duty factor, and recent operating experience has indicated that long-term reliability would probably be good although lifetime tests have not yet been carried out. Measurements were recently made of the molecular ion-species fractions, and it was found that the primary ion beam was typically 10/60/30 for the $H^+/H_2^+/H_3^+$ components. As with the LAMPF H^- source, the conversion of molecular ions to H^- involves an emittance degradation and an energy spread which could be significant. Future measurements pertinent to possible LAMPF use include: pulsing, tests of cesium-consumption rate, and performance under continuous operation for long periods of time.

The Dubnikov source will be built at the former P-12 cyclotron area. Preparation of this lab has begun. Design of the source is now under way, and some parts of the test stand are completed. Most of the commercial hardware (pumps, electronics, etc.) has been ordered or is on hand.

The arc will be pulsed by a transistor pulser now being built. It will be capable of delivering 300-V/200-A pulses at a 6% duty factor. A prototype was built and operated at 210 V/35 A at 6% duty factor on a resistive load. It was also used on the LAMPF ion source test stand briefly. The pulser being built now uses high-voltage transistors, in parallel. The transistor design has the advantages of simplicity and flexibility over the present LAMPF SCR design and may be attractive for use at LAMPF to provide time modulation of the macropulse.

Due to high instantaneous gas flow in the Dubnikov source, it is desirable to pulse the gas flow. A rotating-wheel gas-flow pulser is now being built. Flow rates of the order of 100 cm^3/min will be produced for 1 ms at 120 Hz with substantially constant flow for a 500-μs time interval.

A high-voltage regulator for this ion source is being built with two objectives: regulation of accelerating potential to 0.1% or better, and surge-limiting protection during sparkdown. Parts for such a system capable of handling 50-kV/ 4-A pulses at 6% duty factor are either on hand or have been ordered.

Cockcroft-Walton Generators

Work has continued on preparing the H^+ C-W generator for on-line operation at the end of this year. The slow-stabilizer circuits were completely checked out and set up for optimum performance. Waveforms and operating parameters have been recorded and procedures for routinely checking operation of the generator have been established. There are still some problems in distortion in the oscillator-modulator circuits, particularly when the new phase-locked 5-kHz oscillator is used. These problems have only minimal effect on voltage stability, but are being pursued to improve the general operation of the system.

Particular attention has been directed towards studying different modes of operation of the fast stabilizer or bouncer system. Several different control cards have been built and tests have been carried out using several feedback systems and beam-gate clamping to investigate bouncer performance. The results of these tests indicate that a control board using rate and proportional feedback to provide a flat voltage droop of 200 to 300 V is the simplest and most reliable system and is consistent with linac beam requirements.

The series tube in the bouncer failed after almost a year of operation. A new ML-7668 switching tube with an improved "getter" system was installed in the series-tube position. It is believed that this new tube with increased getter material will provide substantially longer lifetime. Plans have also been made to try an ML-8495 in the series-tube position. This tube is a larger, more rugged design and is used on all the 805-MHz modulators at LAMPF. Its lifetime in this application is known to be three times that of the ML-7668, and should have even longer lifetime in the bouncer application. Its larger physical size will require some mounting modifications inside the high-voltage oil tank before it can be tested.

An additional wall-plate capacitor has been mounted on the H^+ Faraday cage in order to provide redundancy for operation of the bouncer-control circuits and the dome-voltage fast-protect circuits. The original motivation for this installation was to separate the control function and the fast-protect function, but subsequent work has resolved the component-failure problem that led to this separation. The additional wall plate will be used for equipment protection during arc-down faults and to provide redundant information on the dome-voltage status in order to guarantee voltage stability.

The accelerating-tube fast-protect circuits are now functioning properly although there has been an amplifier-drift problem in the electron-trap fast-protect system which monitors beam impingement at the end of the accelerating tube.

The general operation of the H^+ C-W generator at high duty factor operation is now being investigated. Beam tests have been carried out at 1% duty at 18-mA peak current for several hours with no faults, and for eight hours with several crowbars. At 6% duty factor, short beam tests at 18-mA peak have been carried out up to 15 min with no faults. Long-term beam tests at 6% duty factor will be carried out after the final modifications to the bouncer system have been completed and the remaining defective diodes in the C-W rectifier stack have been replaced.

The H^- C-W generator has been on-line this quarter and the only operating fault during this time was due to oscillator-tube failure.

The redundant voltage-monitoring system continues to provide the capability of checking and guaranteeing the voltage stability of both injectors. By using the first tank in the linac as an energy analyzer, the energy of the H^+ and H^- beams can be accurately compared and thus the relative C-W calibrations determined. Since the generators and their calibrations are completely independent, agreement of the beam energies is essentially tantamount to absolute energy determination.

Injector Beam Development

Several linac experiments involving the injectors were carried out during machine development periods this quarter. Beam-transport studies, for matching dual beams, and transport-setup studies for operating with different energy beams from 720 kV to 780 kV, have been carried out.

A rather detailed experiment was conducted this quarter to study the effects of injector energy variations on linac beams with the aim of establishing tolerances to be placed on injector high-voltage systems. This experiment observed both transverse and longitudinal properties of linac beams at various portions of the accelerator as both the dc level and transient waveform of the injector high voltage were varied for beam conditions in the linac that will be used for 100-μA average beams. Permanent apertures installed at the end of the injector beam-transport line limit the voltage excursion possible, without significant loss of injected beam to the linac, to ± 1 kV. Thus, most data in this experiment were taken over a range of 2 kV (from 749.0 kV to 751.0 kV).

In general, the transverse modulation of the linac beam as a result of injector-energy variation over the range studied was small compared to the amplitude of the existing transverse oscillations in the linac and was essentially masked by the horizontal oscillation presently inherent in the operation of the 201-MHz linac. Longitudinal modulation of the energy and phase of the beam for these injector-energy variations were clearly observable when drifts in the phase controllers on the 201-MHz linac were properly controlled. A Δt plot at module 5 showing the energy/phase shifts going into and leaving this module are shown in Fig. V-1 for transient-dome waveform with a flat voltage droop of 250 V.

Basically, this experiment has documented what the effects of injector-energy variation on linac beams are and confirmed that the stability now present is not a problem for 100-μA operation. A more detailed analysis of this data will be carried out to determine permissible voltage tolerances and required trip levels for on-line injector operation.

REFERENCE

1. R. Steiner, K. Merle, and H. G. Andresen, Nucl. Instrum. Methods **127, 11 (1975).**

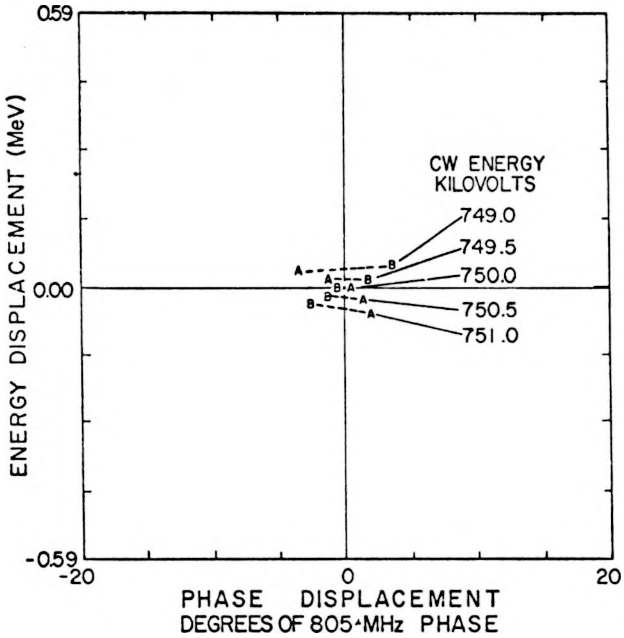

Fig. V-1.
Delta-t energy/phase displacement at module 5 for C-W energy variations from 749.0 to 751.0 kV.

VI. ELECTRONIC INSTRUMENTATION AND COMPUTER SYSTEMS

The activities reported in this section relate to the computer control system for the LAMPF accelerator and experimental areas and to the computerized data-acquisition systems being developed to support the program of experimental physics.

Computer Control System

Control of the LAMPF accelerator and major experimental area beam lines is accomplished through a central control computer (SEL-840MP) interfaced to operator consoles, remote data terminals (RICE), and a network of satellite processors for certain dedicated tasks.

Control Computer

The SEL-840MP was operational throughout the quarter for accelerator development and tuneup. Scheduled periods of downtime were used to isolate hardware difficulties arising from timing problems in the new register-store logic and in an apparent design flaw in the priority-interrupt logic. This latter problem has been latent in the computer since its delivery and was only identified after an intensive study of the system. The study was aided considerably by some of the new hardware added to the computer last quarter. One side benefit of the study was the discovery and correction of a number of lesser problems, primarily system software.

Several additions and improvements were made to the complement of peripheral devices on the control computer. A new Documentation card reader was installed to replace a worn-out unit. A spare disk and disk controller were made operational to provide reliability through redundancy.

An additional driver/terminator chassis is being added for use with a second CAMAC crate controller. Both the disk controller and CAMAC I/O hardware can be tested on the standby SEL-810A computer thereby minimizing the downtime required of the control computer.

A unit to generate 32 addressable pulses is under construction for the control computer. The device will be used in system analysis and trouble diagnosis, and will be available for asynchronous control of peripheral units not requiring feedback to the computer.

A series of formal technician training sessions were initiated to provide adequate backup for the maintenance and general care of the control computer, its peripheral equipment, and the remote data systems. These classes will continue throughout the next quarter with on-the-job training and classroom work.

Control Consoles

Progress was made this quarter in development of the IEEE/ASCII standard interface bus for a new generation of console devices. The bus will interface console devices for the third operations console in CCR, and later take over the functions of the present CIUs.

The CAMAC-based bus-control module prototype was completed and tested. Software was written for testing the INTEL 8080 microprocessor internal to the controller. The design of the prototype Function Button panel, the first device to be interfaced to the bus, and construction of the panel proper were completed. Work will be concentrated next quarter on the integration of the prototype system. An ASCII bus analyzer was procured to aid in bus development and maintenance of installed systems. The analyzer can function as talker, listener, or controller.

A meeting of representatives of those groups using the CCR consoles was held to identify the problems which needed immediate attention and to rank by priority the long-range developments which should be initiated. A new and more flexible system for copying the information stored on the face of the 611 display scopes was judged most urgent. In response to this need, circuits were developed to allow any of several 611 scopes to be switched to a 4610 Hardcopy unit. The prototyping of these circuits will be completed early next quarter, after which all the 611 scopes will be retrofit.

The shaft encoder presently used on the CCR consoles to implement knob controls has proved to be unreliable. A modification was installed in one of the knob modules to test a raise/lower control as an alternative. This scheme was judged adequate for certain operations, but the knobs are still needed. Consequently, a new type of shaft encoder has been installed for test and evaluation. If its reliability is indeed better, all of the shaft encoders will be replaced with the new model.

A series of training classes was initiated. Work was started to formally document all of the man-machine interaction devices in CCR. This effort will continue through the first half of next quarter.

Master Timer

The projected operational requirements for a facility with three ion sources and the expanding need for timing signals in the experimental areas prompted a design study for a new Master Timer. A set of specifications for the new timer and distribution system was developed and approved by a representative cross section of the LAMPF staff and users. A definitive charter for the construction of a system was given and a review committee was appointed to guide the development.

Interface Hardware

Each RICE throughout the accelerator and experimental area is electrically coupled to the control computer RIU by a pulse-code-modulated, serial-data transmitter and receiver. Experience has shown that the present receivers are critical in adjustment and tend to exhibit long-term tune drifts. A new receiver was developed which is straightforward to adjust and requires no special terminations because of line length or quality differences in the transmission lines. A total of 80 pairs of receivers was fabricated by a vendor. The testing of these cards was completed, and installation will be completed next quarter in coordination with the operating schedule.

A series of training classes was conducted on the RICE terminals last quarter in an effort to bring more matinenance technicians up to an adequate level of service expertise. These courses will continue into next quarter.

A PROM programmer for the SN 74188 programmable read-only memory was completed. PROM bootstrap loader cards were installed in all satellite PDP-11/10 processors associated with the control computer. These cards made it possible to load the memories of the satellite processors directly from the control computer, thereby eliminating the time-consuming job of reading paper tapes into the satellites.

A design manufacturer's error was isolated and corrected in all PDP-11 Unibus-CAMAC crate controllers. These controllers are used extensively in the satellite computer network of the control system.

Communications between the central control computer and several satellite processors in remote areas of the facility are accomplished through CAMAC-based data-link modules. To increase the efficiency of communications by reducing the load on the control computer, a microcomputer is being incorporated in the data links. The prototype microprocessor Data-Link CAMAC module (μp-DL) reported last quarter was hardware-tested and operated with another nonmicroprocessor unit. Software development was initiated and will continue through next quarter.

The μp-DL operates between two computer systems via a CAMAC interface on each system. Figure VI-1 shows how the μp-DL is arranged in a system and what signals are transmitted over the cable-implemented communications channel.

The prototype μp-DL shown in Fig. VI-2 was constructed on two CAMAC carrier pc boards such that software development could be accomplished with the aid of a more easily used 8080 development system. Data-link hardware and message memory are contained on the left-hand module, while the

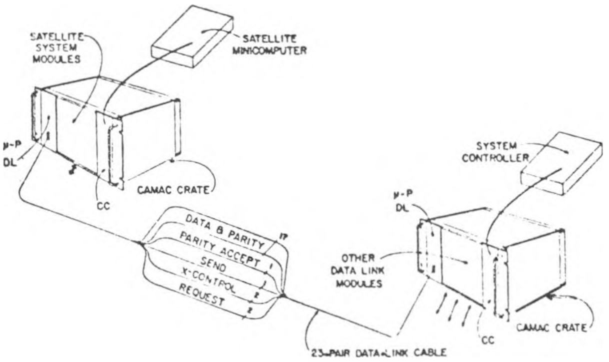

Fig. VI-1.
CAMAC/microprocessor data-link system configuration.

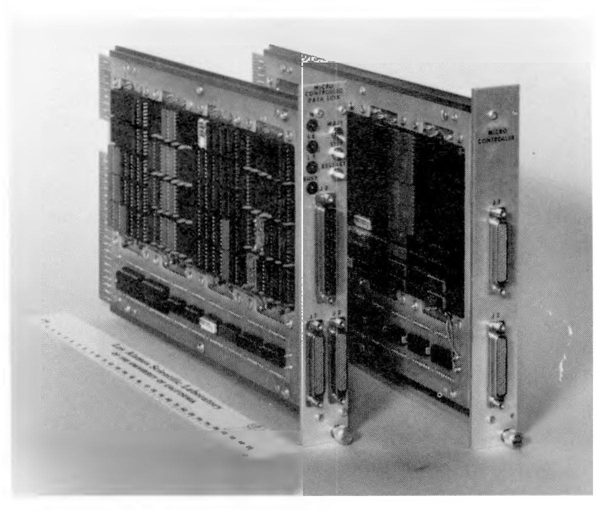

Fig. VI-2.
CAMAC/microprocessor data-link modules.

8080 microprocessor and support hardware (clock, ROM memory, etc.) are contained on the module to the right. Production μp-DL modules will occupy two crate slots in one module and will contain two pc boards rather than the prototype wire-wrapped boards.

Computer Systems Software

Aside from the difficult detective work required to identify the fault in the interrupt system, the effort spent on system software continued to dwindle, being confined principally to repair of troubles which surfaced, adjustments necessary to accommodate new hardware, and support of the remote console facilties at HRS.

In order to simplify the writing of applications programs having interactions with console knobs and button displays, two requested changes were made in the systems software for these devices, one making the displays associated with the knobs accessible via normal FORTRAN write statements, the other improving the console identification feature of the button card handler.

The Tektronix-4010 displays at HRS were operated successfully from SEL-840 software during the quarter. This capability, which is necesay in order for the HRS console operator to be able to run many of the most useful programs on the 840, required extensive work both in the 840-system software and in the HRS PDP-11.

In order to compensate for changes in the timing of the Area A analog multiplexer, certain small changes had to be made in the Area A PDP-11/10 code.

The Injector NOVA computer has proved to be a very satisfactory solution to the problem of maintaining communication with the injectors, the injector control room, and CCR. From time to time, however, certain problems arise in making it resemble the other standard data-acquisition and control equipment along the accelerator. A subterfuge introduced long ago to solve some of the problems is to treat it as two modules—module 0 and module 49.

At the request of the operations group, a means was found to move this dual module capability to a point deeper in the operating system and thus make it available to more programs and facilities without special programming so that these injector devices can be controlled in more standard ways.

Some corruption was discovered in the disk-resident directories to the accelerator channel tables. Consequently, a program was written and put into use to check the directories for consistency and to provide a means to correct any errors in the directories.

Accelerator Application Programs

During the accelerator shutdown, there were many changes in the instrumentation and control hardware for the accelerator. While the general software can cope with these changes if they are entered in the channel tables, much of the most sophisticated and valuable software is necessarily specialized to these devices and must be updated when changes are made. The struggle to keep up with these changes absorbed a major share of the software support effort during the quarter. A sampling of the jobs completed is given below:

1. A button card program for the low-energy harps and view screens was developed.

2. Modifications were made in the fast-protect program, the accelerator status program, the button card program for high-energy harps, the magnet table listing program, the knob assignment programs, the data-scan programs, the current monitor gain control program, the channel table maintenance program, and the liquid deuterium target display program.

3. In order to speed up the acquisition of beam profile data, a major activity of the past months has been the construction and installation of fast wire scanners. The wire-scan system was put into use during this past quarter. Much effort went into checkout of both hardware and software. Some additional capabilities for wire-scanner control and changes to certain displays have been requested and are in progress.

4. One of the beam-line protection mechanisms planned for higher intensity operation is the monitoring of magnet currents by the computer at frequent intervals. An initial version of this monitoring capability was installed on the SEL 840. A selection of beam-line magnets is checked once each minute for drifts.

5. A display program for the Line D position monitors was provided.

6. The new version of the magnet-setting program was put into use, which includes a number of new features or improvements, based on the operating experience gained last year and provides a capability to control beam-line magnets interfaced via CAMAC systems in remote computers (required for Line D operation). This program is a major tool used in beam-line tuning.

7. Programs were written for the control and monitoring of the new stripper hardware, for the control of the calibration-pulse beam-current monitors,

to print the contents of the accelerator monitor files, and to notify the operators when it is necessary to change the gas bottles which provide the propellant for certain beam-line vacuum valves.

8. Programs were written for control of the new A-1 and A-2 target mechanisms and for control of the Line D beam plug.

9. The facilities of the general line-by-line channel display were extended to remote, computer-driven consoles, and it is now possible to use this program on the HRS console.

Experimental Area Controls and Instrumentation

Communications

The installation of a new system of public address speakers in Area A was completed. The new system was required to overcome the noisy environment of the experimental area.

The vacuum tube power supply for the communications system in the Biomedical Facility was replaced with a more reliable solid-state supply. This scheme of upgrading for reliability will continue until all the vacuum tube units on the site have been replaced.

The communications system was extended to several trailers housing experiments.

Switchyard

The controls and instrumentation for the SY were ready for the first beam tests in mid-August. The initial shakedown of the area uncovered several malfunctions, which were corrected. Since that time, the controls have functioned smoothly. The maintenance effort has settled down to 3-4 repairs per week.

Noise on the magnet current signals to the ADS was a serious problem. The initial attempt at filtering the noise with a tantalum filter capacitor introduced an unexpected dc offset to the ADS and DVM readings. The problem was solved by an RC filter on the input to the ADS system. The filter was designed in a way that did not destroy the integrity of the channel calibration.

Two digital panel meters (DPM) were purchased for evaluation as the measuring and readout device on magnet bypass shunts. One DPM was installed on a bending magnet power supply; another on a quadrupole magnet power supply. Initial results were quite promising, and two additional DPMs were ordered.

The new FWSS, which has been under development for three quarters, was completed and has been in use for beam-line tuning for two months, with 19 of the 20 wire scanners installed. The new system can drive all wire scanners simultaneously, thereby reducing the time required to measure beam profiles.

A modification was made on all the FWSS linear-actuator position transducers in order to achieve a factor of 2 better resolution in both position and X-Y beam signals. Noise in the Line B actuators is still a small problem to operators and will be investigated as operations schedules permit. An enable signal from the Line D kicker power supply was added to the FWSS Beam Gate interrupt (to the PDP-11/10 satellite processor) such that Line D operation will not affect Lines A, X, and B profile calculations. A FWSS calibration unit was constructed for checkout and diagnosis of system amplifier problems.

Area A

The main thrust of the effort in Area A was the design, installation, and checkout of the wiring plant which connects the instrumentation along the beam lines to the computer control system.

All the conduit and ductwork needed to handle the beam-line instrumentation cabling along Line A was installed as the shield stacking permitted. The remote-handling aspects of the cabling were reinvestigated as the shielding, especially the in-cell shielding, began to take shape. As a result, some of the conduit and ductwork had to be modified, especially in the A-5 area.

Most of the hardware associated with the upgrading of the harp system was installed—the new north-side MUX rack, the A-3 harp-amplifier rack in the P^3 control area, the Biomed harp-amplifier and instrument rack, several of the current-monitor electronics stands, and termination boxes at A-6, A-5, and the west side of A-2. The south-side MUX rack in Area A was relocated. Several successful in-line tests of the first new harp with carbon wires were conducted. The new ceramic-edge cards for the harp cable connectors were received which means that the cables can be fabricated and installed.

Substantial progress was made on the thermocouple systems for monitoring the shielding and collimator temperatures. Seven chassis for the collimator thermocouple instrumentation were assembled, wired, and installed in the control racks. Some of the interrack wiring was completed. Wire-listing books were prepared and delivered to the electricians. Analogous activities were completed for the thermocouple, thermoswitch, and flow-interlock instrumentation for the shield-cooling system.

Wiring was installed for the A-4 vacuum valve, and connections were made to the limit switches and the valve-control connector. Wiring was installed for the vacuum-controlled water valves. The associated controllers and ion gauges were sent out for testing. Cables for interconnecting the instrumentation were assembled.

The controls for the A-2 target and the target mechanism were tested. A video film of the various operations was prepared for the purpose of training operators. In the process of making a similar film about the operations of the A-1 target, a flaw in the controls interlocking was discovered and corrected. Wiring was installed for the P^3 collimator at the A-2 target.

A large number of changes were made in the channel assignments in modules 65-67 which interface experimental areas A and A-East to the control computer. The wiring to the data-acquisition and control terminals was modified in accordance with these assignments. The channel tables in the control computer were updated to reflect the changes.

EPICS

Work on the controls and instrumentation for EPICS was completed in time for the alpha-particle test. The new general-purpose data-acquisition program was used in the test. After the test, work began on the rerouting of cables (which had to be moved because of shield-stacking requirements). The system will be checked again prior to the repeat of the alpha test.

A preliminary version of the EPICS magnet-setting program was used during the quarter. A more advanced version has been written. The design of the program is thought to be sufficiently general so that it can be transported to other beam-line computers with only modest effort.

The Soft-Spark Detector was installed in the EPICS 400-kV particle-separator power supply. The detector shuts the system down in the event of spark transient at the power supply load. In addition, the documentation was completed on the Hard-Spark (overcurrent) protection system. A closed-loop voltage regulator (0.1% regulation) was designed for the 400-kV power supply. Electronics for 256 channels of the EPICS taut-wire magnet-position sensor system were completed.

Some progress was made on the controls and instrumentation for the spectrometer and separator: the curtain-control chassis was built, along with the spectrometer arm-positioning controls and readout.

Stopped Muon Channel

The installation of new power supplies requiring external regulators has necessitated a rework of the control system. As each new regulator is installed, the remote local controls have to be removed and new local controls installed in a rack outside the counting house. Then, the wiring records and CAMAC channel assignments have to be updated to reflect the changes. This cycle will be repeated until all the power supplies have been modified.

LEP and P^3 Channels

After a number of modifications were made to each channel during the shutdown, the controls were tested. Testing will continue until the channels are judged ready for beam.

Biomedical Facility

Conversion from Version 4 of RSX-11D to Version 6, and the installation of the Diva disks, absorbed substantial effort at Biomed. Version 6 is now the standard system on that computer.

Software was produced for hardware checkout of the XYZ scanner and for interfacing it to the operating system.

As in the case of CCR, it was necessary to revise programs and the beam-line channel tables to adapt to new beam-line hardware.

Beam-Stop Area

Two racks and the associated junction box were completed and delivered by the vendor. They were installed, wired to ac power, and ground. The data-acquisition and control terminal for this area was installed in the racks along with miscellaneous chassis for the instrumentation. Some of the interrack wiring was completed. A new design for the stringer drive-control system was approved; work was resumed on the motor speed controls.

Although preliminary design was developed for the beam-stop controls, work on the detailed design was suspended until a decision is reached on using the beam stop itself to study radiation-damage effects.

Area B/C

The modifications to the controls and instrumentation for Lines B and EP were completed in time for the initial beam tests and production runs on those lines following the shutdown. A variety of devices received attention during the course of this effort. Three new vacuum valves were added along Line EP. A fast-acting vacuum valve was replaced with a 2-ℓ/s ion pump actuator. A second flow switch was added to the Line B beam stop. All the existing magnet controls were checked for proper operation, including the shunt controls and the data channels to the Line B DVM.

