135/ 2-28-77

Di. 747

LA-6678-PR

Progress Report

MASTER

UC-28

Issued: January 1977

Medium-Energy Physics Program

August 1—October 31, 1976

Compiled by

Eleanor Dunn

los alamos scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87545

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
CONTRACT W-7405-ENG. 36

The four most recent reports in this series, unclassified, are LA-6195-PR, LA-6363-PR, LA-6505-PR, and LA-6553-PR.

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price: Printed Copy $5.50 Microfiche $3.00

CONTENTS

GLOSSARY OF TERMS USED IN THIS REPORT

ADC – Analog Digital Converter
ADS – Analog Data System
AMO – Area Manager's Office
APF – Alternating Phase-Focusing
APL – A Programming Language
ASCII – American Standard Code for Information Interchange
bpi – Bytes Per Inch
BPM – Beam Position Monitor
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
cw – Continuous Wave
C-W – Cockcroft-Walton
DACT – Data-Acquisition and Control Terminal
dpa – Displacement Per Atom
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
FSI – Final-State Interaction
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
MG Set – Motor-Generator-Set
m.i. – Mineral Insulated
MIG – Metal Inert Gas
MPU – Microprocessing Unit
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
OER – Oxygen Enhancement Ratio
pc – Printed Circuit
PHA – Pulse-Height Analyzer
PIGMI – Pion Generator for Medical Investigations
PLI – Procedural Language Interface
RAM – Random Access Memory
RBE – Relative Biological Effectiveness
RGB – Red-Green-Blue
RICE – Remote Information and Control Equipment (remote data terminal)
RIU – RICE Interface Unit
ROM – Read-Only Memory
S2K – System 2000 (a large software package for information storage and retrieval)
SCC – Serial Crate Controller
SCR – Silicon Control Rectifier
SM – Sweeping Magnet
SSD – Serial System Driver
SY – Switchyard
TDC – Time-to-Digital Converter
TDI – Temperature Difference Integrator
TIG – Tungsten Inert Gas
Tm – Absolute Melting Temperature
TOF – Time of Flight
TR – Transition Region
VSWR – Voltage Standing-Wave Ratio

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
- ISORAD – Isotope Production and Radiation Damage
- LEP – Low-Energy Pion Channel
- Neutrino A
- P^3 – High-Energy Pion Channel
- 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, 1976

I. SUMMARY

Engineering Support

Over 68 000 socket hours were accumulated on the accelerator during this quarter. Fifteen klystrons and twenty-eight switchtubes required replacement. Three klystrons were rebuilt and twenty-four switchtubes were reprocessed. The design and cold-test modeling of the 1/2-MW, 201-MHz klystron replacement for the 4616/4664 gridded-tube family was completed and fabrication of parts was started.

The bulk of the group's engineering drawings have now been transferred to aperture cards. It is anticipated that their use will substantially reduce the required storage volume while expediting the information retrieval.

Refurbishment of the EPA klystron amplifier with its peripheral electronics was completed and the equipment is now being readied for shipment to Yugoslavia.

The contract for the installation of the two 90-ton magnets in the EPICS spectrometer was signed with an anticipated completion late in the next quarter. Work preparatory to the installation is proceeding on schedule.

The fabrication of the alternating phase-focused, cold-probe cavity was completed and is currently being fitted for bead perturbation studies. The design of a full-power, 6-cell, 450-MHz test cavity (PIGLET) for gradient studies is virtually complete and will shortly be released for fabrication. The design and fabrication of a 1-MW, 450-MHz test stand is well under way. It is anticipated that this stand will be operational late in the next quarter. Work continues on the permanent quadrupole magnet program, the rf window-matching studies, and the rf testing of copper-bright plating of aluminum and steel accelerating cells.

Support for the WNR facility consisted mainly of alignment services and finishing the fabrication and testing of the 24 steering magnets.

The support of the experimental program continued to dominate the group effort. Fifteen experiments were actively supported during the quarter. Fifty-seven optical/scintillation devices and seven wire chambers were constructed for experimental use.

Accelerator Support

The 201-MHz test stand continues as the most important contribution to 201-MHz reliability since the great shutdown. All warrantee 7835s and 4616s have been tested and some older tubes, some out of service for many years, are now being run. The backlog of tubes that can be relied upon for spares continues to grow.

In addition, development of the 8501 driver for module 1, new modulator test procedures, checkout of 4616 cavities and modulators, and testing of many other 201-MHz units and parts are all part of the day-to-day test stand operation.

The extensive modification of the tank resonance control system for the 805-MHz tanks is now 90% complete and appears to be a significant improvement. The new system should decrease routine recalibration and adjustment while holding the water temperature to much tighter tolerances than in the past.

After extensive testing, the new No. 376 indicator lamp has been chosen as the LAMPF standard and is to be used throughout the accelerator as a replacement for the short-lived No. 387.

After running satisfactorily for six months at the test stand, module 2, and the H^- buncher, the 201-MHz solid state IFA has been selected as a replacement for all 201-MHz tube-type IFAs. Fourteen of the units will be built as soon as procurement of parts and updating of drawings is complete.

The redundant phase monitor system installation has proceeded on schedule and should be complete by the end of the year.

Modification of the dual-Acme power supplies to make them compatible with the LAMPF standard regulator module is within five units of completion. A new interlock relay board with built-in memory has been designed and installation has begun on the older power supplies which did not incorporate this useful maintenance feature.

Equipment reliability during this quarter was about the same as that achieved the previous quarter. Total equipment downtime, as a percent of the total hours available was ~2%.

Accelerator Systems Development

The modeling study of the 201.25-MHz linac has yielded a result which fits the experimental data. Work continues on optimization of the existing linac, and on finding lengths for some minimum number of drift tubes which could be changed to bring the field distribution in the first tank closer to the design condition.

Machine experiments concentrated on instrumentation checkout, investigation of high peak-current effects, and steering algorithms.

Investigations into space-charge phenomena continued, in preparation for the extension of present results. Progress was made on the analysis of beam-halo data by reconstructing density distributions from wirescanner data. An analytic form for a least-squares fit to an x-y distribution was developed.

Diagnostic equipment development received a major share of the effort. Development tests of the beam-position monitors were completed and the heterodyne circuit chosen for production. Grounding problems on the multigain wire-scanner were solved and plans made for the required changes along the accelerator. Work was started on the evaluation and correction of errors in the wire-scan process. Microprocessor development showed significant progress.

The biomed range shifter operated very successfully during the quarter, and design work was started on the second-generation device. Design was completed on a force-reflective hydraulic servoarm.

An exchange of personnel was carried out with TRIUMF for two months, trading ideas on instrumentation and other matters.

Injector Systems

Both the H^+ and H^- injectors have been operational this quarter and have provided the simultaneous ion beams required for LAMPF operations. The construction of the polarized ion injector has continued on schedule.

The H^+ injector has been run at increasingly higher beam currents during production runs and is now operating at 30-mA peak current at 6% duty factor. Some bouncer problems have been found and have been corrected.

The H^- injector has been run almost exclusively with chopped beam this quarter. The tuning of the chopped beams has been compromised during production runs by the tuning for the higher current H^+ beams. Additional beam diagnostics for on-line tuning of the chopped beams is necessary to maintain high-current chopped beam.

The C-W generator for the polarized ion injector was successfully commissioned this quarter after final installation of the power wiring. Only minor modifications are needed for on-line operation. The accelerating tube for this injector was bonded and the assembly of the accelerating column is now in progress.

Work continued on implementing a fiber optics system to provide additional data channels between ground and the equipment domes. One data link has been installed and has functioned without problem.

Work has also continued in studying the beam emittance from the injector through the linac. Some problems in carrying out absolute emittance measurements are now being addressed, but preliminary results for peak currents up to 10 mA have been obtained in the 201-MHz linac. The normalized emittance is observed to grow by a factor of 2.6 over that predicted by $\beta\gamma$ damping for the beams now being injected into the linac.

Some work has been started on the injector for PIGMI. Ion source tests have been carried out and preliminary specifications for a high-voltage power supply have been prepared.

Electronic Instrumentation and Computer Systems

A TV-based display of the status of the accelerator and experimental beam lines was put into operation and will soon be available in every experiment counting house.

Work continued on the third console, primarily on the interface electronics. The bus controller and three console devices are in various stages of development. All make use of a set of three microprocessor pc boards developed for general use.

A serial CAMAC system was designed and installed in the transition region to collect data from the TR harps. The usefulness of this system will govern its future enhancements and extensions.

The prototype microcontrolled data link was completed and connected to the satellite computer in the IDS for performance evaluation.

The programming effort this quarter was divided equally among system development, troubleshooting, and programs to aid operations.

An elaborate alarm panel for the tritium experiment (Exp. 90) was fabricated, and electricians installed cabling for 10 alarm circuits plus various interlock and control circuits.

A major advance in the operation of the P^3 channel was made by implementing computer control for the equipment in the channel.

The installation and checkout of controls and instrumentation for Area C culminated in the successful transporting of beam through the HRS.

A summer study of LAMPF's needs for computer support of the experimental program was held during August. A number of conclusions and recommendations were recorded in LA-6543-MS along with supporting arguments. Procurement actions were initiated for equipment to meet several of the highest priority needs identified in the study.

A new release of the general data-acquisition program Q was made. The objectives of this release were reliability, centralized error and status logging, speed, shorter code, and full support of PDP-11/40 systems and LBL magnetic-tape controllers.

The collaboration with LBL continued toward the goals of making Q available under both RSX-11M and RSX-11D. Preliminary system tests are scheduled for late November.

Negotiations for the FY-77 contracts for the maintenance of LAMPF data-acquisition computers were completed with both maintenance teams.

A substantial portion of the $180k allotted to LEEP for NIM and CAMAC modules as well as test and measuring equipment was obligated during this quarter.

Three sessions of the Electronics Perspective Seminars were conducted to help the technical staff stay abreast of advancing technology.

Accelerator Operations

The accelerator was in continuous operation throughout the quarter, with the exception of two scheduled shutdowns which totalled seven days. The typical operating cycle, as in previous quarters, consisted of two weeks devoted to research and one week used for facility development and maintenance.

Starting with operating Cycle 7 early in the quarter, the machine has been run routinely with 100 μA of H^+ delivered to Area A and as much as 6 μA of H^- to area B. Machine availability during research shifts averaged 83% for the H^+ beam and 77% for the H^- beam.

Development of the HRS channel was in progress throughout the quarter and the resolution of the spectrometer was demonstrated to be better than 100 keV. Initial irradiations were conducted successfully in an isotope production stringer at A-6.

Research-quality proton beams to Area A totalled 83 400 μA-h during the quarter, as measured at the A-1 target station.. An additional 190 μA-h went to Area B. The combined total is again greater than the cumulative total of all beams previously delivered to the experimental areas. Forty-three experiments received beam during the quarter.

Machine time allotted for facility development was used for the development of standardized beam-tuning procedures for 100-μA production beams, final testing of beam-position monitor prototypes, measurements of emittance growth with increased beam currents, and beam tests of high average currents in Area A. A series of 5-min tests at 200-μA average current to the A-6 beam stop, with production targets in place, was completed at end of Cycle 9 without retuning the production beam.

A televised accelerator status display, containing computer-generated information on beam-current intensities and target configurations and provision for messages from accelerator operations personnel, was activated during the quarter. Television monitors have now been placed in almost all experimental counting houses and trailers.

Experimental Areas

A preliminary proposal for a minimum shelter to provide weather protection for maintenance work at Area A-East has been prepared.

A compound of four trailers has been set up near Area A as headquarters for the experimental area support staff and for safety activities.

Shielding near the A-1 target has been improved by the addition of a wall built of special concrete blocks, and improved shielding has been installed for the EPICS vacuum system. Substantial additions have been made to the on-site shielding inventory.

Difficulties have been experienced in maintaining the spin-drive systems for the rotating graphite target wheels at A-1 and A-2. On several occasions, nonspinning targets were used for long periods of time at 100-μA beam current. The problems with the spin mechanisms have been corrected for the present.

Remote-handling apparatus was used to repair a water leak in target cell A-2. Several small vacuum leaks were found. However, acceptable vacuum pressures have been achieved so far. A new collimator unit is being prepared as a replacement for the one that is leaking.

About 30% loss of pion flux was reported at the biomed channel caused by delamination and splitting of the A-5 pyrolytic graphite target. The target has been replaced and it should provide better cooling and minimize the consequences of delamination. Installation of a target at A-5 with a water-cooled flange led to a vacuum excursion that destroyed one harp and damaged several others. Targets with this water system have been eliminated for now. Control system troubles, now corrected, were also experienced on the A-5 target.

The installation of a water-cooled window at A-6 is planned for the next shutdown. A new beam-stop assembly will be available at that time, if needed.

Conceptual design has been done for a proton irradiation station to be located at the unused fast-rabbit port near target A-1. Proton beam intensities in excess of 250 $\mu A/cm^2$ can be realized there. Some hardware preparations are in progress and the facility should be ready during the first part of 1977.

A number of improvements have been made to the secondary beam lines: computer controls have been installed on P^3; a large vacuum pump has been installed on SMC; the SMC-East cave has been modified extensively in preparation for a bent-crystal spectrometer experiment using pions. Failure of secondary beam-line components on LEP, SMC, and P^3 caused downtimes of $<1\%$ during this quarter.

The Monitor I remote-handling system is operational and was used successfully for a maintenance job at A-2. The Monitor II crane unit is on hand. However, the controls may not be ready when the first arm is delivered in late January. The remote-handling tooling required for replacing the A-6 window and the 2A collimator is in preparation.

All five radioactive water systems were operated continuously during this report period. Water resistivity was maintained at an acceptable level. An on-line, dissolved-oxygen analyzer system has been installed on each of the radioactive water systems.

The filter chambers on the radioactive-air exhaust system have been upgraded and a damper was installed on the SY duct. The system is now operating at 100% capacity.

Major cryogenic effort was devoted to preparations for Exp. 90, which uses a cold-gas tritium target. Cryogenic support was also given to five other experiments. Repairs were carried out on the large LD_2 target used for neutron production in Area B.

Pumping-speed tests were performed on the ^3He vacuum system for the polarized proton target. Two large blowers had leaks in their pump casings and were returned to the manufacturer.

Beam Line Development

The H^+ production beam intensity was 100-μA average this quarter with test runs in Areas A and A-East up to 200-μA average and 5.1-mA peak.

Residual activation in the A-4 hands-on maintenance region and in the switchyard has been reduced. Phase-space measurements indicate that the output emittance of the linac rises linearly with peak current as the EM-2 jaws are opened. The emittance damps as expected between 300 MeV and 800 MeV in the side-coupled linac. A program of studying beam halos has begun with measurements down to $\sim 10^{-5}$ of the peak beam intensity.

Improvements were made in the current-monitor system, new problems were discovered, and a continuing program of study and development was begun. A case of apparent radiation damage to a toroid occurred.

Harp improvements are centered on the use of silicon carbide wire and a different radiation-resistant cabling for use in high-radiation areas. A wire-scanner ribbon failed at 100-μA beam current and was replaced with a silicon carbide wire.

The properties of the Loss Monitors were studied with a ^{60}Co source. In particular, the procedure of reducing sensitivity by emptying the scintillator from the detector was found to give a reduction of a factor of 100. An additional reduction of 100 is obtained if the remaining scintillator film is removed from the phototube.

A vacuum valve which closes in $\sim$36 ms is now operational and located at the downstream end of Line A-South. Developments are under way to improve the fail-safe nature of the trigger. The 25-ms VAT valve and control electronics will be delivered next quarter.

The first EPICS spectrometer magnet has been mapped with the accumulation of over 400 000 magnetic field measurements. Over four man-months were involved in these measurements.

A new A-1 profile monitor and a radiation-hardened toroid were installed.

Large-Spectrometer Systems

Energetic Pion Channel and Spectrometers

During the past quarter, one dipole was mapped and the second completed and prepared for testing. The new concrete floor was ground and the spectrometer frame was installed. The air pads and drive mechanism were attached to the frame in preparation for full-load tests. A rigging contract has been signed, and we are on a schedule that will allow installation of the dipoles in December and January. It is expected that the spectrometer will be ready for first beam tests in April 1977.

High-Resolution Proton Spectrometers

The HRS facility is now operational. The optics of Line C and the HRS have been verified to essentially meet design specifications. The beam line and the spectrometer optics were properly matched for the energy-loss mode by fine tuning using three linear combinations of various Line C quadrupoles which only affect the focus, dispersion, and twist, respectively, at the target.

Using the beam scanners and pencil beams prepared in Line X by Strippers LX-ST-01-05, the beam line resolution was determined to be $\leq$80 keV. The first spectrum using the HRS was obtained on August 21, 1976. The resolution of this first spectrum was $\sim$500 keV. Most of this width was attributed to multiple coulomb scattering in the thick CH_2 target, and various windows used to separate the chamber from the spectrometer, as well as improper matching of the Line C and HRS optics.

With proper dispersion-matching and a windowless system, we obtained 85-keV (FWHM) resolution for p + ^{209}Bi (10 mg/cm^2) elastic scattering at 25° laboratory scattering angle near the end of the quarter. This particular spectrum was accumulated in $\sim$15 min with full phase-space beam-on-target and full HRS solid angle.

Research

A nice demonstration of resonances in the photodetachment of H^- was carried out in the 800-MeV H^- beam, using a colliding-beam technique with a small N_2 pulsed laser. Two resonances were found, a predicted shape resonance, and, somewhat unexpectedly, an extremely narrow "Feshbach" resonance. The energy dependence of the cross section is in excellent agreement with some calculations by W. P. Reinhardt.

Studies in proton- and pion-induced fission in medium-weight nuclides using range techniques are reported.

Experiments on parity violation in p-d and p-He scattering continue. There is a null result in deuterium with a statistical uncertainty of about one part in 10^7. In helium there is a positive effect well outside of statistics. Studies to eliminate possible systematic effects are continuing.

Preliminary data were taken on the Dalitz decay branch of the neutral pion. The work will continue and be finished in the next quarter.

The EPICS channel has been used for studies of π^+ scattering from light nuclei: ^{6}Li, ^{7}Li, ^{12}C, ^{13}C, ^{16}O, ^{28}Si, and ^{56}Fe at 50 MeV for a variety of angles. Preliminary analysis of the data has been completed. Reactions of (π^-,π) and $(\pi,\pi p)$ in ^{3,4}He and other nuclei have been carried out successfully.

Capture experiments of pions in ^{7}Li, ^{12}C, and ^{181}Ta were carried out using silicon/sodium two-arm detectors.

Experiments on the nuclear resonance effect in pionic cadmium, samarium, and titanium were done. Calculations of the effect in K^- tin atoms were carried out and compared successfully with a recent experiment at the Rutherford Laboratory.

Nuclear Chemistry

Fabrication of the control module and CAMAC interface for the new dual parameter γ-γ-coincidence system has been completed for the Nuclear Chemistry Lab. counting rooms. All components are on hand for assembly, checkout, and programming for this system. Our faulty Ge(Li) detector has been refurbished and is back in operation. A master timer, that updates itself with WWV, has been ordered to drive the laboratory clock system.

The computer-based data-acquisition system has received heavy use during this quarter for Exps. 67, 111, 150, and 239. A printer-plotter has been ordered for the system to increase its efficiency and versatility.

The Beam Variation Correction computer program has been revised to enable it to be run with a portable remote terminal to the CCF. A special χ^2 program has been written for the HP-65.

Installation of the air-free, reverse-osmosis/demineralized water system has been completed and it provides very high purity water to the chemistry labs.

Development work has continued on the branch of the "rabbit" system that runs from the Hot Cell to the Energetic Neutron Station at the main beam stop. Despite many frustrating problems that had to be resolved, the branch appears to be operating reliably now. Devices for remotely controlling and displaying the stopping location of the target carrier in the Neutron Station have been installed in the system control console.

An improved version of the In-Air Target Box, that has seen so much usage and suffered so much radiation damage on the end of proton Line B, is being designed. It is expected to be fabricated in the near future and installed during the December-January shutdown.

A general-purpose targeting device for nuclear chemistry irradiations on an evacuated beam pipe on the P^3 channel has been designed, fabricated, and installed on the Exp. 90 beam pipe.

Practical Applications of LAMPF

In the pion biomedical program, considerable progress has occurred in the areas of hardware development, calculational techniques, and new experimental results. A mechanism for remotely inserting energy-degrading wedges into the dispersion plane of the channel has been designed, and a new slab-carbon production target with a water-cooled upper flange has been installed which should be more reliable and longer lived at production currents above 100 μA. The dynamic range shifter has performed well in a number of experiments. The dose model computer program (BUCKET) has been installed in the treatment planning code (PIPLAN). PIPLAN can now take into account the effects of contaminants, collimator, range shifter, and bolus in predicting dose distributions due to actual beams produced by the channel. In Exp. 236 the RBE and OER have been measured for several cell systems exposed to both narrow and broad momentum distribution beams. Results from Exp. 239 are relevant to the use of the positron activity in pion-irradiated tissues for an *in vivo* dose monitor or for imaging with a positron camera. Within Exp. 270 a large beam (transverse dimensions 8 × 10-cm) has been developed for treatment of deep-seated tumors. The phase-space information now includes particle identification along with momentum and complete trajectory information. A number of therapeutically useful beams have been characterized dosimetrically with relatively flat dose distributions in volumes up to 0.7 ℓ (Exp. 271). Microdosimetry measurements have been performed on those beams planned for use in the near future (Exp. 273).

Design is in progress of Exp. 266 which involves a study of muon spin relaxation in FCC metals with the emphasis on determining the temperature dependence of the muon depolarization rate. Such studies are important for understanding the processes of muon diffusion and trapping in metals and should prove useful for the study of defects in materials. A preliminary study of the radiation damage effects of 800-MeV protons (Exp. 269) has been completed, indicating that some aspects of neutron damage are simulated by that technique thus warranting further, more detailed experiments. Detector systems for the proton axial tomography investigation (Exp. 286) are being evaluated; that experiment should take place in 1977.

In the technology transfer program, there is continuing effort to improve techniques for localized heating of tumors. Encouraging results are reported for the treatment of oral tumors in humans and the "cancer-eye" condition of cattle.

Management

Funding for the first year of a three-year program to support the development of a pion generator for medical application (PIGMI) was authorized by the National Cancer Institute starting July 1976, and a new group was formed in MP-Division, designated MP-14, to deal with our commitment to the NCI for the development of PIGMI.

Individual and total man-rem exposures remained at acceptable levels during this report period. Detailed preparations were made by the LAMPF Safety Office for the conduct of Exp. 90 using the P^3-East channel. Every technical group in MP-Division was intimately involved in the special safety considerations that were required because of the large quantity of tritium used as a target. Personnel directly involved in the operation of the tritium apparatus were trained in the tritium gas-handling and refrigeration systems, operation of emergency generators, alarm and emergency procedures, and the use of Scott air packs and tritium monitors.

The LAMPF Users Group, Inc., now numbers 992 members, of whom 803 are non-LASL and 154 are representatives of foreign institutions.

A new program and proposal committee has been formed, on the recommendation of the LAMPF Program Advisory Committee. The committee is called the Solid State Physics and Materials Science Committee and, as the name implies, its charter will cover the review of those programs so related.

From start-up of the accelerator through this report period, 48 experiments have been completed at LAMPF.

Excluding the "casual" visitors, there were about 250 research guests at LAMPF this quarter.

Publications

N. Ensslin, S. J. Greene, and H. A. Thiessen, "A Stretched-Wire, Remote, Position-Sensing Device for EPICS," Los Alamos Scientific Laboratory report LA-6381 (August 1976).

R. F. Thomas, Jr., J. F. Amann, H. S. Butler, J. M. Gallup, R. H. Jeppesen, S. S. Johnson, W. K. McFarlane, M. W. McNaughton, R. E. Mischke, D. G. Perry, B. M. Preedom, R. J. Ridge, E. B. Shera, and H. A. Thiessen, "Computing in Support of Experiments at LAMPF," Los Alamos Scientific Laboratory informal report LA-6543-MS (October 1976).

M. Leon, J. N. Bradbury, P.A.M. Gram, R. L. Hutson, M. E. Schillaci, C. K. Hargrove, and J. J. Reidy, "Observation of the Repulsive Nature of the P-Wave Pion-Nucleus Interaction at Large Z," Phys. Rev. Lett. **37**, 1135 (1976).

M. Leon, H. Daniel, and J. J. Reidy, "Observation of the E2 Nuclear Resonance Effect in Pionic Cadmium," Phys. Rev. Lett. **34**, 303 (1975).

Papers Prepared for Publication; Papers Submitted at Conferences

C. L. Morris, J. E. Bolger, H. A. Thiessen, and N. W. Hill, "A New Technique for Neutron-Gamma Pulse Shape Discrimination," submitted to Nucl. Instrum. Meth.

M. M. Kligerman, A. R. Smith, J. M. Yuhas, S. Wilson, C. J. Sternhagen, J. A. Helland, and J. M. Sala, "The Relative Biological Effectiveness of Pions in the Acute Response of Human Skin," submitted to the Intern. Jour. Radiat. Onc. Biol. Phys.

A. R. Smith, M. M. Kligerman, C. A. Kelsey, R. G. Lane, P. A. Berardo, M. A. Paciotti, and C. Richman, "Treatment Planning for Negative Pi-Meson Radiation Therapy: UNM-LASL Experience," ibid.

D. A. Swenson and E. A. Knapp, "A Small Proton Linear Accelerator as a Source of Neutrons for Radiotherapy," presented at the Mtg. on Small Accelerators, Denton, Texas, October 25-26, 1976; to be published.

P. Berardo, M. Paciotti, H. I Amols, M. E. Schillaci, J. Bradbury, C. Kelsey, A. Smith, R. Lane, I. Rosen, K. Hogstrom, H. Wright, R. Hamm, and J. Turner, "The Effect of Inhomogeneities on Static Pion Beam Dose Distributions," submitted for presentation at the annual meeting of the Radiological Society of North America, Inc. - The American Assoc. of Physicists in Medicine Work-in-Progress session, Chicago, IL, November 19, 1976.

E. P. Chamberlin, R. R. Stevens, Jr., and J. L. McKibben, "The LAMPF Polarized Ion Facility: Status Report," submitted to the 1977 Particle Accelerator Conf., Chicago, Illinois, March 16-18, 1977; proc. to be published in IEEE Trans. Nucl. Sci.

R. A. Jameson and W. E. Jule, "Accelerator Modeling at LAMPF," ibid.

D. A. Swenson and J. E. Stovall, "Low-Energy Linac Structure for PIGMI," ibid.

M. A. Paciotti, J. N. Bradbury, R. L. Hutson, E. A. Knapp, O. M. Rivera, and D. Laubacher, "Tuning of the Biomedical Channel at LAMPF," ibid.

R. L. Hutson, "Elemental Materials Analysis with Muonic X Rays," to be presented at a Nuclear Chemistry and Technology symposium to be held in New Orleans next spring sponsored by ANL.

M. E. Schillaci, "Capture Ratio of Muons in Binary Solid Metal Solutions," to be presented at the Symposium on Physical and Chemical Applications of Positron and Muon Spectroscopy to be held next spring, sponsored by ANL.

M. A. Yates-Williams, R. L. Hutson, and M. S. Schillaci, "Muonic X-Ray Analysis of Solutions," to be submitted to the Am. Chem. Soc. Mtg., New Orleans, LA, March 20-25, 1977.

R. D. Hiebert, H. A. Thiessen, and A. W. Obst, "Photomultiplier Tube Base for High Pulsed Anode Currents," submitted to Nucl. Instrum. Meth.

J. J. Burgerjon, D. L. Grisham, E. L. Ekberg, R. E. Meyer, R. A. Horne, C. R. Flatau, and K. B. Wilson, "A Solution for Remote Handling in Accelerator Installations," ibid.

M. T. Wilson, L. L. Thorn, L. O. Lindquist, and D. L. Grisham, "The Evolution of the LAMPF High Power Pion Production Target Mechanisms," ibid.

H. I. Amols, D. J. Liska, and J. Halbig, "The Use of a Dynamic Rangeshifter for Modifying the Depth Dose Distributions of Negative Pions," submitted to Med. Phys.

C. L. Morris, J. E. Bolger, G. W. Hoffmann, C. F. Moore, L. E. Smith, H. A. Thiessen, and N. W. Hill, "A New Technique for Neutron-Gamma Pulse Shape Discrimination," submitted to Nucl. Instrum. Meth.

J. R. Faulkner and R. K. Cooper, "The LAMPF Line D Fast Deflector System," ibid.

P. J. Tallerico, "Low Frequency Klystrons for Accelerator Applications," ibid.

A. W. Obst, K. K. Seth, and H. A. Thiessen, "Multichannel Disc Cerenkov Counter for EPICS Pion Spectrometer," submitted to the Mtgs. of the Am. Phys. Soc., Chicago, IL, February 7-10, 1977.

LAMPF Experimental Program Reports and Publications

(Parasite experiment) C. J. Orth, W. R. Daniels, and B. J. Dropesky, "Identification of ^{236}Th," Phys. Rev. C8, (1973).

(Exp. 2) M. D. Cooper, D. C. Hagerman, R. P. Redwine, H. O. Meyer, M. J. Jakobson, R. H. Jeppesen, 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 Mtgs. of the Am. Phys. Soc., Washington, DC, April 28-May 1, 1975.

(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. Jeppesen, "Measurements of $\pi^{\pm}$ Nucleus Total Cross Sections at Energies Below 200 MeV," Abstracts of Contributed Papers for the VI Intern. Conf. on High Energy Physics and Nuclear Structure (Santa Fe, NM, June 9-14, 1975), p. 98.

(Exp. 2) M. D. Cooper, "Pion-Nucleus Total Cross-Section Data from LAMPF and BNL," Proc. Intern. Topical Conf. on Meson Nuclear Physics, Carnegie-Mellon Univ., Pittsburgh, PA, May 24-28, 1976.

(Exp. 2) Redwine, R. P., "Pion-Nuclear Total Cross Sections," prepared for the Mtgs. of the Am. Phys. Soc., Quebec, Canada, June 14-17, 1976.

(Exp. 2) M. B. Johnson and M. D. Cooper, "Improved Analysis of Coulomb-Nuclear Interference Experiment for Pions on ^{16}O," Proc. Intern. Topical Conf. on Meson Nuclear Physics, Carnegie-Mellon Univ., Pittsburgh, PA, May 24-28, 1976.

(Exp. 2) I. Halpern, "Recent Measurements of Total Pion Cross Sections at LAMPF," prepared for the EPA Conf. on Radial Shapes of Nuclei, Cracow, Poland, June 23, 1976.

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

(Exp. 2) M. D. Cooper and M. D. Johnson, "Integrated Pion-Nucleus Cross Sections," Nucl. Phys. **A260**, 352-68 (1976).

(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 Mtgs. of the Am. Phys. Soc., Washington, DC, April 28-May 1, 1975.

(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. 25) G. A. Miller and J. E. Spencer, "Pion Charge-Exchange Reactions with Nuclei," Phys. Lett. **53B**, 329-37 (1974).

(Exp. 25) G. A. Miller and J. E. Spencer, "A Survey of Pion Charge-Exchange Reactions with Nuclei," Los Alamos Scientific Laboratory report LA-5948-MS (May 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, NM, June 9-14, 1975.

(Exp. 27) H. B. Willard, B. D. Anderson, H. W. Baer, R. J. Barrett, and P. R. Bevington, "Absolute Differential Cross-Section Measurements for Proton-Proton Elastic Scattering at 647 and 800 MeV," submitted to Phys. Rev. C.

(**Exp. 29/54**) D. Malbrough, R. D. Edge, C. W. Darden, T. Marks, B. M. Preedom, F. Bertrand, E. E. Gross, C. A. Ludemann, M.J.M. Saltmarsh, R. L. Burman, R. P. Redwine, K. Gotow, and M. A. Moinester, "Measurements of Pion-Nuclear Elastic Scattering at Low Energies," prepared for the Mtgs. of the Am. Phys. Soc., East Lansing, MI, October 28-30, 1976.

(**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 Mtgs. of the Am. Phys. Soc., Washington, DC, April 28-May 1, 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 Measurement of $1S_{1/2}$ Muonium Hyperfine Structure Interval $\Delta\nu$: II. Results," prepared for the Mtgs. of the Am. Phys. Soc., Washington, DC, April 28-May 1, 1975.

(**Exp. 37**) D. E. Casperson, T. W. Crane, V. W. Hughes, P. A. Souder, R. D. Stambaugh, P. A. Thompson, H. Orth, G. zu Putlitz, H. F. Kaspar, H. W. Reist, and A. B. Denison, "A New High-Precision Measurement of the Muonium Hyperfine Structure Interval $\Delta\nu$," Phys. Lett. **59B**, 397 (1975).

(**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," prepared for the VI Intern. Conf. on High-Energy Physics and Nuclear Structure, Santa Fe, NM, June 9-14, 1975; Phys. Rev. Lett. **36**, 942-45 (1976).

(**Exp. 53**) J. C. Evans, Jr., R. Davis, Jr., S. L. Meyer, E. C. Fowler, and J. Cunnane, "Neutron Background Study for LAMPF Experiment No. 53: Study of the Neutrino Capture Cross Sections in ^{37}Cl with μ^+ Decay Neutrinos," Brookhaven National Laboratory report 19880 (March 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, 1974, (Les Presses de L'Universite Laval, Quebec, 1975).

(**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. Northcliffe, 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," prepared for the Intern. Conf. on Few Body Problems in Nuclear and Particle Physics, Laval Univ., Quebec, 1974, (Les Presses de L'Universite Laval, Quebec, 1975); Proc. of the Mtgs. of the Am. Phys. Soc., Anaheim, CA, January 29-February 1, 1975.

(**Exp. 56**) G. Glass, M. Jain, M. L. Evans, J. C. Hiebert, L. C. Northcliffe, B. E. Bonner, J. E. Simmons, C. W. Bjork, P. J. Riley, and C. G. Cassapakis, "Neutron Spectra at Zero Degree from Proton-Proton Collisions Between 647 and 850 MeV," submitted to Phys. Rev. D.

(**Exp. 56**) B. E. Bonner, "N-P and N-D Interactions at Energies up to 800 MeV," prepared for the Mtgs. of the Am. Phys. Soc., East Lansing, MI, October 28-30, 1976.

(**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," prepared for the VI Intern. Conf. on High-Energy Physics and Nuclear Structure, Santa Fe, NM, June 9-14, 1975.

(**Exp. 56**) J. E. Simmons, "Early Experiments with Neutron Beams at LAMPF," prepared for the Mtgs. of the Am. Phys. Soc., Salt Lake City, UT, June, 1974.

(**Exp. 56**) B. E. Bonner, J. E. Simmons, D. W. Werren, H. C. Bryant, C. G. Cassapakis, S. Cohen, B. D. Dieterle, D. M. Wolfe, G. Glass, J. C. Hiebert, L. C. Northcliffe, C. W. Bjork, and P. J. Riley, "Neutron Spectra from 500 MeV Protons on ^{9}Be," prepared for the Mtgs. of the Am. Phys. Soc., Washington, DC, April 1974).

(**Exp. 56**) C. G. Cassapakis, H. C. Bryant, B. D. Dieterle, C. P. Leavitt, D. M. Wolfe, B. E. Bonner, J. E. Simmons, C. W. Bjork, P. J. Riley, M. L. Evans, G. Glass, J. C. Hiebert, M. Jain, R. A. Kenefick, L. C. Northcliffe, and B. W. Werren, "Neutron Spectra at 0° from (p,n) Reactions on ^{9}Be, ^{12}C, and ^{27}Al at 647 and 800 MeV," submitted to Phys. Lett.

(**Exp. 56**) C. W. Bjork, P. J. Riley, B. E. Bonner, J. E. Simmons, K. D. Williamson, Jr., M. L. Evans, G. Glass, J. C. Hiebert, M. Jain, R. A. Kenefick, L. C. Northcliffe, C. G. Cassapakis, H. C. Bryant, B. D. Dieterle, C. P. Leavitt, D. M. Wolfe, and D. W. Werren, "Neutron Spectra at 0° from p-p and p-d Collisions at 647 and 800 MeV Incident Energies," submitted to Phys. Lett.

(**Exps. 60, 67, 86, 102, 103, 104, 105, 106, 111, 118, 150, & 161**) R. A. Williams and B. J. Dropesky, "Status Report on the Initial Nuclear Chemistry Experiments at the Clinton P. Anderson Meson Physics Facility (LAMPF)," prepared for the 168th Am. Chem. Soc. National Mtg., Atlantic City, NJ, September 9-12, 1974.

(**Exp. 60**) J. D. Knight, C. J. Orth, M. E. Schillaci, R. A. Numann, H. Daniel, K. Springer, and H. B. Knowles, "Chemical Effects in Negative Muon Capture in Some Ionic and Covalent Solids and Ionic Aqueous Solutions," Phys. Rev. **A13**, 43-53 (1976).

(**Exps. 67, 102, & 103**) G. W. Butler, B. J. Dropesky, A. E. Norris, C. J. Orth, R. A. Williams, G. Friedlander, G. D. Harp, J. Hudis, S. S. Markowitz, N. P. Jacob, Jr., S. B. Kaufman, and M. A. Yates, "Activation Studies of Pion-Induced Reactions on C, N, O, F, Al, and Cu," Abstracts of Contributed Papers for the VI Intern. Conf. on High Energy Physics and Nuclear Structure, Santa Fe, NM, June 8-14, 1975, p. 113.

(**Exp. 67**) B. J. Dropesky, G. W. Butler, C. J. Orth, R. A. Williams, G. Friedlander, M. A. Yates, and S. Kaufman, "Excitation Functions for the $^{12}C(\pi^{\pm},\pi N)^{11}C$ Reactions over the Region of the (3,3) Resonance," Phys. Rev. Lett. **34**, 821-24 (1975).

(**Exp. 67**) M. M. Sternheim and R. R. Silbar, "Effects of Nucleon Charge Exchange on the $(\pi,\pi n)$ Puzzle," Phys. Rev. Lett. **34**, A25 (1975).

(**Exp. 74**) J. Sperinde, D. Fredrickson, and V. Perez-Mendez, "Double-Charge-Exchange and Inelastic Scattering in $\pi^- + {}^{3}He$," Nucl. Phys. **B78**, 345-69 (1974).

(**Exp. 80**) J. Hudomalj, D. Mann, N. D. Gabitzsch, C. Bordner, and R. J. Macek, "A Computational Technique for Tuning the LAMPF High-Energy Pion Channel," Nucl. Instrum. Methods **126**, 1-5 (1975).

(**Exp. 80**) W. H. Dragoset, G. S. Mutchler, J. Hoftiezer, T. M. Williams, J. Clement, R. D. Felder, J. Hudomalj-Gabitzsch, G. C. Phillips, M. Warneke, L. Y. Lee, B. W. Mayes, J. C. Allred, E. V. Hungerford, and K. Koester, "Pion-Nucleus Forward Scattering Amplitudes Near the 3/2, 3/2 Resonance," prepared for the Mtgs. of the Am. Phys. Soc., East Lansing, MI, October 28-30, 1976.

(**Exp. 80**) N. D. Gabitzsch, D. Mann, G. W. Pfeufer, G. C. Phillips, J. Hudomalj, L. Y. Lee, M. Warneke, J. C. Allred, R. J. Macek, and R. Werbeck, "Tune-Up of the LAMPF High-Energy Pion Channel," Nucl. Instrum. Methods **126**, 7-12 (1975).

(**Exp. 80**) N. D. Gabitzsch, G. S. Mutchler, C. R. Fletcher, L. V. Coulson, E. V. Hungerford, D. Mann, T. R. Witten, M. Furic, G. C. Phillips, B. W. Mayes, L. Y. Lee, J. Hudomalj, J. C. Allred, and C. Goodman, "Pion-Nuclear Total Cross Sections Near the 3/2, 3/2 Resonance," Phys. Lett. **47B** 234-36 (1973).

(**Exp. 80**) G. C. Phillips, N. D. Gabitzsch, D. Mann, L. V. Coulson, C. R. Fletcher, G. S. Mutchler, B. W. Mayes, E. V. Hungerford, L. Y. Lee, C. Goodman, and J. C. Allred, "Nuclear-Coulomb Interference in $\pi\ {}^{16}O$ Scattering," Phys. Rev. **C11**, 1873-99 (1975).

(**Exp.** 81) J. Hudomalj-Gabitzsch, T. R. Witten, N. Gabitzsch, G. Mutchler, J. Clement, T. Williams, G. Phillips, E. V. Hungerford, L. Y. Lee, B. Hayes, M. Warneke, and J. Allred, "Pion Production by 800-MeV Protons in the Reaction $^1H(p,\pi^+,p)N$," prepared for the Mtgs. of the Am. Phys. Soc., Washington, DC, April 28-May 1, 1975.

(**Exp.** 81) T. R. Witten, M. Furić, G. S. Mutchler, C. R. Fletcher, N. D. Gabitzsch, G. C. Phillips, J. Hudomalj, L. Y. Lee, B. W. Mayes, J. Allred, and C. Goodman, "Quasi-Free Scattering and Final State Interactions in the Reaction $^2H(p,2p)n$ at 585 MeV," prepared for the Mtgs. of the Am. Phys. Soc., Washington, DC, April 28-May 1, 1975); Nucl. Phys. **A254**, 269-80 (1975).

(**Exp.** 81) J. Hudomalj-Gabitzsch, T. Witten, N. D. Gabitzsch, T. Williams, G. S. Mutchler, J. Clement, G. C. Phillips, E. V. Hungerford, L. Y. Lee, M. Warneke, B. W. Mayes, and J. C. Allred, "Kinematically-Complete Study of Pion Production by the Reaction $^1H(p,\pi^+p)n$ at 800 MeV," Phys. Lett. **60B**, 215-17 (1976).

(**Exp.** 81) T. R. Witten, T. M. Williams, M. Furić, D. Mann, N. D. Gabitzsch, J. Hudomalj-Gabitzsch, G. S. Mutchler, J. Clement, G. C. Phillips, M. Warneke, B. W. Mayes, E. V. Hungerford, L. Y. Lee, and J. C. Allred, "Final-State Interactions in p-d Break-Up at 800 and 600 MeV," prepared for the Mtgs. of the Am. Phys. Soc., Washington, DC, April 28-May 1, 1975.

(**Exp.** 81) R. D. Felder, T. R. Witten, T. M. Williams, M. Furic, G. S. Mutchler, N. D. Gabitzsch, J. Hudomalj-Gabitzsch, J. Clement, G. C. Phillips, E. V. Hungerford, L. Y. Lee, M. Warneke, B. W. Mayes, and J. C. Allred, "Quasi-Free Scattering in Proton-Induced Deuteron Break-Up at 585 and 800 MeV," Nucl. Phys. **A264**, 397-408 (1976).

(**Exp.** 81) K. R. Hogstrom, I. M. Duck, G. S. Mutchler, G. C. Phillips, T. R. Witten, J. Hudomalj-Gabitzsch, J. Clement, J. A. Buchanan, W. P. Madigan, T. M. Hilliams, R. D. Felder, W. H. Dragoset, E. V. Hungerford, J. C. Allred, B. W. Mayes, L. Pinsky, L. Y. Lee, and K. Koester, "Pion Production from the Reaction $D(P,D\pi)N$ at 585 MeV," prepared for the Mtgs. of the Am. Phys. Soc., East Lansing, MI, October 28-30, 1976.

(**Exp.** 81) J. Hudomalj-Gabitzsch, J. Clement, W. H. Dragoset, R. D. Felder, G. S. Mutchler, T. M. Williams, G. C. Phillips, E. V. Hungerford, M. Warneke, L. Pinsky, and J. C. Allred, "Pion Production by 800-MeV Protons from ^6Li," prepared for the Mtgs. of the Am. Phys. Soc., East Lansing, MI, October 28-30, 1976.

(**Exp.** 81) R. D. Felder, G. S. Mutchler, J. Hudomalj-Gabitzsch, T. M. Williams, J. Clement, W. H. Dragoset, K. R. Hogstrom, G. C. Phillips, E. V. Hungerford, L. Y. Lee, M. Warneke, B. W. Mayes, and J. C. Allred," "Pion Production in P-P Interactions at 800 MeV," prepared for the Mtgs. of the Am. Phys. Soc., East Lansing, MI, October 28-30, 1976.

(**Exp.** 81) E. V. Hungerford, J. Lo, M. Warneke, J. C. Allred, B. W. Mayes, L. Pinsky, J. Clement, W. H. Dragoset, R. D. Felder, K. R. Hogstrom, J. Hudomalj-Gabitzsch, G. S. Mutchler, T. M. Williams, and G. C. Phillips, "Pion Production via a $P\downarrow P \rightarrow D\downarrow\pi$ Quasi-Free Protons in Deuterium," prepared for the Mtgs. of the Am. Phys. Soc., East Lansing, MI, October 28-30, 1976.

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

(**Exp.** 86) G. W. Butler, D. G. Perry, A. M. Poskanzer, J. B. Natowitz, and F. Plasil, "Characteristics of Low Z Fragments Produced in the Interaction of 800-MeV Protons with Uranium," Abstracts of Contributed Papers for the VI Intern. Conf. on High Energy Physics and Nuclear Structure, Santa Fe, NM, June 9-14, 1975, p. 220.

(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," prepared for 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," prepared for 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); Trans. Am. Nucl. Soc. **18**, 98-99 (1974); submitted to Radiology.

(Exp. 102) 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," prepared for the Mtgs. of the Am. Phys. Soc., Washington, DC, April - May 1, 1975.

(Exp. 103) J. Hudis, G. D. Harp, B. J. Dropesky, A. E. Norris, C. J. Orth, and R. A. Williams, "Spallation of Copper by 190 MeV $\pi^{\pm}$ and 349 MeV Protons," prepared for the 170th National Mtg. of the Am. Chem. Soc., Chicago, IL, August 24-29, 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," prepared for the Mtgs. of the Am. Phys. Soc.-Nucl. Phys. Div., Pittsburgh, PA, October 31-November 2, 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," prepared for the Mtgs. of the Am. Phys. Soc., Washington, D. C., April 28-May 1, 1975.

(Exp. 105) C. W. Reich, R. C. Greenwood, R. G. Helmer, R. J. Gehrke, and R. L. Heath, "Nuclear Structure Studies Utilizing LAMPF," Aerojet Nucl. Co. informal report ANCR-1284 (March 1976).

(Exp. 105) R. J. Gehrke and R. G. Helmer, "Half-Lives of ^{134}La and $^{132-135}Ce$," J. Inorg. Nucl. Chem. **38** 1929-32 (1976).

(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. 106) C. J. Orth, H. A. O'Brien, Jr., M. E. Schillaci, B. J. Dropesky, J. E. Cline, E. B. Nieschmidt, and R. L. Brodzinski, "Interlaboratory Comparison of Spallation Reaction Cross Sections for Iron and Copper with 590-MeV Protons," J. Inorg. Nucl. Chem. **38**, 13-17 (1976).

(Exp. 106) V. R. Casella, P. M. Grant, and H. A. O'Brien, Jr., "The Recovery of Spallogenic, Carrier-Free ^{88}Y for Radioisotopic Photoneutron Sources," Radiochimica Acta **22**, 31-34 (1975).

(Exp. 106) 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. of Nucl. Medicine **16**, 300-304 (1975).

(Exp. 106) P. M. Grant, M. Kahn, and H. A. O'Brien, Jr., "The Isolation of ^{82}Sr from 200- to 600-MeV Proton-Irradiated Molybdenum Targets for Biomedical Applications," J. Inorg. Nucl. Chem. **37**, 413-17 (1975).

(Exp. 106) B. R. Erdal, P. M. Grant, V. R. Casella, A. E. Ogard, and H. A. O'Brien, Jr., "Spallation Cross Sections and the LAMPF Medical Radioisotope Program," prepared for the Conf. on Nucl. Cross Sections and Technology, Washington, DC, (NBS Special Publication 425, pp. 492-95, March 3-7, 1975).

(Exp. 106) H. A. O'Brien, Jr., A. E. Ogard, and P. M. Grant, "Radioisotopes from a Medium-Energy Accelerator: The Clinton P. Anderson Meson Physics Facility Radioisotope Program," prepared for the First World Congress of Nucl. Medicine, World Federation of Nucl. Medicine and Biology, Tokyo and Kyoto, Japan, September 30-October 5, 1974, pp. 1485-89.

(Exp. 106) B. Hoop, Jr., R. A. Beh, G. A. Beller, G. L. Brownell, C. A. Burnham, D. J. Hnatowich, R. H. Moore, J. A. Parker, T. W. Smith, P. O. Roux-Lough, T. F. Budinger, P. Chu, Y. Yano, J. W. Barnes, P. M. Grant, A. E. Ogard, and H. A. O'Brien, Jr., "Myocardial Positron Scintigraphy with Short-Lived ^{82}Rb," IEEE Trans. Nucl. Sci. **NS-23**, 584-89 (1976).

(Exp. 111) J. C. Hill, K. H. Wang, and R. F. Petry, "Production of Neutron-Rich Nuclides Using High-Energy Neutrons at LAMPF," prepared for the Mtgs. of the Am. Phys. Soc., Pittsburgh, PA, October 31-November 2, 1974.

(Exp. 111) R. F. Petry, K. H. Wang, and J. C. Hill, "Study of the ^{200}Pt - ^{200}Au Decay Chain at LAMPF," prepared for the Mtgs. of the Am. Phys. Soc., Pittsburgh, PA, October 31-November 2, 1974; Phys. Rev. C**13**, 2484-90 (1976).

(Exp. 111) J. C. Hill, D. G. Shirk, R. F. Petry, and K. H. Wang, "Effective Cross Sections for the (n,2p), and (n,3pn) Reactions Using Intermediate-Energy Neutrons," Phys. Rev. C**12**, 1978 (1975).

(Exp. 121) S. Vigdor, R. L. Burman, P.A.M. Gram, H. E. Jackson, S. B. Kaufman, R. P. Redwine, L. Meyer-Schützmeister, L. L. Rutledge, J. P. Schiffer, R. E. Segel, S. L. Tabor, J. N. Worthington, and M. A. Yates, "Interaction of Fast Pions with ^{62,64}Ni," prepared for the Mtgs. of the Am. Phys. Soc., East Lansing, MI, October 28-30, 1976.

(Exp. 121) L. L. Rutledge, R. L. Burman, P.A.M. Gram, H. E. Jackson, S. B. Kaufman, L. Meyer-Schützmeister, R. P. Redwine, R. E. Segel, J. P. Schiffer, S. L. Tabor, S. Vigdor, J. N. Worthington, and M. A. Yates, "Proton Spectra from Pion-Induced Reactions," prepared for the Mtgs. of the Am. Phys. Soc., East Lansing, MI, October 28-30, 1976.

(Exp. 123) T. P. Ku and P. J. Karol, "Preparation of Powdered Targets," Nucl. Instrum. Meth. **121**, 537-40 (1974).

(Exp. 125) M. L. Evans, G. Glass, J. C. Hiebert, M. Jain, R. A. Kenefick, B. E. Bonner, J. E. Simmons, C. W. Bjork, P. J. Riley, H. C. Bryant, C. G. Cassapakis, B. D. Dieterle, C. P. Leavitt, D. M. Wolfe, and P. D. Werren, "Precision Measurement of n-p Charge Exchange Cross Section at 647 MeV," prepared for the Intern. Conf. on Few Body Problems in Nuclear and Particle Physics, Laval Univ., Quebec, 1974 (Les Presses de L'Universite Laval, Quebec, 1975); Phys. Rev. Lett. **36**, 497-500 (1976).

(Exp. 129) D. M. Wolfe, C. G. Cassapakis, B. D. Dieterle, C. P. Leavitt, W. R. Thomas, G. Glass, M. Jain, L. C. Northcliffe, B. E. Bonner, and J. E. Simmons, "Pion Production in Neutron-Proton Collisions," presented at the VII Intern. Conf. on Few-Body Problems in Nuclear and Particle Physics, Delhi, India, December 29, 1975-January 4, 1976; to be published in proc.