Assistance with instrumentation was given to several of the experimental groups using Area B. Neutron-detector circuitry was added to several trailers. Hardware was installed to remote the LD_2 target operation to one trailer. Controls for the new EP-BL-03 beam plug, chopper, and slits were provided. Timing signals and a TV monitor were installed for Exp. 241. Control circuits were added for the nuclear chemistry rabbit system.

HRS

Modifications were made to correct the erratic operation of the CAMAC module which interfaces the knobs and associated readouts on the HRS control console. The problem was traced to a fault in the implementation of the CAMAC strobe logic.

An improvement was made to the NMR gaussmeter multiplexer to prevent that instrument from losing signal-lock during the process of reading out data. This improvement speeded the magnet-mapping operation. Electronics for 176 channels of the taut-wire magnet-position sensor system were completed for the HRS. The last few units are undergoing their final burn-in to catch early component failures.

Experimental Data-Acquisition System

The LAMPF experimental data-acquisition system includes computers, software, CAMAC modules and interfaces, data links, and an equipment pool, all for the purpose of acquiring and reducing data from nuclear physics experiments.

Experimental Area Computers

All necessary approvals for the purchase of the two new LEEP data-acquisition computers were received by the end of the quarter, and the purchase orders are being issued. The current promised delivery date is the end of January.

Procurement was initiated for additional core memory and a disk for the terminal computer and for a printer-plotter and a disk for LEEP.

Version 6 of RSX-11D was installed on the terminal computer.

Data-Acquisition Software

Work continued on the general data-acquisition software package. The system was used for the collection of data during the EPICS alpha-particle tests and received its initial shakedown at that time. Several difficulties were found and corrected. The features which were brought into operation during the quarter include a simplified startup procedure, an orderly shutdown, tape recording of data, and scale- and peak-selection options in the plotting programs. The replay handler is in the final stages of checkout, and the replay operator commands are under development. The data-acquisition handler and core-histogramming task were written for RSX-11M, but no significant checking has been accomplished. A preliminary draft of the user documentation was completed.

A license for RSX-11D was purchased for the LEP computer, and the system was installed on that computer. All LAMPF PDP-11/45s are now licensed to run this software; this simplifies the problems of support and provides a desirable degree of uniformity for users.

A special MBD code was written to record data on magnetic tape for Exp. 241. This experiment was assembled quickly, without a computer capable of on-line analysis. Data are read from the CAMAC modules, which interface to the experiment, and written directly on magnetic tape via a CAMAC tape interface.

Interface Hardware and Nuclear Instrumentation

A third, and final, portable paper-tape reader was completed for use with all LAMPF PDP-11 computers. The unit contains interface logic to the Unibus, reader, and reader logic and paper-tape catcher. A Unibus cable connector accepts any PDP-11 Unibus with the address set for the standard high-speed reader.

Nuclear chemists at LASL have utilized for many years a Time-of-Year clock system with repeaters in each laboratory. The clock has a resolution of 0.01 mday. A CAMAC readout module for the Time-of-Year clock system at LAMPF was designed and installed on the nuclear chemistry laboratory data-acquisition computer. The module provides an accurate time reference during the analysis activities on the computer system.

Event-Trigger CAMAC modules, reported on last quarter, have been assigned to LEEP for use with Program Q (Data-Acquisition Software). A total of ten units is available to experimenters; five Dead-Time Monitors were also completed. The remaining nine Trigger modules will be completed next quarter.

A special 24-bit CAMAC-input module was designed and constructed for testing and maintenance of the Event-Trigger modules. The module, in combination with the NOVA computer/BASIC language test station (used with LEEP activities) can totally test the Trigger module, thus reducing the time-consuming manual operations that were once required.

A fixed-delay chassis, containing six 64-ns cable-type delay lines, was designed for use by experimenters. A total of 20 units will be available from LEEP with more to be fabricated in the future, provided experimenter acceptance is seen. The delay units complement the existing LEEP stock of switched and active delay units. The cost of the delay box is about $100.

Electronics support for experimenters continued throughout the quarter.

LAMPF Electronics and Equipment Pool

Approximately $180k of FY-76 capital equipment funds have been obligated for LEEP electronics. Event-Trigger modules (20) will require an additional $10k, while the remaining $10k of the $200k budget will be held in reserve to purchase equipment later in the year.

With experimental activities on Line B, LEEP usage has increased to nearly 90%. The usage factor will continue to climb as Area A becomes operational.

Computer Maintenance

The task of maintaining all of the computer systems used by LAMPF and its users has proven to be a big job. For the most part, the maintenance work has been relegated to groups outside of MP Division. Negotiations were completed recently with the Digital Equipment Corporation for the maintenance of all DEC computer systems, the DEC PDP-11 being the standard data-acquisition computer. Negotiations are in progress with the computer maintenance section of the LASL Electronics Division for the maintenance of all non-DEC peripheral devices.

A data base of all maintenance actions is kept to monitor the effectiveness of the maintenance teams and to identify, by device or system, those computers which are performing below the norms. The most troublesome devices are the moving-head disks with removable disk packs. A commercial device for cleaning disk packs was purchased and a program of periodic maintenance of the disks and packs is being organized.

A cabinet for system prints, manuals, and diagnostic programs is being placed adjacent to each computer. This will reduce repair time by ensuring that complete, up-to-date documentation is readily available. A logbook will be placed with each computer so that the service history of the system can be reviewed by maintenance personnel.

Sharing of LAMPF Technology

A member of the staff attended the International Purdue Workshop on industrial computer control and contributed in subgroup meetings on Human Factors Engineering. Two members of the staff attended the NIM/CAMAC working group meetings on hardware and software. Both the Purdue and the NIM/CAMAC organizations represent an internationally recognized effort in equipment and systems standardization.

VII. ACCELERATOR OPERATIONS

General

Machine startup following the seven-month shutdown began just prior to the start of the quarter and operation continued throughout this report period, for a total of 276 shifts. Of the total, 137 shifts were employed in startup functions, 25 for scheduled maintenance, 59 for facility development experiments, 9 for tuneup for production (research) beams, and 46 for research. Beam availability during research shifts was 77%.

Machine Startup

Objectives of the startup were to find and fix the numerous faults expected after the extended shutdown and major overhaul, to develop the capability for dual beam operations at 100-μA H^+ and 1- to 3-μA H^-, and to start a limited program of research in Lines B and EPB with H^- beams of a few μA average current. Milestones of the startup are detailed below:

July 21 – conditioning of 201-MHz tanks started.

August 5 – low-duty 100-MeV H^+ beam reached the 212-MeV beam stop.

August 16 – low-duty 100-MeV H^- beam reached the 212-MeV beam stop by way of the TR side track after much difficulty. The lack of sufficient shunting capability on two of the side-track bending magnets caused difficulties in this effort.

August 17 – simultaneous, low-duty 100-MeV H^+ and H^- beams reached 212-MeV beam stop.

August 23 – first beam was delivered to a temporary beam stop at Line D.

August 30 – a 6.6-μA-average, 800-MeV H^- beam reached the beam switchyard by way of the TR side track. Beam reproducibility studies were started with poor results; i.e., the linac would not reproduce a beam tune with a given collection of phase and amplitude setpoints.

September 6 – a 100-μA-average, 800-MeV H^+ beam was delivered to the SY in 30-s bursts.

September 7 – simultaneous beams of 28-μA-average H^+ and 2.7-μA-average H^- were accelerated to 800 MeV in 30-s bursts. This was an especially significant milestone in that the beam-spill limitations were as stringent as those in effect last year during 10- to 13-μA operation, and demonstrated the effectiveness of the realignment work done during the shutdown.

September 14 – simultaneous beams of 98-μA-average H^+ and 2.9-μA H^- were accelerated to 800 MeV in 30-s bursts.

September 23 – a 5-min high-intensity run of 100-μA-average at 800 MeV was completed to the Line A-Direct beam stop in the SY.

October 3 – a broken lead in a cable connector on an rf probe in a module-14 tank was discovered. This probe is a primary sensor in both the phase- and amplitude-control systems for the rf fields in the tank, and changes in the probe pickup affects beam acceleration in all subsequent modules. Since repair of the probe connector, no unexplained shifts in phase or amplitude have been observed. Three production beams of 2- to 5-μA-average have been tuned and a 5-min high-intensity run was completed successfully with identical 805-MHz phase and amplitude setpoints; this constituted a major improvement in machine reproducibility.

October 7 – start of first one-week production run to Lines B and EPB.

October 29 – completion of a 5-min run at 100-μA-average and 800 MeV with the beam deflected through the Line A-South dogleg to the Line A-South temporary beam stop.

Experimental Program

Only EPB, Line B, and the Line B nuclear chemistry facility were in operation during this period. Average proton beam currents ranged from 1 to 4 μA, for a total of 505 μA-h. The beam supplied to each experiment is shown in Table VII-I.

TABLE VII-I

BEAMS SUPPLIED TO LAMPF EXPERIMENTS

Exp. No.	Channel	Shifts (8 h)	μA-h
42	EPB	13.5	----
106	AB Nucchem	3 runs	3.1
111	LA BS	4 runs	5.5
123	AB Nucchem	2 runs	2.0
129	AB Neutron	35.5	500.0
150	AB Nucchem	1 run	0.02
176	EPB	12.5	----
208	AB Neutron	1.5	4.7
241	EPB	40.5	----

Facility Development

Linac acceptance was studied for injector energies ranging from 720 to 780 keV. Longitudinal emittance of the H^+ beam was measured at 100 MeV. New emittance, phase-scan, and wire-scan hardware was checked out. Measurements were made to determine the sensitivity and reproducibility of the beam-position monitors under development in the linac. Characteristics of the horizontal transverse beam oscillation were measured, but efforts to determine the source of the oscillation did not produce definitive results.

Machine Downtime

Over half of the machine downtime resulting from equipment failures occurred during the first month of the quarter, as was expected. Extreme difficulty was encountered in tuning the machine through the second month, until the broken probe connector in module 14 was discovered, as discussed above. A summary of the machine downtime is given in Table VII-II.

TABLE VII-II

QUARTERLY SUMMARY OF MACHINE DOWNTIME FROM SYSTEM FAILURES

System	Downtime	Percent of Total
Accelerator structures (rf windows)	2	0.3
201-MHz rf	205	31.0
805-MHz rf	129	19.0
Injectors	38	5.7
Vacuum	26	4.0
Beam diagnostics	53	8.0
Interlocks (personnel-safety, run-permissive, fast-protect)	33	5.0
Water	15	2.0
Data-acquisition and control (RICE, SEL-840, etc.)	45	7.0
Miscellaneous (utilities, weather, etc.)	35	5.0
Magnets and magnet power supplies	60	9.0
Reference source	27	4.0
Total	668	100.0

VIII. EXPERIMENTAL AREAS

Facility Operations

Preliminary design work continues on the Experimental Area Operations office proposed as a leased facility to be installed at the south side of Area A. Facility layouts have been developed for the remote computer terminal to monitor the major service systems and experimental setups. Software has been developed and will be ready in the next operating period.

The Experimental Area staff shop has been further upgraded with the addition of a drill press, a large grinder, and a metal brake. The tool crib and the shop are now open to users and employees 17 h a day, 5 days a week. This will be expanded as we enter full operations.

A major improvement was the paving of parking and service areas south of Area A. This has effectively reduced the dust in Area A.

Experimental Area Cooling-Water Systems

Modifications to four of the five radioactive cooling-water systems are complete. The system that services Areas B and C will be modified when the schedule will permit. All systems are in operation.

Installation of the strainers in the Area A and A-East valve caves has been completed.

Fabrication of the flowmeter packages for Area A and A-East is complete and installation has begun.

Remote manual-valve operators for all shielded valve caves are installed and the hand wheels are now being mounted outside of the shielding.

The installation of stainless steel plugs and seats on all throttle valves is continuing in the valve caves.

The pump/heat-exchanger package for the HRS nonradioactive water systems has been installed and checkout of the system has begun. A similar system for use in Area A is being assembled.

The EPICS spectrometer nonradioactive cooling system has been turned over to a contractor and construction has begun. The EPICS beam-line cooling system is complete and is operating.

A spare heat exchanger is now on order. It will be used in an on-the-line spare pump/heat-exchanger package for the radioactive water systems. This system will significantly reduce downtime in case of equipment failure and will allow periodic maintenance with little loss of beam time.

Cryogenics

A hydrogen target system has been built and operated for Exp. 241. This system has been cooled and warmed several times and has been run for several weeks without incident.

The refrigerator assigned to Exp. 56 was found to be defective, and has been replaced with a new system. Arrangements have been made to repair the defective system.

The target system for Exp. 2 was repaired and tested with superfluid liquid helium.

Design of a ventilation system for Exp. 99 is still in progress. A review of the target system for Exp. 90 is in progress to see how the system may be modified to hold more tritium gas.

A new target flask is being built for Exp. 99, and a new flask-support system is being designed.

An additional pump cart and control console are being built for use with the pool refrigerator systems. A universal support stand for these systems is being designed.

Beam-Line Development

Switchyard, Lines B, and EPB

First beam in the revised SY was obtained in mid-August. A temporary stop was installed in Line A-South to allow beam-tuning exercises while the reconstruction work continues in Area A and A-East. First beams were used to check out the revised beam-diagnostic instrumentation (primarily fast-wire scanners), optics, strippers, and beam stops as well as to provide beam diagnostics useful for accelerator development.

By early October, H^- beams were being transported to Lines B and EPB first for checkout of new beam-diagnostic instrumentation (wire scanners, current monitors, and phosphor/TV systems) and then production beams for research. The tunes being used are empirical tunes satisfactory for Lines B and EPB operation at <10-μA average. Tuning for Line C requirements, and use of strippers for phase-space tailoring, has not yet been undertaken.

On occasion, multiple beams have been observed in EPB. Since the stripper which serves as the source for EPB has but one opening, the multiple beams are evidence of occasional granularity in transverse phase space of the H^- beam. Large-intensity fluctuations (factors of 2 to 3) in the EPB current have been observed at times. These appear to be correlated with slow variations in positions and spot size of the H^- beam at the stripper. Accelerator developments aimed at improving the transverse stability of the beam are being planned.

Among the high points in the initial beam operations was dual beam operation in the switchyard. Particular attention was given to the question of overlap of the two beams in transverse phase space, both in centering and size (e.g., first and second moments). Figure VIII-1 shows a wire scan taken with both H^+ and H^- beams present. About one-half of the H^- current was stripped and deflected to the temporary beam stop in Line A-South, with the remainder of the H^- going down Line X. The profiles on LA-WS-01 and LA-WS-07 show the H^- beam core going negative and the H^+ component positive. (The H^- signal polarity reversal is accomplished by use of scanner wires of such size and shape that the collected H^- electrons exceed the secondary emission current.) The profile on LA-WS-11 is produced by about equal parts of H^+ and stripped H^-. It was found possible to tune the front-end quadrupoles and steering magnets to give nearly the same centering and width to the H^+ and stripped H^- components separately on LA-WS-11 and to have the Line A-Line X split between H^+ and H^- well centered.

Dual beam "heat" runs (800-MeV, 100-μA H^+ and 1.5-μA H^-) for 5 min have been achieved in Line A direct. Longer heat runs have not been attempted because of the limited capacity of SY beam stops and the desire to keep SY activation low during this period of frequent access. A successful 5-min heat run of an 800-MeV deflected H^+ beam was achieved in Line A-South as far as the temporary stop. No flanges heated up and transmission was >97%. No low-momentum component was observed on the low-momentum phosphors. Since the limiting apertures for Line A occur between the Line A quadrupole triplets and the temporary beam stop, the results of the heat run in Line A-South are most encouraging for high-intensity operation after the Great Shutdown.

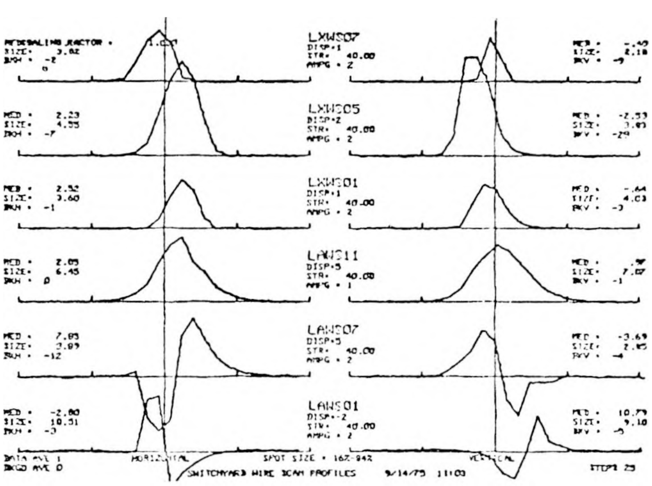

Fig. VIII-1.
Switchyard wire-scanner profiles with H^- in Line X and H^-, stripped H^-, and H^+ in Line A.

The magnet-current calibration data and the readout-system capabilities were reviewed for purposes of ensuring accuracy and reproducibility of the beam-transport set points. In this process, attention was focused on some weaknesses in the present system which have led to intolerably large errors in many of the magnet-current measurements. To bring the system up to specifications, various components were brought back into tolerance (e.g., amplifier gains and offsets), and new calibration data were taken on all the Line A-Line X magnets in use. To help maintain the calibrations, additional test points are being added and the addition of a precision local readout at each power supply or bypass is being evaluated. Attention that was focused on the noise problem experienced with the magnet-current ADS data from the RICE system led to installation of an effective noise filter; this reduced the noise to ±1 or ±2 counts. In addition, several deficiencies in the cable plant and grounding method in the interconnections from the power supply to the control racks were uncovered, and corrective measures are under way.

Instrumentation Development

Fast Wire-Scanner System. Much effort was concentrated on the new wire-scanner system, which has an improved amplifier and a CAMAC/PDP-11 readout system to provide the data-handling speed required to allow profile acquisition with a continuous or "fly" scan rather than a stepping scan. Initial operation of the data system was satisfactory but the scanning mechanism, using basically the same stepping motors as before with new 2:1 step-up gearing, was plagued by vibration and marginal motor torque. The decision was taken to gear the motors down to the old drive speed. Since for all beam rep rates normally used in tuning (above, say, 1.88 Hz) the profile is taken in the fly mode rather than step mode, and since all scanners are driven in parallel (rather than round-robin within one RICE module), the profile acquisition is somewhat faster, ~15 s for a group of six,than in the previous RICE-based system. In addition, the new amplifiers with 10^3 gain-ranging and the new computer programs provide greater operator convenience and wider device capabilities. The new signal cabling and careful attention to grounding have given improved signal-to-noise performance on the Line A-Line X scanners. The Line B scanners are plagued by the same or similar noise problems which afflict the Line B current monitors and the Lines B and EP televisions, and which so far have defied diagnosis.

An on-line (SEL-840) wire-scanner data-reduction capability was initiated which it is hoped will lead to improved real-time estimates of beam parameters. Initial experience indicated the need for additional software to diagnose noise in both position and secondary-emission current signals.

Tests of the effect of clearing fields on wire-scanner signals were made on several wire scanners equipped with a variety of wire materials and sizes using H^- beams. No effect was seen on wire scanners fitted with 0.010-cm-diam tungsten wires. The situation with ribbons was different. An increase in signal by a factor of 1.5 to 1.7 was observed for wire scanners using 0.005-cm by 0.100-cm nichrome ribbons oriented with the thin edge intercepting the beams. Fields as low as 10 V/cm appear sufficient to collect all of the signal.

Line A Harps. All harp card assemblies for Area A were completed and one was tested in the SY. Indications are that one can achieve a 10/1 signal-to-noise ratio with a 3-mm FWHM beam spot and an intensity of 1- to 2-μA average current. This performance was achieved without the use of an amplifier per wire but with an improved harp multiplexer. It also verified that, to the 10-15% level, no serious gain changes occur as the beam is moved along the wire or from one wire to another.

The prototype harp amplifiers being developed by E-Division are ready for extensive testing. The bench performance exceeds design specifications. The wire-continuity tester has been operated and it appears to work satisactorily. The test involves applying a voltage pulse to the high-voltage plane and reading the current induced in the signal wires.

The rad-hard cable assemblies for these harps are completed and ready for installation. Some difficulties have been experienced with the m.i. feedthroughs which are brazed into the harp lids. Too high a fraction of these feedthroughs develop low leakage resistance ($<10^9$ Ω) during the several steps of assembling a complete harp. They can usually be repaired by replacing the glass-bead seal at each end of the feedthrough.

Phosphors/TV Monitors. Two-position air-operated actuators for phosphor insertion have been developed. Several are being fabricated for use in the SY and Lines B and EPB.

Tests of several promising rad-hard phosphors were made. These included: aluminum-oxide thin plates, chromium-doped Al_2O_3 thin plates, thin plates of BeO, and chromium-doped Al_2O_3 on an aluminum substrate as fabricated at SLAC.

The results showed that the chromium-doped Al_2O_3 was best. It is twice as bright as the P-22 phosphor presently in use and is much more immune to radiation damage.

A firm has been located which will grind plates of Al_2O_3 down to a thickness of 0.010 cm. A number of 10-cm square plates, 0.050 cm thick, of chromium-doped Al_2O_3 are on order. These will be used to replace SY and Lines B and EPB phosphors which are subject to radiation damage. A chromium-doped Al_2O_3 plate will soon be installed at the end of Line B.

Curtain Strippers. The three curtain strippers installed in Lines A and B appear to work well.

Magnets

Most of the magnet work for Area A has been completed. Testing of a remote-handling scheme for the 30-cm-bore steering magnets is in progress. New jumpers are being fabricated for the downstream triplet at target cell A-5.

Beam Measurements and Tuning Procedures

Written procedures for tuning SY and Lines B and EPB production beams are being developed. Procedures for monitoring production beams have been written and have been implemented by MP-2 operating crews.

A key problem in developing better tuning procedures is the capability of making adequate measurements of the beam phase space emerging from the accelerator. A related problem is to use this beam in transport calculations that agree with measurements made at various places in the beam line.

Programs have been written which take beam measurements and fit beam parameters to them in a minimum χ^2 sense. Error estimates and goodness-of-fit tests are also made. The results to date are mixed. The estimates of beam parameters have shown greater variability than those expected on the basis of error estimates. Some progress has been made in resolving the apparent discrepancies. For example, errors were discovered in the 840 programs which estimated spot sizes from wire-scan profiles. A systematic review of additional sources of error is under way. This includes the measurement of magnet currents, linearity of wire-scanner response, better estimates of spot sizes from profile data, and variability of the beam itself during the measurements.

Main Beam-Line Installation

At target cell A-1 (which serves LEP and EPICS), all beam-line vacuum-system components have been completed, installed, and aligned with the exception of one collimator which is undergoing repairs. Leak-checking of the installed components is in progress; the vacuum system is tight from the quadrupole magnet downstream to the next target cell. The water-cooled shielding is fabricated except for the collimator shield and the shield over the target box. The in-cell shielding has been designed to the 3-m level and installed to about the 1.3-m level.

At target cell A-2 (which serves P^3 and SMC), all the beam-line vacuum-system components have been completed except the target box, a collimator, and a spool section. Some of the components have been installed and aligned. Leak-checking is complete downstream from the target cell. The water-cooled shielding is fabricated, except for the SMC outer block. The in-cell shielding is designed and partially cut; some of it has been installed upstream of the target.

Most of the components of the main beam between target cells A-2 and A-5 have been installed and leak-checked. A large vacuum bellow must be replaced. The limit switch adjustment for the A-3 plug and installation of a steering magnet, harp, and current monitor will complete work in this area.

At target cell A-5 (which serves the Biomed channel), the main beam components are installed and aligned except the modified vertical vacuum tubes for the target mechanism. These tubes are in the final drafting stage. Vacuum-clamp installation is in progress and leak-checking will start shortly. The water-cooled shielding fabrication is complete, as is part of the in-cell shielding. The water-cooling hookup is in the design stage.

At target cell A-6 (main beam stop), components for the main beam vacuum system are installed except for the window. The beam stop has been fabricated and leak-checked; its variable-position drive system is being redesigned and will be rebuilt. The water-cooled shielding south of the beam stop is designed and plate fabrication is 70-80% complete. The downstream shielding design has started.

All component fabrication of the special (remote-handled) alignment equipment is complete. Base monument posts have been installed in target cells A-1 and A-2; final alignment of the A-1 posts is complete. A telescope mount that can sight on the monument posts has been attached to the first EPICS bending magnet. Alignment fixtures for other magnets are being adjusted.

Secondary Beam Lines

During this quarter, preparations for high-intensity operation of the P^3, SMC, and LEP secondary beam lines have been finished. Also, Lines B and EPB have been brought into operation and are in regular use for research.

Significant accomplishments on the P^3, SMC, and LEP beam lines are:

1. Final installation of vacuum flange clamps, clamp stands, bellows retractors, and K-seals in each of the three lines. All three lines have been made vacuum-tight, including K-seal vacuum connections.
2. All mechanisms (beam plugs, adjustable jaws, collimators, absorber or degrader wheels, and vacuum valves) have been made operational.
3. All magnets in the three lines have been checked out under power following extensive dc recabling and magnet power-supply renovation.
4. The canyon-fill shielding for P^3 and SMC has been redesigned and the installation is complete. Bulk shielding covers over the two lines are essentially complete. The LEP canyon-fill shielding has been designed and is now being cut and installed.
5. Rebuilding of the experimental caves for the beam lines is being planned, and the design for the SMC-East cave is being worked out for early testing operation.
6. Realignment of the three lines has been carried out.

In Area B, minor improvements have been made on Lines B and EPB. Two new steering magnets were installed. Remote vacuum valves replaced two manual valves in Line EPB. The LD_2-target vent system was moved to allow installation of Exp. 179. Seven wire scanners were reworked or replaced. A beam stripper and a current monitor were replaced. Two new TV phosphor actuators were installed and new supports for the vacuum beam line were built.

Since Lines B and EPB were placed into service in early October, substantial support has been given to Exps. 192, 179, 193, 241, 42, 176, nuclear chemists, and users of the LD_2 target. Following shielding improvements inside Area B and at beam stop B, proton beam currents in Line B have been increased from 1 to 2 to ~6 μA. Some radiation leaks have been uncovered at the beam stop and around the LD_2 target and await correction, but it appears that experimenters' trailers are now shielded adequately.

Polarized Proton Target Development

The objective of this project is to develop a hydrocarbon polarized proton target facility for LAMPF users on a variety of experiments.

The preliminary testing of the prototype cryostat has been completed. The cryostat has successfully condensed liquid ^{4}He in the ^{3}He space. The next milestone will be to set the cryostat in its final configuration and measure its refrigeration capability using ^{3}He as a refrigerant.

The target magnets are in various stages of preparation. The microwave and rf systems are under development. The target head and preparation of target material are now under development. At the present level of effort, it will not be feasible to accomplish more than a complete test of the prototype cryostat in FY-76.

Targets

The complete A-1 target mechanism has been installed and checked out. An improved program for computer control has been developed and checked out. The A-2 target mechanism has been final-assembled. It is undergoing bench checkout in preparation for installation. The A-5 target mechanism requires cleanup and checkout before it can be installed.

Remote Handling

Purchasing negotiations are in progress for the acquisition of a set of new servomanipulators. The new manipulator arms will be remotely operated master/slave systems with force reflection. Combined with the Monitor boom system, this will provide a fast and versatile remote-handling capability.

Merrimac

Merrimac has been outfitted with a new control chassis and four TV cameras which enable the operator to monitor the steering and oleo functions. Recent Merrimac operations have revealed electrical system and maneuverability problems that can be corrected.

Monitor

Initial mockup operations with the Monitor system have been carried out. Operations included the removal and replacement of a slit assembly on the Biomed quadrupole triplet and changing a helium window on the same magnet. Both items were well prepared for remote handling and were reasonably straightforward to manipulate, although some modifications were found to be desirable. Mockup studies of standard components will continue.

Work on the Monitor TV system is progressing. All cameras, zoom lenses, and TV monitors are on hand. Further operational experience with the system is expected to lead to improvements in remote viewing and straight-line lift capability.

Shielding

The only design work remaining for the main shielding in the experimental areas is the EPICS and LEP canyon fill, and the fill at the downstream end of each line.

At Target Station A-1, much of the in-cell shielding has been fabricated and installed up to beam height. The balance of this in-cell shield is being fabricated for installation after hardware components are checked out. The steel boxes for the Merrimac doors at A-1 have been assembled and are ready for filling and final covers.

At Target Station A-2, the main shielding has been completed and the steel boxes for two of the four Merrimac doors have been installed and are ready to fill. Canyon-fill shielding in the P^3 line has been installed and the cover completed. The fill in the SMC canyon has been installed and most of the downstream cover has been placed. The in-cell shielding and water-cooled shielding near the target components has been fabricated and installed up to beam elevation. This shielding will be completed after hardware checkout is completed.

All shielding around station A-3 has been completed except for final setting of the cover above the

A-3 beam plug. This has been fabricated and is ready for installation.

Considerable shielding has been added to the A-5 (Biomed) target area. Lead walls have been added along both the main proton line and the Biomed line, providing tight shielding very close to the large magnets. Water-cooled steel shielding has been placed under the A-5 target box and other close-in beam-line components. Additional water-cooled pieces are being fabricated for installation around and above the components after checkout has been completed.

At the Line A beam stop, steel shielding has been completed up to beam-line elevation. The south side of the beam stop forming the movable neutrino shutter has been completely installed. Considerable water-cooled steel shielding near the beam stop is yet to be fabricated and installed.

Operations in Area B have revealed several weak areas in the shielding. Additional concrete blocks have been installed along the EPB beam. Some radiation was noted above the Line B beam stop and additional concrete blocks were placed there.

Other major work included the final closure of the SY. This included the stacking of concrete blocks in both truck accesses and the reinstallation of upper sections of the tunnel plugs in Lines B and C.

High-Intensity Modification Program

Early in this quarter about 360 work activities were added to the PERT totals as a consequence of a detailed redefinition of tasks into smaller steps which allow closer surveillance of progress. As of the end of October the PERT system contained about 380 work activities remaining to be completed before Area A is ready for high-intensity beam. Over 400 tasks were completed during the quarter. Expected completion dates for the remaining tasks are rather evenly balanced. The shielding installation, main beam hardware assembly, beam diagnostics, and EPICS beam-line installation are all running on parallel paths. A projection of the present status, based on the previous performance record, leads to a current estimate that Area A cannot be ready for first beam until mid-January 1976.

IX. LARGE-SPECTROMETER SYSTEMS

Energetic Pion Channel and Spectrometers

EPICS Channel Construction

At the end of the previous report period, the large bending magnets and separator were in place. Since then, all of the intermediate hardware (including four slit mechanisms, three multipole magnets, and vacuum transition pieces) were installed. Final alignment of all magnets was accomplished; an accuracy of better than 0.25 mm was obtained. A second vacuum pumpstand with turbomolecular pump was fabricated and installed. The power supply and trim shunt system for the channel magnets were installed and debugged.

Performance of Channel in Alpha-Particle Test

A ^{242}Cm source was mounted at the location of the pion source and a specially designed helical chamber was placed at the focal plane of the channel. The α spectrum from this source consists largely of two lines at 6.1 MeV separated by 40 keV. (These alphas have approximately the same rigidity as 50-MeV pions). The four channel magnets were set at the same field. With the slits in the channel open, the upper spectrum in Fig. IX-1 was obtained. A scan of the first x slit indicated that a small correction in the form of a combination of quadrupole, sextupole, and octupole was needed. This correction was put into the multipoles and the lower spectrum in Fig. IX-1 was obtained. The linewidth observed is 3.5×10^{-4}, and subsequent tests indicate that the α source has a linewidth of 2.5×10^{-4} or greater. From this we conclude that the design resolution of 2.4×10^{-4} has been achieved.

The vacuum system for the channel consists of two 500-ℓ/s turbomolecular pumps with associated mechanical roughing pumps. We find that about two hours are required to get vacuum good enough to start the turbomolecular pumps, and that in two additional hours, the vacuum in the channel is better than 8×10^{-5}.

The separator tests performed during the α-test run were limited by the fact that the high-voltage-regulator circuit was not available, so that significant high-voltage drifts occurred. Nevertheless, it was possible to show that the wrong velocity particles are thrown away and that the resolution is not significantly changed when the separator is in operation.

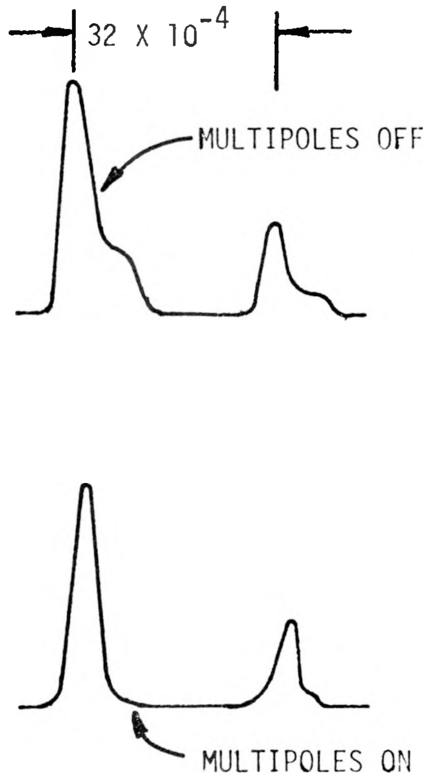

Fig. IX-1.
EPICS momentum-resolution function.

The main power supply for the channel operated satisfactorily during the tests. Typically, in several hours, at the low power level required, drifts were no more than 1 part in 10^4. A test was made for ripple contributions to the resolution and no observable effect was seen with a sensitivity of better than 1 part in 10^4. The shunt system operated satisfactorily at the particle field. However, it was found that insufficient adjustment range is available to match the field in the four magnets for excitations >12 kG. Additional permanent bypass resistors were installed which improved the situation. However, an increase in the dynamic shunt capability is required to get matching at 15 kG and above.

Device Calibration

All of the computer-controlled devices in the channel were calibrated prior to the α-particle tests.

The four-jaw slits were operated on the experimental floor prior to installation. Jaw positions measured with a surveyor's transit were used to calibrate the position-readout potentiometers. Absolute position calibrations are accurate to $\sim$0.13 cm, with relative accuracy of $\sim$0.013 cm.

Position calibrations of the NMR- and Hall-probe assemblies were made with the devices in place. Positions were determined relative to the point in each magnet where the magnetic-field maps were normalized. This point is known to ~0.64 cm. The Hall-probe outputs were calibrated once over the range 4-8 kG. A fourth-order polynomial fit to the calibration data gave rms errors of ~1 G. It remains to be seen whether these calibrations will remain valid over long periods of time.

Accurate current calibrations were made for the multipole magnets by using a precision shunt. Small dc offsets in the readout system presently limit the overall accuracy of the calibrations to ±1 A.

Channel Controls Program

Operating programs for the four-jaw slits and the multipole magnets were written for the α-particle tests. The slit program allows an operator to position a pair of jaws, to move the jaws to their out-limits, or to check the position calibrations. The multipole-magnet program is used to set equal currents in all three windings of a given type. All of these devices operated reliably throughout the α-particle tests.

Initial testing of the magnet power-supply setting code written by Paul Elkins of MP-1 was completed. Procedures for cycling the magnets, optimum rates of current change, and procedures for achieving desired fields were defined during these tests and will be built into the final version of the program.

Particle Separator

The new interlock and control system for the separator has been completed and checked. As part of the α-particle tests, the separator high voltage was set to 50 kV and the separator magnet adjusted to bring the beam back to center. No adverse effects were seen in the α count rate or momentum resolution. These tests were hampered by 5% voltage fluctuations of the high-voltage system, so a regulator was designed and built by Jan Studebaker of MP-1. Short-term tests of the system with the regulator installed showed rms fluctuations of ~30 V at 100 kV.

Substantial time was spent studying the operating characteristics of the C-W high-voltage power supply and retuning it for optimum performance under load. A peculiarity in the behavior of the frequency servo was noted, but this should not affect the operation of the C-W. No testing was attempted at over 100 kV.

Remaining Work

Because of the effort required to complete assembly of the beam line, very little work was done on spectrometer assembly. This situation will not change until all remaining work on the channel has been completed and the shielding cover is in place. Three major areas of the channel need further work. First, the shielding plans are inadequate, and rework of cabling and plumbing are required to allow sufficient shielding in the vicinity of BM-02 and BM-03. The separator door-opening cart has not yet been assembled, and some work needs to be completed on the separator in order to allow full-voltage operation. Finally, the vacuum pumpstand for the front portion of the channel needs to be relocated to the top of the shielding. This job will begin only after the shielding is completed.

High-Resolution Proton Spectrometer

Spectrometer Dipoles

The bulk of the effort during this quarter went into preparations for rigging the spectrometer dipoles into the frame in November. This work basically broke down into specific mechanical work on the dipoles, the frame, the experimental area, and the final magnetic measurements on the two dipoles, HS-BM-01 and -02.

The magnetic measurements consist of two parts: 1) shimming the central-field region of each dipole to obtain an integral field uniformity,

$$1 - \int B_y(r)dr/\bar{B}_y \int dr \rightarrow 0\,, \qquad (1)$$

which is as close to zero as is consistent with the measurement accuracy; and 2) mechanically contouring the nosepieces at the entrance and exit of each magnet to give a prescribed contour to the EFB,

$$Z_E = \mathrm{Sign}\,(1,R)(R^2 - X_E^2)^{1/2} - R$$

$$- X_E^3(CAT + X_E \cdot CFV + \ldots)\,, \qquad (2)$$

defined by the fringing field integrals,

$$\int_{-s_0}^{\infty} B_y(x,0,z)ds\ . \qquad (3)$$

R is the signed radius of curvature of the EFB and s is the normal distance to the EFB at any point (x,0,z). The limits on the integrals in Eqs. (1) and (3) are consistent with one another for each radius over which measurements are taken, with s_0 generally being 2-3 gap heights from the EFB "inside" the magnet gap depending primarily on the location of the central-field shim. Insofar as item 1) is concerned, HS-BM-01 was completed during this period, HS-BM-02 was completed during the previous reporting period. Work on item 2) was completed for HS-BM-01 during this period and work on HS-BM-02 was begun.

Optimization of the central field distributions in both dipoles has been completed with quite good results using shim crates at the entrance and exit of HS-BM-01 and at the entrance of HS-BM-02. The peak-to-peak variation in the internal-field integrals (measured in the median plane along lines of constant radius) is $< \pm 5/10^5$ for a range of ±27.5 cm about the optic axis at an excitation of 14 kG. This field quality deteriorates by a factor of 2 ($\pm 1/10^4$) over the range of excitation 4 kG $<B_0<$ 14 kG. The corresponding rms values are considerably better, however. Table IX-1 summarizes the important steps and our results for the final system with both dipoles:

TABLE IX-I

DIPOLE RESULTS

Operation	Peak-to-Peak ($\times 10^{-5}$)	RMS ($\times 10^{-5}$)
1. basic magnets in original form:	$\lesssim$115	$\lesssim$34.0 (10 kG)
2. disassembly of magnets and hand grinding of pole surfaces:	<57 <55 approximately linear gradients in field distributions	<17.0 (10 kG) <17.0 (14 kG)
3. shimming the leg pieces of the yoke structure:	$\lesssim$24 only for a single field, i.e., shim thickness depended upon B_0	$\lesssim$7.0 (14 kG)
4. addition of 40 motion-constraining steel tabs per magnet spanning the interfaces of adjacent pieces of yoke structure; reoptimization of magnet-excitation procedure:	$\lesssim$30 4 kG $<B_0<$ 14 kG	$\lesssim$8.0
5. addition of symmetric-pair pole-face shims	$\lesssim$10 $\lesssim$20 4 kG $<B_0<$ 14 kG	$\lesssim$2.3 (14 kG) $\lesssim$4.0

A summary of the various measurements and the main results for HS-BM-01 are presented in Fig. IX-2, with the listing of the plots in chronological order. The corresponding results obtained for HS-BM-02 are shown in Fig. IX-3. It is emphasized that no use was made of the H_t windings in any of these results. They are installed and serviceable in both magnets, and will be used before the rigging if time permits.

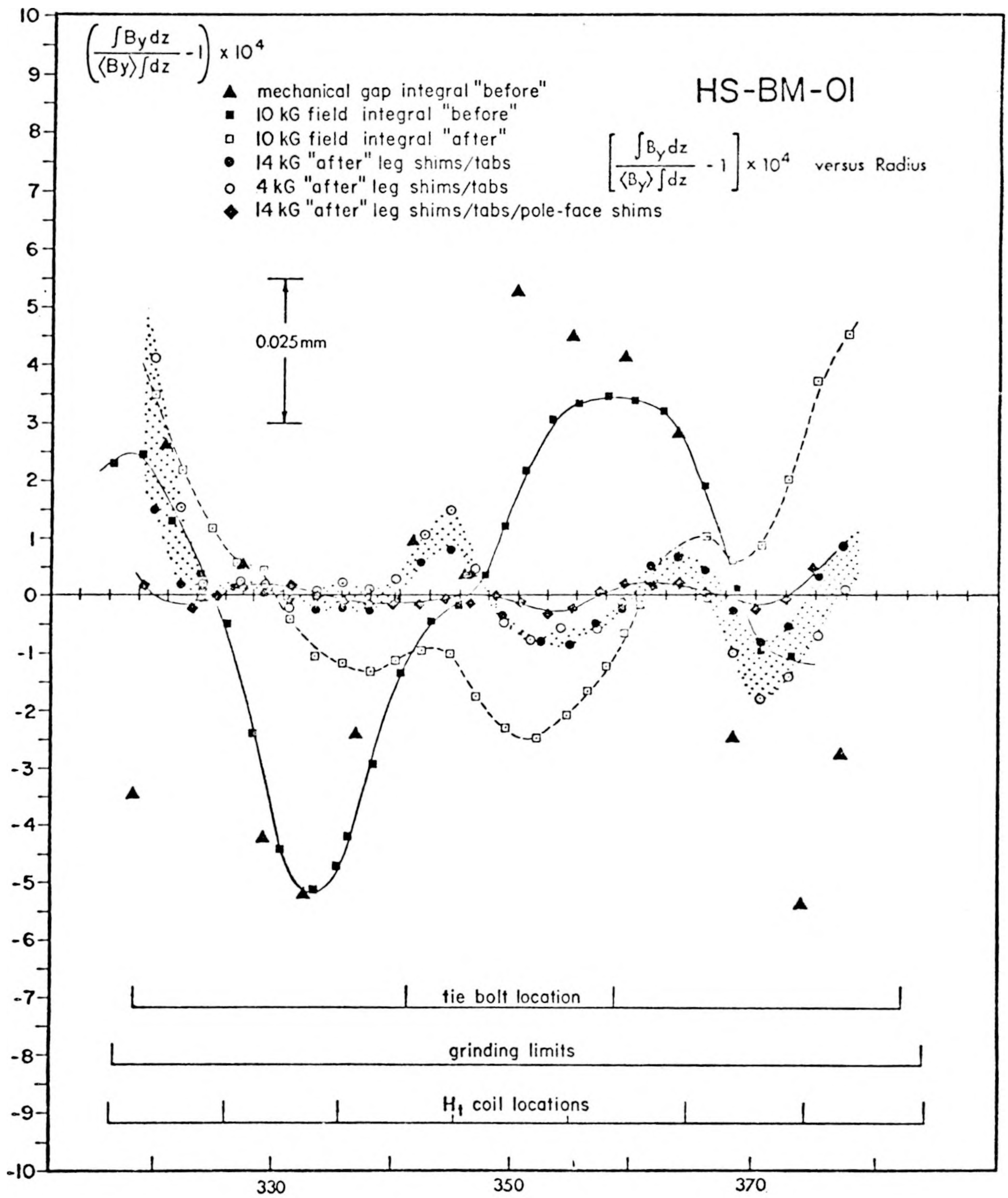

Fig. IX-2.

Variation of central field, integral uniformity in parts in 10^{-4} as a function of magnet cart radius. The optic axis of the spectrometer has a radius of 3.5 m. "Before" indicates the results prior to the hand-sanding operation on the pole surfaces.

Completion of the EFB work in the fringing-field portions of the magnets involved several steps. In the original mechanical design, the pole-end tips were machined as circles on the premise that higher than second-order curvatures in the EFB could be induced through machining corresponding curvatures on the nosepieces of the field clamps. However, the pole-end tips were made separable from the main

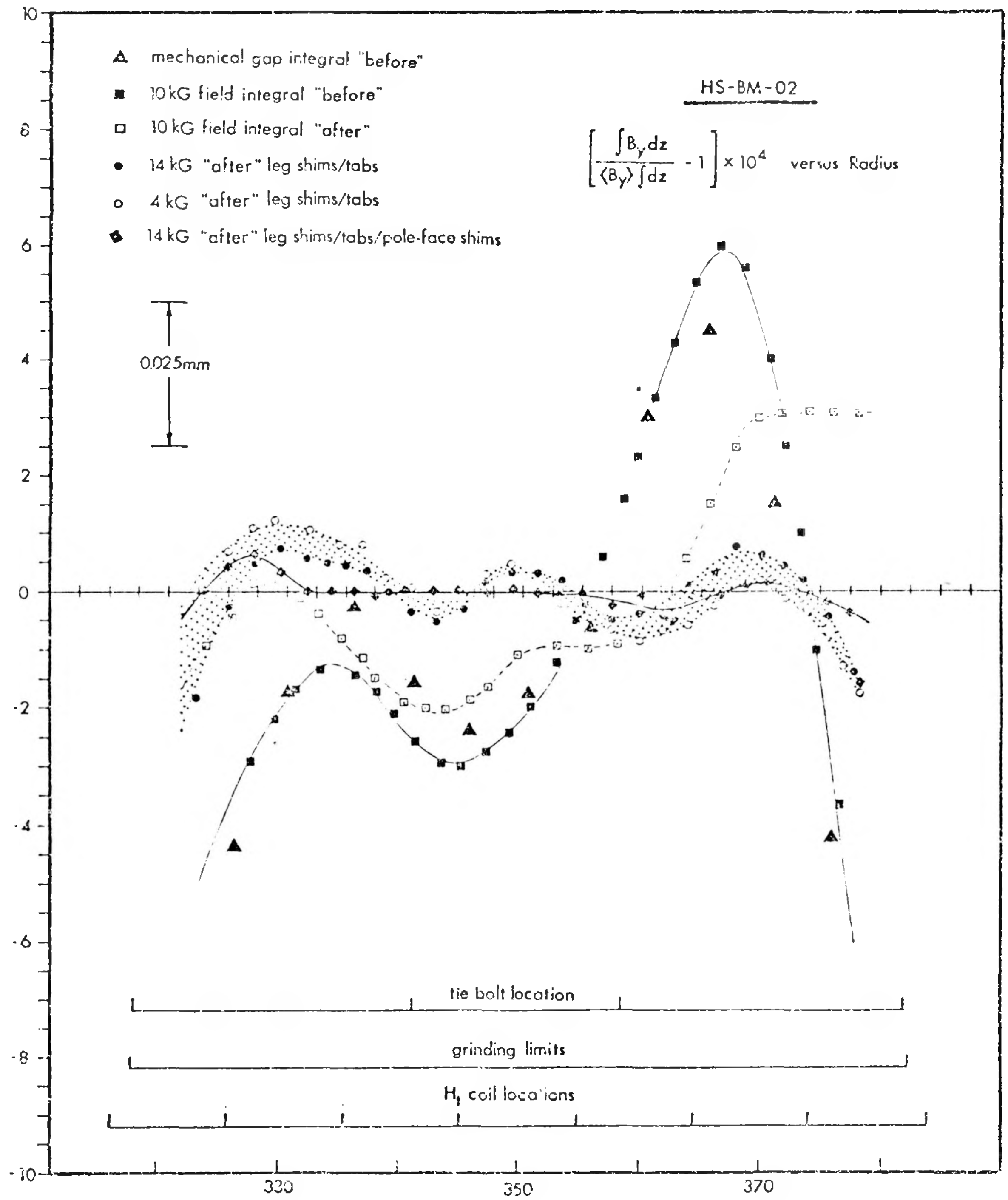

Fig. IX-3.
Same as Fig. IX-2 except for HS-BM-02. The final 4-kG data taken after sanding and the addition of the leg shims, tabs, and pole-face shims was not included (to minimize confusion).

pole to allow the possibility of changes should the need arise. The main problems were then associated with obtaining a given EFB that was stationary in location and shape as a function of central-field level. To obtain stability, it was necessary to minimize motion and saturation of both the pole-end tips and nosepieces as well as consider the influence of the cycling procedure.

The initial measurements were made with HS-BM-02, using circular nosepieces. Although the machined radii of the pole-ends were basically correct, there was motion of the pole tips which was eliminated by welding them to the main body of the pole. A programmed milling machine was selected to make a single segment across the transverse dimension (X). This allowed a more conservative design from the magnetic standpoint, i.e., thicker pieces and better contact to the clamp (Fig. IX-4). It was also felt that this would be cheaper in the long run, if not more than one additional pass on the milling machine was required after the initial one. While the level of accuracy required in the final result as well as the quality of the magnet have a lot to do with how many passes are required, we found that only one pass is necessary if one can shim the nosepiece and translate it relative to the pole.