(Exp. 136) R. L. Ingraham, "A π^- Nucleus Chew-Low Equation for Finite Nuclei," Nuovo Cimento Lett. **9-8**, 331-35 (1974).

(Exp. 137) R. E. Mischke, J. D. Bowman, C. M. Hoffman, D. E. Nagle, J. M. Potter, D. M. Alde, P. G. Debrunner, H. Frauenfelder, D. Good, L. Sorensen, H. L. Anderson, E. Swallow, and R. Talaga, "Limit on Parity Violation in P-Nucleus Scattering at 6 GeV/c," prepared for the XVIII Intern. Conf. on High Energy Physics, Tbilisi, USSR, July 15-21, 1976.

(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 Violation in p-p and p-Be Reactions," to be published in Neutrino '75 Proc., Balaton, Hungary, Fifth Intern. Conf. on Neutrino Science, June 16-21, 1975.

(Exps. 140, 153, & 180) J. F. Amann, P. D. Barnes, M. Doss, S. A. Dytman, R. A. Eisenstein, J. A. Penkrot, and A. C. Thompson, "Studies of Charged Particle Emission in Reactions Induced by 220- and 50-MeV π^+," prepared for the Mtgs. of the Am. Phys. Soc., Washington, DC, April 28-May 1, 1975.

(Exp. 140) J. F. Amann, P. D. Barnes, S. A. Dytman, J. A. Penkrot, A. C. Thompson, and R. H. Pehl, "Use of High-Purity Germanium Detectors for Intermediate Energy Physics Experiments," Nucl. Instrum. Meth. **126,** 193-98 (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 Mtgs. of the Am. Phys. Soc., Washington, DC, April 28-May 1, 1975.

(Exp. 142) M. W. Johnson, W. U. Schroder, J. R. Huizenga, W. K. Hensley, D. G. Perry, and J. C. Browne, "Muon Capture Rates on Actinide Nuclei," prepared for the Mtgs. of the Am. Phys. Soc., East Lansing, MI, October 28-30, 1976.

(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 Normal Skin and Underlying Tissue Surrounding Superficial Metastatic Nodules," prepared for the American Radium Soc. Mtg. (San Juan, Puerto Rico, May 4-9, 1975); Am. J. of Roentgenology, **126**, 261-67 (1976).

(Exp. 143) 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," Proc. 23rd Radiation Research Soc. Conf. (May 11-12, 1975); Radiation Research **62**, 562 (1975).

(Exp. 143) H. Amols, J. F. Dicello, and T. F. Lane, "Microdosimetry of Negative Pions," prepared for the Fifth Symp. of Microdosimetry (Italy, September 22-26, 1975), to be published in the proc.; prepared for the Radiological Soc. of North America (Chicago, IL, December 6, 1974).

(Exp. 143) 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," prepared for the Radiological Soc. of North America, Chicago, IL, December 6, 1974); Radiology **116**, 183-85 (1975).

(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 Soc., 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. 143) C. Richman, "Characteristics of a Negative Pion Beam in a Therapeutic Application," prepared for the 60th Mtg. of the Radiological Soc. of North America (Chicago, IL, December 1-6, 1974); Radiology **116** 187-89 (1975).

(Exp. 143) H. I. Amols, J. F. Dicello, M. E. Schillaci, M. A. Paciotti, T. F. Lane, J. N. Bradbury, D. L. Roeder, and J. A. Helland, "Absorbed Dose and Radiation Quality for Background Radiation from a Negative Pion Beam," prepared for the 17th Mtg. of the Am. Assoc. of Physicists in Medicine (August 3-7, 1975); Med. Phys. **2**, 162 (1975B).

(Exp. 143) M. M. Kligerman, H. T. Davis, R. A. Thomas, C. J. Sternhagen, L. Gomez, J. F. Dicello, and D. F. Petersen, "Initial Comparative Response of Experimental Tumors to Peak Pions and X-rays," prepared for the 60th Conf. of the Radiological Soc. of North America jointly with the American Assoc. of Physicists in Medicine; Radiology **116**, 181-82 (1975).

(Exp. 143) M. R. Raju, J. F. Dicello, T. T. Trujillo, and M. M. Kligerman, "Biological Effects of the Los Alamos Meson Beam on Cells in Culture," Radiology **116**, 191-93 (1975).

(Exp. 143) E. A. Knapp, "Physical Properties of Charged Particle Beams for Use in Radiotherapy," prepared for the Intern. Particle Radiation Therapy Workshop (Key Biscayne, FL, October 1-3, 1975).

(Exp. 143) M. M. Kligerman, E. A. Knapp, and D. F. Petersen, "Biomedical Program Leading to Therapeutic Trials of Pion Radiation Therapy at Los Alamos," Cancer **36**, 1675-80 (1975).

(Exp. 143) M. A. Paciotti, J. N. Bradbury, J. A. Helland, R. L. Hutson, E. A. Knapp, O. M. Rivera, H. B. Knowles, and G. W. Pfeufer, "Tuning of the First Section of the Biomedical Channel at LAMPF," prepared for the Particle Accelerator Conf. (Washington, DC, March 12-14, 1975); IEEE Trans. Nucl. Sci. **22**, 1784 (1975).

(Exp. 143) J. F. Dicello, "Dosimetry of Pion Beams," to be published in the Proc. of the Intern. Particle Radiation Therapy Workshop (Key Biscayne, FL, October 1-3, 1975).

(Exp. 143) M. M. Kligerman, "Meson Radiobiology and Therapy," prepared for the 7th Intern. Conf. on Cyclotrons and Their Applications (Zürich, Switzerland, August 21, 1974).

(Exp. 143) M. M. Kligerman, "Pion Radiation Therapy," to be published in the Proc. of the Intern. Particle Radiation Therapy Workshop, Key Biscayne, FL (Chicago: American College of Radiology).

(Exp. 143) C. Richman, "Characteristics of a Negative Pion Beam for the Irradiation of Superficial Nodules in Cancer Patients," to be published in Radiation Research.

(Exp. 143) M. R. Raju, "Pions and Heavy Ions in Radiotherapy: A Brief Review," Excerpta Medica Intern. Congress Series No. 353, **5**, Surgery, Radiotherapy and Chemotherapy of Cancer; Proc. of XI Intern. Cancer Congress (Florence, 1974); Excerpta Medica Amsterdam (ISBN 90 219 0287 7) pp. 161-67.

(Exp. 143) P. W. Todd, J. F. Dicello, C. R. Shonk, G. B. West, and M. M. Kligerman, "Spatial Distribution of Effects of Negative Pions on Cultured Human Cells," Radiology **116**, 179-86 (1975).

(Exp. 146) G. R. Satchler, "New Giant Resonances in Nuclei, an Interim Review," Phys. Reports **14C**, 97-127 (1974).

(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, pp. 333-37.

(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, August 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," prepared for the Mtgs. of the Am. Phys. Soc., Washington, DC, April 28-May 1, 1975; submitted to Phys. Rev.

(Exp. 153) J. F. Amann, P. D. Barnes, M. Doss, S. A. Dytman, R. A. Eisenstein, J. A. Penkrot, and A. C. Thompson, "Studies of Particle and Gamma Spectra in Reactions Induced by 800-MeV Protons," prepared for the Mtgs. of the Am. Phys. Soc., October 31-November 2, 1974; submitted to Phys. Rev.

(Exp. 161) E. L. Haines, J. R. Weiss, D. S. Burnett, and D. S. Woolum, "Thorium-Uranium Fission Radiography," Nucl. Instrum. Meth. **135**, 125-31 (1976).

(Exp. 161)E. L. Haines, I. D. Hutcheon, and J. R. Weiss, "The Fission Track Record of Apennine Front Kreep Basalts," Proc. Sixth Lunar Science Conf. (1975), pp. 3527-40.

(Exp. 162/170) Y. Shamai, J. Alster, D. Ashery, S. Cochavi, M. A. Moinester, A. I. Yavin, E. D. Arthur, and D. M. Drake, "Measurements of the (π^+, π°) Reaction on Light Elements in the (3,3)-Resonance Region," Phys. Rev. Lett. **36**, 82 (1976).

(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**, 535-38 (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, NM, 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. 163) J. W. Negele, "Elastic Electron Scattering and Muonic X-Ray as Constraints on Nuclear Theory," prepared for the Mtgs. of the Am. Phys. Soc., Pittsburgh, PA, October 28-November 1, 1974.

(Exp. 163) E. B. Shera, E. T. Ritter, R. B. Perkins, G. A. Rinker, L. K. Wagner, H. D. Wohlfahrt, H. D. Fricke, and R. M. Steffen, "Systematics of Nuclear Charge Distributions in Iron, Cobalt, Nickel, Copper, and Zinc Deduced from Muonic X-Ray Measurements," submitted to Phys. Rev.

(Exp. 165) R. D. Stambaugh, D. E. Casperson, T. W. Crane, V. W. Hughes, H. F. Kaspar, P. A. Souder, P. A. Thompson, H. Orth, G. zu Putlitz, and A. B. Denison, "Muonium Formation in Noble Gases and Noble Gas Mixtures," Phys. Rev. Lett. **33**, 568-71 (1974).

(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. Lett. **34**, 492-95 (1975).

(Exp. 166) R. J. Powers, F. Boehm, A. Hahn, P. Vogel, A. Zehnder, T. R. King, A. R. Kunselman, and P. Roberson, "Precision Measurements of E2 and E4 Nuclear Charge Moments of ^{181}Ta and ^{161}Dy," prepared for the Mtgs. of the Am. Phys. Soc., Washington, DC, April 28-May 1, 1975; submitted to Phys. Rev. Lett.; CALT-63-253.

(Exp. 167) J. Comiso, T. Meyer, F. Schlepuetz, and K.O.H. Ziock, "Measurement of the Alpha-Particle Spectrum Resulting from π^- Capture in ^{12}C," Phys. Rev. Lett. **35**, 13-15 (1975).

(Exp. 175) P. A. Souder, D. E. Casperson, T. W. Crane, V. W. Hughes, H. F. Kaspar, R. D. Stambaugh, P. A. Thompson, H. Orth, G. zu Putlitz, A. B. Denison, and M. Camani, "Depolarization of Negative Muons in Helium Gas: Search for Muonic Helium Atom," prepared for the 4th Intern. Conf. on Atomic Physics, Heidelberg, Germany, 1974.

(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 Mtgs. of the Am. Phys. Soc., Washington, DC, April 28-May 1, 1975.

(Exp. 181) R. H. Heffner, "Design of a Pion Spectrometer at LAMPF," Proc. Intern. Topical Conf. on Meson Nuclear Physics, Carnegie-Mellon Univ., Pittsburgh, PA, May 24-28, 1976.

(Exp. 195) J. N. Bradbury, M. Leon, H. Daniel, and J. J. Reidy, "Observations of the E2 Nuclear Resonance Effect in Pionic Cadmium" prepared for the Am. Phys. Soc., Anaheim, CA, January 29-February 1, 1975; Phys. Rev. Lett. **34**, 303 (1975).

(Exp. 195) J. N. Bradbury, P.A.M. Gram, R. L. Hutson, M. Leon, M. E. Schillaci, C. K. Hargrove, and J. J. Reidy, "Observation of the Nuclear Resonance Effect in the Pionic ^{110}Pd Atom," Proc. of the Fifth Intern. Conf. on Atomic Physics, Berkeley, CA, July 25-30, 1976.

(Exp. 196) H. Daniel, J. J. Reidy, R. L. Hutson, J. N. Bradbury, and J. A. Helland, "Two-Dimensional Visualization of Stopping Pion Distributions," submitted to Radiation Research.

(Exp. 205) P. J. Riley, C. W. Bjork, C. R. Newsom, M. L. Evans, G. Glass, J. C. Hiebert, M. Jain, R. A. Kenefick, L. C. Northcliffe, B. E. Bonner, J. E. Simmons, N. Stein, and C. G. Cassapakis, "^{6,7}Li (P,N) and (N,P) Measurements at 800 MeV," prepared for the Mtgs. of the Am. Phys. Soc., East Lansing, MI, October 28-30, 1976.

(Exp. 206) R. G. 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," Phys. Rev. **A11**,, 1175-86 (1975).

(Exp. 225) H. H. Chen, J. F. Lathrop, R. Newman, and J. C. Evans, "A Measurement of Stopped Pion Decays in a Copper Beam Dump with Incident Protons of 720 MeV (A Calibration of the LAMPF Neutrino Source Intensity)," UCI-Neutrino No. 17, (1976).

(Exp. 241) C. M. Hoffman, A. A. Browman, J. S. Frank, H. H. Howard, R. E. Mischke, D. C. Moir, D. E. Nagle, L. B. Auerbach, V. L. Highland, and W. K. McFarlane, "Search for Direct Lepton Production in pp Collisions at 800 MeV and 256 MeV," prepared for the Mtgs. of the Am. Phys. Soc., Washington, DC, April 26-29, 1976.

(Exp. 241) A. A. Browman, J. S. Frank, C. M. Hoffman, H. H. Howard, R. E. Mischke, D. C. Moir, D. E. Nagle, L. B. Auerbach, V. L. Highland, and W. K. McFarlane, "Search for the Direct Production of Positrons by 256- and 800-MeV Protons," Phys. Rev. Lett. **37**, 246-49 (1976).

(Exp. 241) R. E. Mischke, A. A. Browman, J. S. Frank, C. M. Hoffman, H. H. Howard, D. C. Moir, D. E. Nagle, L. E. Auerbach, V. L. Highland, and W. K. McFarlane, "Limits on the Direct Production of Positrons by 256- and 800-MeV Protons," prepared for the XVIII Intern. Conf. on High Energy Physics, Tbilisi, USSR, July 15-21, 1976.

(Exp. 241) R. E. Mischke, "Production of Direct Positrons at 256 and 800 MeV," Proc. High Energy Physics. Conf., Vanderbilt University, Nashville, TN, February 29-March 3, 1976.

(Exp. 245) J. Källne, H. A. Thiessen, J. E. Bolger, K. Boyer, W. J. Braithwaite, C. F. Moore, J. McCarthy, C. L. Morris, G. R. Burleson, M. Devereux, and S. Verbeck, "Study of the (π^-,N) and (π,π'P) Reactions in Light Nuclei," prepared for the Mtgs. of the Am. Phys. Soc., East Lansing, MI, October 28-30, 1976.

(Exp. 246) S. A. Dytman, J. F. Amann, P. D. Barnes, J. N. Craig, M. Doss, R. A. Eisenstein, J. D. Sherman, W. R. Wharton, R. J. Peterson, G. R. Burleson, S. Verbeck, and H. A. Thiessen, "Scattering of 50-MeV π^+ from Light Nuclei," prepared for the Mtgs. of the Am. Phys. Soc., East Lansing, MI, October 28-30, 1976.

(Exp. 265) J. J. Kraushaar, J. McGill, C. F. Moore, C. L. Morris, R. J. Peterson, R. A. Ristinen, G. Smith, L. E. Smith, J. E. Bolger, H. A. Thiessen, and W. J. Braithwaite, "Evidence for Strong Transitions to $5/2^-$ States in A = 11 Induced by π^+ on ^{12}C," prepared for the Mtgs. of the Am. Phys. Soc., East Lansing, MI, October 28-30, 1976.

(Exp. 265) J. E. Bolger, W. J. Braithwaite, J. J. Kraushaar, J. McGill, C. F. Moore, C. L. Morris, R. J. Peterson, G. Smith, R. A. Ristinen, L. E. Smith, H. A. Thiessen, and J. Whitenton, "Measurements of the ^{7}Li ($\pi^\pm$,$\pi^\pm$N)^{6}Li Cross Sections Compared to Free Pion-Nucleon Results," prepared for the Mtgs. of the Am. Phys. Soc., East Lansing, MI, October 28-30, 1976.

(Exp. 273) C. Richman, "Characteristics of a Negative Pion Beam for the Irradiation of Superficial Nodules in Cancer Patients," Radiation Research **66**, 453-71 (1976).

Stopped Muon Channel

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. C7, 1206 (1973).

G. Rinker and M. Rich, "Some Implications of a Recent Text 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).

Biomed

S. E. Robbins and D. M. Crawford, "Nursing and the Pion Project," presented at the NM Nurses Assoc. annual convention, October 13, 1975; presented at the "Nurses Role in Breast Cancer" workshop, December 12, 1975; submitted for publication in the Am. J. of Nursing.

II. ENGINEERING SUPPORT

LAMPF Accelerator

Accelerator Support

The seven beryllia waveguide windows which failed on the accelerator were evaluated by the vendor. Five will be repaired and two, which are not economically repairable, have been returned to LASL.

Most of the MP-8 drawings are now on aperture cards. An aperture card is returned to the group when new drawings are sent to the Engineering Design and Drafting Services Group (SD-2) to be copied for their card file. A reader-printer has been ordered that can be used to return a 457- by 610-mm print. These sheets are 3/4-D size and are clear and easily read.

A quadrupole doublet magnet coil shorted to ground in the 805-MHz portion of the linac. Temporary repair permitted continued operation until a two-day maintenance shutdown, at which time a spare unit was installed.

805-MHz RF System

The VA-862A klystrons have accumulated over 846 000 fh with 11 failures, and the L-5120 klystrons have more than 159 000 fh with 10 failures. No high-power klystrons failed during the quarter. However, one (S/N 301) had poor vacuum and was returned to the vendor. The other klystron (S/N 302) passed the acceptance tests. A third VA-862A has been shipped by the vendor.

The klystrons were operated for a total of 68 570 fh in this quarter. Fifteen klystrons and twenty-eight modulator triodes were replaced on the accelerator. The LPT-44 triodes have now accumulated more than 1 050 000 fh with 26 irreparable failures. Twenty-nine triodes required reprocessing in the quarter, and twenty-four of these were successfully reprocessed. The entire order for 25 modulator triodes has now been received.

A new gasket, which is to prevent water from entering the modulator resulting from plumbing, collector, or body leaks, has been tested and proved successful. A production quantity of the gaskets has been ordered. A minor redesign on the pole piece which holds the gasket in place is required.

Klystron Repair Facility

Two L-5120 klystrons (S/N 2018R1 and S/N 2022R1) and one VA-862A (S/N 207R1) were rebuilt. The S/N 2018R1 was tested and is not installed on the accelerator. The other L-5120 (S/N 2022R1) failed the acceptance tests in the same manner as three L-5120 klystrons which were rebuilt in the previous quarter. It was determined that the problem with these four klystrons was electron emission from the focus electrode which surrounds the cathode. At least five precautions (using a more dense cathode coating; extra cleaning of the focus electrode after spraying on the cathode material; using a slower, lower pressure bake-out process; starting the cathode activation while the klystron is hot; and operating the klystron with a substantially reduced filament voltage) will be employed to insure that this problem does not recur. It may be possible to repair these four klystrons by building external tuners for each input cavity to compensate for the damage done by the unfocused electrons.

The S/N 207R1 klystron has not yet been tested, although its perveance at 500 V is normal. The output cavity of another L-5120 (S/N 2014) was damaged on the accelerator and could not produce $1^1/_4$ MW. An external tuner was designed and built for the output section and the klystron with the tuner passed the standard acceptance tests.

An old L-5120 klystron (S/N 2001) was disassembled and the output window and waveguide coupler were transferred to SLAC where it will be used as an rf window in the SPEAR ring.

Installation of the cleaning facility, including rinse tanks, sink, fume hood, deionized-water system and heater, etc., is nearing completion at the ETL building.

201-MHz Klystron

Parts for two 201-MHz klystron cavities have been fabricated and are being inspected prior to final assembly by hydrogen-furnace brazing. These sections when assembled will form cavities 1-1 and 1-2 of the

201-MHz klystron. A cavity tuner has been assembled vacuumtight and an order for three assemblies has been placed with the shops. Design and drafting are complete for cavities 2-3 and 3-4, and an order to fabricate these assemblies has been written.

The electrical design of the output cavity and coupler is now complete, and the modulator tank was fabricated this quarter. The design results in a klystron with an overall length of 3.25 m.

Area A

An optical alignment setup was required to install a new A-2 target assembly, which included an entirely new 6.1-m-long mechanism in addition to the target. The new target was matched to the original in terms of the position in the beam line.

The air-bearing turbomolecular vacuum pump installed in the A-3 pumping station was evaluated during the quarter. After placing the unit in service, the Line A vacuum pressure was reduced from $\sim 1 \times 10^{-3}$ to 0.6×10^{-3} torr. Based on this operating experience, an order was written to purchase the pump.

Line C

Alignment services were performed on the modified scattering chamber, located over the pivot point, and the associated scintillator detector assemblies. Quadrupole magnets QM-12 and -13 were realigned.

Weapons Neutron Research Facility — Line D

The second of the three 90° vertical bending magnets for the WNR experimental area was processed in the tooling dock. Tooling hole locations were inspected and the physical dimensions of the magnet were measured and recorded. In addition, the field clamps were aligned and fixed in position.

Water manifolds were fabricated for the three 90° bending magnets and mounted on the first unit installed in the line. The remaining manifolds will be mounted on the remaining bending magnets when they are assembly-checked on their respective support structures.

Fabrication of all 24 of the steering magnets has been completed, and power tests have been conducted on all but two of the units.

Preliminary survey work was performed in the Experimental Area in preparation for installation and alignment of the magnets and other beam-line components.

Energetic Pion Channel and Spectrometer

A contract between ERDA and Utilities Services Engineering, Inc., Denver, Colorado, has been signed for the installation of two 90-ton magnets in the EPICS spectrometer. This work is scheduled to start by mid-December 1976 and be completed in about four weeks. Detailed work plans and installation procedures have been submitted by the contractor and are being reviewed by LASL.

A contour map of the floor indicated that grinding was required to achieve the required flatness. Alignment crews worked with the grinding crews to provide direction. The main frame was completed, the pivot was installed and aligned, and air pads were installed. Plumbing for the air pads is in progress. Modification of the drive units has been completed, and the design for the drive-control system has begun.

Biomedical Beam Line

Experience with the vertical slit of RT-SL-01 revealed that the stepper motors occasionally lost counts during operation. Addition of a 4.33:1 gear reducer provided increased torque, and the unit is now operating satisfactorily.

The cowl covering the last magnet in the treatment room was removed after assembly-checking and is now in the process of being painted. Final installation will take place when access to the area permits.

Electron Prototype Accelerator

The klystron and modulator testing for the electron accelerator (being rebuilt for Yugoslavia) is now complete. The crowbar and crowbar controls from the EPA were rebuilt and tested. Logic units for control and protection of the klystron were constructed. The emphasis has been to build or rebuild those special units for which LAMPF had the tooling or special expertise. A set of drawings of EPA equipment (or the present LAMPF version) has been accumulated. Sketches and procedures used in LAMPF maintenance have been added as guides for maintenance and operating the new accelerator. Equipment is being assembled for packing and shipment.

Pion Generator for Medical Irradiations

Effort is continuing on PIGLET, the six-cell powered model of the drift-tube portion of the linac.

A prototype drift-tube stem seal has been fabricated as shown in Fig. II-1. This seal design utilizes a machined copper gasket which incorporates a controlled squeeze feature for mechanical alignment and which also functions as an electrical rf joint. The first gasket designed with an o.d. contact surface was torqued to the theoretical requirement of 170 N·m and leak-checked vacuumtight. Another gasket with an i.d. sealing surface will also be tested.

A 406-mm-diam vacuum cavity is being fabricated to test various configurations of vacuum seals for the PIGLET rf tank. Machined copper seals and constrained copper wire gaskets will be tested with this cavity.

A copper-plated 450-MHz cavity for Q measurement studies has been received and is being assembled. Test results of Q measurements made on various 1350-MHz cavities are given in Table II-I.

Ceramic disks for rf window development were received but not metalized as requested on the drawings. These units have been returned to the factory for metalizing.

PIGLET design and drafting are 95% complete. A fabrication order will be written as soon as final drawings are released. Major fabrication features of PIGLET are illustrated in Figs. II-2 and II-3.

The alternating phase-focused cold-probe cavity has been completed and assembled. The bead-pull equipment has been designed and is presently being fabricated. Fabrication of the drift-tube bodies and stems will commence when the analytical studies have been completed.

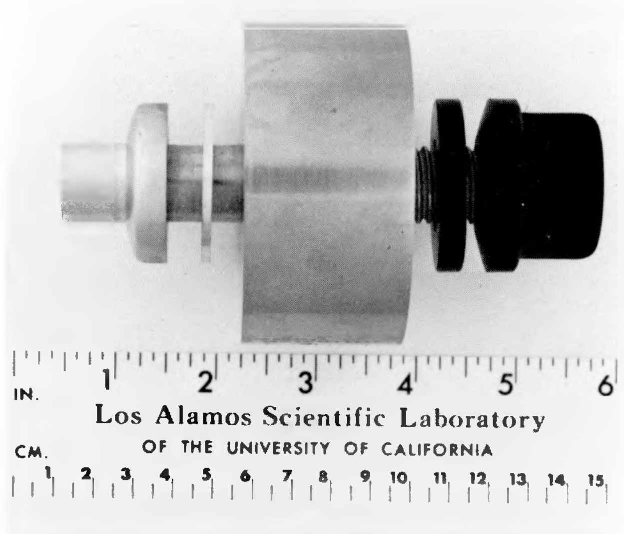

Fig. II-1.
Prototype of PIGLET Drift-Tube Stem Seal.

Experiment Support

Intense support of LAMPF users continued this quarter. These activities covered detail planning, design, fabrication, testing and installation of apparatus such as magnets, chamber and detector support structures, target chambers and stands, target holders, containment enclosures, and modification of some items reported in the previous quarter.

Also completed was the modification and installation in P^3-West of the hodoscope magnet. Design and fabrication are under way for the Cerenkov chamber needed for a later phase of the experiment.

Fabrication of the new water-cooled coils for the Ames "C" magnet are ~50% complete. Hardware and fittings are being collected to rebuild the magnet when it becomes available.

Fifteen experiments that received significant support this period are as follows:

- ***Experiment 4 (HRS).*** Fabrication of a platform was completed to support an electronics rack, vacuum pump and a liquid nitrogen dewar above the HRS scattering chamber. This finished platform is in storage awaiting the installation period of the experiment.