As a result, the basic procedure consisted, wherever possible, of initially machining the nosepiece profile to a radius compatible with the higher order profile, making magnetic measurements on the resulting system, comparing these results to the final desired result, including the higher orders, and doing a final machine pass to eliminate the difference between the existing and desired shapes. We will not discuss the algorithm which relates the actual nosepiece contour to that of the EFB. Any discrepancies which remained after the second machining were then removed by adding shims to the surfaces of the nosepieces facing the magnet. These surfaces were periodically drilled and tapped so that the shim could generally be added without removing the nosepiece from the clamp. Figure IX-5 shows a plane view of the exit of HS-BM-01, which is typical of the other boundaries, comparing the final results to those for an ideal magnet, i.e., ignoring side effects. Figure IX-6 shows the measurement results at various stages, together with the sensitivity to higher order terms. The final result in this case shows a peak-to-peak variation of ≤ 0.2 mm over the region within 25 cm of the optic axis between 4-14 kG. Since the absolute location accuracy of the measurements is not better than

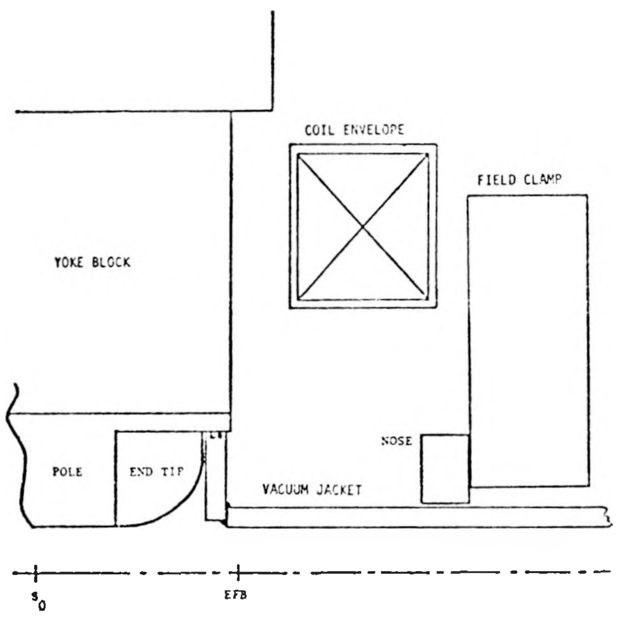

Fig. IX-4.
Typical section view of the fringing-field region of HS-BM-01/02 showing the main components. The symmetric-pair, pole-face shim crate is located to the left of S_0 in the figure.

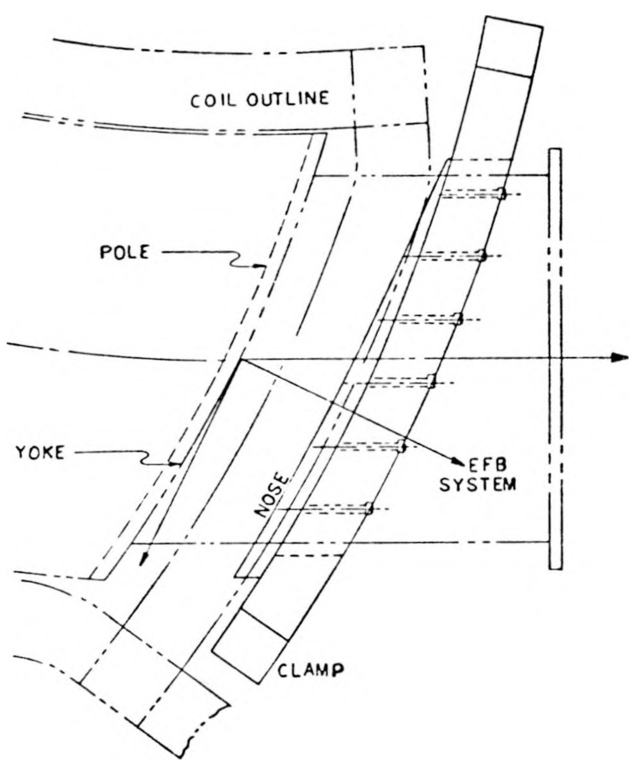

Fig. IX-5.
Schematic top view of the pole, yoke, nose, and clamp for the exit of HS-BM-01.

±0.25 mm, the absolute locations at the different fields are considered consistent with one another.

An interesting characteristic of all the field maps (Figs. IX-2, -3, -6) is the existence of narrow bumps as small as a half gap (~5 cm) or so in the X dimension. It is clear that the conventional multipole expansion is not well-suited for such situations. Figure IX-7 shows the multipole magnet which was designed in collaboration with the Univ. of Texas to go between HS-BM-01/02 to make up the QDMD system. Since there is a vertical waist between the two dipoles, this greatly simplifies the requirements on such a magnet. If one is able to independently excite each pair of opposing "teeth" with the same current in Fig. IX-7, then the result is as shown in Fig. IX-8. The main result is a single-pole profile with a FWHM of 0.7 g. Considering this profile as a basis function, one can then superimpose them to construct essentially any multipole or linear combination of multipoles as shown in Fig. IX-9.

In addition to finalizing the magnets based on the field measurements, there was a considerable amount of work on preparing the area for rigging (removing magnets, beam pipe, scanners, etc.) from Area C as well as two very necessary and interesting operations as discussed below.

Optical fiducials were positioned on both magnets to define the centerlines of the entrance and exit beam and their intersections. These will permit mechanical alignment of these magnets after assembly into the structure. The structure was optically surveyed and targets were placed so that the crossmembers to which the support lugs attach and the support lugs can be positioned closely to their calculated positions. This should minimize the repositioning of these magnets after their initial

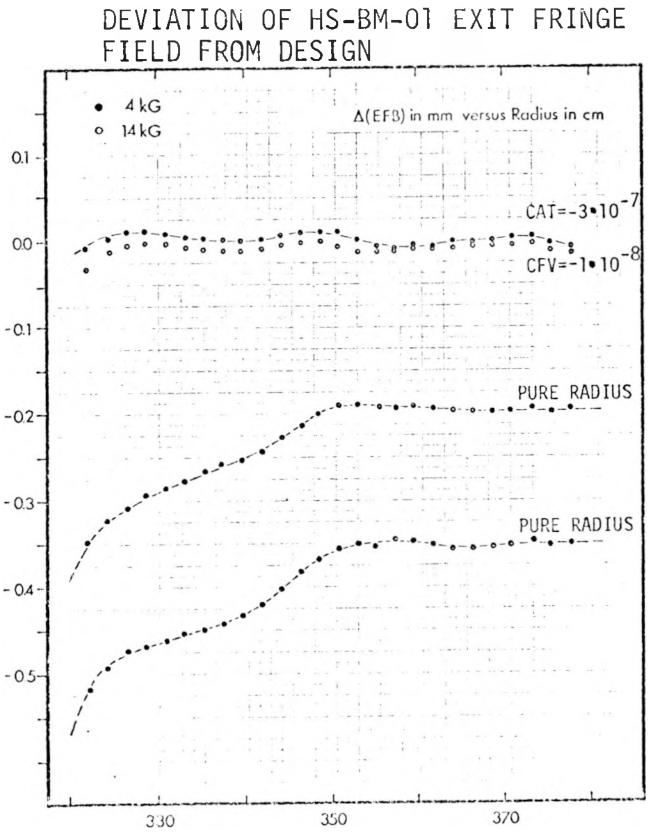

Fig. IX-6.
Measurement results at various stages of the end-field optimization. The bottom curves show the results where the nosepiece is machined to a concentric circle with the pole and when the clamp and nose combination is translated 1.27 cm away from the pole. The upper curves are the final results when the deviations in the bottom curves are removed and the indicated higher order curvatures are included. CAT has units of cm^{-3} *and CFV has* cm^{-4}.

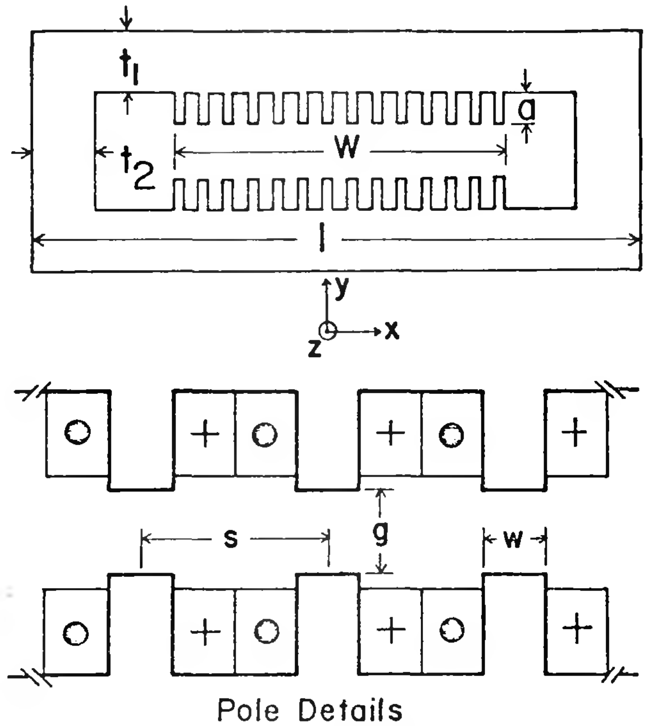

Fig. IX-7.
Top: The x-y cross-sectional iron geometry for the HRS multipole element. The magnet extends in the z-direction a distance which is large compared to the gap g. Bottom: Pole-coil details of the corrective magnet. The relevant dimensions are indicated.

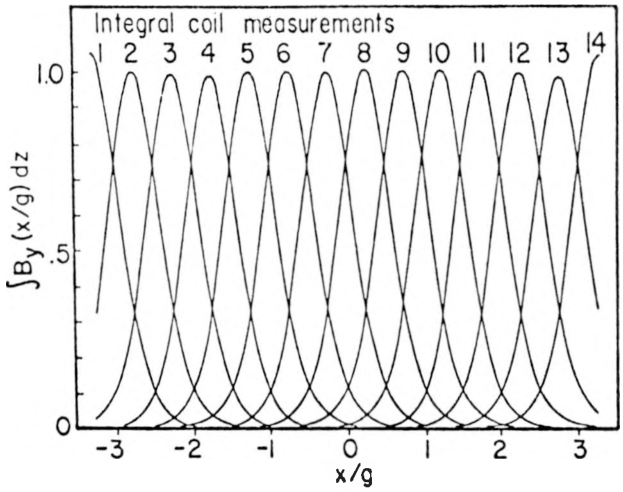

Fig. IX-8.
Results of integral coil measurements for the individual distributions of all 14 pole-pairs. The vertical scale is arbitrary.

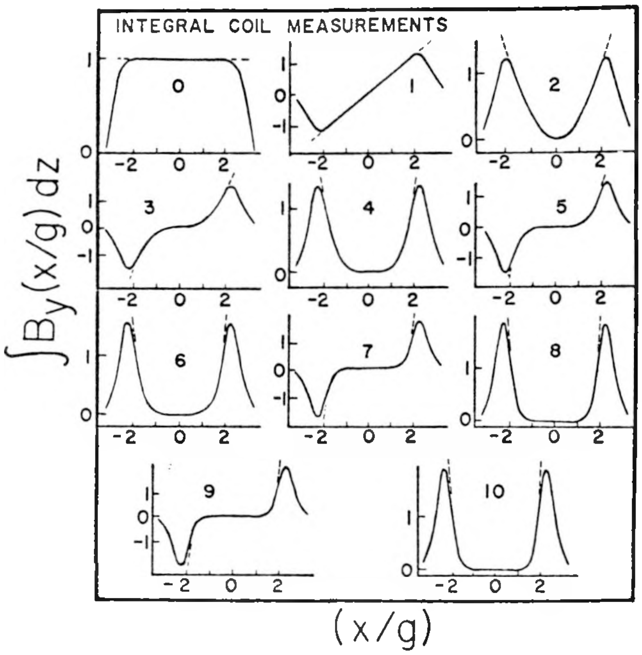

Fig. IX-9.
The solid lines are the integral coil measurements for the various multipole modes (up to tenth order) using distributions 2-13. The dashed lines are curves of pure multipolarity $(x/g)^i$. The order of multipolarity is indicated next to each curve and the vertical scale is normalized to 1.0 at x/g = 2.0.

placement in the structure. The necessary structural members needed for repositioning of these magnets were designed and fabricated during this period.

These above-mentioned magnets are supported in the structure by attachments consisting of lugs, pins, bolts, and spherical bearings (monoball type). The decision was made during design of these components that a considerable monetary saving could be accomplished by performing an overload test on these components rather than extensive nondestructive tests, such as x-ray, ultrasonic, or magnetic-particle tests, to find defects in the many small parts. The Zia Co. has a testing facility capable of performing these tests. Material was purchased to specification, and fabrication was performed to weld specifications to rather tight requirements. The welders were qualified to ASME Pressure Vessel Code IX. Preheat and interpass temperatures were controlled throughout welding.

The end result was that all mounting-lug assemblies were pull-tested to 1.3 times their design load. Strain gauges were positioned and monitored during these pull tests. These strain readings, when converted to stress, confirmed the design calculations very well. The highest stress, as determined from these strain gauges, confirmed that the assemblies have a safety factor of ~2:1.

Area C Counting House

During the past quarter, hardware and software to support the remote console in CCH linked to CCR have been tested and debugged. We have been able to communicate with programs residing in the 840 computer in CCR from a Kinetic-Systems CAMAC-driven character scope in CCH and to plot results on the Tektronix 4010s in CCH. Protection software in the 840 to disallow inadvertent access to accelerator or other beam-line parameters has been checked and shown to be functional. A CAMAC module to interface a panel of "slew" knobs to the PDP 11/45 has been implemented. Software to run these knobs under the RSX operating system has been written and is being tested. Two CAMAC crates interfaced directly through the bus to the PDP 11/45 have been installed for control and monitoring as well as one through the MBD for data acquisition. The Q program for data acquisition is running under RSX on this system and is now being used to test counters and software for the HRS particle-identification system.

Particle-Identification System

The basic particle-identification system for the HRS is based primarily on particle flight times and energy losses in scintillators. The determination occurs in two stages. The first, consisting of the fast electronics, is designed to permit efficient data-taking with a rather flexible system which allows selection of one or more particle types together with a simultaneous sampling of possible background sources and event losses. This stage also provides data for the second stage which is based on analysis in the computer where additional and redundant information is available to provide a more precise determination.

Two large-area scintillation counters (1.3 × 36 × 178 cm) and their support frames have been delivered, assembled, and tested. Two smaller area scintillation counters (1 × 14 × 107 cm) for timing and spectrometer-acceptance determination have been assembled and tested. The frames for these counters as well as the structural support allowing independent x-y motion of both counters were built by the Univ. of Texas.

The final installment of fast electronics has been acquired and tested under realistic conditions, i.e., with phototubes and scintillators using minimum ionizing particles. The CAMAC electronics have also been obtained and installed. A light-flasher system with 30 light flashers remoted to CCH from the spectrometer frame is under construction which will provide nanosecond timing setups as well as pulse-height calibration for each detector. In addition, a remotely programmable, CAMAC-driven 16-channel delay box has been laid out in collaboration with E-Division which provides up to 100 ns/channel of delay and will pass NIM logic levels having widths down to 6 ns (FWHM) with <10% deviation at the output.

The basic system has been installed in Area C for testing with cosmic rays prior to tests with the pencil beam. Preliminary programming of the CAMAC data-acquisition system for this setup using the MBD and Q program of MP-1 has begun without appreciable delay or incident. The final report on this system will soon be distributed to HRS users.

X. RESEARCH

Tests, Data Runs, and Analyses of Experiments

Total Pion Cross Sections (Exp. 2)
(Univ. of Montana, New Mexico State Univ., Univ. of Basel, LASL, Univ. of Washington, Stanford Univ., California Inst. of Tech.)

The last quarter has been a time of preparation for the upcoming experiment to measure total pion-nucleus cross sections. The emphasis has been on the construction of new equipment which will either increase our capabilities or be more convenient to operate.

The beam-defining system will have new counters for double-event rejection and geometric definition of the beam. A computer-controlled mechanism for target changing has been built and tested. The construction of four MWPCs with 1-ns/wire delay-line readout is complete and the chambers are undergoing tests. For measurements near 20 MeV, another stack of counters for measuring the scattered beam has been constructed which contains 3.2-mm-thick counters. A new data-acquisition program is nearing completion, and data-analysis programs for use during the experiment are being developed for the CDC-6600 computer (to be accessed by remote terminal at LEP).

Analysis is continuing on the preliminary data for the first run which may yield reliable results for the differences in neutron and proton radii in neighboring isotopes.

Elastic Scattering of π^+ from Deuterium (Exp. 34)
(Univ. of Virginia, LASL)

We have continued to analyze data from the scattering of π^+ on deuterium. The experiment has already been described in previous reports. In brief, using targets of CD_2 and D_2O, positive pions were scattered from the P^3 beam and detected in a spectrometer. A second arm was used to detect and identify the recoil deuterons with an E-ΔE system. Helical chambers measured the trajectories of the scattered pion and recoil deuteron. Alternate CH_2 and H_2O targets were used to take data for normalization by comparison with πp scattering.

Our previous uncertainty in the determination of the beam size, which affected the solid angles calculated for the system using a Monte Carlo routine, has been investigated and reduced significantly. This was done by examining mappings of the target using selected subsets of the data. These subsets were chosen so as to have the best trajectory information available.

At present we are evaluating the efficiency and sensitivity of the cuts on the data. This is particularly important to the assignment of error bars on the data as previously presented in the July 31, 1975, progress report.

Evaluation has been made in regard to the corrections for pion decay, deuteron breakup, and nuclear interactions in the apparatus. These corrections are still not complete but are less than the expected 5% correction in most cases. Deuteron breakup is significant (50%) in a few cases with high deuteron-recoil energies.

The analysis on the 550-MeV/c data is nearing completion, and the analysis of the 650-MeV/c data has been started.

Breakup of Few-Nucleon Systems and Nuclei (Exp. 42)
(LASL, Univ. of Southern California, Univ. of California at Santa Barbara)

Participants in Exp. 42 plan to measure the probability of forming deuteron clusters in ^{6}Li and triton clusters in ^{7}Li by the ^{6}Li(p,pd)α and ^{7}Li(p,pt)α reactions.

At the present time, several preliminary runs have been made. The proton spectrometer and the heavy-particle telescope (measuring the direction and energy of the deuteron or triton) are functioning properly. It is expected that the data-taking phase will be completed during the next quarter. Software for data acquisition is essentially complete, and the software for data analysis is under development.

Analysis of Neutron Spectra from the Reaction pp → n at 0° and 647, 766, and 800 MeV (Exp. 56)
(Texas A&M Univ., Univ. of Texas, Univ. of New Mexico, LASL, Univ. of Geneva)

Analysis of the data has continued with special regard to corrections arising from multiple events in the MWPCs and also with regard to the absolute normalization. At the Santa Fe Conference in June 1975, we became aware of comparable data from the Saclay-Caen group which will provide interesting comparisons. A draft of a paper is in progress.

Forward Elastic Scattering of π^+ and π^- from ^{12}C, ^{16}O, ^{40}Ca, and ^{208}Pb (Exp. 80) (Rice Univ., Univ. of Houston)

The analysis of the first data taken on Exp. 80 is now complete, and a manuscript is in preparation for publication. The small-angle scattering of π^+ from ^{40}Ca was measured at laboratory kinetic energies of 205, 174, and 145 MeV, while π^+ from ^{12}C and ^{208}Pb was measured at 145 MeV. The angular range of these measurements was from 6° to 22° in the laboratory. The real part of the forward elastic-scattering amplitude, $\mathrm{Re}f_n(0)$, extracted from our ^{12}C data, agrees well with values of other authors as well as dispersion calculations.[1,2] The agreement between the $\pi^+-{}^{40}Ca$ data of this experiment and the $\pi^--{}^{40}Ca$ data of Blecher *et al.*[3] is less satisfactory.

Figure X-1 shows the experimental arrangement. The P^3 beam provided a 5-cm-diam beam spot, with 2% (FWHM) momentum bite at the scattering target T. Protons in the beam were removed by the P^3 degrader-absorber system and were further discriminated against by dE/dx losses in scintillator S1. A 1-m-long gas CO_2 Cerenkov counter served as a positron veto. The remaining $\pi^+-\mu^+$ beam is recorded by a threefold coincidence between S1 and the two multistrip scintillation counters (MSSC1, MSSC2).

The magnetic spectrometer consists of a "C" magnet, a "D" magnet, and six MWPCs mounted on the Kontiki platform. The Kontiki platform is able to rotate from −2° to 24° about a pivot directly beneath the target T. The pion-scattering angle is determined from the coordinates of MSSC1, MSSC2, P1, and P2 with a resolution of 1° (FWHM). These same coordinates determine the position of scattering. The momentum of the scattered pions is determined independently by both the "C" and "D" magnets with a momentum resolution of 1% (FWHM).

The solid angle of the spectrometer and beam purity are determined from Monte Carlo simulations of the experimental apparatus. Initial pion orbits are obtained in special runs where MSSC1 and MSSC2 record the beam-phase space on magnetic tape for later use. To calculate the solid angle, pions allowed to scatter from the target and their trajectories are traced through the detectors of the spectrometer. The ratio of pions passing through the active area of all detectors to all pions scattered determines the solid angle. To calculate the beam purity, the flux of μ^+ resulting from the decay $\mu^+ \rightarrow \mu^+ + \nu$ that would pass through the magnetic spectrometer is predicted by a Monte Carlo simulation. The ratio of this predicted flux to the observed flux is taken as the beam purity.

Figure X-2 is a graph of the elastic differential cross section observed for $\pi^+-{}^{40}Ca$ at 204 MeV. The

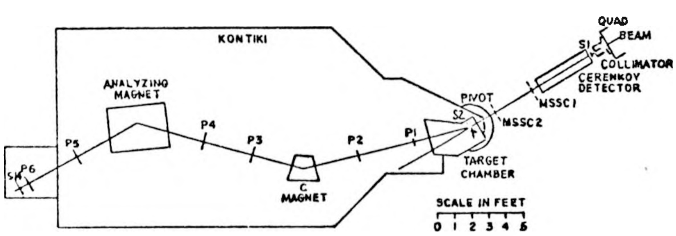

Fig. X-1.
Layout of Exp. 80.

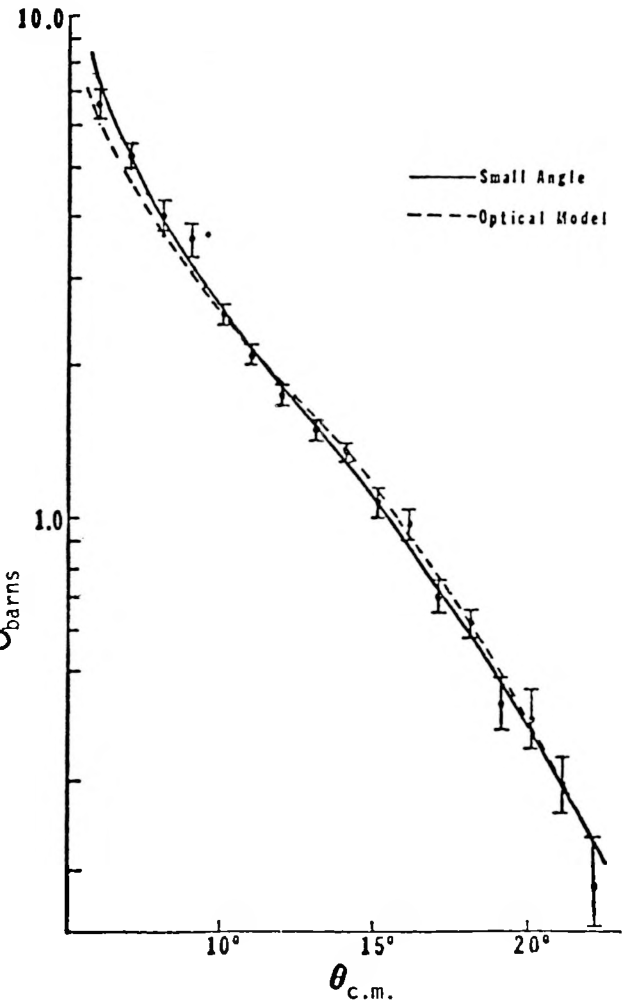

Fig. X-2.
Elastic differential cross section for $\pi^+-{}^{40}Ca$ at T = 204 MeV. The solid curve is the best fit of the diffraction model, while the dashed curve is the best optical-model fit.

dotted line is the best fit of the optical model code DAMIT[4] using a Laplacian potential. The solid line is the best fit of a modified small-angle diffraction model suggested in Ref. 2. The modifications to this model include corrections for electromagnetic effects and a recalculation of the nuclear-Coulomb phase difference. This modified phase calculation was explained in our preceding report, and a detailed discussion of the electromagnetic correction is given in Ref. 5. It is seen that both theoretical models fit the data well and predict similar results.

Table X-I lists the values obtained by fitting this diffraction model to our ^{40}Ca and ^{12}C data. There are four possible fit parameters which are σ_{tot}, $\alpha(0)$ (the ratio of $\mathrm{Ref}_n(0)/\mathrm{Imf}_n(0)$, R_S, and K). In all cases, K was chosen to be zero. For ^{40}Ca the other three parameters were allowed to vary, while ^{12}C σ_{tot} = 690 mb (interpolated from CERN σ_{tot} work) was held fixed. This model gives reasonable fits for all targets. Figure X-3 is a graph of $\mathrm{Ref}_n(0)$ *versus* kinetic energy for ^{12}C from our work and Refs. 1 and 2. The solid curve is the dispersion calculation of Ref. 2. Thus our ^{12}C data is in good agreement with previous work. Figure X-4 is a graph of $\mathrm{Ref}_n(0)$ *versus* kinetic energy for the $\pi^+ - {}^{40}$Ca data of this experiment. It is seen that the $\mathrm{Ref}_n(0)$ passes through 0 at a kinetic energy of ~170 MeV, which agrees well with previous results for ^{12}C and ^{16}O (Refs. 1, 2, and 5). A more complete analysis of π-^{40}Ca nuclear-Coulomb scattering awaits measurement of $\pi^- - {}^{40}$Ca scattering and accurate determination of total cross sections for negative and positive pions.

Deuteron Breakup by Protons and Pion Production in Proton-Proton Interactions at 800 MeV (Exp. 81)
(Rice Univ., Univ. of Houston)

Participants in Exp. 81 have been investigating three reaction mechanisms: quasi-free scattering (QFS), final-state interactions (FSI) from a kinematically complete experiment on p + d → p + p + n, and pion production from p + p interactions. The apparatus has been described in previous progress reports.

The analysis of p-p QFS data, corresponding to p-p elastic-scattering angles, has been completed. The data are in good agreement with the Hulthén deuteron wave function out to a spectator momentum of 180 MeV/c. The final analysis and correction of the QFS data taken at symmetric laboratory angle pairs is in progress.

The analysis of the n-p FSI data is essentially complete, and a manuscript is in preparation for publication. Shown in Fig. X-5 is the n-p FSI cross section divided by phase space *versus* the n-p relative momentum. The proton momentum spectra corresponding to these p-d elastic-scattering angles have been presented in a previous quarterly report. Using the theories of Goldberger-Watson and Watson-Migdal, the spectra in Fig. X-5 have been fitted to the singlet and triplet contributions to n-p scattering plus a constant term. The solid curves in the figure represent the sum of all contributions, the triplet term plus constant term, and the constant term alone. The main difference between the

TABLE X-I

VALUES OBTAINED BY FITTING THE DIFFRACTION MODEL TO EXP. 80 DATA

Target	T(MeV)	$\alpha(0)$	σ_{tot} (mb)	R_s (fermi)	χ^2/DF
^{40}Ca	205	-0.478 ± 0.131	1299 ± 131	4.76 ± 0.12	1.04
^{40}Ca	174	0.030 ± 0.051	1647 ± 57	4.93 ± 0.09	1.43
^{40}Ca	145	0.197 ± 0.079	1637 ± 78	4.56 ± 0.22	1.52
^{12}C	145	0.059 ± 0.042	690[a] ± 7	2.74 ± 0.18	0.881

[a] σ_{tot} was not varied. Value taken from: "A Comparison of π^+ and π^- Total Cross Sections of Light Nuclei Near the 3-3 Resonance" by C. Wilkin, C. R. Cox, J. J. Domingo, K. Gabathuler, E. Pedroni, J. Rohlin, P. Schwaller, and N. W. Tanner, Nucl. Phys. **B62**, 61 (1973).

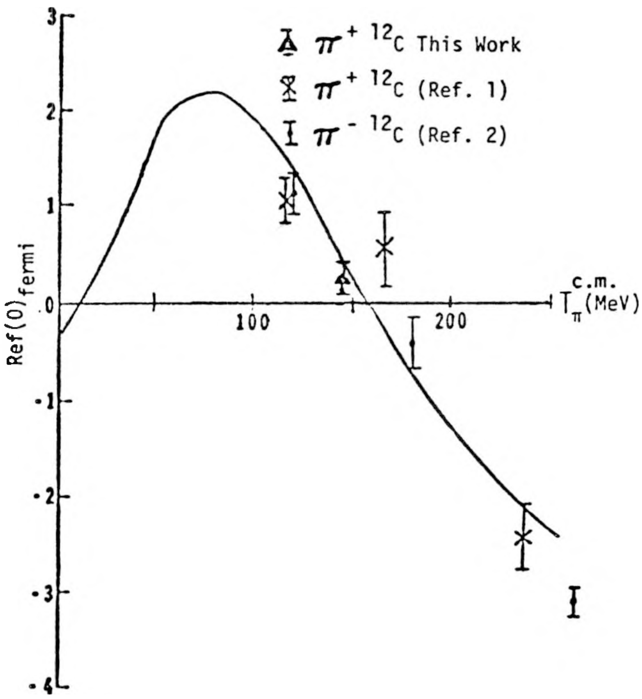

Fig. X-3.
Graph of $Ref_n(0)$ **versus** *kinetic energy for our $\pi^+ - ^{12}C$ data at 145 MeV along with the values of Refs. 1 and 2. The solid curve is the dispersion calculation published in Ref. 2.*

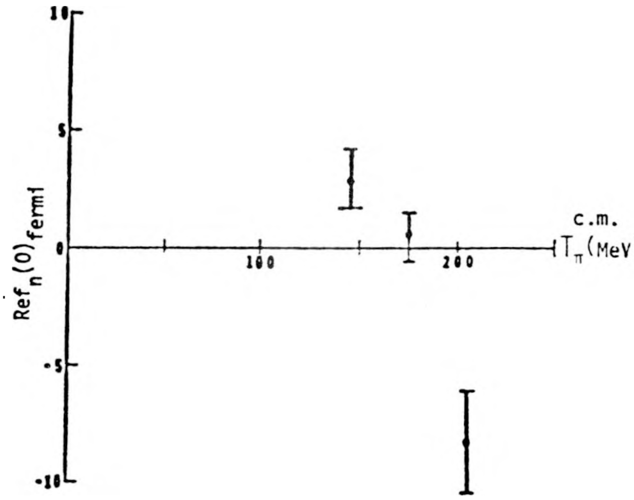

Fig. X-4.
Graph of $Ref_n(0)$ **versus** *kinetic energy for our $\pi^+ - ^{40}Ca$ data.*

Goldberger-Watson and Watson-Migdal fits to the data is the size of the constant terms, which are given separately in Fig. X-5. The ratio of the triplet-to-singlet contributions was allowed to vary and was found to be larger than the 3:1 ratio predicted by spin statistics. Calculation of the cross sections for the production of d^* triplet and d^* singlet integrated out to various n-p relative energies is in progress.

The analysis of the pion-production data taken in 1974 is in its final phase. The following reactions have been measured and analyzed:

1) $p + p \to \pi^+ + p + n$
2) $p + p \to \pi^+ + d$
3) $p + p \to \pi^+ + (pn)$

Reaction (1) has been studied by detecting the pion and proton in coincidence, in a coplanar geometry for the angle pairs: $\theta_p = 25°$ and $\theta_{\pi^+} = 25°$; $\theta_p = 30°$ and $\theta_{\pi^+} = 30°$, 40°, and 50°. At these kinematical conditions the π^+-p relative energy is close to that of the $\Delta^{++}(3/2,3/2)$ isobar, while the π^+-n and n-p relative energies are far from the region where the final-state interactions via $\Delta^+(1/2,1/2)$ or the d^* are significant. The differential cross section as a function of the pion momentum is shown in Fig. X-6,

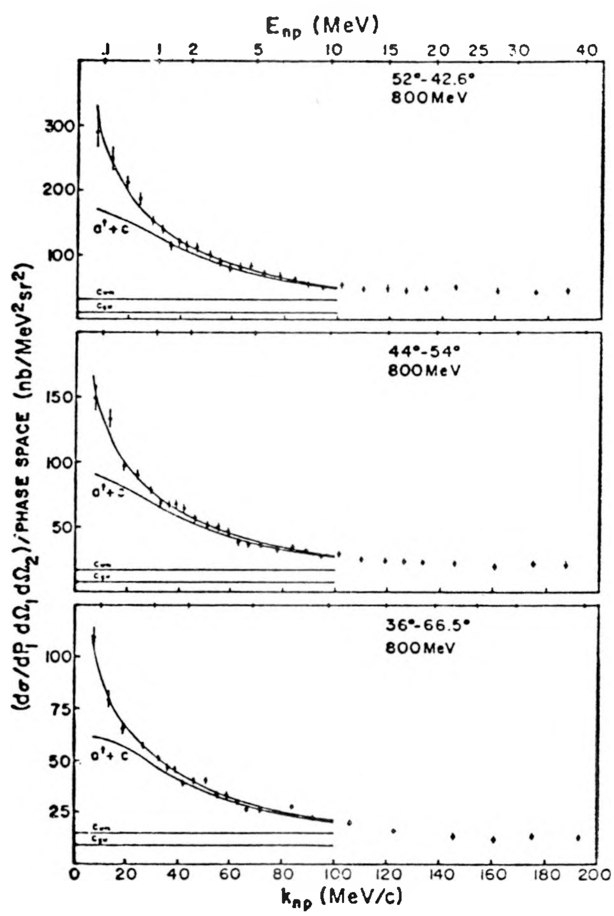

Fig. X-5.
The n-p FSI cross sections as a function of n-p relative momentum. The solid curves are the result of fits to the data as explained in the text.

after being corrected for solid angle and pion decay. The arrows indicate the expected enhancement due to the formation of the Δ^{++} isobar, while the peaks at the maximum pion momenta are produced by the three-body phase space. Under the assumption that the dominant reaction mechanism is the formation of the Δ^{++} isobar, a kinematical variable of interest is the invariant energy of the π^+-p pair. If the phase-space contribution is divided out of the cross section, the data plotted as a function of this variable exhibit the features of the Δ^{++} isobar as shown in Fig. X-7. To reproduce the expected width and position of the resonance, a simple isobar model similar to that of Mandelstam[6] was used to obtain the dotted curves in Fig. X-7. The model assumes that the momentum dependence of the spectra is due entirely to the Δ^{++} resonance between the pion and proton in the FSI. Phase-shift values for the J = 3/2, T = 3/2 π^+-p resonance were obtained from Ref. 7. The agreement between the measured and calculated cross sections is satisfactory for the data with proton angle 30°, while for the most forward proton and pion angles (25°-25°) there is considerable discrepancy. This might be caused by the rather big angular opening of the system and the limitations of the isobar model. These results have been submitted for publication.

Pion production has also been studied in a single-arm experiment, detecting only the charged pion. A typical pion spectrum (Fig. X-8) contains a broad peak corresponding to reaction (1) and a narrow peak corresponding to either a deuteron from reaction (2) or a d* from reaction (3). The momentum resolution is not sufficient to distinguish between reactions (2) and (3). A study of the angular distribution of all three reactions is in progress.

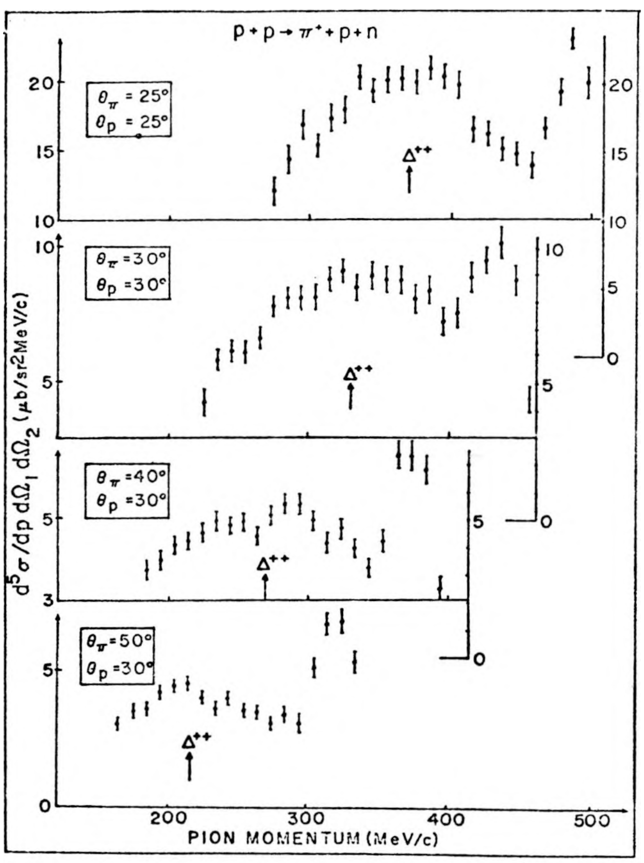

Fig. X-6.
Pion momentum angular distribution for the two-arm experiment data.

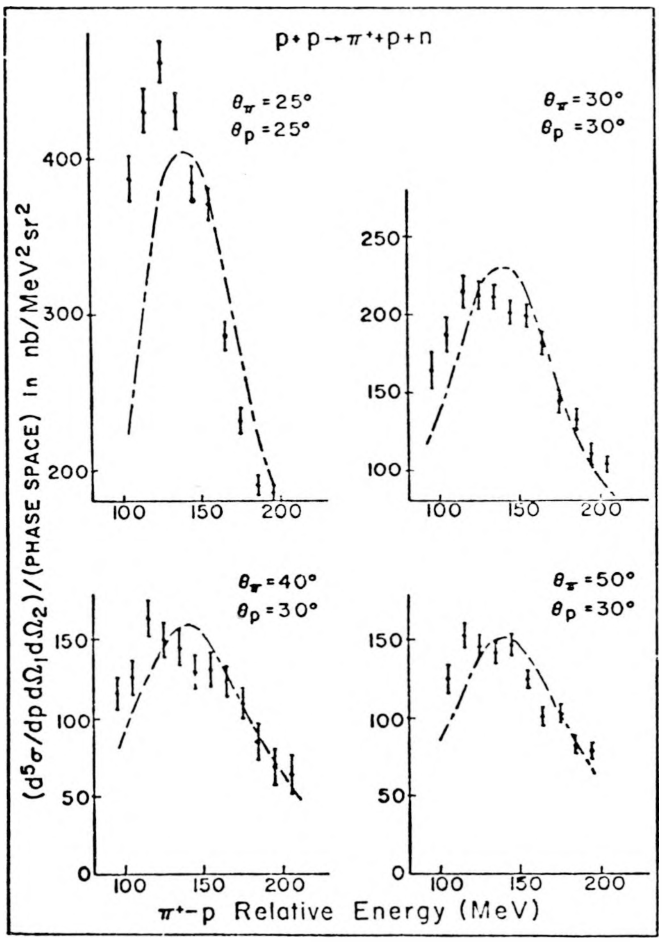

Fig. X-7.
Relative energy distribution of the π^+-p reactions. The dotted line represents the prediction of the isobar model.

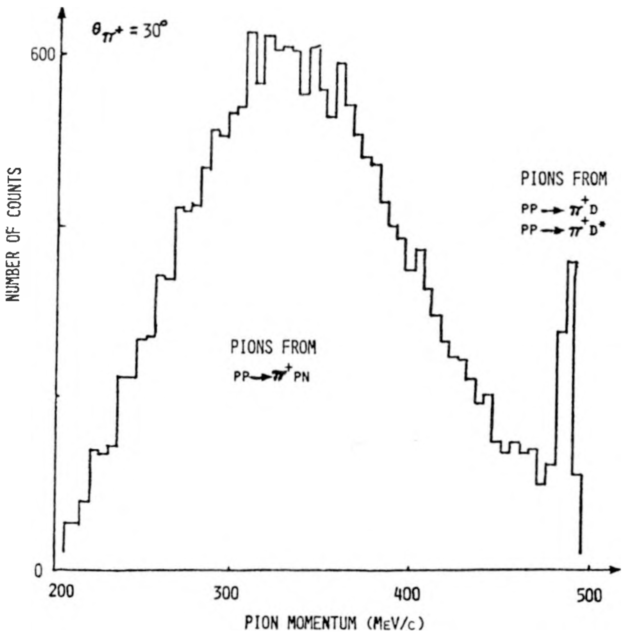

Fig. X-8.
Pion momentum spectrum for the single-arm experiment data, $\theta_{\pi+} = 30°$.

Counter Experiments in the Thin-Target Area (Exp. 86)
(LASL, LBL, Texas A&M Univ., ORNL, BNL)

Fragment Production in the Interaction of 800-MeV Protons with Uranium. The energy spectra of boron-magnesium nuclides produced in the interaction of 800-MeV protons with a uranium target have been determined at 90° (lab) by dE/dx and TOF techniques with a silicon detector telescope. The experiment was done in the LAMPF TTA at a proton beam intensity of 10 μA. Fragment flight times were determined over the 25-cm distance between the ΔE and E detectors and simultaneously over the 4.3-m distance from the target to the ΔE detector, utilizing the 201-MHz linac rf pulse as one of the timing signals. The nuclear charge (Z) of the fragments was determined from the dE/dx information, and the mass (A) of the fragments was determined from both the TOF and the energy signals via the non-relativistic equation $M = E \times T^2$. The time resolution over the 25-cm flight path was 0.25 ns (FWHM) for carbon nuclides, corresponding to a mass resolution of 5.2%. The time resolution over the 4.3-m flight path was 0.9 ns (FWHM), corresponding to a mass resolution of 1.1% for ^{13}C. Essential for this dramatic improvement in mass resolution was the use of the information from the short flight-path measurement to determine which rf pulse the fragment originated from. The sodium-mass spectrum

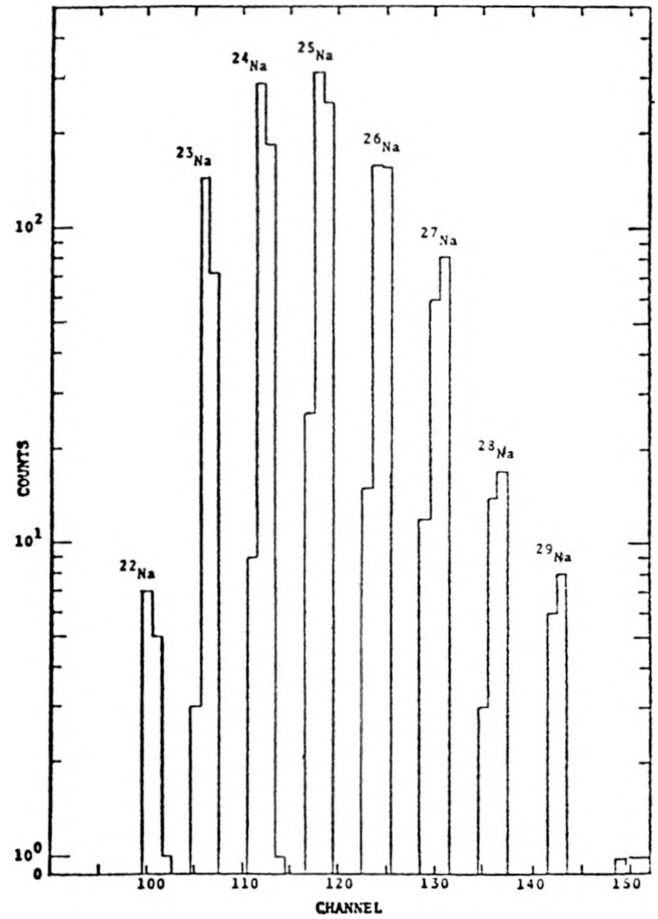

Fig. X-9.
Sodium-mass spectrum resulting from a TOF determination over a 4.3-m flight path.

shown in Fig. X-9 has a mass resolution of ~1.5%, whereas previous comparable experiments have had difficulty resolving adjacent isotopes in this mass region. The observation that there is still an appreciable yield of neutron-excess sodium isotopes at 800-MeV proton energy has encouraged us to extend our studies of high-energy nuclear reactions to those involving higher mass nuclear fragments.

Measurement of the Cross Section for $\pi^- + p \rightarrow \pi^- + \pi^+ + n$ with a Magnetic Spectrometer (Exp. 99)
(Colorado Coll., Univ. of Virginia, LASL, LBL, Massachusetts Inst. of Tech., Univ. of Wyoming)

Preparation of a paper on the π^+-C elastic-scattering work we have discussed previously is under way. We plan to present these results at a winter meeting of the APS.

A new Cerenkov counter has just been brought into satisfactory operation after a rather long tuning procedure using cosmic rays. This counter has a FWHM resolution of ~30%, which will enable us to improve considerably the rejection of positrons from among the pions we want to count.

A new preamplifier for the solid-state detectors has been developed. It is somewhat more complex than the previous four-transistor model and uses an FET input stage. However, we have managed to keep the simple power source scheme of the previous design, which reduces potential ground-loop problems. The new preamplifier achieves a noise level (for our application) as low as the best commercial models.

To go with this new design, we have improved the pulse-shaping networks of the main amplifiers. This change, along with a modification to the output stage that makes its behavior nearly independent of the load it drives, can be accomplished by component substitutions on the existing circuit boards. Construction on both projects is under way.

With the new electronics, we will be able to sharpen the time resolution and pulse-height threshold definition of the logic in which it participates. We have done this with an eye to the difficult new threshold measurements we plan to embark upon with a 100-μA beam.

Search for New Neutron-Rich Nuclides Produced by Fast Neutrons (Exp. 111) (Iowa State Univ., Univ. of Oklahoma, LASL, Baylor Univ.)

Until high fluxes of fast neutrons are again available at beam stop A, our studies of relatively unstudied neutron-rich nuclei are continuing using the LAMPF 100-MeV proton beam.

A study of the decay of ^{197}Ir($\tau_{1/2}$ = 7 min) was initiated. Only one gamma ray had been observed in previous studies. A fast (10-min) radiochemical separation procedure was developed to separate iridium from gold, platinum, and osmium in the irradiated platinum target. The iridium was converted to Ir^{3+} and separated from the other elements on Dowex-1 anion column.

Samples of 20 mg of ^{198}Pt (enriched to 95.83% ^{198}Pt) were irradiated for 10 min with about 10 μA of 100-MeV protons. Good yields of ^{197}Ir were generated by the ^{198}Pt(p,2p)^{197}Ir reaction, but contamination from low-mass iridium isotopes was significant. Gamma rays were observed using a Ge(Li) detector and five successive 500-s runs were accumulated in order to identify the peaks by half-life. About 25 gamma rays were observed to decay with a half-life of 10 min and were attributed to ^{197}Ir decay. The 346-keV gamma ray depopulating the $13/2^+$ isomeric state in the ^{197}Pt daughter was observed to grow in indicating that probably the expected high-spin isomer in ^{197}Ir had been populated. More detailed studies are planned to clarify the decays of the two ^{197}Ir isomers.

Results for n-p Charge-Exchange Scattering (Exp. 125) (Texas A&M Univ., Univ. of New Mexico, LASL)

During the past quarter, final results have been obtained for the n-p charge-exchange scattering cross section (CEX) at 647 MeV for $\theta_{c.m.}$ in the range 145° to 180°. Data were obtained by two different methods. In the first, the spectrometer was positioned at 0° in the laboratory and seven magnet currents between 700 and 145 A were used. The acceptable angular region of the spectrometer, for a given momentum bite, shifts to larger value of θ_{lab} as the current is lowered. This enabled us to obtain the n-p CEX for $\theta_{c.m.}$ between 174.5 and 180°. In the second method, data were analyzed for spectrometer positions at 0°, 4°, and 8° in the laboratory and the magnet current was set at 800 A. This yielded data for $\theta_{c.m.}$ between 145° and 180°. A short paper concerning results at back angles is in preparation.

Measurement of the Pion Spectrum from the Reaction n + p $\rightarrow \pi^+$ + nn at 800 MeV (Exp. 129) (Univ. of New Mexico, Texas A&M Univ., LASL)

Data from pion production is subject to decay corrections owing to the fact that some of the pions decay in flight before reaching the end of the spectrometer. A Monte Carlo program has been written to simulate these decays. Preliminary results indicate that the muon contamination in our raw pion spectra is of the order of 10-15%. The muons and pions cannot be distinguished by TOF or pulse-height information. However, the Monte Carlo program indicates that a large percentage of these muons can be identified and removed from the spectra because of abnormal values of ZLOC (ZLOC is the point of intersection of the incoming and outgoing particle trajectories). During the next quarter, we hope to finish the data-taking on Exp. 129 and to obtain the angular distribution of the spectra of positive and negative pion production as a function of angle at 800 MeV.

Measurements of "P," "R," and "A" Parameters in $\pi^{\pm}$-p Elastic Scattering/Measurements of "D," "R," and "A" Parameters in p-p Elastic Scattering (Exps. 132/160) (LASL, Virginia Polytech. Inst. and State Univ., State Univ. of New York at Genesco, and Texas A&M Univ.)

Plans are under way to measure the R and A parameters in elastic $\pi^{\pm}$-p scattering (Exp. 132), and the D, R, and A parameters in elastic p-p scattering (Exp. 160).

The proton spectrometer which is in use for Exp. 42 will be used. However, larger helical chambers have been completed and are ready for installation. The polarized proton target required for these experiments is under development and reported in Sec. VIII. The polarimeter components are now assembled, but further testing will be required to render it operational.

Search for Parity Violation in P-Nucleus Scattering at 6 GeV/c (Exp. 137B) (LASL, Univ. of Illinois, Univ. of Chicago)

We have submitted a proposal to the ZGS Program Committee to pursue our search for parity violation (PV) in p-nucleus scattering at 6 GeV. The proposal has been approved and is scheduled to run in March. In our earlier ZGS experiment (E354), we measured the helicity dependence of the transmission of protons through thick targets. We obtained results of $(\sigma^+ - \sigma^-)/(\sigma^+ + \sigma^-) = -5 \pm 9 \times 10^{-6}$ for $\vec{p}$ beryllium scattering and $(\sigma^+ - \sigma^-)/(\sigma^+ + \sigma^-) = 15 \pm 22 \times 10^{-6}$ for $\vec{p}$ water scattering. The former result has been reported in several publications.[8-10] The latter nonzero result is discussed in last quarter's progress report.