TABLE II-I

TEST RESULTS OF Q MEASUREMENTS OF VARIOUS 1350-MHz CAVITIES

Cavity Description	X	Before Welding	After Welding	Before Bake-Out	After Bake-Out	After Brazing
ALUMINUM						
Electroplate		9518	13700			
Bare Joint						
Plated Bore						
STEEL						
Electroplate		7138	13689			
Bare Joint						
Plated Bore						
STEEL						
Electroplate		11681	16288			
Plated Joint						
Plated Bore						
ALUMINUM						
Bright Plate						
Plated Joint				13817	16060	
Bare Bore						
450-kg Squeeze						
STEEL						
Bright Plate						
Plated Joint				10258	13498	
Bare Bore						
3200-kg Squeeze						
OFHC COPPER						17125

- ***Experiment 28 (LEP).*** The scattering chamber was extensively modified to include a target holder which shows linear and angular position. Heavy-Met shielding and a vacuum system were provided. A stand was fabricated to support counters and detectors.
- ***Experiment 29/54II (LEP).*** Inspection of the Bicentennial magnet was performed in the tooling dock along with the addition of tooling holes to permit later alignment in the experimental area. Design, drafting, and fabrication were completed of four vacuum chambers and the target (source) holder and its x-y adjustment mechanism. Also completed was the fabrication of a structure for support of detector chambers at the downstream end of the Bicentennial magnet. An experiment-mounting activities list and plan layout were released. Field support for the mounting of the magnet, spectrometer stand, structures and chamber supports is presently under way in Area A.
- ***Experiment 31 (Neutrino Area).*** Fabrication was completed and field engineering was furnished for the installation of a shielding lid (design of this lid was reported in last quarter's report) for the Cerenkov counter in the neutrino experimental area. Technician help was furnished for leadbrick stacking.
- ***Experiment 50 (LEP).*** Design, drafting and fabrication of an air-pad platform for the twin "C" magnets were completed. The assembly of this platform is being carried out in preparation for placing the magnets into position to allow the scheduled fieldmapping to start in late October. Experiment engineering planning is

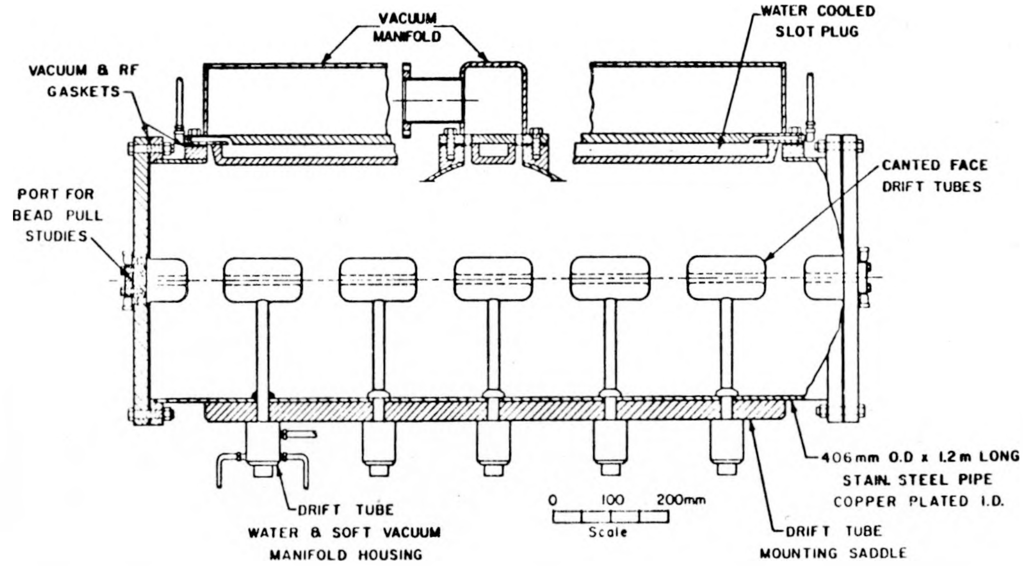

Fig. II-2.
Major fabrication features of PIGLET (showing elevation).

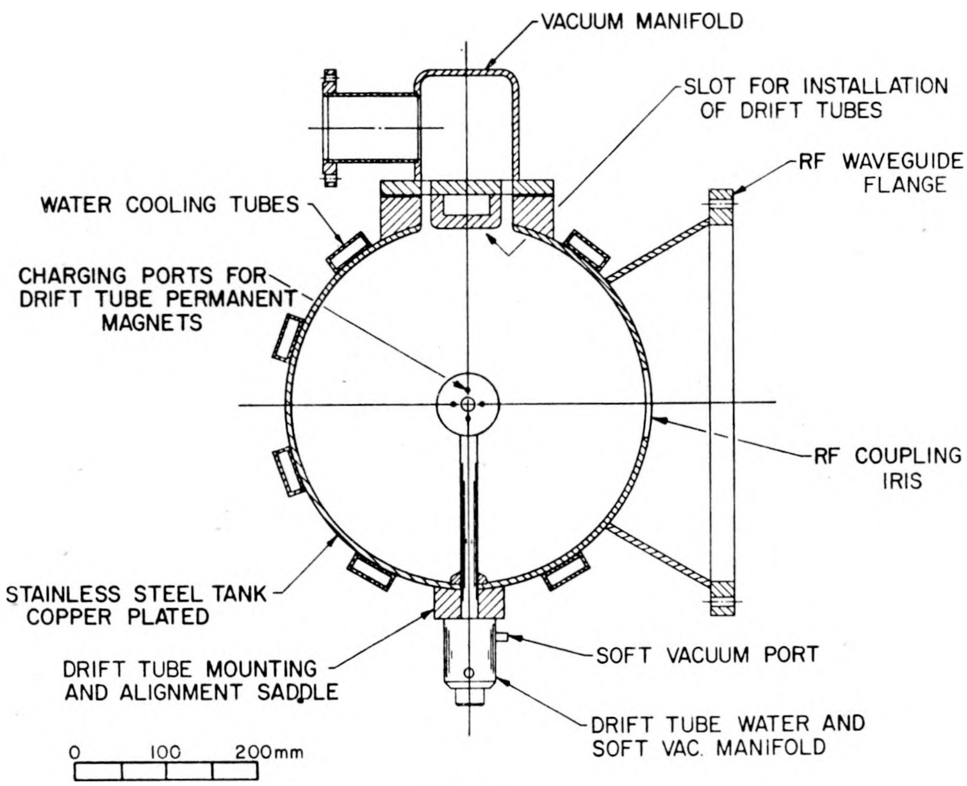

Fig. II-3.
Major fabrication features of PIGLET (cross-sectional view).

also under way in preparation for the mounting date early next year.

- ***Experiment 90 (P^3-East).*** This experiment represented a substantial effort in the areas of design, fabrication, vacuum consultation, alignment, and technician support. A major portion of the effort involved the containment enclosure over the P^3 cave for the tritium gas phase of this experiment. The enclosure is complete and has been tested for use of tritium gas.
- ***Experiment 93 (P^3-East).*** Fabrication was completed of the four chamber-and-detector stands required for this experiment. These stands will be bolted to the deck of Kon-Tiki during the mounting period. Also completed was an adapter for the support of Exp. 93 scattering chamber on the existing rotation fixture at the pivot point of Kon-Tiki. This rotation fixture was previously reported and is now in use by Exp. 90 in P^3-East.
- ***Experiment 133 (EPICS).*** Experiment engineer support is in progress. An activities list and plan layout of the experiment setup have been prepared and distributed.
- ***Experiment 181 (LEP)***. Mechanical engineering support in the form of design, drafting, fabrication and procurement continues on the π^0 spectrometer array. A model of the system has been updated for review by the user team members. Vendor shops, the LASL shops, and the fabrication section are being used in support of the fabrication activities required to build the spectrometer.
- ***Experiment 197 (EPB).*** A plan layout drawing of this setup on EPB and an activities list covering the support needed to mount this experiment have been distributed. Design of a beampipe support structure is under way. This structure restrains the carbon steel beam pipe when the "C" magnet, mounted on Dinghy, approaches the pipe at the small angles planned. The carbon steel pipe, with Mu-metal inner liner, is to prevent the magnet field from deflecting the beam.
- ***Experiment 200 (EPB).*** Design and fabrication of a target chamber support and a support arm for the optical bench were completed. A layout drawing (on EPB Line) was prepared and reviewed with the user team.
- ***Experiment 221/222 (P^3-West).*** A plan layout drawing and activities list were prepared and distributed. The chamber and instrument support structures and target holders were designed, fabricated, and installed. Wire chambers were provided with targets to permit alignment in the experimental area.
- ***Experiment 239 (Biomed).*** Design and fabrication were completed of the targets, supports, holders, and shielding.

Fabrication Activities

The number of jobs processed and completed increased from 75 last quarter to 91 this quarter.

Activities ranged from welding, machining, H_2 furnace heats, vacuum leaktesting, etc., to installation.

Fabrication service and technician support were provided to the following experiments: Exps. 200, 197, 90, 221, 245, 29/54II, 50, 13, 239, 265, 93, 28, 124, 176, and 181.

A total of 24 hydrogen-furnace heats was completed during this quarter: accelerator support (10 heats), klystron rebuild (6 heats), ion pump rebuild (3 heats), PIGMI (3 heats), and heat treatment of experiment components (2 heats). A total of 48 components required furnace activity and, for optimum usage of furnace time, the heats were coordinated wherever possible.

The Fabrication Section effort (based on the completed jobs) for this quarter is as follows:

Experiment Support — 55%
Accelerator Support — 20%
Klystron Rebuild — 10%
Other (Biomed, PIGMI, EPA, HRS, EA development, and WNR) — 15%

Light-Pipe Shop

Forty-eight light pipes were completed during the quarter in addition to the repair of four different units.

Nine scintillators were fabricated.

Wire-Winding Shop

Seven chambers were completed for three experiments and one signal plane was wound. The new gluing room was set up during the quarter and placed into service. Work is now in progress on six chambers, and several spare frames are presently being fabricated. Sample frames are being fabricated by an outside vendor. If they prove to be satisfactory, it will permit a more optimum utilization of personnel for the specific task of winding and assembly.

III. ACCELERATOR SUPPORT

201-MHz RF Systems

An average of 1650 h was accumulated on each of the 201-MHz rf modules during the quarter. This is 86% of the total time available during the period.

Two 4616s were lost. Both failed with "hot" control grid shorts.

The 4664 in module 1 has now accumulated over 10 000 h of filament time and continues to perform adequately.

The new 4664 cavity was put in service in module 1. After one failure caused by a poor solder joint it has performed satisfactorily. The modification and rebuild of the second new cavity will begin as soon as manpower is available. The 4664 cavity that was removed appeared to be exhibiting high rf leakage on the anode lead. No problems were found that explained this leakage and more work on blocker length for this cavity is planned.

The Rexolite vacuum barrier on Tank 4 was replaced after accumulating 8300 h of high duty time. It exhibited the black mark at the bullet edge that is assumed to be the beginning of a failure. Based on the running time on this window, it is planned to routinely change windows on a one-year interval.

A high tube drop on one of the operational PA modulators was investigated at the test stand. A significant portion of the low drive could be attributed to low filament voltage on one of the smaller tubes in the modulator. Considerable time was devoted to developing test procedures for the modulators in order to be able to evaluate the performance of the unit and to isolate problems at the test stand.

A problem with low power out of one of the 7651s in the machine was also discovered to be associated with low filament voltages. Improper wire sizes were found in some of the filament supplies along with poor regulation on some of the transformers. All the supplies are being checked for wire size and tested for transformer problems.

Modifications to the IPA modulator power-distribution units are nearing completion. Winding was finished on the prototype oil transformer for the IPA modulator and electrical tests show the transformer to be satisfactory. Fabrication of a container is now in progress.

In spite of considerable time lost to cooling-water problems at the test stand and personnel being tied up in machine maintenance, three 4616s were tested and processed, and testing was completed on two 7835s. The 4616 with the patched anode leak was run at full duty without any problems, but the tube continues to need reprocessing after short periods of storage.

Development of a voltage control loop for the IPA modulator was completed at the test stand. This completes the design of the new interface transformer driver card. The card was evaluated for margin in several modulators on line and it appears that no gain or response adjustments will be necessary.

The two new 7651 cavities were rack-mounted and installed in the test stand. Work on the control system switching unit and 8501 amplifier interlocking continues in an effort to upgrade the stand for 4664 operation. Preliminary data on the 8501 amplifier indicates that it can be driven with only one 7651 stage, thus eliminating a stage of amplification in module 1 when this amplifier is installed.

805-MHz RF Systems

The extensive modification of the tank resonance control system is 90% complete. At the end of the first phase of this program it appears that about 80% of the achievable improvement in temperature stability has been realized.

All modules have now been equipped with rf power meter heads that have much better stability than the original units which eliminate the need for periodic rezeroing.

All controllers have been equipped with modified circuit boards which exhibit the following characteristics:

- Improved accuracy and stability of water temperature measurement.
- Buffering of the temperature and power meter signal for the A/D system.
- Reduced EMI from external sources.
- Improved generation of the rate-of-change-of-temperature signal.
- Improved interchangeability — a maximum shift in control temperature of 0.11 Celsius degrees may occur when replacing a controller.
- Stable voltage-to-pulse-rate converters (transfer function is 26.7 Hz/V for converting the control voltage into pulse trains for the stepping motor controller. The converters are linear from 7.5 V to 10 mV, corresponding to pulse periods of 5 ms to 2 s.

The modified controllers have been in use in Sector D since June. The only component failures have been ±15-V Zeltex power supplies.

During the next quarter the desirability of separating the controller signal grounds from the 24-V common and the effects of cooling-water temperature and pressure changes will be investigated. Decisions will be made concerning what diagnostic aids would be useful and the exact steps to be taken in the second and final phase of the modification.

Test results continue to demonstrate the superiority of the No. 376 indicator lamps over the No. 387. Sector D has the new (No. 376) lamps and Sector C is the control sector, with the old (No. 387) lamps. In the eight months of the test thus far, 142 of the old lamps have failed and 9 of the new lamps have failed. Based on these test results, all No. 387 lamps will be replaced with No. 376 lamps as they fail.

Assistance was provided at the WNR facility in the purchase and modification of ion-pump power supplies. The 805-MHz section will also be responsible for the maintenance of these power supplies.

Other activities during the quarter included the following:

- New amplifiers were installed in the Δt system.
- The rerouting of tank power indication to CCR is 30% complete.
- The modification of the quad magnet power supplies to alleviate start-up problems by replacing four open-style relays with enclosed relays is 30% complete.
- The Belden 8871 hv cable under test at ETL has 10 053 hvh and 8662 h drawing current.
- The RG-218 insulation growth test has revealed that the insulation expands with an increase in temperature and shrinks with a decrease in temperature whether the cable is in air or in oil. Tests will now be conducted in air and in oil with both held at a constant temperature.

Low-Level RF

The prototype 201-MHz solid-state IFA was run three weeks in module 2 and is now running as a driver for the H^- buncher. For five months prior to its installation in module 2 it was run in the 201-MHz test stand. The unit has performed satisfactorily in all locations.

Based upon this evaluation it was decided to produce 14 more units to replace the tube-type 201-MHz IFAs now in use. Updating of drawings and procurement of long lead-time items have begun.

Studies have continued on the prototype 805-MHz IFAs now in use. Some minor changes have been incorporated to achieve better stability over a wide range of power outputs, but the greatest amount of effort has gone into improving the phase loop and attempting to accurately measure small phase shifts at this frequency.

Control circuits and interlocking of the 8501 amplifier which is located at the 201-MHz test stand have been completed.

Delivering a usable 12-MHz timing signal from the beam chopper to the experimental area has been a problem for some time. The available coax lines are very lossie so an amplifier at the beam chopper end was required. Over 50 W were needed to get a usable signal to the experimental area. A surplus amplifier was modified and used for several months while something more permanent was under construction. A 100-W solid-state amplifier has now been completed and installed.

Phase and Amplitude Control Systems

Fabrication and installation of the redundant phase monitor system are proceeding on schedule. Phase monitor systems have been installed through module 24. Adjacent monitor isolation was found to be inadequate and isolators were added to prevent coupling between units. Most of the parts necessary for the remaining monitor systems have been received and if a large block of beam tunnel access time is available in December, installation throughout the rest of the accelerator should be complete by January 1977.

Because of the heavy emphasis on redundant phase monitor systems, phase subsystem work has been limited primarily to repair of failed units. Only two additional phase subsystems have received the major modifications outlined in the last quarterly report.

Support was given to MP-9 by providing and installing hardware for Exp. 76/17. This involved phase monitoring in five 805-MHz locations.

In addition, studies were continued in the following areas: 1) feedforward and phase and amplitude control of high beam currents; 2) modifications to phase and amplitude boards to eliminate unnecessary control pots; 3) improving buncher control operations; and 4) phase error gain conditions in phase loops using phase subsystems with solid-state diodes.

Power Supplies

Five dual-Acme power supplies have been modified and installed in the SMC. There remain two more units on the power supply platform and three units in Cave A to be removed, modified, and reinstalled.

The first of the two new by-pass shunt systems for LEP has been installed and is operational. The second unit is under construction.

New parts for the reversing switch rebuilding program have been ordered. A new silver-plating technique is under development that will allow all contact plates to be machined at once to insure good contact.

The interlock chains in most of the magnet power supplies do not have memory. Since many faults, such as over-temperature or temporary loss of water flow, will shut off a supply and then clear, it can be very difficult to determine just what interlock took the supply down. A new interlock relay board with built-in memory has been designed as a way to facilitate troubleshooting in these intermittent cases. The new board has been installed in about 10% of the power supplies.

The dc cable installation for the WNR Line 1L is 75% complete.

Transductors for the Line A target cell triplet power supplies have been ordered and are scheduled for delivery in time for installation during the December maintenance period.

Work has begun on the test setup required for evaluation of the high-voltage transistors to be purchased for the by-pass shunt system in the EPICS spectrometer magnets.

Beam Diagnostics

Routine maintenance and repair of equipment, organization and scheduling of maintenance activities, procurement of spare parts, and development of new equipment were continued as major activities during the quarter.

Maintenance included the repair of linear actuator drive modules, linear actuators with mechanical problems, sample-and-hold boards, and signal amplifiers. The sample-and-hold boards in the low-gain chassis in the TR were changed to the high-gain configuration. Damaged emittance collector plates and harp boards were replaced. An intermittent ground problem in the horizontal channel of 09WS01 was found to be caused by an incorrectly fabricated beam box. A new box will be fabricated and installed during the next quarter.

Operational tests were run several times this quarter on the linear actuators in the beam diagnostics system using the central control computer. Writing was continued on a computer test program that will allow much faster performance of these tests. The design was continued on a portable microprocessor-controlled test system that will provide the capability for performing some of the operational tests on the actuators without the use of the central control computer.

Procurement of spare parts and fabrication of checkout equipment were continued.

Progress was made on the continuing review of all beam diagnostics systems drawings and the writing of a manual which will contain general information about the systems.

Testing and development activities included the following:

- The fabrication of the new sample-and-hold system that uses the fast wire-scanner amplifier is nearing completion. The bias circuitry and gain control module that is a part of this system was designed and a prototype was built.
- The design was continued on a flat 40-wire cable (for use with harps and emittance collectors) with better vacuum characteristics than the type presently in use. The wires will be wound on the LAMPF wirewinding machine and several different types of insulation will be investigated. The wirewinding frame has been completed by the fabrication shops. A company that fabricates flexible circuitry has been contacted in an attempt to find a commercial source for the wire.
- The design work was continued on a smaller harp board that will provide greater clearances between devices in the same beam box. Connectors for the boards have been received. Replacement of all large-size harp boards with ceramic boards has been delayed because an attempt to print conductors on the ceramic boards was not successful. New printing methods and/or different boards will be tried.
- The design of a new linear actuator with a 5-in. (12.5-cm) stroke was completed and the parts were ordered. This actuator will be used to insert harp No. 3 at the end of the drift-tube linac. The 4-in. (10-cm) stroke actuator, on

which the harp is now mounted, does not allow sufficient travel for proper insertion of the harp.

- The design of a test beam line to be installed in the transport area was initiated. This line will allow performance testing of beam diagnostics equipment with the H^+ beam when the H^- beam is being accelerated.
- Gain switches were installed in half of the fifty-two 805-MHz wire-scanner amplifier modules. These switches provide for a gain range of x 10. Switches will be installed in the remainder of the modules during the next quarter.
- A new beam box and wire-scanner actuator were installed in the TR at the request of MP-2. The control circuitry was installed in the TR racks. The control bin used was designed to accept either the 805-MHz wire-scanner amplifier or the fast wire-scanner amplifier. Provisions were made in the bin for a fast wire-scanner power supply and an automatic calibration system. The bin will be used to determine the feasibility of replacing all 805-MHz wire-scanner amplifiers with the fast wire-scanner system.
- The signal wiring of all 805-MHz wire scanners was checked to assure that the horizontal and vertical signals were not interchanged and that the polarity of the signals was correct.

Vacuum Systems

Vacuum support for the accelerator was moderate. Most problems were associated with actuator and diagnostic-device maintenance. It was necessary to change out a couple of ion pumps and one rf window on the 805-MHz tanks.

Vacuum support in the SY was light with no serious problems encountered.

A fast valve was modified for faster and more reliable operation and was installed in Line A along with several spark plugs (bad vacuum detectors) to activate the valve in case of vacuum failure.

Support in Area A was primarily limited to pump maintenance and leak-checking.

With the installation of new experiments and the maintenance of existing ones, experiment support in Area B continued to require a large amount of time.

Several vacuum line modifications are under way in Area C to accommodate the installation of new viewing ports and the conversion of ion pumps to turbo pumps and cryo pumps. Considerable time is being spent on this work along with the routine vacuum manipulation associated with running the spectrometer and scattering chamber.

Tests with the shock tube have been completed.

Mechanical Support

A major portion of the effort this quarter has been directed to general accelerator maintenance including work on such items as water systems, pumps, tuning slugs, diagnostic hardware, and rf amplifiers.

The two spare 201-MHz tuning slugs were completed but both had vacuum leaks in their bellows. New bellows were purchased and are being installed in the units.

All hardware for assembly of WNR diagnostic actuators is on hand. Assembly of these units has been initiated and will be continued as time permits.

Drive clutches for the 7835 amplifier cavity tuning drives are being fabricated and will be installed on each amplifier as accelerator downtime permits.

One spare 201-MHz-tank drive loop is complete and two others are nearly finished.

Design of the EPICS cable bridge is complete and a purchase order for the assembly has been written. Routing of water, air, and electrical services is in progress and all necessary hardware is on hand.

Reliability

The study of operations and maintenance reports continues in an attempt to pinpoint those rf units with high failure rates. Table III-I is a list of those units with the most failures during the FY-76 transition quarter. All other rf units had seven or less faults during the quarter.

The total number of klystron crowbars for the FY-76 transition quarter was 347, or an average of 4.62/-day. On an hourly basis, the rate for all 44 klystrons was 4.44 crowbars/1000 h. This represents an increase from the previous quarter. Of the 347 crowbars, 244 were on the six Litton tubes and 103 were on the 38 Varian tubes.

Comparing this quarter with the fourth quarter of FY-76 reveals that although the total number of rf failures increased 2.7%, the equipment downtime decreased 54%. The total equipment downtime, as a percent of the hours available for operations, declined from 3.4 to 1.7%. The mean time between failures decreased from 5.4 to 4.7 h.

When all aspects of the above are considered, MP-11 equipment reliability was about the same as the previous quarter.

More detailed reliability reports are available from the MP-11 group office.

TABLE III-I

MAJOR RF UNIT FAILURE-RATE HISTORY

Unit No.	Name	Section	No. of Failures
1147	Modulator switch tube	805	41
1111	IFA	Low level	30
2001	Quad magnet power supply	805	20
1142	Klystron	805	18
1121	Pulse amplifier	805	12
83	Modulator control - 2	201	8
142	Power amplifier filament power supply	201	8

IV. ACCELERATOR SYSTEMS DEVELOPMENT

Beam Dynamics

201-MHz-Linac Field Distribution

A model of the first two accelerator tanks which gives a good fit to the experimental data was achieved this quarter. The concern mentioned in the last report about field distributions at high power differing from those at beadpull power levels due to deflection of the rf end curtains was unfounded. The experiment using dial-indicator devices showed no movement of the upstream curtain. The final model requires the hypothesis of a 5.8-keV energy error in the experimental injection energy to achieve a good fit. The field distribution in the first tank at a tilt and amplitude setting that gives the best match in the central part of the tank to the design distribution is shown in Fig. IV-1. The corresponding acceptances are shown in Fig. IV-2. Work is now proceeding on two fronts: first, to find the optimum injection and acceleration parameters for the existing machine and, second, to determine new drift-tube lengths for a minimum number of drift tubes to produce a smoother field distribution. Both of these efforts are progressing satisfactorily.

Accelerator Structure Design

Some design work was accomplished for the PIGMI project using the SUPERFISH code. Relationships between cavity diameter and drift-tube size in the APF structure were studied to find the feasibility of a larger cavity diameter and, hence, a smaller drift-tube diameter, for the first few meters of the structure.

Another study was done using SUPERFISH to determine the effect of a sleeve surrounding the center portion of the drift tubes in the DT2 section of PIGMI.

Some work is being done on the possibility of varying cavity dimensions in an APF structure to obtain confluence in the pi mode. This work is still in the early stages but, if successful, could lead to greater stability in the structure.

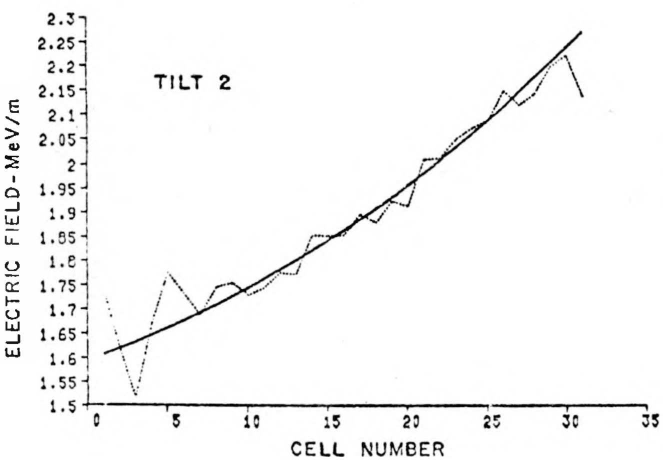

Fig. IV-1.
Design and measured field distributions in the first tank of the 201.25-MHz linac (750 keV to 5 MeV).