There is a PV background present in both of the above results arising from polarization transfer to hyperons produced in the target. This background is discussed in last quarter's progress report. The size of the PV hyperon-background effect is estimated to be $\sim 10^{-5}$, but a quantitative calculation is impossible because of lack of data on the needed polarization-transfer parameter.

We are intrigued by the observation of a positive result and will carry out an experiment which will not be sensitive to the hyperon background. It will be eliminated by introducing dipole magnets to sweep out hyperon decay products. A layout of the experiment is given in Fig. X-10. As in our previous experiment, the polarization is aligned with the momentum by bending the beam through 7.75°. The incident beam intensity is measured by detector I. The beam then impinges on a thick (81.28-cm) water target having a thickness inhomogeneity of less than two parts in 10^5. The transmitted beam is bent down through an angle of 15.5° so that the polarization is again aligned with the momentum when the transmitted intensity is measured by detector T. The transmitted beam is focused on detector T by the quadrupole triplets. Charged hyperon decay products have a lower momentum than the transmitted beam and are swept out of the beam by the dipole magnets. We calculate that the highest-momentum hyperon decay products will be focused 45 cm below detector T, which has a full height of 10 cm. The PV hyperon background will thus be completely eliminated.

We will draw heavily on apparatus, techniques, and experience developed in experiment E354. As before, integral counting techniques will be used. The transmission will be redundantly measured by scintillation detectors and ionization chambers which will be improved versions of those used before. The properties of these detectors will be used to monitor beam properties and control systematic errors. These techniques have worked well in experiment E354.

In addition to the elimination of the hyperon background effect, three other specific questions have been considered in the design of the experiment: 1) obtaining a statistical accuracy of a few parts in 10^7 for $(\sigma^+ - \sigma^-)/(\sigma^+ + \sigma^-)$; 2) controlling systematic errors arising from changes of beam properties which are correlated with polarization reversal to better than one part in 10^7; and 3) controlling systematic errors associated with imperfect alignment of the momentum and spin of the incident proton beam to one part in 10^7.

Good statistics will be obtained by running for 60 shifts at high intensity (5×10^8/pulse). If the same

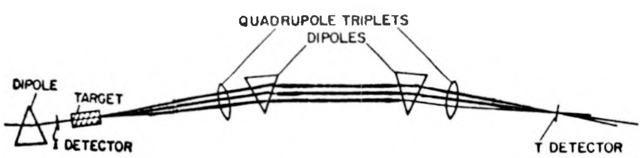

Fig. X-10.
Layout of the beam optics of the proposed experiment. The vertical plane is shown.

statistical accuracy is obtained in the proposed experiment as was obtained in the high-intensity test run during experiment E354, a statistical accuracy of 5×10^{-7} will be achieved. We expect to improve our statistical accuracy by improving our gain-monitoring system and thus achieve an accuracy of better than five parts in 10^7.

Systematic errors associated with changes in beam properties correlated with polarization reversal will be controlled using an array of auxiliary scintillation detectors which measure beam properties. As before, the techniques of regression analysis will be used to calculate the sensitivities of the measured transmission to beam properties and to make first-order corrections. The systematic errors after correction decrease in the same way as the statistical error in the transmission as data is accumulated. Since this source of systematic error was small in E354, it will be small in the proposed experiment: we estimate one part in 10^7.

Systematic errors associated with imperfect alignment of the polarization with the momentum will be controlled by measuring the components of beam polarization and the position of the beam at the defining aperture of the channel. An auxiliary array of scintillation detectors will be used for this purpose. Solenoid magnets will be installed in beam line 2 (see Fig. X-11) to allow adjustment of the horizontal and vertical components of beam polarization at the target. As in experiment E354, correction coefficients will be determined and a first-order correction applied. In experiment E354 this correction was a few parts in 10^6 and was known with an accuracy of one part in 10^6. In the proposed experiment the size of the correction will be decreased since the momentum analysis decreases the ratio of scattered to unscattered beam striking detector T. We intend to decrease the uncertainties in the correction by improvements in our gain-monitoring system.

In summary, we will pursue the intriguing observation of a positive PV effect at 6 GeV/c. The PV hyperon background will be eliminated. The goal of the proposed experiment is to unambiguously observe a possible interference between strong and weak scattering amplitudes of one part in 10^5 indicated in experiment E354 or set an upper limit of a few parts in 10^7 if the positive result had its origin in the hyperon background.

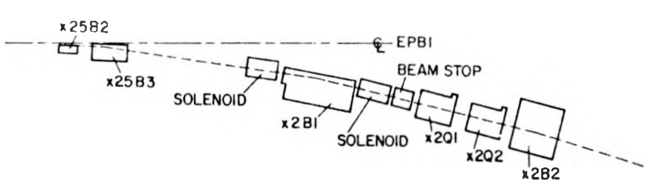

Fig. X-11.
Plane view of beam line 2 showing position of additional solenoid magnet.

Measurements of the (π^+, π^0) Reaction on Light Elements in the (3.3) Resonance Region* (Exp. 162/170) (Tel-Aviv Univ., LASL)

There is considerable theoretical interest in the pion single-charge-exchange reaction since various theoretical predictions for the excitation function show either a minimum or a maximum in the (3.3) resonance region. While PWIA for (π^+,π^0) analog transitions predicts a maximum near the (3.3) resonance energy, multiple scattering or DWIA calculations which include absorption give a minimum in the same energy region.

We report here measurements of the excitation functions for the (π^+,π^0) reaction on ^{7}Li, ^{10}B, and ^{13}C from 70 to 250 MeV. We obtained $(1 \rightarrow 3)\ 10^7$ π^+/s with $\Delta p/p = \pm 2\%$, at the LEP channel.

We bombarded isotopically enriched ^{10}B (99%), ^{13}C (98%), and natural lithium. The cross sections were obtained by measuring the radioactivity induced in the product nuclei. For ^{13}C, the beam intensity was measured by the simultaneous bombardment of a ^{12}C sample, followed by a measurement of the ^{11}C activity, induced by the reaction $^{12}C(\pi^+,\pi N)^{11}C$ (see Exp. 67). The same runs were used to calibrate an argon-gas ionization chamber which was later used as a beam monitor for the other reactions. The proton contamination in the beam was eliminated by the use of differential absorbers. The contribution of muons and electrons is negligible. Secondary protons produced in the target contribute to our measured cross section. Their contribution was estimated by using known proton-production data, energy loss tables, and (p,n)-reaction cross sections. For ^{7}Li and ^{13}C this gave a 15% effect which was subtracted from the measured cross section at all energies. A more exact subtraction will be possible when higher pion fluxes are available, which will make it possible to use thinner targets.

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*The results of this experiment were reported at the VI Intern. Conf. on High-Energy Physics and Nuclear Structure and were also submitted for publication in the Phys. Rev. Lett. All relevant references can be found in the latter publication.

The lithium samples were disks of thicknesses ranging from 0.5 to 2 g/cm^2 and 5-cm diam. The ^{7}Be activity was measured by counting the 478-keV gamma rays resulting from a 10.4% branch of the decay, in a shielded 65-cm^3 Ge(Li) detector, at sea level. In this way we measured the sum of the reaction cross sections to the analogs of the target ground state and first excited state.

The ^{10}B samples consisted of powder, 3 cm in diameter, and 2 g/cm^2 thick, pressed into thin aluminum cans. The ^{10}C nucleus produced in the reaction ^{10}B(π^+,π^0)^{10}C has two bound levels neither of which is an analog of the ^{10}B ground state. It has a half-life of 19.4 s and decays through the 717-keV level in ^{10}B. Two ^{10}B samples were mounted on the ends of a pendulum which oscillated between the beam and a 65-cm^3 shielded Ge(Li) detector. This was done automatically every 30 s. Figure X-12 shows sample gamma spectra from irradiated ^{7}Li and ^{10}B targets.

The ^{13}C target consisted of powder, 3.2 cm in diameter and 0.72 g/cm^2 thick pressed into a thin beryllium can. The nucleus ^{13}N has only one bound level, which is the analog of the ground state of ^{13}C, so activity measurements yield the charge-exchange cross section for the analog transition only. The ^{13}N nucleus decays to ^{13}C with a half-life of 10 min. The β^+ activity was measured by detecting the annihilation gamma rays in coincidence, with two NaI(T1) detectors. The bombardments were carried out for periods of about 15 min and the activity was then measured for a few hours. We observed both the 10-mm activity of ^{13}N and the 20.4-mm activity of ^{11}C, the last one arising from reactions like ^{12}C(π^+,πN)^{11}C on the 2% contamination in the target, and from reactions such as ^{13}C(π^+,pn)^{11}C. The decay curves were analyzed with a least squares fitting program. The normalized χ^2 values for the fits were approximately unity. In Fig. X-13 we show an example of the measured β^+ activity as a function of time. The solid lines are the obtained fit and the contribution of the 20.4 activity alone.

The observed cross sections for the three charge-exchange reactions are shown in Fig. X-14. We arrive at the following qualitative conclusions regarding (π^+,π^0) transitions in light nuclei: 1) nonanalog transitions with ΔT = 1 (^{10}B $\rightarrow$ ^{10}C) are relatively weak; 2) analog transitions [^{13}C $\rightarrow$ ^{13}N, and most likely also ^{7}Li $\rightarrow$ ^{7}Be (ground state)] are relatively strong; 3) nonanalog transitions with ΔT = 0 [^{7}Li $\rightarrow$ ^{7}Be (excited state)] could still be strong; and 4) there is neither a marked maximum nor a marked minimum at the (3,3) resonance.

We propose to measure in the future the same cross sections, especially for ^{7}Li with thin targets

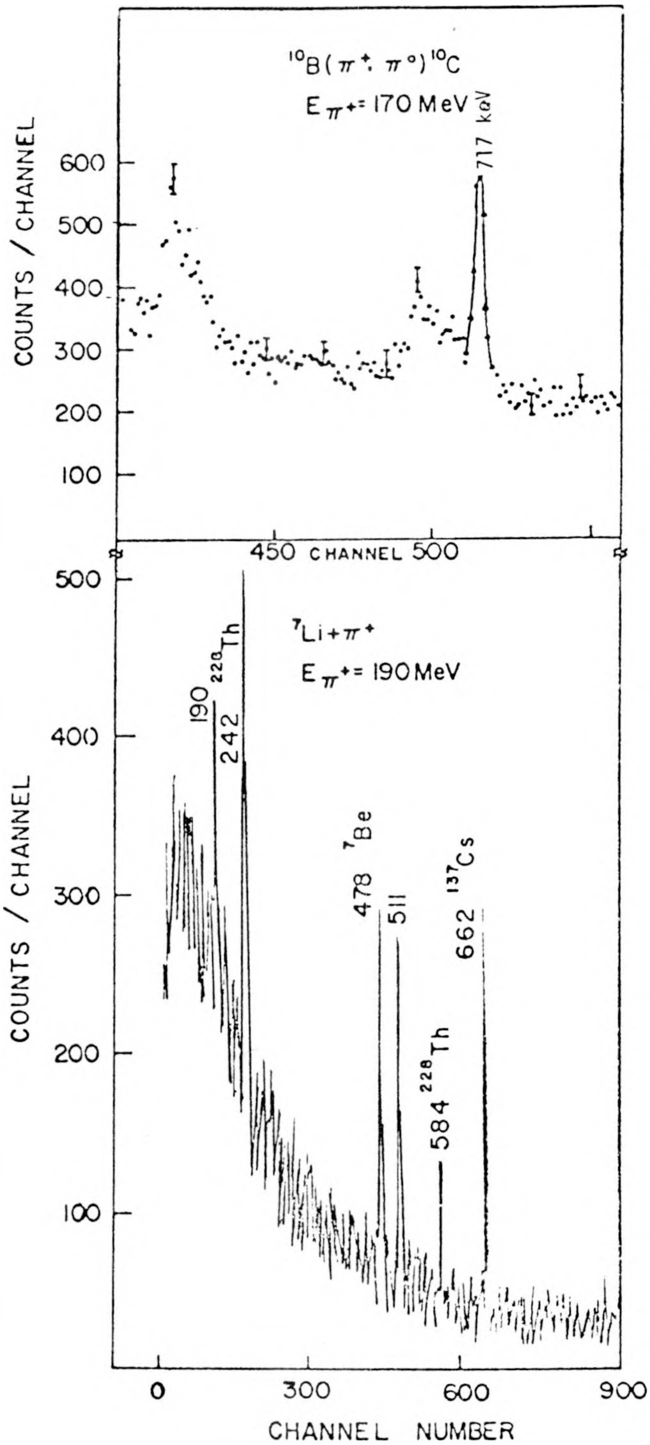

Fig. X-12.
Gamma spectra from targets of ^{7}Li and ^{10}B. The gamma radioactivity from the ^{7}Li target was counted for 30 h, 120 days after the irradiation; the 478-keV line comes from the ^{7}Be activity. The radioactivity from the ^{10}B target was counted while the target was mounted on a physical pendulum. The 717-keV line comes from ^{10}C activity.

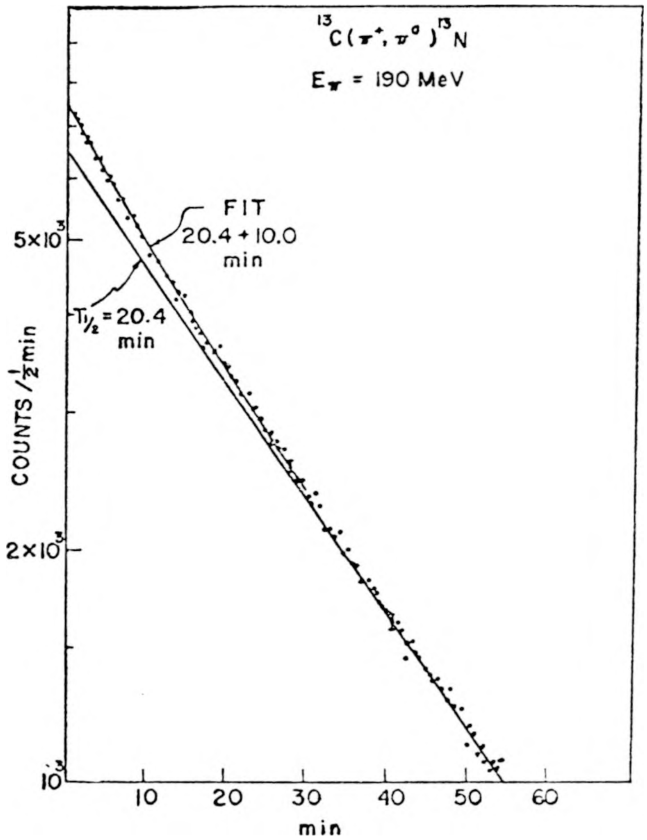

Fig. X-13.
β^+ decay curve, measured by the coincident detection of the annihilation gamma rays. The fit has a normalized χ^2 value of 1.1. The lower solid line shows the contribution of the 20.4-min β^+ activity of ^{11}C. The rest is the 10-min ^{13}N activity.

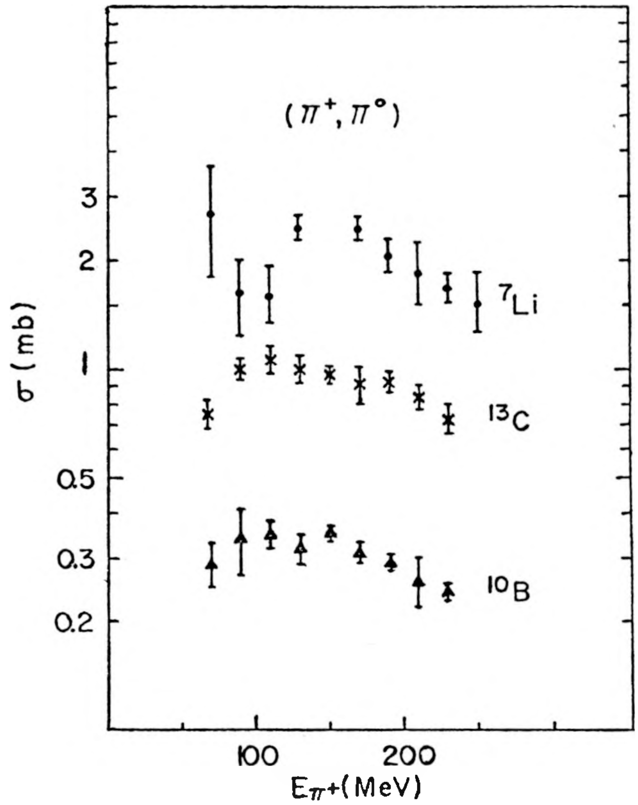

Fig. X-14.
Activation cross section for the (π^+,π^0) reaction on ^7Li, ^{10}B, and ^{13}C.

and high fluxes to get a better estimate of the secondary proton effect. Bombardments with π^- can result in the same residual nucleus only through the secondary processes. Thus it will serve as another tool to measure this effect.

When higher beam intensities are available we will extend the measurements to lower energies, where the calculations predict a steep variation of the cross sections as a function of E_{π^+}.

The Measurement of Differential Production Cross Sections of Multiply Charged Fragments (Exp. 179)
(LASL, Washington State Univ.)

The measurement of masses of low-energy heavy ions by TOF techniques requires very thin detectors having good timing characteristics. In the initial phases of Exp. 179 the emission of charged fragments produced in the bombardment of elements from carbon to iron by 800-MeV protons will be studied. Typical fragment ranges are 1 mg/cm^2. Mass and charge identification will be accomplished by a counter telescope which measures the velocity, rate of ionization (dE/dx), and total energy (E) of the fragments. The dE/dx counter will be a gas ionization chamber with a thickness of 400 μg/cm^2. The velocity measurement will be carried out using two carbon-foil time-pickoff detectors. The carbon foils will each have a thickness of 10 μg/cm^2. The mass resolution will be dominated by the time resolution (see Fig. X-15) of the pickoff unit. To date a time resolution of about 200 ps has been measured using a 5.4-MeV alpha source. This corresponds to a mass resolution of 2.3% for a 25-cm flight path at 1 MeV/amu.

The low-energy cutoff of the telescope is determined by the combined thickness of the dE/dx and carbon foil detectors and will be ~0.3 MeV/amu. This lower limit is about a factor of 10 below what can be done with silicon detectors alone.

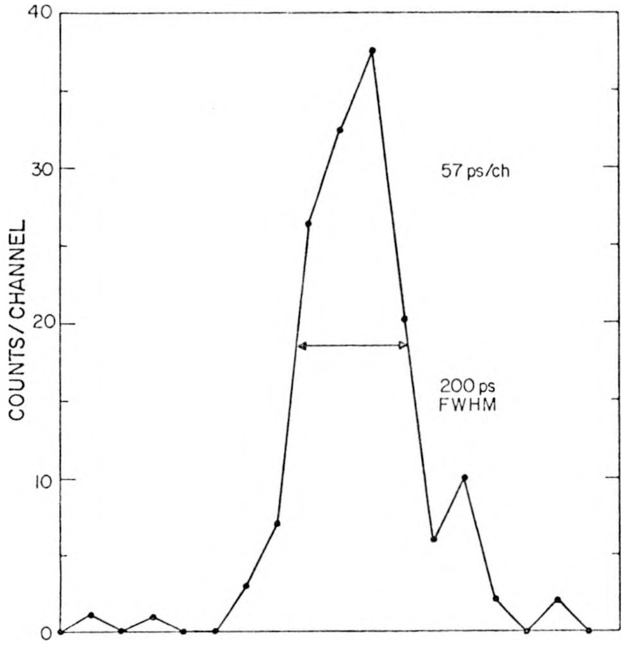

Fig. X-15.
Histogram showing the time resolution of carbon-foil time-pickoff detectors. The spectrum was obtained by measuring the TOF of 5.3-MeV alpha particles between two time-pickoff detectors.

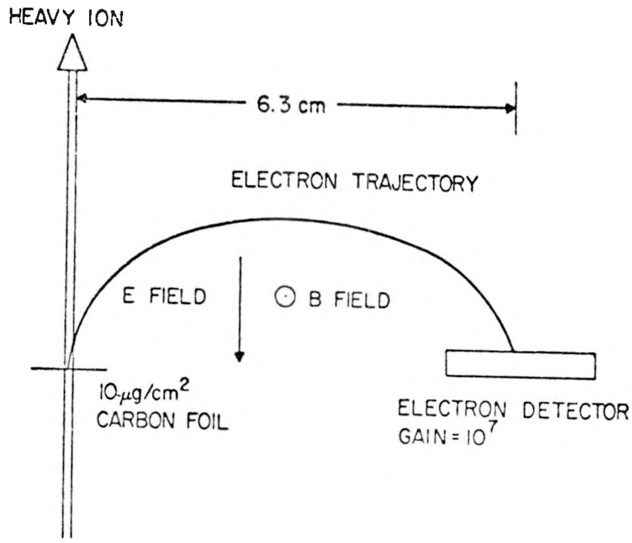

Fig. X-16.
Schematic diagram of carbon-foil time-pickoff detector.

The carbon-foil time-pickoff detectors operate as follows (see Fig. X-16). A heavy ion passes through a carbon foil and knocks out low-energy electrons. These electrons are accelerated by a homogeneous electric field and bent by a crossed homogeneous magnetic field. The electrons move in cycloidal paths to a channel-plate electron detector which is a type of open electron multiplier having a risetime of 100 ps and a transit time of 2 ns. The remainder of the signal processing is carried out by standard electronics.

The development of these time-pickoff detectors opens up several interesting research areas. As stated above, the first experiments will involve the measurement of differential cross sections in the spallation of the elements carbon through iron by 800-MeV protons. These data will be very useful for astrophysics, reaction-mechanism calculations, and biophysics (proton radiography and therapy). The second area of application is isotope hunting. The lightest undiscovered isotope which is predicted to be particle-stable is ^{19}B. We estimate with the good mass resolution of the carbon-foil time pickoffs and the intense beams available at LAMPF we will have a factor of 100-1000 advantage over previous efforts. Finally, the carbon-foil time-pickoff detectors will be invaluable in the detection of heavy ions produced by stopping and moving pions. Production cross sections for heavy ions are important to pion radiotherapy since heavy ions constitute the high linear-energy-transfer portion of the dose. These data are also interesting from the point of view of reaction-mechanism studies. The good time resolution of the carbon-foil time-pickoff detectors will allow a short flight path and large solid angle in these low-rate experiments.

Measurement of the $\pi^- p \rightarrow \pi^0 n$ Angular Distributions and Calibration of the π^0 Spectrometer (Exp. 181)
(Tel Aviv Univ., Case Western Reserve Univ., LASL)

During the last quarter we have concentrated on developing a practical and theoretical understanding of the energy resolution of lead-glass total-absorption shower counters. The energy resolution of the shower counters strongly affects the overall energy resolution of the π^0 spectrometer for Exp. 181. Tests of several types of commercially available glasses were carried out at Stanford's Mark III electron accelerator. The results indicate that lead glass having a low lead content gives better energy resolution than high-lead-content glass. We have developed a model which gives a qualitative understanding of this behavior, and are pursuing refinements of the model. The goal of this work is to be able to understand the dependence of the energy resolution on the physical properties of the type of lead glass used. It appears that a very light glass such as LF5 or LLF6 will give better energy resolution than more conventional types.

Measurement of $\pi^0 \to e^+e^-\gamma$ and $\pi^0 \to e^+e^-$ Branching Ratios (Exps. 221 and 222) (LASL)

We have begun detailed design studies which will determine the physical sizes and characteristics of the apparatus to be fabricated. These studies involve Monte Carlo calculations to optimize the detector designs. Particularly helpful have been some calculations for $\pi^-p \to ne^+e^-$ by Prof. Norman Dombey of the Univ. of Sussex. This process is a major background in Exp. 222.

The hodoscope magnet, which will be used in both experiments, has been sandblasted and is ready for assembly. We have borrowed some lead-glass shower counters from Temple Univ. for use in photon detection in Exp. 221.

Direct Lepton Production (Exp. 241) (LASL and Temple Univ.)

During this quarter an experiment to search for direct lepton production in p-p collisions has been proposed, designed, constructed, and executed. The experiment was motivated by observations at high energies of electrons and muons produced with large values of transverse momentum in excess of those expected from π and K decay. The observed ratio of lepton/pion is $\sim 10^{-4}$, relatively independent of transverse momentum and incident energy. There is no satisfactory explanation for these phenomena, and an experiment at LAMPF would yield information about the energy threshold for these leptons.

A spectrometer was designed which would have adequate momentum resolution, excellent electron identification, and could be constructed on short notice. It consists of a magnet, two isobutane-filled threshold Cerenkov counters, and hodoscope counters. The hodoscope counters were constructed from Pilot 425 (a plastic which contains only a wavelength-shifter for Cerenkov light) in order to avoid triggering on protons. (See Fig. X-17.) An array of lead-glass shower counters is used to confirm the identification of pions and electrons. Data have been taken with a 1-nA proton beam incident

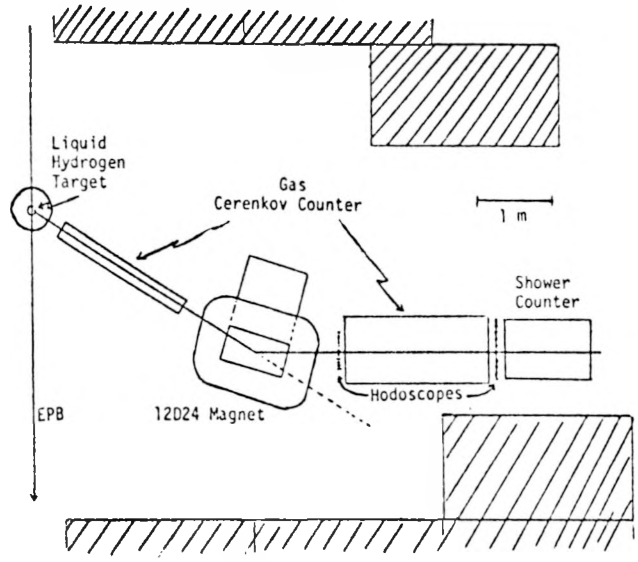

Fig. X-17.
Schematic of the apparatus for Exp. 241.

on a 0.4-g liquid H_2 target. Recently the experiment has been operated at much lower incident-proton currents ($\leq$100 pA), which has permitted the addition of small scintillation counters in front of and behind C_1 to better define the origin of particles.

Details of the data anlysis will be given in the next quarterly report. At this time we can say that the system is working very well and that we see positrons at the level of a few per 10^4 π^+. It may be that all of these are due to known background processes: Dalitz decay of π^0s and pair production from high-energy photons.

General Research Projects

Beam-on-Target Monitors

Insulation difficulties with the MkI version of the ion chamber persisted when two new brazed structures were built. A new structure, fitting into the old shell, was designed and tested. This is a rather conventional insulating post design, using alumina tubing and self-supporting foils. It is adequately strong and will hold off 3-kV bias with a leakage current in the picoampere range.

Two of these MkII ion chambers are ready for installation. This fulfills the present requirements.

Theory

Integrated Cross Sections

An improved analysis of total-cross-section experiments ("transmission" experiments) has been developed. This method is specifically designed for instances when the influence of the Coulomb interaction is especially great; e.g., for the case of 1) large Z target and/or 2) low-energy projectile, or, in other words, when the influence of the Coulomb interaction is especially great. We are, furthermore, interested in the analysis when no separate measurement of elastic scattering is available.

Previous analyses used for transmission experiments require that a polynomial be fit to the data. These analyses are not strictly valid because a polynomial is not a proper representation for Coulomb-nuclear interference. Therefore, when the Coulomb interaction is strong, a new type of fitting function is required. Our result is that the total-cross-section data should be fit by a function of the form

$$\int_{>\Omega} |f_c|^2 d\Omega' + \sum_{n=1} A_n \Omega^n + \left(\sum_{n=0} B_n \Omega^n\right) \cos W + \left(\sum_{n=0} C_n \Omega^n\right) \sin W \quad , \qquad (1)$$

where f_c is the point-Coulomb elastic-scattering amplitude and

$$W = \gamma \log \Omega/4\pi - 2\sigma_0 ,$$

where σ_0 is the point-Coulomb phase shift for S-waves. Here, Ω is the solid angle subtended by the counter for the scattered events. With the usual normalization, we identify

$$B_0 = (4\pi/k) \, \mathrm{Im} \, f_N(0) \qquad (2)$$

$$A_0 = (4\pi/k) \, \mathrm{Re} \, f_N(0) , \qquad (3)$$

where f_N is related to the complete forward-elastic amplitude F(0) by

$$F(0) \equiv f_c(0) + f_N(0) . \qquad (4)$$

We discuss how the finite charge distribution and other Coulomb corrections can be taken into account. "Coulomb nuclear-interference" scattering experiments provide complementary information, with which both the real and imaginary parts of f may be more accurately determined. For low Z and sufficiently high energy, this method is the same as the previously used method of polynomial extrapolation.

We also discuss an indirect method of analysis which is useful when the data is not sufficiently accurate to determine well all coefficients needed in Eq. (1) to represent the data. This involves introducing a model, but we argue that the results are completely independent of the details of the model. A computer-generated example is examined.

We argue that the reaction cross section σ_a and the so-called "total cross section" σ_R,

$$\sigma_R \equiv \sigma_a + \int |f_N|^2 d\Omega , \qquad (5)$$

should not be the object of the data anlysis because these require the elastic amplitude at angles not measured in transmission experiments. A complete description of this work is available from the authors in preprint, "Integrated Pion-Nucleus Cross Section," submitted to Nucl. Phys. A for publication.

Pions Interacting with Nuclear Matter

In collaboration with Prof. Hans Bethe of Cornell Univ., a systematic expansion for the pion "self-mass" has been developed for the case of fixed nucleons interacting with pions through separable potentials. Special attention has been given to the role of nuclear correlations: each contribution in the expansion is explicitly independent of the off-shell extrapolation of the pion-nucleon amplitude when the range of the nucleon-nucleon distribution function is sufficiently long-ranged compared to the pion-nucleon.

The expansion to lowest order in f (pion-nucleon amplitude) has been examined in detail for low-density and high-energy (150-200 MeV) pions. Effects examined are: 1) short-ranged correlations, calculated from Pandharipande's variational theory; 2) long-range (Pauli) correlations; 3) finite range of the pion-nucleon form factor; 4) possible ρ-meson intermediate states; 5) Fermi motion; 6) lab-c.m.

transformations (including "angle transformations"); and 7) S, P, D, and F partial waves. We estimate that at the nuclear density $\rho = 0.04 \text{ fm}^{-3}$, nuclear-matter results may be compared to experiments on real nuclei. The resonance is predicted to lie at 175 MeV; at this energy the real part of the forward nuclear amplitude should vanish.

Several attempts have been made to include "higher order corrections" to the theory. A power series in the density does not appear to converge at low energies (unless a low-momentum cutoff is introduced via the pion-nucleon form factor) or at resonance. A self-consistency condition on the amplitude f appears to lead to identification of a small parameter in terms of which a convergent expansion can be defined. Detailed calculations are under way.

Nuclear Resonance Effect in Hadronic Atoms

During this period, a LASL-Rutherford High-Energy Lab. (RHEL) collaboration was formed to measure (at RHEL) nuclear resonance effects in some hadronic (especially K^-) atoms (cf LA-5994-MS). So far, positive results have been seen only in pionic cadmium, confirming the results of an earlier LAMPF experiment (No. 195). In addition, a measurement of the 2^+ excitation energy of ^{112}Cd was made; when the data anlysis is complete this should result in an error several times smaller than the current value. This excitation energy is crucial for making a more stringent comparison between theory and experiment for pionic cadmium.

A rigorous calculation was carried out of the x-ray line profile coming from a transition to closely coupled resonant levels in a hadronic atom. The result, which differs from a previous one, has been included in a paper submitted to Nucl. Phys. ("Hadronic Atoms and Ticklish Nuclei").

Atomic Capture of Negative Mesons

It has recently been established that the Fuzzy Fermi-Teller Model for negative-meson capture and deexcitation in atoms is capable, through adjustment of some internal parameters, of reproducing the drastic variations in absolute kaonic x-ray yields observed by Wiegard and Godfrey [Phys. Rev. **A9**, 2282 (1974)]. Using the kaon data to fix these parameters, the resulting model will be tested on pionic absolute and relative yields, muonic relative yields, and muon capture ratios. Papers describing the Fermi-Teller and Fuzzy Fermi-Teller Models have been submitted to Ann. Phys. ("Atomic Capture of Negative Mesons, I and II."

Finally, a rather crude computer program has been developed for describing the atomic cascade of negative hadrons in hydrogen. A number of experimental groups are attempting or planning experiments to detect x rays from such systems, and have expressed interest in such a program.

REFERENCES

1. M. Scott, G. Mutchler, C. Fletcher, E. Hungerford, L. Coulson, G. C. Phillips, B. Mayes, L. Lee, J. Allred, and C. Goodman, Phys. Rev. Lett. **28**, 1209 (1972).

2. F. Binon, V. Bobyr, P. Duteil, M. Gorianere, L. Hugon, J. Peigneux, J. Renuart, C. Schmidt, M. Spighel, and J. Stroot, Nucl. Phys. **B33**, 42 (1971).

3. M. Blecher, K. Gotow, D. Anderson, R. Kerns, R. Minehart, K. Ziock, R. Bercon, J. Vincent, and R. Johnson, Phys. Rev. **C10**, 2247 (1974).

4. E. V. Hungerford, Nucl. Instrum. Methods **III**, 509 (1973).

5. G. S. Mutchler, C. Fletcher, L. Coulson, D. Mann, N. Gabitzsch, and G. C. Phillips, Phys. Rev. **C11**, 1873 (1975).

6. S. Mandelstam, Proc. Roy. Soc. (London) **A249**, 491 (1958).

7. J. R. Carter, D. V. Buff, and A. A. Carter, Nucl. Phys. **B58**, 378 (1973).

8. J. D. Bowman, C. M. Hoffman, C. F. Hwang, R. E. Mischke, D. E. Nagle, J. M. Potter, D. M. Alde, P. G. Debrunner, H. Frauenfelder, L. B. Sorensen, H. L. Anderson, and R. Talaga, Phys. Rev. Lett. **34**, 1184 (1975).

9. D. E. Nagle, "Parity Violation in p-p and p-Be Reactions," to be published in Neutrino '75 Proceedings, Balaton, Hungary, Fifth Intern. Conf. on Neutrino Science, June 16-21, 1975.

10. J. D. Bowman, "Parity Nonconservation in p-p and p-Nucleus Scattering," presented at Symp. on Interaction Studies in Nuclei, Mainz, Germany, February 17-20, 1975.

XI. NUCLEAR CHEMISTRY

This is the first report to be included in this Progress Report series on the development of the LAMPF nuclear chemistry facilities and general program activities. Heretofore these reports were carried, in much less detail, in the LAMPF Users Newsletter.

Nuclear Chemistry Laboratory (NCL)

Counting Room Equipment

During the Great Shutdown the following radiation counting and nuclear spectroscopy equipment was rearranged to the listed configuration to provide for more efficient utilization and now constitutes the assemblage of systems available for nuclear chemistry activation experiments:

Routine α and β Counters (Rm. D-109)

1) Three standard β proportional counters
2) Two low-background β proportional counters
3) Two standard α proportional counters
4) Two surface-barrier silicon α detectors
5) One Frish grid α chamber

Scintillation Counters for γ and β Radiations (Rm. D-111)

1) One standard 76- × 76-mm NaI(T1) γ detector
2) One well-type 50- × 50-mm NaI(T1) γ detector
3) One $\beta-\gamma$ coincidence system consisting of a 76-× 76-mm NaI(T1) γ detector and a plastic scintillator β detector
4) One $\gamma-\gamma$ coincidence system consisting of a pair of 76-× 76-mm NaI(T1) γ detectors
5) Two 400-channel and one 1600-channel pulse-height analyzers (old)

Ge(Li) γ Spectrometers (Rm. D-113)

1) Three large (60 cm^3 or larger), high-resolution (2 keV at 1.33 MeV) Ge(Li) γ detectors
2) One smaller volume (31 cm^3), lower resolution (3.4 keV at 1.33 MeV) Ge(Li) γ detector
3) Two modern 4096-channel pulse-height analyzers with fast magnetic-tape output facilities

Data-Acquisition System (DAS)

Considerable effort has been expended during the shutdown to bring the NCL data-acquisition system in D-107 to operational status. The system consists of a DEC PDP-11/40 computer with two 1.2M-word disk drives, two IBM 729 magnetic tape drives, and a pair of Tektronix 4010 graphic terminals. The computer is interfaced to a CAMAC branch highway through a MBD, and four CAMAC crates are currently operational. Each crate is in a different room, three of which are counting rooms containing α, β, and γ counters and pulse-height analyzers. By means of interfaces, data from these instruments will be transmitted to the computer. The human interface to the computer is facilitated by the graphic terminals at the computer and by CRT terminals in each counting room.

The computer is being operated with the DEC RSX-11/D operating system. Software, to support the acquisition of data from and control of the counting room equipment, is through program "Q," a general data-acquisition program written by MP-1.

The DAS is now partially operational. As soon as software can be written, we will be able to control a Canberra 8100 Multichannel Analyzer (MCA) from the computer, with memory data being written onto magnetic tape and also printed out. CAMAC interfaces are also on hand to take data from 10 routine α or β counters, two 400-channel MCAs, and from one 1600-channel MCA.

Computer Programs

Several programs of general usefulness to researchers on activation experiments have been assembled, modified, or written for execution on the large CCF computers:

1) GAMANAL - for energy and intensity photopeak analysis of complex Ge(Li) γ spectra.
2) CLSQ - for multicomponent radioactive decay curve analysis, including correction for "grow-in" of daughter species. This BNL-originated program has been modified to accept β-γ coincidence data and determine absolute disintegration rates.
3) LAGLS - for least squares fitting a curve to an arbitrary functional form.
4) BVC - for correcting the induced activity during an irradiation for fluctuations in beam intensity, given the half-life of the species of interest and the time pattern of the fluctuations.
5) PALL - for machine-plotting of any type of data.

Nuclear Chemistry Hot Cell

Two surplus stainless steel containment boxes have been obtained and are being modifed for use in the Area A hot cell. One will be for dry operations only, such as remotely dismantling complex "hot" target assemblies or transferring an irradiated target from a "hot" rabbit to a "cold" rabbit for sending to the Nuclear Chemistry Laboratory. The other box, which will be connected to the first via an air-locked passageway, will be used for wet chemical operations on highly radioactive targets. This box will also be connected to the operating face of the hot cell via another air-locked passageway through which additional apparatus and chemicals can be introduced.

Pneumatic Rabbit System

The rabbit system is a complex array of 76-mm and 102-mm underground tubes, a blower package, remotely operated air valves, receiving terminals and irradiation stations, and a control console. This system is designed to transport a target in a carrier, or rabbit, to an irradiation station and, at the end of a bombardment, to quickly return the target to one of several receiving stations for the experimenters either to commence the nuclear measurements or to carry out radiochemical separations followed by the measurements. Although under development for several years, the last major component of the system, namely the control console, was installed this past quarter adjacent to the nuclear chemistry hot cell which contains the central switchgear for the system. When the "shakedown" testing is completed (in the near future), the following stations or terminals will be operational: 1) proton irradiation station in Line B; 2) energetic neutron irradiation station at the A-6 beam stop; 3) hot-cell receiving terminal; 4) chemistry hood receiving terminal adjacent to the hot cell; 5) nuclear chemistry laboratory receiving terminal (D-126); and 6) truckloading receiving terminal. Adequate provisions have been made in the control console for future additions of both irradiation stations and receiving terminals.

Theoretical Support

A new member has been added to Group T-5 to provide direct theoretical support to the nuclear chemistry program. The initial support effort has been concentrated on a detailed study of the BNL-developed VEGAS[1] intranuclear cascade code with the objective of developing significant improvements. An informal conference of experts on this topic was held at LAMPF on August 2, 1975, and many suggestions for this study were provided.

The VEGAS program has proven very useful for analyzing or predicting the inelastic cross sections for nucleon- and pion-induced reactions in complex nuclei. The program uses a Monte Carlo technique to follow the intranuclear cascade generated by the fast (50 to 1000 MeV) incident particle. The remaining excited nucleus is then treated with the DFF evaporation code.[2] The differential cross sections for the spectrum of emitted nucleons, pions, and light particles, in addition to the residual nuclei, are computed.

The following revisions have been made recently to the VEGAS and DFF codes:

1) The latest total and differential pion-nucleon cross sections[3] have been incorporated.

2) The separation energies for protons and neutrons are now set to be different rather than the same, and their values are coded as the known energies.

3) In the evaporation program, the pairing energies have been updated to Cameron's latest values.[4]

4) An option has been added to VEGAS to disregard those cascades which result in the emission of more than a preselected number of fast nucleons or pions, thus saving computer time for special problems.

REFERENCES

1. K. Chen, Z. Fraenkel, G. Friedlander, J. R. Grover, J. M. Miller, and Y. Shimamoto, Phys. Rev. **166**, 949 (1968); G. D. Harp, K. Chen, G. Friedlander, Z. Fraenkel, and J. M. Miller, Phys. Rev. **C8**, 581 (1973); G. D. Harp, Phys. Rev. **10**, 2387 (1974).

2. I. Dostrovsky, Z. Fraenkel, and G. Friedlander, Phys. Rev. **116**, 683 (1959).

3. A. A. Carter, J. R. Williams, D. V. Bugg, P. J. Bussey, and D. R. Dance, Nucl. Phys. **B26**, 445 (1971).

4. J. W. Truran, A. G. W. Cameron, and E. Hilf, Intern. Conf. on the Properties of Nuclei Far from the Region of Beta Stability, CERN 70-30, **1**, 275 (1970).

XII. PRACTICAL APPLICATIONS OF LAMPF

(Summarizes work being performed under the auspices of USERDA Division of Research, USERDA Division of Biomedical and Environmental Research, and the National Cancer Institute.)

Radiobiology and Therapy Research Facility

During the past three months, emphasis has been placed on preparing systems and apparatus for beam turn-on. The following tasks were accomplished:

1) Slit 1 temporary wiring was installed and the control hardware was checked out.
2) The new magnet-current readout system was installed.
3) A revised control system for BM-02 shunt was wired and checked out.
4) A new, manual magnet-current and metering-control panel was installed and checked out.
5) The new magnet-current digital-to-analog converter modules were finished and checked out.
6) Wiring for the magnet power-supply-polarity control was revised and checked out.
7) New I&C cables for the triplet were checked out.
8) The new "Magnet On" warning light system was checked out.
9) Magnet interlocks for BM-03 and QM-04-08 were checked out.
10) The gas-monitoring system was reviewed and all LASL fabricated parts were received.
11) Work was begun on cable terminations for the patch panels to go in the cowling at the end of the beam line.
12) The new computer interface for the three-dimensional dosimetry scanner was completed and checked out. Cables were made to allow use of the scanner in the x-ray room.
13) An auto-answer adapter was designed, prototyped, and checked out to allow direct coupling to the phone line of the recently purchased acoustic-coupled modems.
14) The console light system was checked out, and the console button system checkout was initiated.

Two lectures were given on the Biomed Control System to E-Division's Frontiers of Applied Electronics class. Also, two brief presentations were given to the Biomed Control Committee on the present hardware configuration.

Biomedical Channel Development

Most of the channel effort was directed toward the shielding surrounding the entrance triplet. The magnet-core-cooling circuits (cooling panels bolted to the sides of the magnets) were determined to be unnecessary and were removed. The addition of lead castings to the sides of the triplet produces a flat surface, making possible a satisfactory shield design. On the east side, an aluminum wall backed with lead fill was installed. On the west side, lead-filled boxes complete the canyon-fill design. The shielding on top of the triplet is complicated by plumbing and electrical leads. The plumbing is being rerouted to accommodate new shielding. The entrance aperture of the triplet is to be shielded by a brass collar against charged particles produced in the tungsten collimator used to protect the harp assembly from target backscatter. Additional steel support structures are being added at the rear of the triplet to accommodate shielding that surrounds Slit 1, which is mounted at the back of the triplet.

Channel-tuning studies were aimed at improving the agreement between the calculated and measured beam properties at the end of the channel. Quadrupole field measurements were performed to determine the extent of the interaction between adjacent quads in the beam-shaping section of the channel. The results of these measurements were used to estimate more accurately the effective lengths of the quads in the section as a function of relative excitation of adjacent quads. These new quad lengths are being used to recalculate beam properties for comparison with previous measurements.

Design is 75% complete on logic circuitry for pulsing MWPCs and LET ion chambers during the low-intensity beam pulses which will occur on a 10% basis. A commercial regulated power supply has been modified to deliver pulses of up to -4900 V into a 12 000-pF load with a 10^6-Ω bleeder resistor. No chambers have actually been pulsed at this date, and it is likely that further problems will be encountered during the pulse-rise and decay periods with the electronic amplifiers that monitor the chambers.

Pion Dosimetry Program

Work has continued on converting and modifying computer codes for on-line analysis of dosimetry and microdosimetry experiments. The recent conversion of the biomed computer to RSX-11 Version 6 required all codes to be recompiled and task-built.

New codes have also been written for initial testing of the three-dimensional scanner interface (the program package, SCANNER-TASK, was written by M. Lieber, LASL consultant). The software system appears to be operational, although hardware problems still exist. Work is progressing on programs which will allow on-line dosimetry using the new scanner interface.

The microdosimetry equipment—including chamber holders, source holders, and preamplifiers—has been rebuilt and tested, and will be ready for neutron dosimetry experiments at the Univ. of California at Davis cyclotron in early December.

Dose Calculations

There now exists a working code, BUCKET, which can be used to calculate the three-dimensional dose distribution in a water phantom due to a realistic π^- beam. The pion beam is modeled by selecting a number of random events recorded by the MWPCs in the biomed channel, the information used being the position, angular direction, and momentum of each particle. Each such event selected is then taken to represent a pencil beam entering the phantom. The three-dimensional dose distribution resulting from a pencil beam of specified momentum is calculated and stored. The analytical model used in this calculation includes measured muon and electron contamination, multiple-scattering, and straggling effects. The contributions to the total dose are the primary ionization of the three constituents of the beam and the pion star dose, which is divided into three parts: 1) locally deposited dose due to heavy star fragments and star protons of <10-MeV energy; 2) dose due to star protons of energy >10 MeV; and 3) dose due to peak-region star neutrons having a spatial distribution determined from a previous calculation.[1] The dose distribution for this pencil beam is calculated by averaging over unit cells rather than on a point-to-point basis.

The volume of interest within the water phantom is divided into unit cells of specified dimensions and, in the past, a running sum for each cell was kept of the dose due to each pencil beam. To save time, running sums are now kept only for those cells that are involved in a particular calculation. Thus, if a depth-dose scan is desired, only those cells with, say, (x,y) = (0,0) enter into the calculation. Figure XII-1 shows such a depth-dose scan, comparing calculation with experiment[2] for 5000 pencil beams. Although the calculation is normalized to the experiment at the peak, the absolute doses agree within experimental uncertainty. This calculation, together with two x−y plane scans, required less than one minute of CDC-7600 computer time. Reducing the number of beams to 1000 (20-s running time) does not change the peak region at all but does cause variations in the entrance dose.

The code now has the flexibility of including a separate RBE for each component of the dose. Moreover, modifications are being made to include the effective dose model of Katz *et al.*[3] With this addition, we will be able to calculate three-dimensional cell-survival distributions, which can be compared with radiobiology studies. This program represents a useful approach toward treatment planning for clinical trials.

Practical Applications Experiments

Tissue Analysis with Muonic X-rays (Exp. 100)

Analysis of the x-ray data obtained from tissue samples was completed. Table XII-I shows some selected data illustrating the comparison between the measured x-ray yields and the yields predicted on the basis of applying the Fermi-Teller Z Law to the results of conventional chemical analysis.

Results for three of the samples (tissue-equivalent liquid, Shonka plastic, and dog blood) exhibit very good agreement between measured yields and predicted yields. Results for the other samples are not always so consistent. This we attribute to the fact that although the first three samples mentioned are very homogeneous and their composition is well known the other samples are not very homogeneous and, as a result, the pieces (usually of the order of 1 mg in weight) used for chemical analysis are unlikely to be representative of the sample as a whole.

This problem of obtaining a small sample which is representative of the bulk sample for conventional chemical analysis points out an important advantage of using muonic x rays for bulk analysis.