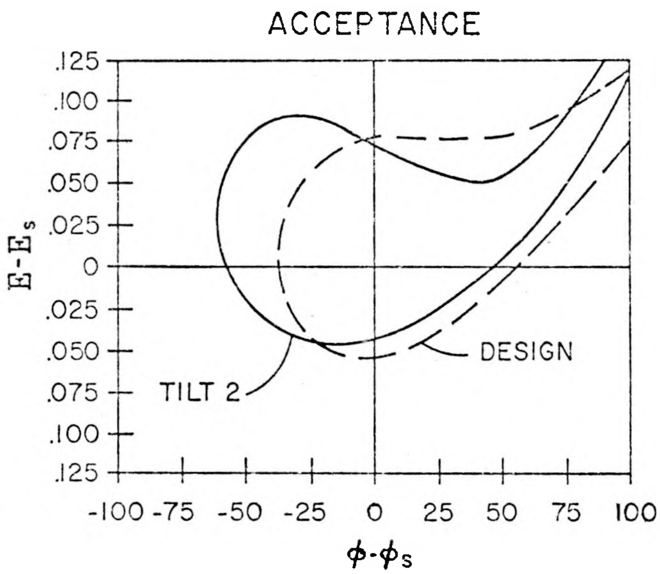

Fig. IV-2.
Design and actual longitudinal acceptance of the first tank of the 201.25-MHz linac.

805-MHz Linac Steering

Ways of automating the process of steering simultaneous H^+ and H^- beams such as to reduce the transverse oscillation amplitude of both beams are under development. A beam trajectory is fitted to measured transverse position data for each polarity beam. Steering to improve the trajectories are then calculated. For an initial approach to the problem, the position data are obtained from wire scanners, the trajectories are calculated assuming no misalignments, and the steerings are calculated for blocks of four steering coils. At the present time the trajectories do not fit the position data very well, and the derived reductions in transverse oscillations are small. Ways to improve the accuracy of the position data used and the model for calculating the trajectory are being studied.

Peak Beam-Current Effects

The Δt solution for 805-MHz linac module phasing is observed to change as the peak beam current is changed. Phase changes up to 6° are indicated when changing peak current from 2 to 8 mA in modules 5 to 12. Various studies are in progress to help understand this effect. One study has been made to see if there are changes in amplitude or phase along the accelerator structure within individual modules that would account for the Δt results. The amplitude at the monitor loops in the end tanks of module 12 was observed to droop about 1% during a 9.5-mA peak beam-current pulse. This amount of droop is consistent with a theoretical estimate of beam-loading effect using a coupled-resonator model. However, changing the amplitudes of the 805-MHz linac modules by 1% does not appear from the results to date to compensate the Δt change. The phase changes between the ends of modules 5-6, 6-7, 11-12, and between the end of module 11 and the reference drive line were measured as a 9-mA peak beam pulse came on. These phase changes were found to be less than one degree, which again is too small to explain the observed Δt effect. In another study, a low-momentum component detector in the beam switchyard was used to check if off-energy components of the beam were present, since such components might affect the Δt results. No off-energy components were detected. Finally, the peak current was changed in three ways: in the injector transport system using jaws, with jaws in the transition region, and by turning off the prebuncher and then both bunchers. The change in Δt result was essentially the same in all three cases. In summary, the explanation of the observed effect is still unknown, but some of the possible causes have been eliminated from the list.

Horizontal Oscillation Control

The twin-electrode assembly for horizontal oscillation control studies has been fabricated and is ready for installation in the H^+ transport line during the December shutdown. Operational amplifiers capable of ±600-V, 50-kHz service have been designed and are also under fabrication. These amplifiers will be used to close control loops between fast position-monitor sensors and the control electrodes.

Space-Charge Effects

An investigation was made to determine what can be calculated for the halos without having to solve the difficult problem of determining the evolution for the distribution function. (Distribution function here means a one-particle distribution function which gives the probability that a particle exists at a certain point in phase space.) It appears that the distribution function behavior in the halo region alone cannot be calculated without knowing the core behavior in detail, i.e., without completely solving the problem.

It is possible, however, to study the stability properties of various equilibrium distribution functions. An equilibrium distribution function is one which is independent of time. A general distribution function will oscillate about an equilibrium distribution function. Since particle loss is the criterion, the mere knowledge that a certain equilibrium distribution is stable is not enough; that just means oscillations about the equilibrium distribution do not go to infinity. Thus it is useful to compare calculated equilibrium distributions with experimentally observed particle distributions.

The Vlasov equation describes the behavior of the single-particle distribution function when correlations between particles are neglected (a good approximation in our case). Some equilibrium distribution functions (stationary solutions to the Vlasov equation) in three dimensions with azimuthal symmetry (two degrees of freedom) have been investigated. This follows similar work by Gluckstern, Chasman, and Crandall which studied a certain class of equilibrium solutions in transverse space with azimuthal symmetry (one degree of freedom). The present problem involved the solution of a nonlinear Poisson-like equation in an iterative procedure that used at each step a cylindrical Poisson solver (the Poisson solver used is the one related to SUPERFISH). So far, calculated results for several stable equilibria have been obtained; further study will include potentially unstable equilibrium solutions. An example is shown in Fig. IV-3. Three quantities may be varied:

1) AMU describes the particle density at the bunch center (it equals unity at the space-charge limit).

2) ALPHA is the ratio of the longitudinal external focusing force to the transverse external focusing force (it determines bunch length).

3) NEX specifies which of a certain class of equilibrium solutions is to be determined.

In comparing the various distributions, it will be necessary to determine what quantities to hold fixed in the comparison. The previous work held the rms emittance fixed. The authors made the point that since this is not a conserved quantity, interpretation of the calculation results is difficult.

One important application for these solutions would be to use them as input to a particle-tracing code. Previous studies done in transverse space showed that a Kapchinsky-Vladimirsky distribution (an equilibrium distribution) was relatively unchanged in traversing the accelerator while other distributions led to substantial emittance growth. This will be repeated for rz space. Tracing an equilibrium distribution through the accelerator model is a check on the effectiveness of the code in handling collision effects. This knowledge may be important if in the future a very accurate particle-tracing calculation is done. Also, by tracing an initial distribution function which differs slightly from a known equilibrium distribution, information can be obtained on the existence of nearby equilibria, if any, and stability can be studied in a quantitative way relating initial conditions to losses.

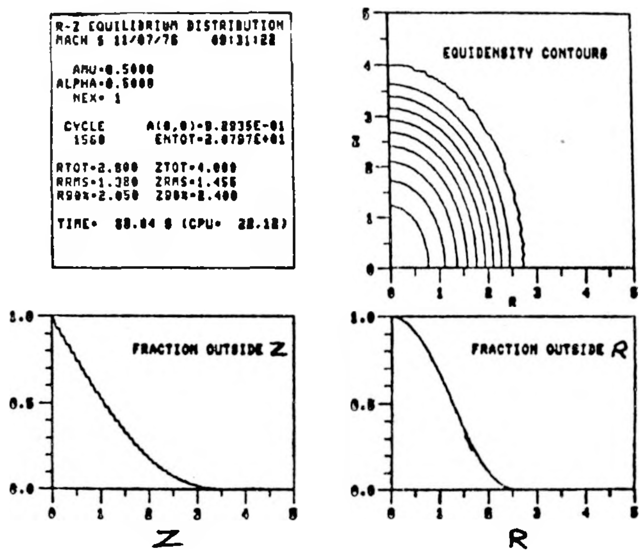

Fig. IV-3.
Particle-density results for a typical equilibrium-distribution-function calculation in rz coordinates. The equidensity contours and fractions of particles in the bunch outside a given value of r or z are plotted.

Beam Halo Analysis

Progress was made on the problem of reconstructing emittance data from wire-scan profiles. It was found that, for the data obtained from a single scan, and without imposing any theoretical shape on the beam in real space, a unique best, discrete, least-squares fit can be obtained in analytic form and, thus, can be calculated in less than $2n^2$ multiplications for an n-step scanner. If the profile data were generated by a bell-shaped surface, then the model would reflect this fact. The reconstruction is currently being investigated analytically for halo at one wire scanner before extension to a system of transformations is attempted.

Magnet-Field Calculations

A preliminary investigation was made into discrete numerical methods for iterative calculations of magnetic induction and associated problems of convergence for differing magnetic permeability.

Long-Term Stability Development

Data Management

The display for recording parameters of the transport, 201-MHz linac, and transition regions was redesigned to show all quantities appropriate to both H^+ and H^- beams. Thus the operators may use the same display for positive, negative, or simultaneous beams. Further information is given under "General Computer Control System Code Development" below.

Stability Plots and Records

The tables controlling the long-term stability plots have been updated such that the plots include the new module-to-module phase indications for modules 13-24, and include prebuncher phase set point information. An event recorder system has been put into operation for studying H^+ injector arcdowns. When the data scan monitor program detects that an arcdown has occurred, an event recording program saves the time and the mode status of the master pulser. Another program is available to print out the recorded times and operating modes as required for analysis.

Stability plots were also made for the beam-position monitors under development.

Operations — Support Development

Operations and Maintenance Equipment Reporting Database

In addition to continued support of the operations and equipment maintenance database, design work was initiated to incorporate equipment additions and simplify the data structure.

General

All databases were reviewed to check permfile use procedures, add the "clear automatically" command to all command files that access the databases in the update mode, and implement the labeled tape capability.

Assistance was provided to W. Simms of BNL in explaining the LEEP database; BNL is interested in using this approach for their HEEP pool.

Bibliographic Database

Requirements were determined for making a film record of complete documents referenced in the database, and the first 275 documents were submitted for filming. Data entry of material abstracted during the summer continued.

Diagnostic Equipment Development

Beam-Position Monitors

Evaluation tests on the two forms of fast beam-position monitor (crystal detector and superheterodyne) were carried out this quarter. No significant performance differences were found between the two systems and both proved capable of meeting the specification sensitivity limit (100- μA-peak beam, 1 mm off-axis produces a discernible and calibrated signal at CCR). Difficulties were encountered in determining the exact position of the beam because of lack of sufficient knowledge of the alignment of the wire scanner cross-hairs. Therefore, the BPMs were zeroed on the assumed center position of the wire scanners. The electronic tests were primarily devoted to checking gain, reproducibility, sensitivity, and stability. Though no significant performance differences were noted, the decision was taken to recommend complete installation of the superheterodyne system in the machine. The reasons for this choice are based on the potential superior dynamic range, linearity, and stability of the superheterodyne technique in general applications over the simple crystal-detector method. Furthermore, the need for rf isolators in the signal lines of the crystal-detector system reduces the original cost advantage of this method and eliminates cost as a primary consideration.

Some development work is still required to find a satisfactory power supply for the BPMs to overcome 805-MHz feedthrough from the pickup loops and to finalize engineering details for production.

Beam-Profile Instrumentation

A packaging configuration for the multigain wire-scanner amplifier was found which solves the grounding and shielding problems with reasonable consistency. The signal ground lead and the shield are grounded at the actuator. The signals are brought out of the tunnel on separate 2-conductor shielded cables. The amplifier itself is installed in an isolated case which continues the shield. The shield cannot be dc-grounded to the ADS system, but with an ac-ground at this point, a clean four decades of data can be obtained on the pulsed beam signal.

In collaboration with MP-11, work began on other problems which limit the accuracy and use of the wire scanners, including intermittent shorting to the beam box during the scan in some modules, and the procedures for deriving the position of the wires during the scan and correcting for various types of error.

A program was written which will allow physical measurements on the harps to be entered via the control console. The constants for the harp program are then calculated, and the hardware is exercised to obtain position pot setpoints. The code then enters these pieces of information in the proper fields.

Δt Hardware

Difficulties with automatic locking of the system were traced to timing problems caused by poor overlapping of the beam gate delivered by the timing system and the true beam current pulse, especially with the slow-risetime circuit installed in the injector.

Emittance Measurement Equipment

A heat run on the EM-2 left jaw was attempted in an effort to determine if the jaws would indeed withstand a full duty beam. Various combinations of rep rate and peak current were used to obtain up to 0.45-mA average current. The power removed from the jaw as determined by the temperature rise between the input and output water agreed with the power input to better than 5%. The maximum rise in water temperature was less than 10K. The plot of power removed vs average current was linear. Extrapolating to 1 mA, one can safely conclude that the present design is adequate to remove the average power dissipated in the jaw. One should remember, however, that dense beams will cause localized heating and damage.

Microprocessor Development

Applications. In collaborations with other MP-Division groups, the new design for the microcontroller debug box has been tested and accepted and four such units are presently under construction. The PROM programmer has been checked out and is in use. Tweek knobs and a joystick have been interfaced to the microcontroller and can be used to control a cursor on the 611 display scope. The biomedical range-shifter driver is being reconfigured to allow a tape input of dose tables rather than requiring the tables to be "burned" into PROMS. A memory card for all associated plotting routines has been designed and breadboarded . This card will contain all nonvolatile memory necessary for 611 scope-plotting routines. This card along with the 611 driver board are the only boards necessary to plot on the 611 storage scope. A preliminary design of a battery-run backup clock has been made in a collaboration with Temple Univ. users.

The motor driver boards designed for MP-11 have been fabricated but not yet checked out.

A binary data interface card has been designed and submitted to E Division for etching.

Software. Re-entrant math routines have been written for the microcontroller. These routines include 16- and 32-bit multiply, divide and square root.

A PROM programmer code for the new PROM programmer has been written and checked out. It makes use of the flexibility of the utility programs that are part of the teletype system monitor program.

Routines which plot on the 611 storage scope have been written which include a grid drawing routine, vector plotting routine, character plotting routine, a routine which will interrogate the clock and display the time on a plot, and a routine which interfaces the tweek knobs or joystick to the 611 cursor. CTR Division has expressed interest in this software and its associated hardware.

Final versions of the teletype system monitor are now in use.

A code was written which uses the beadpull period counter to measure the period of a sine wave input to the board.

Documentation. All boards presently in use with the microcontroller system are documented on standard C-size schematics.

A preliminary draft of the documentation for the teletype system monitor software has been prepared.

General Computer Control System Code Development

The software for displaying and selecting parameters for adjustment in the transport, 201-mHz linac, and transition regions was rewritten. The specification of what channels are displayed for the various positions on the display is now taken from a table in disk memory. A program was written to set up this table from operator designator information on punched cards. This will facilitate making changes in the display when desired and helps ensure that the hardware channel numbers in the display table are consistent with the assignments in the master channel tables.

Collaborative Programs

Biomed Range Shifter

The range shifter has been used successfully at the LAMPF biomedical pion channel for over six months. During that time, it has performed reliably with no major breakdowns, and has frequently operated continuously for periods of up to 48 h. Numerous experiments in dosimetry, microdosimetry, and radiobiology have been performed using this machine. As a result of this satisfactory performance, human preclinical trials of pion irradiation of large (volumes of up to 0.8 ℓ) head and neck tumors are planned for next quarter.

Design work has been started on the new range-shifter head and the specifications have been altered to provide an 18-cm stroke with a 2-cm minimum thickness including the windows. An even greater stroke can be achieved by utilizing ethylene glycol as the energy-absorbing fluid. The stroke can be increased in this way by the ratio of densities by ~20%.

Improvement of the electronics has taken place with provision being made to command the microprocessor functions from a remote terminal mounted at the computer console and to read the shaft encoder signals directly into the computer for monitoring the response of the servomechanism. A system for using a volatile MPU memory chip for setting up a new function and then conveniently burning this function into nonvolatile memory when satisfied is also being developed. The general use of the MPU during actual treatments is dictated by the fact that the main control computer (PDP 11/45) is marginally too slow to drive the fast analog servo and insufficiently dedicated due to its multiplicity of tasks, although a program is available for running directly from the main computer for experimental purposes.

Hydraulic Servoarm Development

All components have been ordered and the design completed on the operational force-reflective model. The unit is presently under fabrication. Because of the cost, only two servovalves were ordered. These servovalves will allow a single-degree-of-freedom (DOF), completely mechanical model or a two-DOF model using an analog computer for the slave channels and the servovalves for the master channels.

EPICS Separator

Changes in scheduling prevented the separator from being opened for inspection this quarter so this procedure has been postponed. A commercial 400-kV power supply has been ordered to replace the present supply. Despite its ability to operate the separator at design fields, the present supply is proving too unreliable in continuous service. The commercial unit will be "plug-in compatible" with the existing hv cable and will be packaged in a spare C-W tank to allow pressurization with SF_6 as is done with the present system.

Scientific Exchange

During the last quarter an exchange of personnel was arranged between LAMPF and TRIUMF for the purpose of sharing accelerator technology developed at each lab. The LAMPF representative worked for two months with the TRIUMF beam-diagnostics group to design radiation-hard instrumentation for the accelerator and primary beam lines. Ceramic harps of the type used in the LAMPF accelerator were designed to monitor the beam profile and position near the targets. Suitable materials were procured and tested and some prototypes were fabricated. This work will be carried on by a visitor to TRIUMF from the Soviet Union who will also benefit from the exchange. A second detector of the multiplate secondary emission type was designed to measure beam spill inside the cyclotron. This design also incorporates several concepts proven effective in the diagnostic instrumentation in use at LAMPF.

V. INJECTOR SYSTEMS

H^+ Injector

The H^+ injector has been on-line all of this quarter to provide the H^+ beams required for LAMPF operations. The injector has been operated at increasingly higher peak currents, up to 30 mA, in production runs in an ongoing effort to explore operational problems to be expected at 1-mA-average operation. Some problems have occurred in the bouncer and dome voltage fast-protect systems as a result of operation at these increased peak currents. Various modifications have been tried in the bouncer preamplifier and a final design has been established. Permanent pc cards are being fabricated and will function adequately with the present 35-mA ion source.

Some difficulties have also been experienced in the operation of the prebuncher, and it has been necessary to aperture the beam at the entrance of the prebuncher in order to permit production beams to be run with the higher peak currents in the injector.

Plans to install the final 50-mA ion source in the H^+ injector have been postponed indefinitely until 300-μA production beams are a reality. The ion source now installed in the injector is capable of 35-mA peak current which will result in only 10-mA accelerated beam in the linac with the present injector-aperturing.

Several transformers were lost this quarter in the operation of the H^+ C-W generator and were replaced with spare units. The cause of these failures were, in part, a result of previous flooding damage from ruptured cooling-water lines, but in part were also a result of the finite lifetime of these components. Present spare part inventories are again being considered, particularly in view of the initial sparking history in the operation in this injector. Some spare parts have recently been obtained from BNL following the upgrading of their C-W generator.

One of the H^+ injector ion pumps failed this quarter after 18 months of service and was replaced with a spare unit. Several spare pumps are now being built using surplus pump housing procured from NASA. These additional spares will enable the ion pump rebuilding effort to be carried out on a more reasonable and better planned schedule.

H^- Injector

The H^- injector has been operational this quarter with either 40- or 80-ns chopping usually being provided. The tuning of the H^- beam for high-current chopped beams with low satellite contamination continues to be a problem and work is now in progress to improve the dual-beam tuning procedures and to provide adequate chopped beam diagnostics.

Several improvements to control systems in the H^- dome have been carried out. The suppressor voltage has been interlocked to trip run-permit when the voltage falls below a specified trip level, as has already been done on the H^+ injector. The control systems for the high-voltage power supplies in the H^- dome now have been properly isolated and terminated and no further problems with the turnon or turnoff of any of these supplies have been encountered. An intermittent interlock problem in the equipment dome occasionally trips the entire injector and is being investigated. Additional surge protection is being implemented in the canal power supply so that higher voltage operation can be considered.

Injector Development

Work continued this quarter on studying the transverse emittance damping in the 201-MHz linac. Systematic procedures for carrying out absolute emittance measurements are being developed and preliminary experiments to measure emittance for various percentages of the total beam current have been carried out. There are still some questions as to the accuracy of the present injector emittance determinations, particularly in the vertical plane at low peak currents. The present results, however, do indicate that for the beams now being prepared and for peak currents up to 10 mA the damping in the linac is 0.22 and, thus, with this current density, a normalized emittance growth of 2.6 is present. Studies are in progress to determine the dependence of this damping on the current density and to extend these results to higher peak currents.

Work has been started to develop a suitable pulse driver and closed-loop controller for the transistorized arc-pulse modulator. The first designs have been built and checkout tests are now in progress. These modulators will provide more versatile pulsing capability for all three injectors.

Some development work has been started on a low-priority basis to look into some of the injector problems for PIGMI. Ion source tests have been run to determine the performance of the LAMPF duoplasmatron as a possible ion source for this application. The emittance of a beam extracted at 360 MHz with a 10-μs pulse width was measured and compared with a beam extracted at LAMPF duty factor of 120 Hz at 500 μs; no significant differences were observed. Thus, the performance of the LAMPF H^+ injector may be used to predict PIGMI performance with a LAMPF duoplasmatron. Some problems were experienced in obtaining proper control of the modulator, which resulted in its going into a dc mode of operation. These problems can easily be rectified for an operational system.

Investigations were started to determine possible high-voltage power supplies for use on the PIGMI injector. Several possibilities exist for this supply, but a small cascade rectifier system now appears the most attractive. Work has also started on studying a voltage divider that would be operable in this system.

Work continued on the implementation of a fiber optics system to provide additional data channels between ground and the injector equipment domes. One link has been installed in the H^+ dome with the fiber optic cable being routed down one of the hollow support legs. To date, no problems have been experienced in the operation of this channel. Further investigations with analog and pulse data channels are being made.

Polarized Ion Injector

The C-W high-voltage generator for the polarized ion injector was successfully commissioned this quarter and final acceptance tests were carried out with an engineer from the vendor's plant. Minor problems were encountered and corrected. Some corona-leakage currents were observed at operating voltage caused by ionization of the air on the input drive line; this problem was not encountered in tests at standard atmospheric pressure. The high-voltage connections to the rectifier stack will be modified to reduce the voltage gradient at this point. Further operation of the high-voltage systems, however, must wait until the installation of the ion source systems in the equipment dome has been completed. Personnel-safety and final electrical wiring on the C-W generator are still in progress.

All of the vacuum housing assemblies for the ion source (except the duoplasmatron housing) have been mounted and vacuum-tested. Initial alignment of these units has been carried out. The duoplasmatron housing has been in the shop since August and should be out sometime in November. The duoplasmatron source has been operated in the test stand and has functioned as expected. The status of all assemblies for the polarized source is presented in Table V-I.

A severely cracked weld joint has been located in the spin-filter solenoid vacuum housing. An attempt is being made to seal the leak without unwinding the solenoid.

The argon charge-exchange canal has been completed. Initial plans were to move the one currently in the P-9 source. The cryogenic refrigerator will be moved from the Van de Graaff to LAMPF in late November after the present series of parity violation experiments is completed. This will allow final assembly of the charge-exchange system.

The spin-precessor magnet has been received and installed. The drawings of the vacuum box are now complete and ready to be sent to the fabricator. Because this vacuum box incorporated magnetic field shunts, final magnetic-field measurements of the precessor will be delayed until box fabrication is complete. Other elements of the transport line are either being fabricated or assembled.

Fabrication of the gas control systems (hydrogen and argon) is now complete. These systems, together with the gas thermometer system for the argon cryopump, are soon to be installed.

All parts of the accelerating column have been received from the shop. The accelerating tube has been bonded and tested. Assembly of the entire column can now be carried out.

Design of the 1-MHz bandwidth light-link receiver amplifier is now finished and amplifier boards are being fabricated. The optic assemblies are currently being put together.

Progress in source assembly has been impeded by an unexpected manpower shortage and shop fabrication delays.

TABLE V-I

STATUS OF POLARIZED ION SOURCE COMPONENTS

	Design Completed	Drawings Completed	In Shop or to Vendor	Received from Shop or Vendor	Installed	Tested
Duoplasmatron Ion Source	x	x	x	x	x	*
Duoplasmatron Vacuum Housing	x	x	x			
Cesium Cell	x	x	x	*		
Spin Filter	x	x	x	x	*	
Rapid-Reversal Region						
Argon Cell	x	x	x	x	*	
Focusing Lens	x	x	x	*	*	
Extraction Lens	x	x	x	*	*	
Accelerating Column	x	x	x	x		
Precessor Magnet	x	x	x	*	*	
Transport Quadrupoles	-	-	x	x		
Transport Diagnostic Equipment						
Ion Pumps	-	-	x	x		x
Ion Source Stand	x	x	x	x	x	*
Ion Source Gas Systems	x	x	x	*		
Injector Dome	x	x	x	x	x	*
Injector C-W Power Supply	x	x	x	x	x	*
Injector MG Set	x	x	x	x	x	x
Dome Wiring	x	x	x	x	x	*
Ion Source Electronics	x	x	x	x	*	*
NOVA Computer Program	x	x	x	x	x	x
CCR Computer Program	x	x	x			
NOVA Interface	x	x	x	x	x	x
Control Modules	x	x	x	x	*	*
ICR Console	x	x	x	x	x	x

x Previously completed.
* Completed this quarter.

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 procurement action for a new disk system to expand the program and data storage capacity of the control computer proceeded on schedule. An order was placed for a controller and three disk drives with a total capacity of 40-million, 24-bit words. The disk system will be interfaced to the SEL-840 through a PDP-11/34 minicomputer to minimize the overhead on the control computer for disk accesses and to take advantage of extensive file-handling software offered with the PDP-11/34. This scheme for interfacing also anticipates the addition of a larger PDP-11 computer later this year to take over some of the load from the SEL-840. The hardware and software designers held a series of meetings to develop the specifications for the digital interface between the SEL-840 and the new PDP-11/34. A communications protocol was established. The interface will be constructed next quarter.

Several new additions to the control system are interfaced to the SEL-840 via the CAMAC standard. Since most of the slots in the first CAMAC crate were full, a second CAMAC crate was installed and put into operation. A spare crate and controller are available in case of a failure.

The first modules installed in the new crate were for the beam status display. These modules drive a TV monitor on which are displayed the date, time, energy, injector status, rep rate, duty factory, experimental area Run-Permit status, beam-plug and target status, beam currents in the experimental areas, experiments on-line, and operator messages. This last feature allows operators in CCR to flash messages of general interest to the experimenters. After a few more video cables are installed, the display will be available in every experiment counting house.

A disk unit failed during a scheduled maintenance period and was replaced by a spare. The malfunctioning unit was repaired off-line so that no beam time was lost. The card reader was overhauled during a scheduled maintenance period.

Microprocessor Developments

Microprocessors can be viewed from two different perspectives:

1) Viewed as a computer, the microprocessor is the lowest level of sophistication in the hierarchy of computers or the "least intelligent" device in a distributed control system. A number of industrial firms have, for some years, offered microprocessors packaged with input/output options to function as a cheap but effective minicomputer.

2) Because this type of equipment was available commercially, MP-1 concentrated its efforts on the second aspect of microprocessors, that of a microcontroller. From this point of view, the microprocessor is the most sophisticated integrated circuit available and represents an effective means to replace large arrays of logic in a way that is far more flexible than hardwired systems.

Figure VI-1 shows the first of three pc boards developed so that microprocessors can be used effectively in LAMPF applications as microcontrollers. The CPU/Memory board features an Intel-8080A microprocessor with 2000 words of PROM and 256 words of RAM for a stack. A clock chip and address line drivers are also part of the card. A total of nine CPU/Memory boards were built and tested with diagnostic software resident in a set of three PROMs.

Figure VI-2 shows the Input/Output card, the first of two companion pc cards. This card provides three 8-bit I/O ports which can be configured as input or output ports under program control. This is the

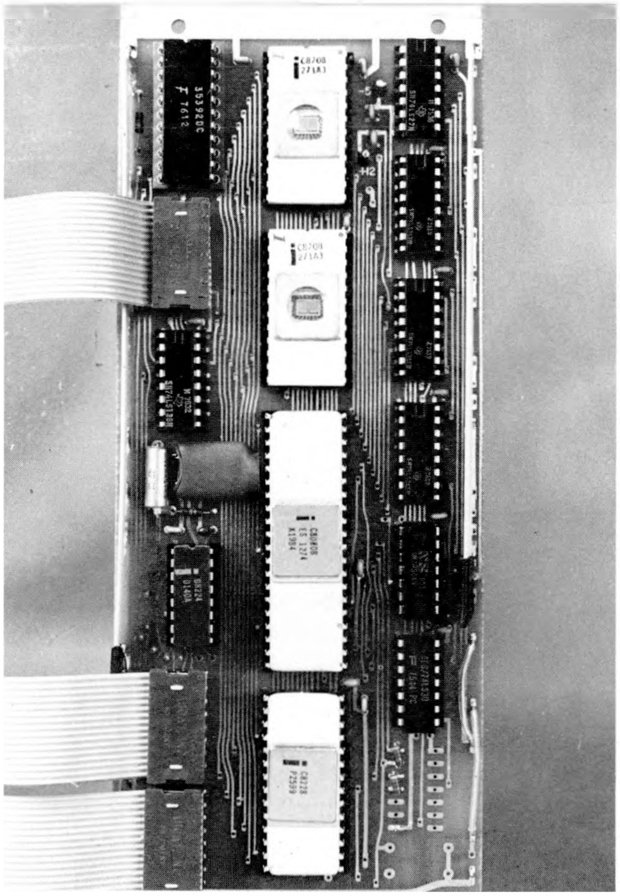

Fig. VI-1.
This CPU/Memory pc board which mounts in a CAMAC module includes an Intel-8080A microprocessor with 2000 words of PROM and 256 words of RAM.

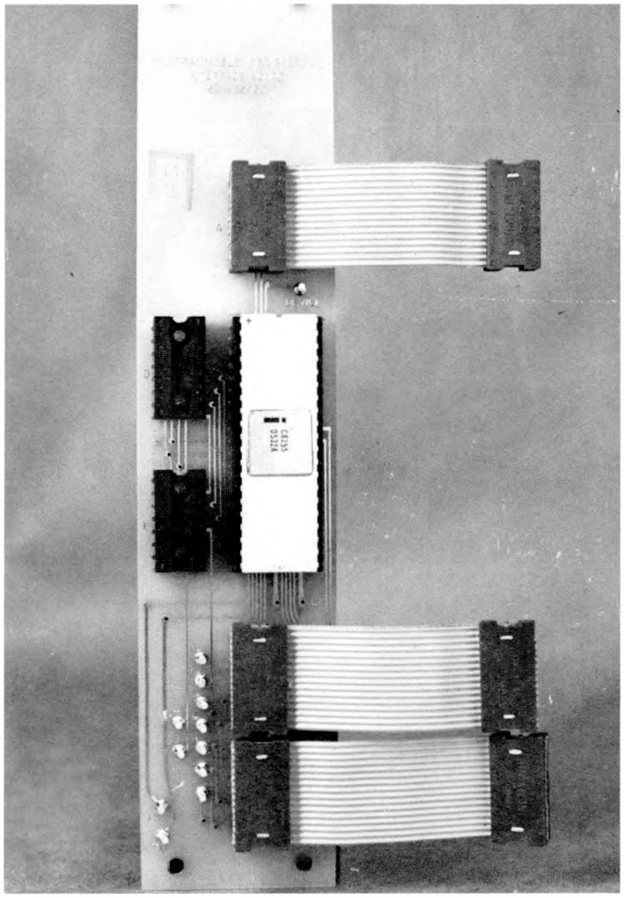

Fig. VI-2.
This I/O pc board allows the Intel-8080A microprocessor to communicate with the external devices it may control.

board that allows the microprocessor to communicate with the external devices it may control.

The third pc card, an Interrupt card which incorporates eight priority encoded, individually maskable interrupts, was designed and sent to drafting. This card receives and communicates to the CPU/Memory card the fact that an external device needs attention.

All three pc cards were designed with physical and electrical characteristics that allow a complete microprocessor system, along with some hardware designed for a particular application, to fit into a single-width CAMAC module. Depending on the complexity of the particular application, some modules might be double- or triple-width. These pc cards will serve as the fundamental building blocks for numerous microprocessor applications, such as the third console.

Third Console

The third accelerator control console is being prepared for installation in CCR in December after the terminal computer is moved. Plans for the intercom and paging equipment in the console were completed. This equipment will be fabricated and installed before the console is set in place in the CCR.

Communications between the control computer and various devices in the console will be carried over a data bus — the IEEE-488 General-Purpose

Instrumentation Bus (GPIB). The bus approach was chosen to reduce the cabling requirements and to provide flexibility in experimenting with new console devices. The final system test of the microprocessor-based bus controller and the first device, a function button (FB) panel, was delayed because of incompatibilities between the panel hardware and the development machine. This impasse was resolved by the construction of a new development machine that uses the same microprocessor board and interrupt structure as the FB panel. In this way, all that is required at the end of the test is to take the program that has been executing in RAM in the development machine, burn it into PROM, and insert those PROMs into the device.

The new keyboards for the third console were ordered; delivery is scheduled for early next quarter. The interface has been designed.

A new microprocessor-based Knob/Readout chassis was designed for use on the third console. Out of this design came a standard method for interfacing the GPIB using the Intel-8255 programmable peripheral interface. The Burrough's Self Scan displays in the chassis were interfaced to the microprocessor using the Intel-8255s in a handshaking mode.

An 8080-compatible Hardware Multiply/Divide unit was ordered and received. This module performs an 8-bit by 8-bit multiply in 5 μs. Performance evaluation will begin next quarter. If reliability and performance prove to be adequate, the unit will be incorporated into the new Knob/Readout chassis to allow high-speed scaling between knob output pulses and system command pulses.

The microprocessor-based interface to the function button panel was rebuilt to use the CPU/Memory board and interrupt structure as well as the Intel-8255 I/O ports. The device now has what is expected to be a standard interface for the GPIB.

The new hardcopy system for the operator console is nearing completion. This system will allow an operator to get a 22- by 28-cm black and white print of the information on the face of any storage scope on the console by pressing a button on the scope. At present, only one scope can be copied. This improvement required electronic and mechanical modifications to each of the Tektronix-611 storage scopes and the Tektronix-4610 Hardcopy Unit. The system will be installed 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 the design of a new Master Timer.

The 840 Master Timer interface chassis was checked out on the SEL-810A computer to the extent possible until the microprocessor chassis is ready to be integrated with it.

Assembly work was started on the intensity modulation cable-driver chassis and cable-terminator chassis.

The 23 timing gate generator modules for the Master Timer were completed by E-Division and delivered. Testing is in progress.

Using assistance from E-Division, fabrication was completed on a timing-pulse delay chassis for CCR, four timing distribution chassis for CCR, and about 30 cable driver pc cards for the timing distribution system. These will all be checked out as time permits.

The main system program for the microprocessor was written and assembled. Several secondary programs for handling communications and interfacing remain to be written.

Serial CAMAC System

A serial CAMAC system was designed and installed in the transition region to collect data from the TR harps. This approach was an alternative to the addition of a second ADS to a nearby DACT in order to acquire the 40 channels of data. The system also provides a way of testing the rack of 40 second-generation sample/hold modules being developed to take harp data. In particular, the serial crate provides the necessary gain-changing capability. In the future, the Serial Highway may be extended to operate a microprocessor-based emittance station which can execute emittance scans at a faster rate than presently possible and, at the same time, reduce the load on the central control computer.

The serial CAMAC system consists of a Serial Driver module developed at LAMPF. This module was installed in the second CAMAC crate on the SEL-840. Two pairs of cables connect the Serial Driver to the serial-crate controller in the TR. These cables form a bit-serial loop-highway over which data and commands can be transmitted. Additional modules in the CAMAC crate perform the multiplexed A/D conversion and control the gain-changing relays. The serial link presently operates at a 500-kHz bit rate, equivalent to ten thousand 12-bit data words/s. The link is capable of a rate of 5-MHz with signal repeaters. The serial CAMAC standard also supports a byte-serial highway which ups the effective transmission rate by another factor of 8. The usefulness of this system will govern future enhancements and extensions.

Accelerator Interface System

Microcontrolled Data Links (MCDL) are being developed to reduce the overhead on the main control computer associated with handling the satellite control computers. The prototype MCDL was completed and installed. When the performance of the prototype is fully satisfactory, the design of the wire-wrapped version will be transferred to a pair of pc cards which will fit into one double-width module instead of the present two modules. Then all of the present data links will be replaced with the upgraded version.

The project to provide a remote restart capability for the satellite control computers was completed. The operating programs in each of the five satellites can be reloaded and restarted from CCR by a command from the accelerator operator to the appropriate RICE. The PDP-11 is then loaded from the SEL-840 across the CAMAC parallel data links. This capability will save the operators time and energy because they no longer have to walk several hundred meters to the satellite computers.

The multiplexer card in the ADS has proved to be an extremely difficult card to diagnose and repair. Because of developments in IC technology since the multiplexer cards were bought seven years ago, it is possible to produce a much simpler card. A new multiplexer card was laid out using PMOS logic, and two prototypes were built, one employing sockets for the ICs. Both cards passed all tests and the version with sockets proved to be much easier to repair. This card was sent to an outside fabricator for an estimate of the cost to replace all 320 multiplexer cards in the facility.

The Area A-East DACT was expanded for another 64 channels of analog data and 60 channels of binary data.

Several manweeks of effort went into the diagnosis of difficult DACT problems and into the repair of RICE system components in support of the operations staff.

The LAMPF harps (ISIC) reset module was modified such that the LAM enable (LE) bit does not need to be set in order for the module to accept beam gate pulses and generate reset pulses.

The harp system in Area A was modified so that the PDP-11 can correct transmission monitor threshold and tolerances for changes in the beam repetition rate. The 120-pps rf gate signal is counted to establish an accurate 1-s timing interval, and the number of beam gates during this interval is counted to determine beam repetition rate. The same scheme was used in Line B and the FWSS to determine the beam repetition rate and to save software overhead.

Computer System Software

A modest effort was directed toward the maintenance and improvement of the SEL-840 system software. This effort included the diagnosis and correction of faults and the addition of new features or capabilities to the system. Some of the improvements made during the quarter are noted below.

The system modification to use the hardware save and restore register was installed and checked out. This feature resulted in a 5 to 7% saving in SEL-840 CPU cycles in normal operation.

The more frequently used diagnostic programs for the SEL-840 were modified to exercise the new instructions in the mainframe and to operate with the new TI terminal on the programmer's console. Several of the diagnostic programs were rewritten to run under the SEL-840 operating system so that the mainframe can be exercised, if need be, during accelerator operations.

A new on-line diagnostic program for the CCI scopes was written and used to facilitate the repair of one of the scopes.

The system magnetic tape drivers and system subroutines were modified to improve the handling of packed source tapes.

The time-delay tables which control the taking of pulsed data were discovered to have problems which were traced to a design flaw in the RIU driver. In the course of correcting this oversight, it was discovered that the system subroutine which acquires timed data had been updated to reflect changes made in the RIU driver one year ago, but had not been installed on the disk. This required the recompiling of a number of programs.

During the last two months, the disks were repacked (segmentation reduced) twice. The disks are currently 96% full and this will make disk space a very critical resource during the next few months while the new disk system is being developed.

System software was written and tested to support the operation of the new microcontrolled data links. The system-resident data-link driver was modified to accommodate either the new microprocessor links or the old-style links. A table in the driver contains information on what kind of link is in use and by patching the table and by moving the data-link cables, one can change from one link to the other.

Ten new system subroutines were developed. Six were assembly language routines for character manipulation and three provided a FORTRAN interface to the disk sector read/write and the variable field scan routines in the operating system. The store-in-common subroutine, STICOM, was revised to provide greater protection to the system common. A program can no longer store outside its own common, nor store at all if the calling program has not established common properly.

Accelerator Applications Programs

The major part of the software support for accelerator operations is directed toward programs which provide new facilities for accelerator control and monitoring, improve existing capabilities, or support new accelerator and beam-line hardware.

The software for the accelerator status display was completed. The driver for the CAMAC modules which write characters on the TV monitor was made a part of the format output package so that a user can write a status display using standard FORTRAN output statements. Other programs associated with the status display include an updater which runs once per minute and a program for the CCI scope that allows an operator to type in messages.

The preparation of reports documenting the performance of the accelerator from the standpoint of beam statistics was taking too many manhours. To reduce this load, work began on a series of four programs to automate the reports. The first program accepts beam statistics from the operators and stores it on the disk. The second program accesses the data base and produces the Cycle Summary. The third program folds the short-term disk data into a longer term data base stored on magnetic tape. The final program processes the tape data base to produce the Quarterly Report. The four programs are in various stages of development and should be completed next quarter.

The general accelerator monitor program in the 840 was modified so that for each section of the accelerator one can define two separate sets of channels to be monitored on request. One set of channels will be monitored for present "theoretical" values while the other set will be checked for the current values of the channels when the monitoring process is begun. The program which prints the data files used by the accelerator monitor was revised to include the module and channel numbers in the printout.

Work was completed on the first version of a program to provide a more highly automated and efficient scheme for testing beam-diagnostic equipment along the accelerator. This program will undoubtedly evolve as the originator gains experience in using it.

A major update to the ADS test program was completed. This program tests the ADS amplifier gains and measures the excitation supply voltage for each multiplexer. A total of eight data files is required to describe all of the ADS equipment along the accelerator, including the anomalies in certain modules. A printout of the measured gains and offsets is available on request.

The program which reads and sets the Master Timers was revised to eliminate the setting of the rf gate and to output all timer information to the logging typewriter.

The program which prints out channels by module and hardware numbers was revised so that the lengthy instructions output to the teletype will be written only if someone types "HELP" after being prompted by "NEXT."

A program was written to read the information on the CCI scope and copy it to the storage scope so that it can be recorded on the hardcopy unit.

A program was written to give an operator the capability for resetting from CCR any RM-16 radiation detector that trips.

Work began on a major update of the programs that set up the focusing and steering magnets in the side-coupled linac and TR.

Numerous programs received attention to correct minor errors or deficiencies. Among them were the programs for the SY wire scanners, RM-16 display, Run-Permit system, rf turn-on, A-2 target control, rf monitor, and hardware exerciser.

Experimental Area Controls and Instrumentation

Most of the equipment along the primary beam lines is operated through the central control computer or one of the satellite control computers. The equipment along the secondary beam lines is controlled from the associated experimental area computer.

Switchyard

A system for controlling a new fast-acting valve for downstream Line A was designed and will be installed soon in the SY. This valve will protect the harps in Area A. A temporary system is presently in operation which uses sparkplugs, in four areas, to sense a vacuum fault and close the valve.

Area A

Several modifications and improvements to the controls and instrumentation in Area A were suggested by experience. Controls for 3A SV 01 were designed, built, installed, and tested. This valve isolates the new air-bearing turbopump. A sensitive relay was installed in the string of thermal switches in 2A QT 01 and 02 to counteract the high impedance of the string. The modification and bench-testing of a ground-fault detector for bipolar regulator systems were completed. The A2-P^3 collimator chassis was modified to supply a signal to CCR. Considerable effort went into wiring and rewiring the A-1 and A-2 target controls to cope with various failures and modifications in the target mechanisms.

Experiment 90 had top priority as the quarter ended. An elaborate alarm chassis was fabricated, and electricians installed cabling for 10 alarm circuits plus various interlock and control circuits. The checkout of the system is tentatively planned for early November.

The Current Monitor program in Area A and the SY as well as the Transmission Monitor code in Area A were modified to read out once per second instead of once each beam gate. This modification includes the reading of two scalers containing the actual number of beam gates and rf gates, the latter providing the 1-s time source. The rf gate and beam gate scaler readout were used by the Transmission Monitor program to correct the threshold and tolerance for changes in rep rate.

LEP, SMC, P^3, and Test Channel

The personnel safety systems on these secondary channels were modified to give a key release automatically whenever the "Ready" circuit is complete. The "Area-A-Open" signal was deleted from the logic circuits.

In the SMC, two more power supply control systems were moved to the new racks and the remote-control capability was verified.

A major advance in the operation of P^3 was made by implementing computer control for the channel. This step was relatively easy because of the advance planning that went into the CAMAC controls. The beam plug and vacuum valve chassis had to be modified. The CAMAC Branch Highway cable was moved to the west cave. One CAMAC module (Model 3087) had to be modified so that restarting the computer did not turn off equipment. The DVM-to-CAMAC interface via the Model 3420 CAMAC module was documented. It is now possible to operate the beam line, including setup and problem diagnosis, from the counting house.

EPICS

Several modifications and additions were made in the controls and instrumentation for the EPICS area. Only one failure in the separator control system was reported in the past three months; the problem was in a power supply.

Bending magnets -05 and -06 were added to the EPICS magnet-setting code. The EPICS DVM code was changed to include a LAM "Clear" after switching the MUX to prevent getting a false LAM due to the high common-mode voltage and the resulting ground loops that sometimes occur.

The NOVA CALL BASIC system was put into use this quarter for the on-line analysis (axis location) of EPICS spectrometer magnet BM05.

Beam Stop Area

The wiring installed the previous quarter for the ISOP stringer controls was checked out. The only problem remaining is one of reliability in the optronic switches used in the speed ramp. A modification is planned to correct this situation. For the present, a procedure was written so that with a few jumpers it is possible to drive the stringer into the beam to irradiate a target.

The binary data capability of Module 67 was expanded by five more words or 60 bits.

Lines B and EPB

Permanent wiring was installed between the CNC-11 trailer and the target cave for nuclear chemistry experiments.

An instrument for monitoring the field of a "C" magnet in EPB was fabricated and installed. It is designed to shut off the power supply to this magnet when the field exceeds 4 kG for Exp. 200.

The upstream vacuum-isolation valves for all areas were interlocked with the Personnel Safety system so that entry to any area will close the upstream valve to prevent a vacuum disaster.

Line C and HRS

The bulk of the work during the first part of the quarter went toward completing the controls as originally designed for the HRS. The following devices were put into operation:

(1) three target-control motors with digital readout of shaft encoders locally and in the counting house;
(2) six NMR probe mechanisms and associated electronics;
(3) two ISIC beam monitoring systems;
(4) two bending magnets and a quad magnet on the HRS frame; and
(5) controls required for moving the spectrometer, curtain, and rod transfer mechanism. The controls required for the HRS regulator system were fabricated. This system includes 8 bins of controls and 2 racks of regulators for 28 additional magnet windings of 200 A or 60 A each. These controls will be installed next quarter.

After beam was passed through the HRS, a new list of controls was prepared. The following items on the list were completed:

(1) controls for six TV phosphors;
(2) controls for two new vacuum solenoid valves;
(3) interlocks on the HRS water system to shut off the pump in case of extended water leaks;
(4) two new 24-V dc power supplies to increase the amount of control current available from 50 A to 150 A;
(5) additional coax cables (40) from the top of the HRS frame to the CCH;
(6) twelve 256-ns delay lines for the CCH; and
(7) cables (40 twisted pairs) from the scattering chamber to the CCH.

In addition, the layouts for many of the coax patch panels in the CCH were rearranged and a Model 3420 CAMAC module was installed.

In anticipation of future installations, work orders were submitted to the crafts for the following:

(1) thirty additional RG-213 cables for the SZ scanner system;
(2) twelve additional 256-ns delay lines;
(3) one additional magnet operation warning light;
(4) interlocks between the HRS magnets and the pump which supplies cooling water;
(5) wiring for 28 magnet windings;
(6) control wiring for 22 temperature and flow interlocks for the H_t windings and several power supplies; and

(7) additional 208-V, single-phase outlets for 24-V dc power supplies.

The HRS computer system received a great deal of attention because of an intermittent fault. The problem was finally traced to a memory module, that was replaced. In the course of the investigation, it was noted that the Unibus was heavily loaded with peripheral equipment and a bus repeater was recommended. The system was carefully grounded for better performance.

During the quarter, a substantial effort was devoted to fixing program bugs, helping users track down problems, and expanding system documentation. To make maximal use of core in the HRS PDP-11/45, a new partitioning scheme was implemented and the latest release of program Q was installed. The remote plotting scheme in the 11/45 was revised so that plotting programs in the 840 were not excessively slowed down.

An 840 program was written to warn the operators if the stripper, which sends beam to Line C and HRS, is inadvertently left positioned (after termination of Line C operation) so that beam is spilled at the entrance to the line, creating "hot" areas.

The use of control vectors for tuning Line C was implemented in the SEL-840. The success of this preliminary version may point the way to a more powerful version.

Communications System

The LAMPF communications system continued to grow and evolve. In response to requests, communications stations and speakers were installed in five locations: the Yale trailer, the UCLA trailer, the Area B/C trailer, at the entrance to Area B/EPB, and outside of the Area B/C aisle. Four speakers were modified for the volume control and speaker cutout option. Two of the universal stations, each with a regular speaker and a paging speaker, were installed — one in the Health Physics office in the Operations Building and one in the Health Physics trailer in the P^3 area. These special stations provide the capability to page anywhere in LAMPF except the Laboratory-Office Building. The wiring diagrams and blueprints for the communications systems in the operator consoles were brought up to date in preparation for developing the third console. The equipment for this installation is being assembled.

As the communications system grows larger and more complex, the requirements for maintenance grow at an even faster rate. Failure reports are answered each day. Once a month the whole system is inspected for broken equipment and degraded performance. Faulty equipment is replaced from the spares inventory. The broken items are repaired and logged into the spares inventory.

One factor which undermines the maintenance effort is the lack of adequate documentation of the communications wiring in the experimental areas. This wiring was put in by electricians under field direction and wire lists were not prepared. To recover from this situation, a wire-run specialist from ENG-4 was assigned to help with the documentation effort, which was given a high priority.

The effort to improve the volume on the CCR line continued. The high-input impedance amplifiers for the speakers monitoring the CCR line were completed. When installed next quarter, these amplifiers should reduce the load on the CCR line, thereby increasing the volume.

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

A study of LAMPF's needs for computer support of the experimental program was held during the month of August. Fourteen people, drawn from MP-Division users, outside users, and LAMPF support staff, studied the present status of computer support at LAMPF and attempted to forecast future needs. A number of conclusions and recommendations were reached with respect to future needs, and a report[1] was prepared for presentation to the users at the annual meeting in November. The principal requirements for additional support were found to be in the area of facilities for the preparation and checkout of experiments, data analysis, and user software support.

Procurement activities were initiated for the acquisition of equipment to meet several of the highest priority items identified in the study, namely, new magnetic tape units to provide 9-track, 800 bpi capability; a new computer for testing of apparatus and software at the Area A test channel; and additional memory to bring all experimental computers to the minimum recommended core capacity of 96k words.

A bus repeater was installed on the terminal computer as recommended last quarter and the system was reconfigured. A proper configuration for the MBD-bus repeater combination was established.

A DEC-RX11 floppy disk system was installed on the PDP-11/05 development computer. Evaluation of the system has begun and will continue into the next quarter.

Data-Acquisition Software

The development of the general data-acquisition package Q, which runs on the PDP-11s under RSX-11D, continued. A new release of Q was made early in the quarter. The objectives of this release were reliability, centralized error and status logging, speed, shorter code, and full support of PDP-11/40 systems and LBL magnetic-tape controllers. These goals appear to have been met. Fifteen problem reports relating to the release were filed. All received attention and no unresolved problems are impacting system operation at this time.

The replay data-acquisition handler QP was modified to take advantage of the speed gained in the new data-distribution scheme developed for the data-acquisition handler QA. The replay command processor which begins the playback of a run was rewritten to allow the user to specify whether 1) the tape is to be rewound, 2) files or records are to be skipped, and 3) a search algorithm is to be employed in finding the desired run on the tape. Several other replay command processors were revised to correct bugs which had been uncovered.

The much requested user codes were made generally available in early October; they have been employed to increase the speed at which certain data-acquisition operations can be performed and to detect and protect against faulty data-acquisition hardware.