Technology Transfer

Localized-Current-Field Tumor Therapy

Design and construction of a portable temperature controller for LCF tumor therapy is complete. A low-power rf oscillator is contained in the same chassis; this 500-kHz source is modulated by the temperature-control circuitry and is used to drive a higher power rf amplifier. (The high-power rf amplifier may be a commercial device such as the ENI 240L 150-W unit.) A variable turns-ratio

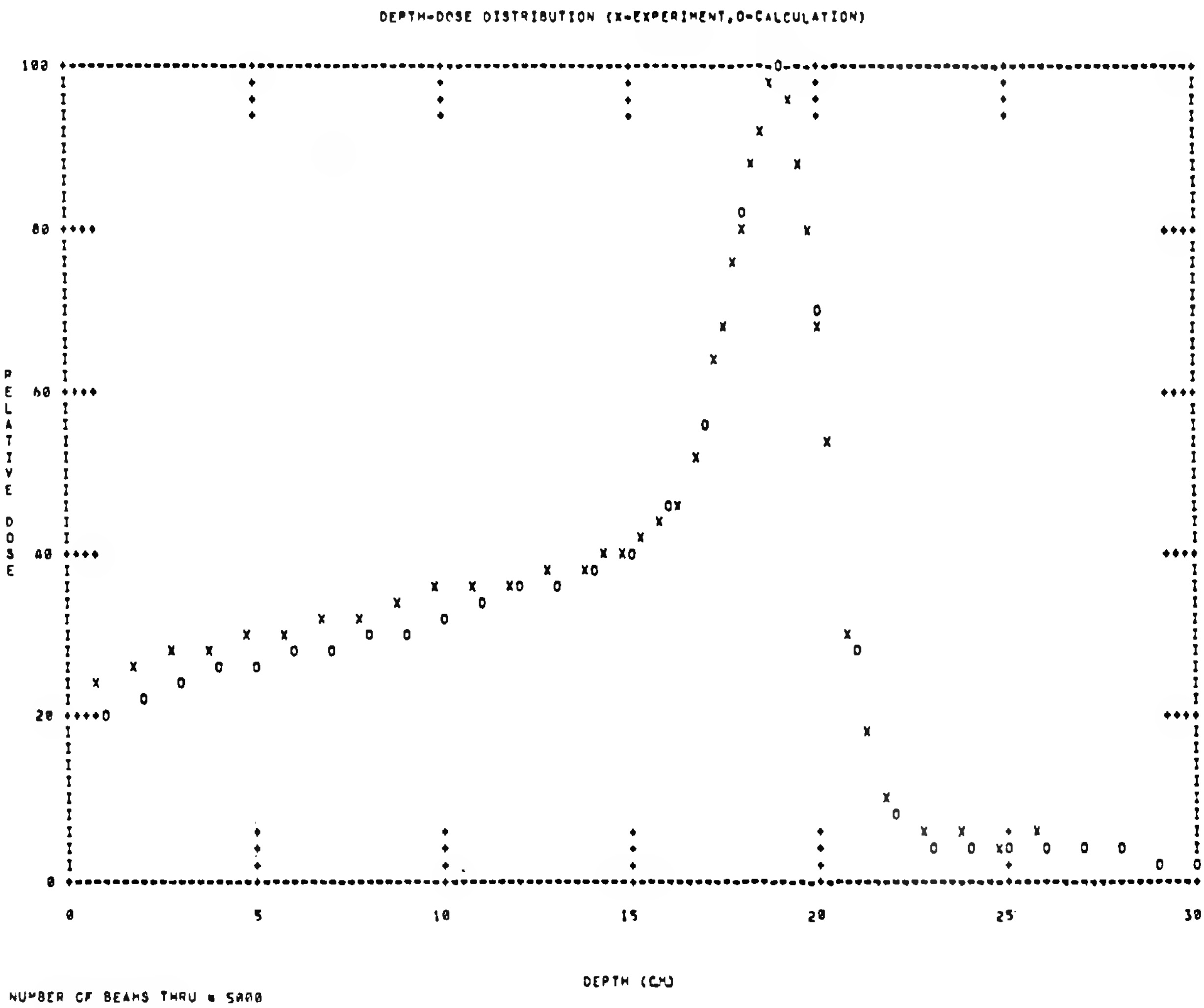

Fig. XII-1.
Depth-dose distribution, comparing calculation with experiment.

transformer has been designed for use on the output of the high-power amplifier. Tissue-load impedance from ~ 10 Ω to 300 Ω may be matched to the 50-Ω source. Documentation on this instrumentation has been requested by other groups who are involved in tissue-hyperthermia research, and should be available within two months.

Two malignant tumors have been treated with LCF during the past two months. In one case, a canine mast-cell sarcoma, complications developed and therapy was halted. In the second case, an equine schwannoma on the eye, the outlook is promising. Several equine sarcoids have been treated during the past three months.

Bioelectric Potentials

The apparatus for measurement of differential breast-skin potentials will probably be transferred to Univ. of New Mexico School of Medicine within the next three months. Tentative plans are being made there to take data on several normal subjects as well as a few subjects with breast malignancy.

Advanced Accelerator Development

Proton and ion linacs appear attractive for generating pions and neutrons for medical applications, protons for material-analysis studies, and protons and neutrons for radiation-damage studies. The low-energy portion of such linacs has been particularly troublesome in terms of size, expense, and reliability. An array of alternating phase-focused (APF) linac structures has been investigated which shows promise for acceleration of protons and heavy ions at higher frequencies and from lower energies than currently possible with the magnetic quadrupole focused drift-tube linac structure. The available phase spaces in both the longitudinal and transverse planes are quite comparable to those of the latest generation of proton linacs. The acceleration rate is somewhat inferior to the conventional drift-tube structure (down 30-40%) due to the investment of some of the accelerating potential in this new focusing role.

A very preliminary design of an APF linac accelerates protons from 0.25 MeV to 14 MeV in 2.6 m at 450 MHz with gradients varying from 4.1 MV/m at the low-energy end to 10 MV/m at the high-energy end with a transverse admittance of 10 π-cm-mrad for a beam radius of 0.5 cm, and 70° and 70 keV of phase acceptance.

REFERENCES

1. M. E. Schillaci and D. L. Roeder, Phys. Med. Biol. **18**, 821 (1973).
2. J. F. Dicello, H. I. Amols, T. F. Lane, A. S. Lundy, J. D. Doss, H. B. Knowles, and J. E. Barnes, Rad. Res. **62**, 562 (1975).
3. R. Katz, B. Ackerson, M. Homoyoonfarard, S. C. Sharma, Rad. Res. **47**, 402 (1971).

TABLE XII-I

MUONIC X-RAY YIELDS

Samples		Elements				
	*	C	N	O	P	Ca
Pig Muscle	M	16.04 ± 0.84	4.48 ± 0.45	79.48 ± 0.95		
	P	12.90	3.55	83.55		
Pig Fat	M	52.96 ± 1.05	1.81 ± 0.21	45.22 ± 1.05		
	P	47.43	2.21	50.37		
Bovine Liver	M	12.27 ± 0.74	3.03 ± 0.42	84.70 ± 0.84		
	P	13.36	2.70	83.94		
Bovine Bone	M	40.68 ± 1.07	3.37 ± 0.20	47.83 ± 1.10	1.90 ± 0.29	6.22 ± 0.93
	P					
	*	C	N	O	F	Ca
Shonka Plastic	M	87.78 ± 0.77	3.67 ± 0.16	6.48 ± 0.26	1.06 ± 0.23	1.01 ± 0.68
	P	87.68 ± 0.37	3.71 ± 0.08	6.40 ± 0.65	1.14 ± 0.07	1.08 ± 0.08
Te Liquid	M	14.12 ± 0.55	3.94 ± 0.22	81.94 ± 0.59		
	P	14.7	5.0	80.3		
Dog Blood	M	9.03 ± 0.49	3.14 ± 0.25	87.83 ± 0.55		
	P**	10.75 ±	3.23	86.02		

*M-measured; P-predicted from chemical analysis.
**Prediction based on composition of human blood.

XIII. MANAGEMENT

Budget and Personnel Levels

The proceedings have been distributed of the recent Santa Fe and Los Alamos Conference on High Energy Physics and Nuclear Structure, which was edited by members of LASL with help from Stony Brook and the National Research Council of Canada. Coming out as it did in less than four months after the meeting ended, the prompt publication of the volume is a tribute to the efforts of the authors, editors, and the A.I.P. publishing staff.

Total operating costs to date for FY-76 exceeded the budget forecast by $50k, or approximately 0.1%. About 69% of the fiscal-year capital equipment allocation has been obligated or costed. The average number of full-time equivalent employees chargeable to medium-energy-physics funding is 355, one more than forecast.

Safety

Safety Staff

The LAMPF Safety staff has been augmented by the arrival from Switzerland of Mr. Rudolf Frei, who will be associated with the LAMPF Safety Office for one year. He will be working on safety system analysis, safety program review, and preliminary application of the Management Oversight and Risk Tree (MORT) system safety program and its techniques to the LAMPF program.

Radiological Safety

Close control of the radiological safety aspects of work on the accelerator and in the experimental areas continued. Individual exposures as well as total man-rem exposures were kept to an acceptable level. The total exposure for LAMPF-associated personnel, excluding crafts, was 30.6 man-rem for the months July through September. This exposure was divided among 182 people. The maximum individual exposure was 1.65 rem. Craft personnel exposures were not included in the figures this quarter because many received exposures at areas other than LAMPF.

A form was developed which must be completed before work can begin in certain radiation areas. Previously, written operational plans were a requirement; however, it was discontinued because many people originated these plans, and it was difficult to present the required information in a uniform manner. The new form provides uniformity. Thirty-nine operational plans were prepared this quarter for radiation work.

A procedure was prepared which specifies methods for control and disposal of solid, liquid, and gaseous radioactive waste.

Training

Three division-wide safety sessions were held this quarter. Current safety items were discussed and formal talks were given on special safety topics which included the DESY and Brown's Ferry fires, safe shop practices, the handling and control of mercury, and potential chemical carcinogens. The LAMPF Director spoke on the concerns for the safety of visitors from other laboratories and their work under LAMPF safety rules and procedures.

Other safety training included some section meetings in which special safety topics were discussed.

Electrical Safety

Members of the Electrical Safety Committee formed inspection teams to investigate the overall status of electrical safety. The primary purpose of this investigation was to identify classes of electrical equipment at LAMPF that may present electrical hazards and require further study. Equipment design, maintenance procedures, and maintenance personnel practices were included as items to be investigated.

Safety Review of Experiments

Safety reviews of experiments continued and became more formalized. A new safety review form is being used to evaluate safety aspects of each experiment. The use of these forms minimizes the possibility of safety items being overlooked, and they also provide a permanent record of safety reviews. All experiments are now required to have an on-site safety representative. During the safety review, a commitment is obtained from the experiment spokesman to see that team members have read, or will read, the safety section of the Users Handbook.

Accidents

Twenty-nine accidents were reported this quarter. Most injuries were minor and consisted of lacerations, sprains, abrasions and foreign bodies in the eye. One accident resulted in two fingers being broken. No accidents caused any significant loss-of-work time.

Program Advisory Committee

The next meeting of the Program Advisory Committee will be held at LAMPF on January 16-18, 1976. Of the 30 new proposals received, 27 will be considered at the meeting in January.

Visitors Center

Leases have been obtained for 100 Los Alamos Medical Center efficiency apartments and two 2-bedroom apartments for subleasing to LAMPF users. These apartments will be assigned to users on a priority basis, according to the scheduling of experiments. Six of the Medical Center apartments will revert to the Univ. of New Mexico Cancer and Treatment Center for scheduling as soon as patient treatments at the Biomedical Facility begin.

In addition to visitors on conducted tours, 248 "casual" visitors, from 12 foreign countries, were received at MP Division, There were 250 visitors at LAMPF to participate in the research programs, with 191 visitors received and 131 checked out during this report period.

Meetings and Tours

Organized tours of the LAMPF were conducted for the following organizations:

- 8/ 5 – Military Officers from Ft. Bliss, TX
- 8/ 6 – Trinity Section, American Nuclear Society
- 8/ 7 – Management Group, U.S. Forest Service Regional Office
- 8/ 9 – LASL monthly tour for general public
- 8/11 – Cancer Society
- 8/13 – Regis College
- 9/23 – Washington Defense Nuclear Agency personnel
- 10/ 3 – Insilco Corp.
- 10/ 4 – LASL monthly tour for general public
- 10/ 4 – New Mexico Pediatrics Society
- 10/ 7 – Smith International Corporation (petroleum)
- 10/ 9 – USSR Controlled Thermonuclear Research Materials Team
- 10/ 9 – Navajo School Teachers
- 10/16 – Univ. of New Mexico Graduate Nuclear Engineering Students
- 10/17 – Attendees of Life Sciences Symposium
- 10/24 – Univ. of New Mexico Art Dept.
- 10/31 – Biology Club, Ft. Lewis College

LAMPF Users Group, Inc.

Liaison Office

The annual election of officers on the Board of Directors of the LAMPF Users Group, Inc. was conducted by mail ballots sent to 1034 members of the group on September 19, 1975. The Nominating Committee, consisting of Mark J. Jakobson, Chairman (Univ. of Montana); Hans E. Frauenfelder (Univ. of Illinois); Jon D. Shoop (Univ. of New Mexico); Richard R. Silbar (LASL); and Klaus O. Ziock (Univ. of Virginia), prepared a slate of candidates. An additional candidate was placed on the ballot by petition. Following is the slate of candidates:

Chairman-Elect: Alfred S. Goldhaber (State Univ. of New York at Stony Brook)
Harvey B. Willard (Case Western Reserve Univ.)

Members: Bernard M. K. Nefkens (UCLA)
Rolf M. Steffen (Purdue Univ.)
Paul Todd (Pennsylvania State Univ.)

The two candidates for members of the Board receiving the most votes will replace Robert E. Anderson, M.D. (Univ. of New Mexico School of Medicine) and Robert M. Eisberg (Univ. of California, Santa Barbara), who are completing their two-year terms of office. The deadline for the return of ballots to the Liaison Office is November 3, 1975, and the results of the balloting will be announced at the Ninth LAMPF Users Meeting.

Preparations for the Ninth LAMPF Users Meeting to be held at Los Alamos on November 10-11, 1975, are being made by Chairman Herbert L. Anderson (Univ. of Chicago) and the Liaison Office. Preliminary programs, reservations forms, and other meeting information were mailed to all members on September 19, 1975. The program will consist of Opening Remarks by Harold M. Agnew, Director of LASL; LAMPF Status Report by Louis Rosen, Director of LAMPF; Status of the Accelerator by Donald C. Hagerman, Chief of Operations for LAMPF; and Status of LAMPF Experimental Areas by Lewis E. Agnew, MP-7 Group Leader. Invited talks are scheduled by Daniel R. Miller, Acting Director, Division of Physical Research, ERDA, "The ERDA Approach to Nuclear Science"; Edward C. Creutz, Assistant Director for Mathematical and Physical Sciences and Engineering, NSF, "National Science Foundation Support of Nuclear and Medium-Energy Physics"; Stanley Brodsky, SLAC, "The Impact of Quantum Electrodynamics";

William Bertozzi, Massachusetts Inst. of Tech., "Inelastic Electron Scattering"; and Luis Alvarez, LBL, "Scientific Detective Work." Reports on LAMPF experiments will be given by Robert A. Naumann, Princeton Univ., and Jere D. Knight, LASL, "Chemical Effects Accompanying Muon Capture—Survey and Recent Experimental Results"; Morton M. Kligerman, M.D., Univ. of New Mexico Cancer Research and Treatment Center and LASL, "Human Pion Radiobiology"; Martin D. Cooper, LASL, "Pion Nuclear Total Cross Sections"; and Richard E. Mischke, LASL, "Direct Lepton Production." The annual Users Group report will be given by Chairman Herbert L. Anderson, who will also conduct the general business session. In addition, all Working Groups will hold meetings on November 11.

The September issue of the LAMPF Users Group Newsletter was mailed on September 24, 1975. A letter giving a progress report on the EPICS channel and the agenda for the forthcoming Working Group Meeting was mailed to all members of the EPICS Working Group on October 7, 1975. The notice of annual meeting and call for nominations and amendments to by-laws were mailed August 4, and the 1976 membership-renewal forms, mailed September 19, were sent to the entire membership of the LAMPF Users Group, Inc., in compliance with the by-laws.

Board of Directors and Technical Advisory Panel

The Board of Directors and Technical Advisory Panel will meet at Los Alamos on Wednesday, November 12. The newly elected officers of the Board of Directors for 1976 will be invited to attend these meetings. Agendas have not been prepared as yet.

Statistics

Listed below are statistics of the LAMPF Users Group, Inc. as of September 9, 1975:

Membership

Non-LASL	859
LASL	183
Total	1042

Fields of Interest

1. Nuclear and Particle Physics	777
2. Nuclear Chemistry	175
3. Biomedical Applications	368
4. Not Specified	18
5. Other (including administration, facilities, operations, coordination, theory, data acquisition, and miscellaneous applications)	466
6. Isotope Production	131
7. Radiation Damage	143
8. Weapons Neutron Research	119

(Note: These numbers do not add to total membership because there are duplicate interests.)

Institutional Distribution

1. Membership by Institute	
LASL	183
Other National or Government Laboratories	138
U. S. Universities	422
Industrial	52
Foreign	146
Hospitals and Medical Centers	101
Total	1042

2. Number of Institutions	
National or Government Laboratories	34
U. S. Universities	111
Industry	36
Foreign	71
Hospitals and Medical Centers	61
Total	313

Regional Breakdown

East (PA, NJ, DE, Wash DC, MA, NY, CT, VT, RI, NH, ME)	163
Midwest (OH, MO, KS, IN, WI, MI, IL, ND, SD, NB, LA, MN)	142
South (MD, VA, TN, AR, WV, KY, NC. SC, AL, MS, LA, GA, FL)	89
Southwest-Mountain (MT, ID, UT, WY, AZ, CO, NM, OK, TX)	184
Far West (AK, HI, NV, WA, OR, CA)	135
Foreign	146
LASL	183
Total	1042

APPENDIX A

LAMPF GUESTS THIS REPORT PERIOD

John C. Allred	Univ. of Houston
James F. Amann	Carnegie-Mellon Univ.
Alan N. Anderson	Univ. of Idaho
Bryon D. Anderson	Case Western Reserve Univ.
Herbert Anderson	Univ. of Chicago
Wendell A. Anderson	UNM Cancer Center
George W. Atkinson	UNM School of Medicine
Leonard B. Auerbach	Temple Univ.
Helmut W. Baer	Case Western Reserve Univ.
Thomas J. Baird	Rensselaer Poly. Inst.
Howard I. Balshem	Temple Univ.
Peter D. Barnes	Carnegie-Mellon Univ.
Fred E. Bertrand	ORNL
Philip R. Bevington	Case Western Reserve Univ.
Christopher W. Bjork	Univ. of Texas
Gary S. Blanpied	Univ. of Texas
Joseph E. Bolger	Univ. of Texas
Jonathan S. Boswell	Univ. of Virginia
Kenneth Boyer	Univ. of Texas
Wilfred J. Braithwaite	Univ. of Texas
Hubert Brandle	UCLA
David W. Brock	Univ. of Colorado
George A. Brooks	Univ. of California
Howard Bryant	Univ. of New Mexico
Joseph J. Burgerjon	TRIUMF
George Burleson	New Mexico State Univ.
Roger D. Carlini	Univ. of New Mexico
Donald E. Casperson	Yale Univ.
Constantine Cassapakis	Univ. of New Mexico
Herbert H. Chen	UCI
Robert K. Cole	USC
Joseph N. Craig	Carnegie-Mellon Univ.
Thomas W. Crane	Yale Univ.
Dorothy M. Crawford	UNM Cancer Center
Frank H. Cverna	Case Western Reserve Univ.
John P. Davidson	Univ. of Kansas
Dietrich K. Dehnhard	Univ. of Minnesota
Arthur B. Denison	Univ. of Wyoming
Byron Dieterle	Univ. of New Mexico
Joey B. Donahue	Univ. of New Mexico
Mohan Doss	Carnegie-Mellon Univ.
Steven A. Dytman	Carnegie-Mellon Univ.
Thanasis E. Economou	Enrico Fermi Lab.
Robert M. Eisberg	UC, Santa Barbara
Robert Ellis	Univ. of Montana
Norbert Ensslin	Univ. of Colorado
Michael L. Evans	Texas A&M Univ.
Herman Feshbach	Massachusetts Inst. of Tech.
John C. Fong	UCLA
Robert Fong-Tom	Yale Univ.
Rudolf Frei	Switzerland
Sherman Frankel	Univ. of Pennsylvania
David R. Giebink	Univ. of Texas
George Glass	Texas A&M Univ.
Alfred Goldhaber	State Univ. of NY, Stony Brook
David E. Good	Univ. of Illinois
Kazuo Gotow	VPI/State Univ.
Pierre Grand	BNL
Nancy E. Greene	Univ. of New Mexico
Steven J. Greene	Univ. of Colorado
Mark B. Greenfield	Florida A&M Univ.
Chilton B. Gregory	Univ. of New Mexico
Isaac Halpern	Univ. of Washington
William B. Harvey	New Mexico State Univ.
Walter Hensley	Univ. of Rochester
H. Roland Heydegger	Purdue-Calumet
John C. Hiebert	Texas A&M Univ.
Virgil L. Highland	Temple Univ.
John C. Hill	Iowa State Univ.
Lawrence H. Hinkley	Case Western Reserve Univ.
Gerald Hoffmann	Univ. of Texas
Bo Hoistad	UCLA
David B. Holtkamp	Univ. of Texas
Roger Horne	CERN
August Hruschka	Univ. of California
Vernon W. Hughes	Yale Univ.
Ed V. Hungerford	Univ. of Houston
Harvey Israel	Los Alamos
Steve Iversen	Northwestern Univ.
Mahavir Jain	Texas A&M Univ.
Mark J. Jakobson	Univ. of Montana
David A. Jenkins	VPI/State Univ.
Randolph H. Jeppesen	Univ. of Montana
Kenneth F. Johnson	New Mexico State Univ.
Kelly Kanizay	Univ. of Colorado
Charles A. Kelsey	UNM Cancer Center
Arthur K. Kerman	Massachusetts Inst. of Tech.
Nicholas S. P. King	Univ. of California
Thomas R. King	Univ. of Wyoming
Harrold B. Knowles	Washington State Univ.
Lynn D. Knutson	Univ. of Washington
Thomas Kozlowski	BNL
Kenneth S. Krane	Oregon State Univ.
Gary Kyle	Univ. of Minnesota
Wing Chee Lam	VPI/State Univ.
Richard G. Lane	UNM Cancer Center
Phillip M. Lang	Northwestern Univ.
Carl B. Larson	Univ. of Colorado
John F. Lathrop	Univ. of California
Chris P. Leavitt	Univ. of New Mexico
Marilyn M. Lieber	Univ. of New Mexico
Rodger P. Liljestrand	Univ. of Texas

Ronnie D. Lipschutz — Univ. of Texas
Stanley Livingston — Los Alamos
Earle L. Lomon — Massachusetts Inst. of Tech.
Steven C. Luckstead — Washington State Univ.
David G. Madland — Univ. of Minnesota
Donald J. Malbrough — Univ. of South Carolina
Fesseha Mariam — Yale Univ.
Thomas Marks — Univ. of South Carolina
Roscoe E. Marrs — California Inst. of Tech.
Nina Marsh — UNM Cancer Center
Bill N. Mayes — Univ. of Houston
James M. McCarthy — Univ. of Virginia
W. Kenneth McFarlane — Temple Univ.
Claude Metzger — CERN
John F. McIntyre — Univ. of Texas
Michael McNaughton Case Western Reserve Univ.
Hans Otto Meyer — Univ. of Basel
Murray A. McInester — Tel Aviv Univ.
C. Fred Moore — Univ. of Texas
Christopher Morris — Univ. of Virginia
Zvonko Mozetic — Yugoslavia
Donald W. Mueller — Los Alamos
Robert A. Naumann — Princeton Univ.
Bernard Nefkens — Univ. of California
Peter Nemethy — Yale Univ.
Lee C. Northcliffe — Texas A&M. Univ.
Andrew W. Obst — Northwestern Univ.
Herbert Orth — Univ. of Heidelberg
Alden Oyer — Univ. of Wyoming
Garrett A. Pelton — VPI/State Univ.
Roy J. Peterson — Univ. of Colorado
Robert F. Petry — Univ. of Oklahoma
John M. Phillips — Univ. of Wyoming
Barry M. Preedom — Univ. of South Carolina
Glen A. Rebka — Univ. of Wyoming
James J. Reidy — Univ. of Mississippi
Walter H. Reist — Univ. of Berne
Jeffrey D. Richman — Los Alamos
Robert J. Ridge — UCLA
Peter J. Riley — Univ. of Texas
Robert M. Rolfe — UCLA
Isaac I. Rosen — Univ. of New Mexico
Ted R. Rupp — Univ. of New Mexico
Marvin Sachs — Univ. of New Mexico
Mark A. Schardt — Arizona State Univ.
Darwin T. Scott — Univ. of New Mexico
Kamal K. Seth — Northwestern Univ.
Subhash C. Shah — Southern Univ.
Hasan Sharifian — Carnegie-Mellon Univ.
Joseph D. Sherman — Carnegie-Mellon Univ.
Donald Shirk — Iowa State Univ.
Frank Shively — LBL
Donald Slater — Univ. of Virginia
Alfred R. Smith — UNM Cancer Center
Stanely E. Sobottka — Univ. of Virginia
Larry B. Sorensen — Univ. of Illinois
Paul A. Souder — Yale Univ.
Morton M. Sternheim — Univ. of Massachusetts
Richard J. Sutter — BNL
L. Wayne Swenson — Oregon State Univ.
Willard Thomas — Univ. of New Mexico
Roger C. Thompson — Univ. of Rochester
Hossein Tootoonchi — Univ. of New Mexico
Gerald E. Tripard — Washington State Univ.
Anthony L. Turkevich — Univ. of Chicago
Alan K. F. Turner — Colorado State Univ.
James Valentine — Temple Univ.
Philip Varghese — Univ. of Oregon
Charles N. Waddell — Univ. of South Carolina
E. Alan Wadlinger — Univ. of Virginia
Louis Wagner — Univ. of Florida
John B. Walter — Univ. of Wyoming
Charles Whitten — UCLA
Harvey B. Willard — Case Western Reserve Univ.
Suzanne E. Willis — Yale Univ.
David M. Wolfe — Univ. of New Mexico
Frederick O. Woodsome — Univ. of Colorado
Mary Ann Yates — Carnegie-Mellon Univ.
Mark Zaider — Tel Aviv Univ.
Alex Zehnder — CIT
Hans Ziock — Univ. of Virginia
Klaus O. H. Ziock — Univ. of Virginia
Klaus P. Ziock — Univ. of Virginia

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