The users have requested that the functional equivalent of the programs WORKER and ALLTEST be made part of the Q program and supported by the MP-1 staff. Toward that goal a set of listings and other documentation were obtained from the resident expert for each program. The use made of these programs during a run was observed for several shifts to gain an appreciation of the operator interface. The preliminary conclusion of this work is that ALLTEST is compatible with Q and can be integrated easily. On the other hand, WORKER will have to be redesigned internally before incorporating it into Q. A design paper on each program will be prepared for review by the users before implementation begins.

The collaboration with LBL continued toward the goals of making Q available under RSX-11M as well as under the current RSX-11D systems at LAMPF. This effort will protect a large software investment in case DEC decides to phase out RSX-11D in the next two years as has been rumored. But more important, the collaboration has led to several improvements in Q because of the critical review by two independent groups.

After extensive consultation with LBL, joint 11M/11D development disks for all subsystems of Q other than histogramming were established. The prefix file which guarantees generation of compatible code for assembly language files was completed. A set of conventions to allow automated production of 11M and 11D command files was devised and tested using a simple set of editing commands. A sophisticated command file processor to perform this function in a highly automated fashion is being written by LBL. User libraries were made 11M-compatible; separate libraries for system-dependent tasks were generated. While the development system in its entirety has not been verified, it was used successfully to generate all 11D replacement modules for the recent release of Q. Complete validation will be done in November at LBL.

An extensive investigation of the compatibility between RSX-11D and RSX-11M was required for the Q conversion project. Of the 60 to 70 system directives available under RSX-11D, 41 were found to be incompatible with RSX-11M. Fortunately, Q is sensitive to only a few of these. However, modifications to the 11M Executive program are required and are being made at LBL. Many other incompatibilities between the two systems were uncovered and a summary of them will be presented in a paper at the DEC Users Society (DECUS) meeting in Las Vegas. In view of DEC's sensitivity to this subject, the company was invited to a preview of the paper at the RSX-11/IAS SIG Steering Committee meeting on October 16. The heads of the DEC development teams for RSX-11M and RSX-11D/IAS were present. As a direct result of this presentation, it now appears that DEC will attempt to remedy some of the unreported deficiencies as part of the next release of RSX-11M.

The number of Versatec printer/plotters at LAMPF is growing so that it is appropriate to invest some effort in organizing the software for more effective use of these devices. Ideally, the plotting software should be compatible with that used for the Tektronix-4010 graphics unit so that a display on the storage tube could be duplicated in journal quality on the Versatec unit. LBL is also interested in the problem. As a beginning, all users possessing a Versatec unit were asked for a description of the software being used to drive the plotter. From a study of this information, a design paper will be developed for review by the users.

The task of providing software support to the users continued to be a major activity. Generating RSX-11D systems, consulting on the Q program, helping to find hardware and software faults, and advising experimenters on the use of the software system required the equivalent of two full-time programmers. The latest step taken to provide support to the users was the posting of a 24-h call list in CCR. Experimenters who need assistance beyond that provided by their team specialist can call the CCR operators who, in turn, will contact the appropriate software expert.

Computer Maintenance

During the quarter, ~280 service calls for computer maintenance were answered. Roughly 85% were handled by the E-5 maintenance team while the other 15% were covered by DEC.

In an effort to provide better coordination of the maintenance effort, periodic meetings were scheduled between the MP-1, E-5, and DEC staffs. These meetings will usually precede the start of a run cycle when there is an increased urgency to get the experimental computers into reliable operation. Critical systems are to be identified and a priority on resources assigned. Some time in the meetings will also be devoted to long-range maintenance problems.

Negotiations for the FY-77 maintenance contracts were completed with both maintenance organizations. The major change from last year was a reduction from 24-h/day to 12-h/day, 7 days/wk, in the hours of extended coverage. This extended coverage is given to computers connected to experiments receiving beam. The justification for the change was an analysis of maintenance statistics done as part of the summer study.[1] This analysis showed that only 10% of the calls for service were coming outside the basic hours of coverage (8-h/day, 5 days/wk) and yet the extended coverage represented 32% of the total maintenance contract costs. The 12-h/7-day coverage seemed to offer a reasonable compromise. The premium is only 54% higher than the basic monthly charge as opposed to a 100% premium for 24-h coverage. Preliminary experience with the new system indicates that no major blocks of beam time are being lost because of the reduced hours. This is partly because of a "work-through" provision which guarantees that repairs started before 2000 hours will be continued to a successful completion at no additional charge no matter how long it takes.

Another recommendation of the summer study was that each experimental team appoint a system manager for the computer system who would coordinate the requirements for software and maintenance with MP-1 personnel. Letters went out to all spokesmen for experiments announcing this new policy.

The existence of a system manager should help alleviate another problem, that of keeping the counting houses clean. Maintenance statistics show clearly that a dirty environment increases the frequency and severity of computer problems. If the system manager assumes the responsibility for keeping the counting houses clean and tidy, the experimenters can look forward to fewer frustrations from lost beam time.

LEEP

The LEEP inventory contains 2259 items valued at ~$1.5 million. These figures do not include computer systems. The projected budget for FY-77 calls for an expenditure of $180k for NIM and CAMAC modules as well as test and measuring equipment. A major portion of these funds has already been committed.

The LEEP hex delay boxes continue to be in high demand and short supply. Twenty of the boxes were made originally and eighteen more were completed this quarter. The delivery of connectors has put a temporary halt to further construction. An effort is being made to acquire a similar delay box having LEMO connectors.

Work began on a computer program to test CAMAC A/D converters and time-to-digital converters. The features to be tested are the integral and differential linearities. These properties require a histogramming capability not currently available on the NOVA minicomputer assigned to LEEP. The required program should be completed next quarter.

On several occasions, users have asked for prescalers in a NIM module. The LEEP inventory does not contain such a unit and a market survey did not locate a manufacturer. The schematic for a homemade unit was acquired recently and the possibility of having some fabricated is being investigated. Some of the scaler manufacturers are being encouraged to produce one commercially. Further developments are expected next quarter.

Special Instrumentation

Cryogenic Pressure Servo

The cryogenic pressure servo described last quarter was thoroughly bench-tested. The circuit was built into a chassis that contained alarms, a digital pressure indicator, high- and low-trip points, a set point, power supplies, power drivers for resistive heaters, interface connections, etc. This prototype will be used to monitor and control pressure in a liquid hydrogen target. The constant pressure thus attained will stabilize the temperature which, in this instance, is the variable to be held constant. The digital indication of pressure is proportional to the temperature. The acceptance tests scheduled are a closed-loop bench test and a field test in the experimental area. The unit was installed for these tests. At least six units will be required in the future.

Vacuum Loss Detector

In a continuing effort to support the Vacuum Task Force, the second version of a trigger system for the fast-acting valves was designed and constructed. The new design incorporates several improvements suggested by experience with the initial model. While the second version is performing satisfactorily, it would not be surprising if the evolution continued with version 3.

Sharing LAMPF Technology

Some of the software developed for the PDP-11s at LAMPF has achieved national attention through DECUS. During this quarter, programs were requested by and sent to the FAA in Oklahoma City, Hughes Aircraft in Los Angeles, EG&G in Los Alamos, M.I.T. Bates Linear Accelerator Laboratory, ORNL, and LBL. In return, programs were received from the Hughes Aircraft Co. and Bates.

One staff member attended the NIM-CAMAC Working Group on software which met as an adjunct to the 1976 Nuclear Science Symposium. A representative also participated in a meeting of the Advanced System Study Group, a NIM-CAMAC effort to lay the groundwork for a specification for a faster (10X) CAMAC system to take advantage of the latest developments in electronics technology.

Electronics Perspectives Seminars

The effort to keep the technical staff abreast of the latest in technology continued through the Electronics Perspectives Seminars. Ralph Morrison of Communications Manufacturing Co., a nationally known authority and author, was invited to give an all-day workshop on "Grounding and Shielding Techniques in Instrumentation." One hundred people attended. He followed up the subject the next day with a seminar on "Practical Instrumentation System Considerations."

Darrell Call, CTR-7, gave a two-session presentation on "Computer-Aided Design Using NET-2," a powerful computer program developed at LASL for simulating and analyzing new electronic circuits.

Frank Naivar, MP-1, conducted a two-session introduction to "Instrument Interfacing Using the IEEE-488 Standard Interface Bus." Particular attention was given to the design of a GPIB controller implemented with a microprocessor and packaged in CAMAC.

REFERENCES

1. R. F. Thomas, J. F. Amann, H. S. Butler, J. M. Gallup, R. H. Jeppesen, S. S. Johnson, W. K. McFarlane, M. W. McNaughton, R. E. Mischke, D. G. Perry, B. M. Preedom, R. J. Ridge, E. B. Shera, and H. A. Thiessen, "Computing in Support of Experiments at LAMPF," Los Alamos Scientific Laboratory informal report LA-6543-MS (October 1976).

VII. ACCELERATOR OPERATIONS

General

The accelerator was in continuous operation throughout the quarter, with the exception of two, short, scheduled shutdowns which totalled seven days. The typical operating cycle, as in previous quarters, consisted of two weeks devoted to research and one week used for facility development and maintenance.

Starting with operating Cycle 7 early in the quarter, the machine has been run routinely with 100 μA of H^+ delivered to Area A and as much as 6 μA of H^+ to Area B. Machine availability during research shifts averaged 83% for the H^+ beam and 77% for the H^- beam.

Development of the HRS channel was in progress throughout the quarter and the resolution of the spectrometer was demonstrated to be better than 100 keV. Initial irradiations were conducted successfully in an isotope production stringer at A-6.

Experimental Program

Research-quality proton beams to Area A totalled 83 400 μA-h during the quarter, as measured at the A-1 target station. An additional 190 μA-h went to Area B. The combined total is again greater than the cumulative total of all beams previously delivered to the experimental areas.

In the typical operating mode for the H^+ beams, the intensity of every tenth pulse was reduced by a factor of several hundred to permit measurements of secondary particle distribution. With the exception of those occasions when the H^- beam was used for nuclear chemistry irradiations, the H^- beam chopper was used to remove either 7 of 8, or 15 of 16 micropulses from the beams delivered to Area B. User requirements for $\leq$0.5% transmission of the rejected micropulses have resulted in major complication of the H^- beam-tuning process.

Forty-three experiments received beam as shown in Table VII-I. This tabulation does not include the beam use for facility development or tuneup activities.

Facility Development

Machine time allotted for facility development was used for the development of standardized beam-tuning procedures for 100-μA production beams, for final testing of beam-position monitor prototypes, for measurements of emittance growth with increased beam currents, and for beam tests at high average currents in Area A.

We found that optimum admittance at Tank 5 was obtained by introducing H^+ beams 4-mm low and H^- beams 1.5-mm low, and parallel to the accelerator axis at the EM-3 station in front of Tank 1.

A series of 5-min tests at 200-μA average current to the A-6 beam stop, with production targets in place, was completed at the end of Cycle 9 without retuning the production beam.

A televised accelerator status display, containing computer-generated information on beam-current intensities and target configurations and provision for messages from accelerator operations personnel, was activated during the quarter. Television monitors have now been placed in almost all experimental counting houses and trailers.This installation has resulted in a marked reduction in the number of disruptive calls to CCR when operators are fully occupied with machine problems.

Operating Experience and Downtime Accounting

Machine operation continued to be reliable and moderately stable, although increased vigilance on the part of operations personnel was required for detection and correction of drifting parameters. An excessive number of noisy data channels complicated the problem of detecting real drifts. A summary of the machine downtime is given in Table VII-II.

TABLE VII-I

QUARTERLY REPORT OF BEAM PROVIDED FOR EXPERIMENTS

Experiment No.	Channel	Shifts (8 h)	μA-h	Experiment No.	Channel	Shifts (8 h)	μA-h
7	SMC	29.0	18 900	200	EPB	2.5	----
25	LEP	83.0	59 100	221	P3	14.0	8 800
28	LEP	29.0	19 800	234	LEP	2.5	1 630
31	Neutrino	114.5	49 900	235	Biomed	2.0	1 090
35	LEP	2.5	1 320	236	Biomed	2.5	1 240
37	SMC	43.5	27 400	239	Biomed	8.0	4 050
60	SMC	13.0	7 450	245	EPICS	50.5	35 800
67	LEP	2.5	1 550	246	EPICS	2.5	1 320
86	TTA	8.5	6 300	254	Neutrino	45.5	19 100
90	P3	45.0	28 700	262	AB Neutron	8.5	20
99	P3	48.0	29 400	263	AB Neutron	12.0	22
100	SMC	12.0	7 530	264	AB Neutron	3.0	6
101	SMC	18.5	10 800	265	EPICS	46.0	31 800
103	P3	3 runs	1 840	270	Biomed	11.5	6 350
105	AB Neutron	3 runs	33	271	Biomed	18.5	9 500
118	P3	1.0	745	272	Biomed	6.0	3 060
119	P3	1.0	705	273	Biomed	6.0	2 830
124	EPB	48.0	----	274	Biomed	43.0	23 100
148	Neutrino	114.5	49 900	275	Biomed	12.0	6 450
150	AB Nucchem	4 runs	48	279	EPB	10.0	----
179	AB Neutron	6.5	11	300	Biomed	5.0	2 720
				301	AB Nucchem	3 runs	47

TABLE VII-II
QUARTERLY SUMMARY OF MACHINE DOWNTIME

Category	Downtime (h)	Percent of Total
201-MHz amplifiers and transmission lines	39	20
805-MHz amplifier systems	60	31
Vacuum	12	6
Magnets and magnet power supplies	20	11
Interlocks	11	6
Injectors	10	5
Water	3	1
Computer control and data acquisition	15	8
Reference source	3	1
Beam stops, plugs, targets, strippers, scrapers	1	1
Beam diagnostics	3	1
Timing distribution systems	2	1
Miscellaneous (utilities, etc.)	15	8
TOTAL	194	

VIII. EXPERIMENTAL AREAS

Facility Operations

A preliminary proposal to build a minimum shelter over the A-5 and A-6 target stations has been prepared. These target areas serve the main LAMPF proton line. There is no weather protection except for a temporary canvas cover at A-6, which is the main beam stop, and a removable roof cover at A-5, which is the target for the biomed channel. Both stations have shielding plugs that must be lifted out with a crane. Any maintenance or modification work requires the use of a large mobile crane and a considerable number of riggers and laborers.

The specifications for the proposed shelter call for a steel-frame structure with a partial roof and siding. A 30-ton bridge crane will be provided; it will extend east from the existing experimental area building past A-6 far enough to give access to the service yard level.

Quarters for experimental area operations and support staff have been set up just south of Area A. This compound, consisting of four ~4- by 15-m trailers, provides work space for the following support activities: H-1 Radiation Monitoring and Health Physics, LAMPF Safety, Remote-Handling and Targeting, Cryogenics, Process Cooling-Water and Radioactive Exhaust Systems, Experimental Area Manager, and Area Control and Monitoring.

Also included in this new complex is a combination lunchroom and meeting room. Vending machines have been installed. The complex is open around the clock, seven days a week. The facility is accessible to all users of the LAMPF experimental areas, and its use is encouraged.

A storage and refill system for bottle gases and liquid nitrogen containers has been established. This system is set up throughout the experimental area and makes supplies available on an as-needed basis.

Area Manager's Office support to experimenters averaged 60 man-hours per week in August, 80 in September, and 132 in October. Machining support in the staff shop averaged 32 man-hours per week in August, 56 in September, and 42 in October. Shielding work averaged 40 man-hours per week in August, 60 in September, and 98 in October.

Shielding

Concrete blocks for the north face of the A-1 target shield near EPICS were fabricated and installed. These specially designed blocks provide a tighter, more effective shield in this area, as well as allow more floor space for spectrometer travel. The large shield cave around the EPICS spectrometer was installed.

A shield cave of concrete blocks was installed at the top of the main shield mass around the EPICS vacuum pump. The large-diameter pump-line penetration allowed radiation leakage to the top of the shield; this additional shielding has reduced the general background in that section of Area A.

Extensive reworking of experimental cave shielding was done in Area B along the EPB line.

Concrete shielding blocks (costing ~$120 000) have been fabricated and delivered to the experimental areas. These blocks, ranging from 1 to 17 metric tons, are being used in the construction of additional experimental caves and to increase the main shielding where needed; 16 special concrete blocks have been ordered to build a shield cover above the Isotope Production area at the main beam stop.

Scrap lead, polyethylene sheets (some boron-loaded), and lead-loaded paraffin bricks have been obtained from government excess stock.

Main Beam Line and Target Cells

Target Cell A-1

In a routine inspection of the A-1 targets in August, the spinning mechanism was found to be inoperative (all other functions were normal) although the graphite target was continued in use, after a minor modification to prevent the beam from hitting a spoke. The mechanism was removed in October to replace a flexible drive coupling that had failed in the spin drive. The repair work was done in the hot cell. The mechanism was reinstalled after a four-day test of the drive system.

The 3-cm graphite target that was removed in October, after six weeks of 100-μA beam, exhibited discoloration and slight evidence of beam passage, but no substantial damage.

At present, there are three 3-cm ATJ graphite-wheel targets loaded in the magazine of the A-1 target mechanism.

Target Cell A-2

Because of vacuum and water leaks, the A-2 target cell was opened in early August. This investigation revealed the following:

1. A vacuum leak was determined to be on the upstream bellows of Collimator 2A-CL-04.
2. A closure bolt on a vacuum flange clamp on the same collimator was loose. Tightening did not change the vacuum-leak indication.
3. A small vacuum leak exists on the A-2 target box lid in the vicinity of a broken hold-down bolt.
4. The water leak occurred in a pipe from the water-cooled shielding; it was repaired and placed back in service.

The vacuum leaks, while easily detectable, do not prevent the system from reaching pressures of 1 μm of mercury and below. This is acceptable performance for the Line A vacuum system. The entire repair and vacuum-check operation was done remotely, with personnel remaining above the 7.5-m level (shielding top) in the target cell. The design of a new 2A-CL-04 collimator assembly is now complete. Bellows have been ordered and fabrication is in progress.

The target mechanism history is as follows:

- The Mod II target mechanism (installed in February) malfunctioned in July by losing the snap ring that holds the target wheel to the fork. This broke the Ferris-wheel-rotate gearing. A single nonspinning target was then put into the beam for six weeks of 75- to 100-μA beam operation. Upon removal, there was definite evidence of surface erosion by oxidation. About 1 mm of material was lost in the immediate area of the beam spot. The pion-production performance was unaffected.
- The Mod III target mechanism (a single 6-cm ATJ graphite wheel with spin motion and a cable from back to pull in and out of the beam) stopped spinning shortly after installation at the end of September. After two weeks of running time — not spinning — considerable damage to the target resulted. The wheel cracked completely across, and some evidence of erosion (or oxidation) was visible (see Fig. VIII-1). This target was subjected to a number of short 200-μA beam tests before withdrawal.
- Mod IIA (now installed) has the same characteristics as Mod III; it is spinning at this date.

Target Cells A-3 and A-4

The operation of the A-3 beam plug has continued this quarter without the need for repair. The 0.013-cm stainless-steel window in the beam line at A-4 was removed to help alleviate the activation problem in A-4 and A-5.

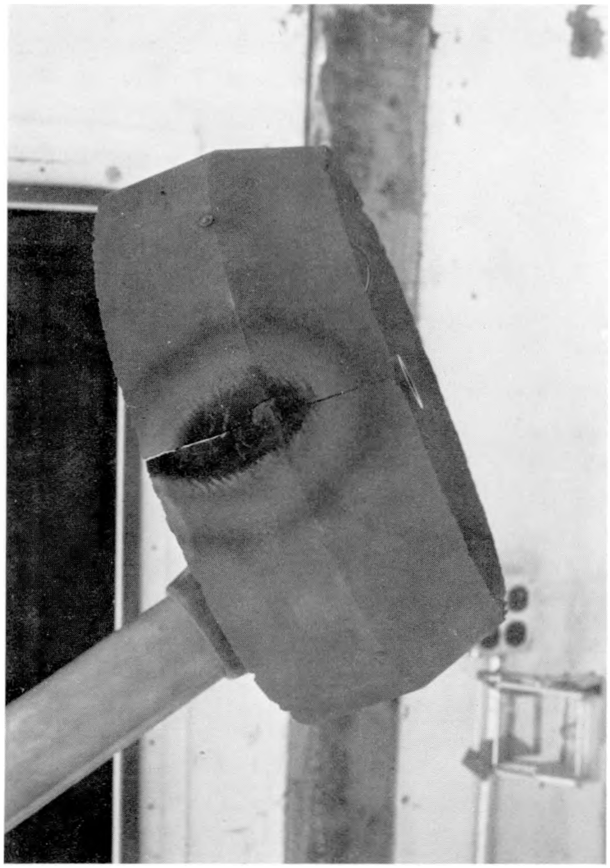

Fig. VIII-1.
The 6-cm ATJ graphite wheel target (rhomboidal cross section) that was removed from target cell A-2 after two weeks of nonspinning is shown. It was subjected to a number of 5-min beam tests at 200 μA. The wheel is cracked and there is some surface erosion evident.

Target Cell A-5

The water-cooling to one target box baseplate was removed to bypass a leak in its cooling coils. Thermocouples have been installed to monitor the plate temperature.

The A-5 target mechanism and its controls worked with only minor problems until the start of Cycle 10. The pyrolytic graphite slab target (2-cm wide by 8-cm along the beam direction; ρ = 2.2) that was removed after Cycle 9 was found to be delaminated and split in a vertical plane along the beam axis (see Fig. VIII-2). About 30% loss of pion flux was reported on the biomedical channel. The replacement target has the same dimensions, but the orientation of the laminated graphite has been changed to provide better radiation cooling and to minimize the consequences of delamination.

The first experimental water-cooled flange for the A-5 target was installed for Cycle 10. This was the beginning of a series of problems: at least two vacuum "burps" (to ~250 μm) apparently destroyed harp 5A-HP-02 and did some damage to other harps. The burps are believed to be caused by water leaks into the system from the A-5 target-cooling system, since water was found in the A-4 and A-6 vacuum pumps. The water system was blown out with air; a soft vacuum is now on the water lines. Numerous control-system problems, and a failure of the readout pot drive, have contributed to the lost beam time, which totaled about five shifts for the biomed channel and nearly two shifts for Line A. The system has been repaired. All known design faults have been corrected. Design studies for a simpler drive system are under way.

Fig. VIII-2.
The pyrolytic graphite slab target, removed from target cell A-5 after Cycle 9, is shown. The target, shown end-on in this photograph, is 2-cm wide and 8-cm long. It is suspended vertically from a cylindrical steel assembly with a graphite retainer disc. A crack can be seen in the disc; discoloration is present on the slab, in the direction of the laminations. Delamination subsequently occurred; the design was changed to provide better cooling and minimize the consequences of delamination.

Target Cell A-6

A new beam-stop assembly, with a redesigned drive system, is in fabrication and will be available for the December-January shutdown. The design of a water-cooled window is in progress; the window will be installed during the shutdown.

Proton Irradiation Station

Conceptual design and preliminary schedule have been completed for a facility to allow the irradiation of thin samples in a high-intensity proton beam. Meaningful radiation damage can be induced in a reasonable time with beam intensities >250 $\mu A/cm^2$. At present, beam currents at only four locations meet this intensity criterion: a waist in the SY at about the Line A-direct beam stop; another at LA-WS-17 in the SY; and two locations near A-1 and A-2 targets. The vicinity of the biomed target becomes eligible at beam currents >200 μA. A review of the accessibility of these regions and the consequences of the scattered beam favored the use of the fast-rabbit port that was installed in target cell A-1 between the profile monitor and the A-1 target.

Access to the port itself was blocked by both steel and concrete shielding. It was possible to remove the steel pieces by jacking the shielding up above it and prying the pieces out. Pipe supports have been welded in to replace the jacks. A 45-cm-diam hole has been core-drilled through the 90-cm-thick concrete shielding. There is now direct access from the EPICS floor to the vacuum flange on the fast-rabbit port. Engineering design has recently begun on the details of the hardware for the new facility. A goal is the replacement (during the December-January shutdown) of the present shielding within the fast-rabbit port by new shielding that will support an access pipe. The completed facility should be ready to accept samples during the first part of 1977.

Secondary Beam Lines

The major work of the secondary beam-line section during the past quarter has been to continue to render assistance to experimenters and to improve and upgrade the secondary beam lines.

Major activities were as follows:

1. Hardware for computer control of P^3, LEP, and SMC has been ordered and computer control of P^3 has been implemented. Plans to implement a complete software package for computer control of the channels are being worked out.
2. The large vacuum pump package (rough pump/blower system) in SMC has been installed and is operational. The P^3 pump package has been rebuilt and is operational.
3. The counting house in SMC has been remodeled and will receive carpeting during the December shutdown. The utilities in the experimental caves (ac power and cooling water) have been updated.
4. The two SMC-East beam plugs were installed and incorporated into run-permit. Extensive floor support was given to Exp. 101 (the study of pion fluxes, stopping rate, and spot size) at SMC-East. In preparation for Exp. 173 (a bent-crystal-spectrometer experiment using pions), the two SMC-East quadrupole magnets (QM24 and QM25) were removed and the experimental cave was substantially rebuilt.
5. Five of the ten dual-Acme magnet power supplies in SMC were rebuilt (by MP-11) and reinstalled with LAMPF's standard regulator systems. Plans to complete this rebuilding during the December shutdown are being finalized.
6. A new current bypass shunt for BM01 at LEP has been built (by MP-11) and installed. The shunt for BM04 is being built, and will be installed during the December shutdown.
7. Extensive engineering and floor support were given to LEP Exps. 29/54 and 25. Floor support was given to Exp. 28.
8. The test channel has been used extensively by several approved experiments. Setup and run support was given to Exps. 35, 96, 221/222, and 133.
9. Plans are being finalized to move the Line A vacuum pump in the test channel to the top of the bulk shielding above the channel.
10. In P^3, substantial floor support was given to Exp. 90 in preparation for running a tritium target. Experiment 99 was removed from the P^3-West cave and Exp. 221/222 was installed.
11. Substantial floor support was given to Exp. 150 (Nuclear Chemistry) and Exp. 262/263/264 in Line B. The LD_2 target was rebuilt and made operational for Exp. 262/263/264.
12. In EPB, substantial support was given to Exp. 124/279; then it was removed and Exps. 197 and 200 were set up. Vacuum repairs to EPBL01 were carried out (by MP-11), and instrumentation and control improvements to channel devices were accomplished (by MP-1).

Production Cycles 7, 8, and 9 were run during this quarter. During the time that usable beam was targeted in Area A, the failure of beam-line components caused channel downtimes of 1.0% in P^3, 0.5% in SMC, and none in LEP.

Remote-Handling Equipment

Monitor I (PAR and Servoarm) is operational and was used for the entire A-2 vacuum-leak investigation in August with quite good results. New color and high-resolution black and white television systems are on order and will be operational by the December-January shutdown. The Monitor II (TOS two-arm system) hydraulic crane unit is on hand. Some of the other mechanical systems for Monitor II are in fabrication. Controls for Monitor II will not be installed until there is an increase in technical staff (expected in December); these controls may not be ready for the first TOS arm, scheduled for delivery in late January. In that case, the first TOS arm will be mounted on Monitor I in place of one of the existing manipulators. Monitor II is expected to be ready before the delivery of the second TOS arm, scheduled for April. The hot-cell facility is operational for simple tasks that do not need magnified viewing. The addition of the Kollmorgan periscope and more tools and fixtures will increase our capability.

The tooling required for replacing the A-6 window and the 2A collimator is being prepared. The preparation of tooling requirement lists is ~ 60% complete, the actual tooling design is 20-30% complete, and the operational procedures are ~75% complete.

Experimental Area Cooling-Water Systems

All five radioactive water systems were operated continuously during this report period. As of October 30, 1976, the water specific resistivity for each of these systems was as follows:

Water System	(MΩ-cm)
X02	~ 8.0
X03	~12.9
X04-6	~10.2
X05	~ 1.4
X04-8	~14.5

The three nonradioactive systems were also operated continuously during this period; these systems service Area C, EPICS, and Area A experimental magnets. The EPICS system was used for the mapping of the new spectrometer magnets.

The installation of cooling-water lines for experimental magnets in the LEP cave is now complete.

The design of the new spare pump/heat-exchanger package was completed during this time, and procurement of parts has begun. This system will be an on-line spare for the radioactive systems. It will reduce the beam-loss time for maintenance or repair of those systems. Fabrication will begin in January 1977, with installation tentatively scheduled for next summer. An on-line, dissolved-oxygen analyzer system has been installed on each of the radioactive water systems, which will permit continuous monitoring of the oxygen concentration in these cooling systems. The checkout will progress during beam-off periods.

Radioactive Exhaust System

During this quarter, the filter chambers for the stack fan were modified and resealed to prevent radioactive particulate from bypassing the filters. A manual damper is now installed in the SY duct. This system is now operating at 100% capacity.

Cryogenics Support

Modifications and repairs were carried out on the large LD_2 target used for neutron production in Area B. New fans for the LD_2 circulating loop were installed, and a number of leaky electrical feedthroughs were replaced. The system is now operating satisfactorily.

Major effort was devoted to preparations for Exp. 90, which involves pions in a cold (~30 K) gas tritium target. Extensive modifications were made to the existing gas-handling system: (a) to accommodate additional gases (H_2, ^4He, ^3He, and T_2), (b) to provide suitable pressure protection, and (c) to provide suitable T_2 safety measures.

Some of the preparations for the tritium run included writing lengthy and detailed operating procedures, selecting and training operators, installing instrumentation for monitoring the gas and cryogenic systems, and providing emergency generators. Considerable effort went into unsuccessful attempts to repair the leaky UCLA target flasks. Heroic last-minute efforts by members of the research team and the MP staff to build and test an alternate design for a tritium flask were successful after two attempts.

Support for Exp. 245 (π-^{3}He scattering; EPICS channel) was provided. A cryostat on loan from the Univ. of Virginia was modified and placed in operation, and a ^{3}He gas-pumping system was obtained from Group Q-26 and adapted for use with this experiment.

Cryogenic targets and 10-W refrigerator systems were installed and operated for four additional experiments (124, 197, 221, and 262) during this period.

Polarized Proton Target Development

Pumping-speed measurements of the ^{3}He vacuum system (9B4 diffusion pump backed by two WS-250 Roots blowers and an Edwards mechanical pump) were performed in order to estimate the refrigeration capacity of the pumping system. These measurements indicate that, in principle, one should be able to dissipate ~5-10 mW at 0.6 K. At 0.5 K, where ~1 mW of microwave power per cubic centimeter of sample is required for maximum polarization, the pumping speed may only be adequate for a small target.

Two Leybold-Heraeus Roots blowers (WS-500 and WS-150) were sent back to the factory earlier for leak tests. Leybold-Heraeus verified the measurements performed here: that the pumps leaked directly through the casings. The leak rates were of the order of 10^{-6} atm cm^3/s. These leak rates are within the manufacturer's specification of 10^{-5} to 10^{-7} atm cm^3/s. The main problem with the pumps leaking air through the casings is that the air must be removed lest it freeze in the ^{3}He line inside the cryostat. Traps, using activated charcoal (cooled to liquid nitrogen temperature), are commonly used to help remove the air from the ^{3}He. For extended run cycles of about two weeks, it may be necessary to run with two traps in parallel. Earlier problems encountered with the traps plugging up were discussed with consultants from Leybold-Heraeus and the P-Division polarized target group. The probable cause of these problems was oil mist from the Edwards mechanical pump. Some suggestions have been received which should help reduce the difficulties in the future.

Several safety measures have been taken during this report period. Pressure relief valves were installed on the liquid nitrogen trap and on the ^{3}He feed line to the cryostat. A plastic safety shield was installed in front of the panel containing the pressure gauges for the cryostat.

The superconducting solenoid on loan from P-3 was assembled and leak tested. Difficulty is being experienced in gluing leak-tight plastic windows to the outer vacuum jacket.

Preliminary design of a target insert for the cryostat has begun. The design will be patterned after target inserts used at CERN. The incident particle beam will enter the cryostat through a thin window and then traverse the cryostat down its longitudinal axis.

IX. BEAM LINE DEVELOPMENT

H^- Beam

Line A Tunes

Three production cycles of 100-μA average current were completed this quarter as well as tests with average currents up to 200 μA and peak currents to 5.1 mA. The limitation on average current was imposed by the temperature rise of the A-6 window. This window will be replaced during the next quarter and the limitation removed. The losses in the SY and Area A which are associated with transporting these beams to the A-6 beam stop appear to be acceptable. The previously reported unacceptable spills in the A-4 area were eliminated by removal of two vacuum isolation windows and some quadrupole tuning in the SY and the A-3 region. We are presently accommodating a 3.5-mg uranium target at the thin-target station and have had decreasing residual activity in the A-4 region, even with higher beam currents. The thin target will be decreased in thickness when a smaller spot size is required at A-1.

Phase-Space Measurements

The aforementioned high-current tests provided an opportunity to document the phase-space parameters of the linac beam up to 5.1-mA peak current. Measurements were made with four wire scanners in a drift space in the SY. The emittance results are shown in Fig. IX-1 for the ellipse which contains 40% of the beam, i.e., $\pm 1\ \sigma$ of a Gaussian-shaped profile.

The transverse phase-space parameters were also documented for energies between 200 and 800 MeV at the end of the linac by delaying the rf at the appropriate module and allowing the beam to drift to the SY. The expected adiabatic damping of the emittance was observed at energies above 300 MeV. At lower energies the measurements indicate that the beam was poorly steered and probably disturbed by aberrations. Additional data is contained in an MP-13 internal report.[1]

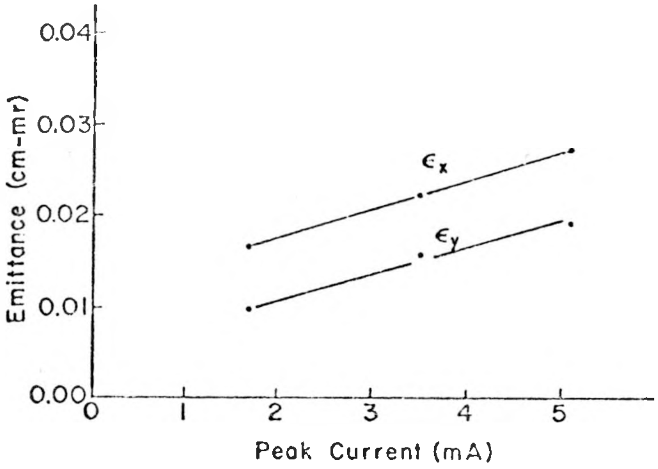

Fig. IX-1.
Results of phase-space measurements for the ellipse which contains 40% of the beam at the end of the linac. The emittance is the area of the phase ellipse divided by π.

Halo Studies

As part of the study of high-current production beams, a characterization of the beam "halo" as well as "core" is required since the outermost portion of phase space is the first to be intercepted by beam line plumbing. A method initiated at LASL by H. Koziol from CERN is currently being evaluated in LAMPF switchyard measurements. The method employs a simple plate, driven straight across a high-peak-current low-duty beam, with the amount of intercepted beam recorded by a suitable detector. The resulting cumulative distribution gives a beam profile free from the ambiguities of interpretation possible with secondary-emission profile monitors. Furthermore, the use of a scintillator and phototube detector permits a wide dynamic range, since phototube gain can be controlled over several orders of magnitude. Figure IX-2 shows a cumulative beam-profile distribution plotted on a probability ordinate scale, which would give a straight line for a Gaussian. The plot shows a small excess above the Gaussian continuation of the core of the beam. The measurements shown here used a 200:1 phototube gain range. Approximately one more decade of data

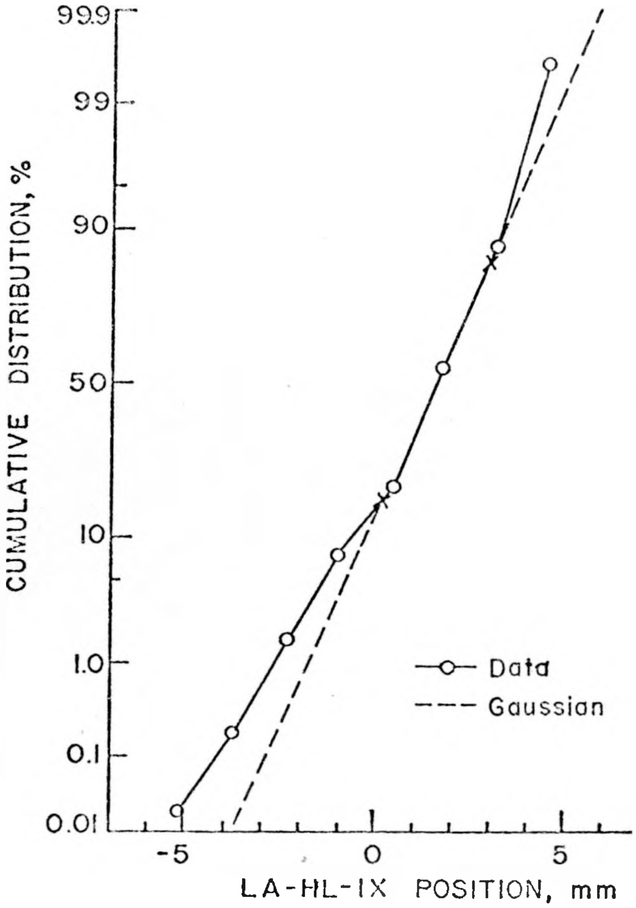

Fig. IX-2.
Beam cumulative distribution plotted on a probability scale, as measured on "halo plate" LA-HL-IX. The crosses mark the 16 and 84 percentiles, or $\pm 1\sigma$ on a Gaussian. The dashed straight line corresponds to a Gaussian of width 2σ.

(down to 10^{-5}, not shown on the plot) was taken until the background noise limit was reached. The data have been compared to wire-scanner profiles, which have about one decade less sensitivity but track the halo-plate profiles quite well down to their noise limit.

Instrumentation and Controls

Beam-Current Monitors

Additional capabilities in the current-monitor readout system were designed and implemented. The requirements were to make the transmission monitor operation independent of beam duty factor and to resolve the competition between the harps and current monitors for computer time in the Area-A PDP-11 CAMAC system. The basic solution was to provide the PDP-11 with an absolute time base and a scheduling algorithm for the harps and current monitors. The time reference signal is the rf gate, which always runs at 120 Hz but is close in time to beam-gate. The scheduling algorithm directs current-monitor servicing to every other 120-Hz pulse. The harps can be serviced on the alternate 120-Hz pulses, with the harps controlling the phase so that harp readout can occur immediately after beam-gate at low rep rates. This scheduling improves background stability of the harp display by ensuring a fixed interval between the beam pulse and readout. The transmission monitor now takes data and does its calculations at fixed one-second intervals regardless of beam duty factor. The system probably can be made to monitor transmission at a rate as high as 60 Hz if that requirement develops.

It is planned to implement similar scheduling algorithms in the SY and LB/LC satellite computers when additional current-monitor readouts are added.

A program for ensuring the data quality from the beam-current monitor system has been instituted. The program involves a periodic and thorough study of the system response using the calibrate pulse as a probe. For example, tracking accuracy among the six toroids used in the transmission monitor is $\sim\pm 1\%$ for 1- to 5-mA pulses. Although the program is intended primarily for watching the electronics, it is possible to anticipate failure in the toroid transformer itself by degraded response. The occurrence alerting us to this possibility was an apparent beam-transmission fault traced to increased pulse droop on

2A-CM-3, a 10-cm target cell toroid, from ~4% to ~28% droop in 500 μs, corresponding to a loss of inductance from a nominal 280 mH to 43 mH. This is the first case of apparent beam-associated damage to a toroid, which will be subject to examination when removal is possible. In the meantime, the data from 2A-CM-2, a 20-cm toroid installed just upstream for redundancy, are used in place of data from 2A-CM-3.

Harps

A harp improvement program is proceeding, albeit slowed by procurement delays. A new silicon-carbide wire was investigated last quarter and found to be well suited to our purposes. We have now received some wire and are proceeding with replacement harps and spares. Procurement has been initiated for new radiation-resistant cable as a replacement for the m.i. cable presently being used. We hope for partial delivery by mid-December. This new cable is more flexible and does not require special glass terminations as does the m.i. cable. In addition, we hope to be able to eliminate the connector at the harp lid by soldering the cable directly to the harp feedthroughs. This will greatly improve the reliability of the harps.

Attempts were made to determine the actual radiation dose at a designated location while beam was on to give a better idea of the amount of radiation which a component, e.g., a harp connector, would receive during the course of a year. A neutron-sensitive ionization chamber was placed at harp 5A-HP-2, and by changing the filling gas, the fast neutron and slow neutron doses can be determined. And, with an ionization chamber that is mostly sensitive to gammas, and also by changing the gas, the amount of dose for each radiation can be determined.

A-1 Profile Monitor

A new radiation-hardened current monitor (described in last quarter) and a harp with 0.5-mm spacing in the vertical plane were installed in the A-1 profile monitor penetration. The improved harp wire spacing will aid in the determination of the proton spot size at the A-1 target.

Wire Scanners

At 100-μA average current and beam size of 3.0 by 3.2 mm (FWHM), the 0.008-mm wide by 0.203-mm-deep Stablohm-650 ribbons on LA-WS-17 failed. This is the first and only failure since the production runs resumed in January 1976. The ribbons were replaced by 0.10-mm silicon-carbide wires with no apparent loss in signal. These new wires have survived four weeks of 100-μA current without failing. We expect to eventually install silicon-carbide wires on most of the wire scanners in the SY.

Two additional wire scanners, LA-WS-05 and LA-WS-11, have had silicon-carbide wires installed. High-voltage clearing-field wires of the same material were also installed on LA-WS-05. The signal wires are 15-cm long and are attached by a small spring at each end to provide a tension of ~40 g.

Activation-Protect and Loss-Monitor Systems

Steps were taken to obtain better understanding and documentation of the Activation-Protect (AP) and Loss-Monitor (LM) systems (shown in Figs. IX-3 and IX-4) in the SY and the main beam lines. A notebook is now maintained in the CCR which contains an up-to-date list of the high-voltage setting for both the APs and LMs and the actual calibration technique used (including beam-current data, magnet settings, repetition rate, and notes). In addition, the notebook contains information on the systems (block diagrams, gain curves), location data, and detailed information on the location of the APs and LMs relative to the components of the SY.

The installation of new electronic units for the APs required a complete recalibration of the switchyard APs. The calibration consisted of preparing a 100-nA-average beam from a 50-μA-peak H^- beam by adjusting the beam-gate and repetition rate. This beam was spilled near the locations of the APs using the signal from the associated LMs as a means of maximizing the spill at the location of the AP. The APs were then set to a phototube voltage just at the threshold of signal integration by the electronics in the monitor station unit. After a beam line tune is set for a production cycle, the LM phototube high voltages are set to give a signal output of one-quarter scale on the computer readout system in the CCR.

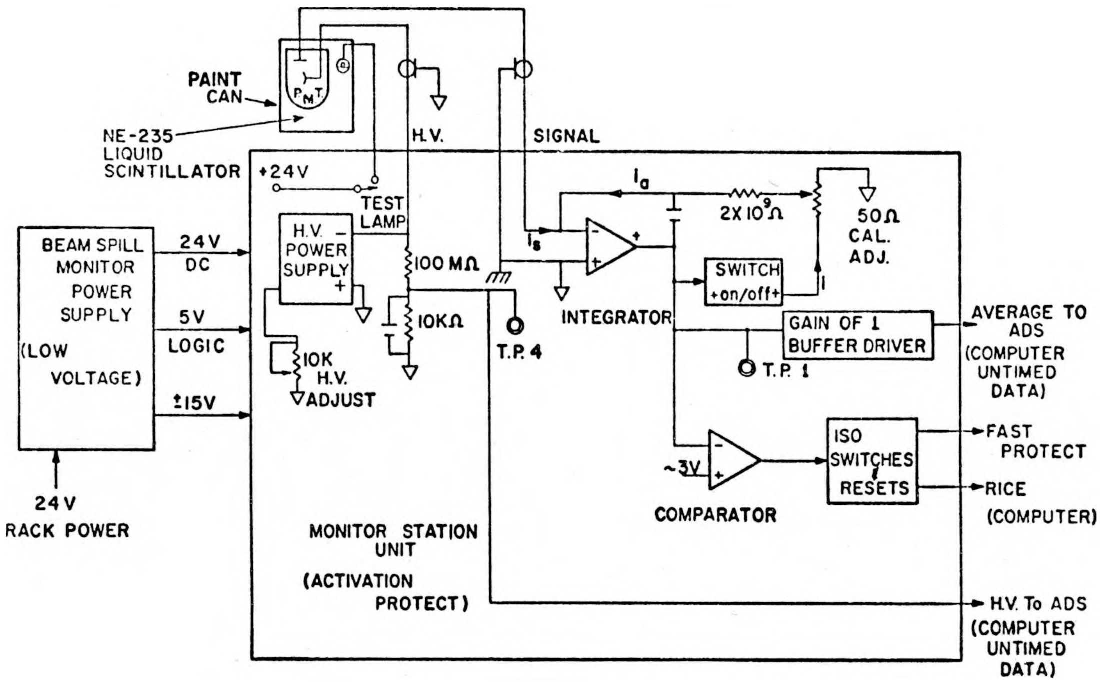

Fig. IX-3.
Block diagram of AP system.

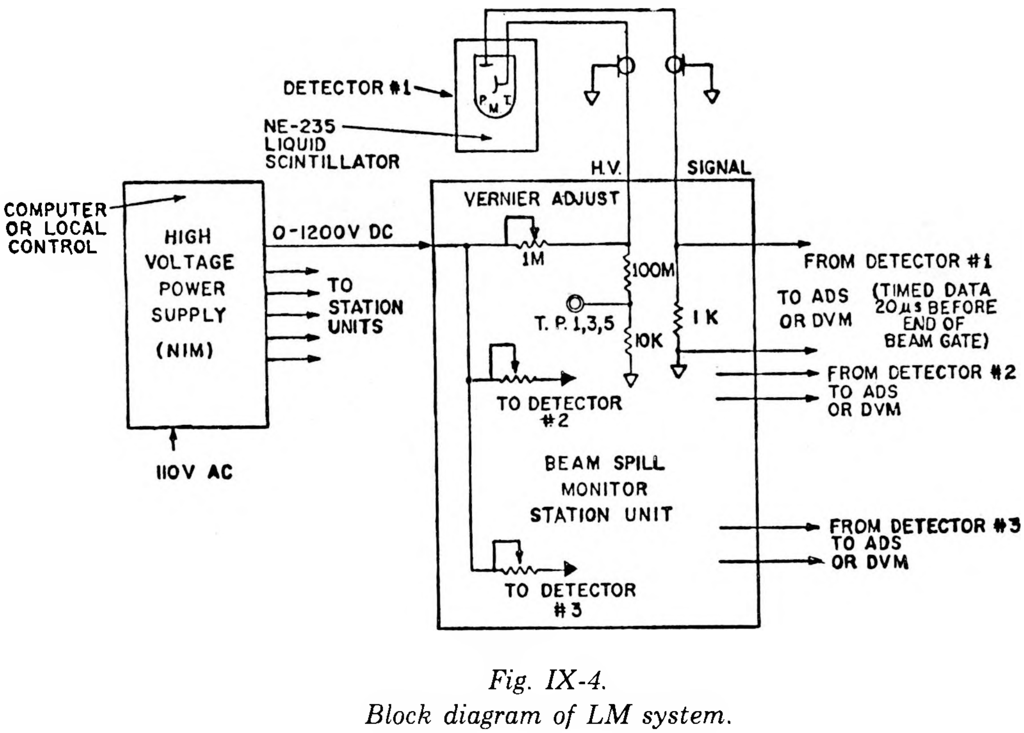

Fig. IX-4.
Block diagram of LM system.

This setting is convenient for monitoring any changes in the spill pattern along the main beam lines.

To study the basic response of the LM system, gain curves of the phototube and the LM readout electronics were made for several combinations of the phototube and scintillator using a ^{60}Co source of 37 mCi in a fixed geometry attached to the paint can enclosing the phototube.

The output current was measured as a function of the phototube high voltage. The gain curves are well fit by power-law relations between the signal and phototube high voltage. The form of the law is $S = kV^a$ where k and a are constants for a given condition, V is the voltage on the phototube (in volts), and S is the output signal (in mA). The data show that a varies between 7.19 and 7.83. This is in agreement with the data obtained by O. van Dyck[2] using the beam to spill near an LM in the switchyard. (His value for a was 7.11.) Using the curves, one can extract values for k which are a measure of the sensitivity of the device to ^{60}Co gamma rays. Table IX-I gives the values of k derived from study of the basic response of the LM system.

The scintillator, NE-235, provides about 10^4 improvement over an air-filled can with no film of scintillator on the phototube. A thin film of scintillator on the phototube gives an improvement of 10^2 over an empty can, but the arrangement is not necessarily stable and the sensitivity is expected to change as the scintillator drains from the phototube surface. Better methods of providing an intermediate sensitivity are being investigated.

The response of experimental area LMs and APs to a given amount of beam spill is strongly influenced by the geometry of the layout. An example of this is shown in Fig. IX-5 where the response of LA-LM-4 is plotted as a function of beam energy (last module accelerating) for a fixed amount of beam current spilled. Low-energy components of the beam are deflected through larger angles by the first SY bending magnets (LA-BM-1, -2) and thus produce different spill patterns in the vicinity of LA-LM-4. Activation-protect monitor LA-AP-4 is set to shut off the beam for spills above 50 nA from off-energy beam accelerated through module 42. From Fig. IX-5 we deduce that it will require 22 times as much spill (~1.1 μA) for low-energy components last accelerated through module 24. More uniform overall protection can be obtained by judicious placement of additional APs.

TABLE IX-I

STUDY OF BASIC RESPONSE OF LM SYSTEM USING A ^{60}CO SOURCE OF 37 mCi IN A FIXED GEOMETRY

Conditions	Values for k
Paint can filled with old scintillator (at least one year in the beam area)	1.6×10^{-24}
New, clean can, with no scintillator, using a phototube covered with old scintillator	1.8×10^{-26}
New, clean can, with no scintillator and a phototube wiped dry of scintillator	1.5×10^{-28}
Dipped, clean phototube in new scintillator and put in an empty, clean can	2.1×10^{-26}
New, clean can, filled with new scintillator	3.3×10^{-24}

Guard Rings

Amplifier systems have been constructed and installed by MP-4 for all nine of the secondary-emission guard-ring assemblies. Analog RICE channels have been acquired and computer monitoring will commence as soon as the cabling is complete. A hardware threshold detector is under development by MP-4 for inclusion in a hardwired fast-protect system to detect incorrectly steered beams.

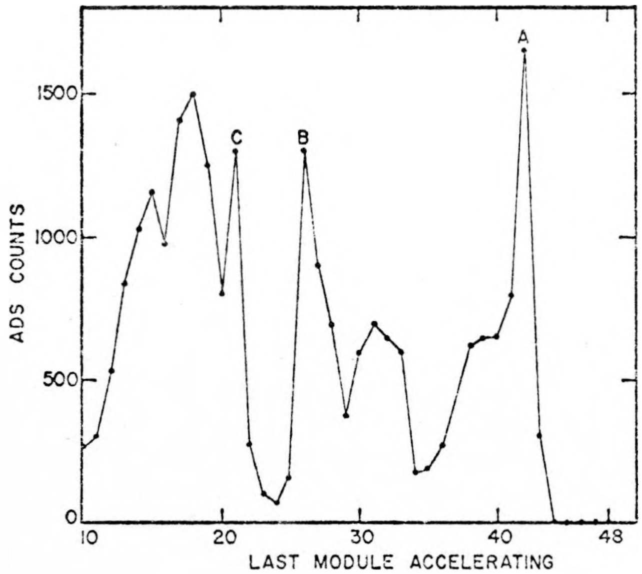

Fig. IX-5.
Response of LA-LM-4 to off-energy beams:
(A) Spill at the right-hand side of Line A pipe flange.
(B) Spill at the left-hand side of Line D pipe flange.
(C) Spill at the right-hand side of Line D pipe flange.

Beam-on-Target Monitors

A plan for implementing the beam-on-target (BOT) monitoring system has been devised and electronics modules have been ordered. Installation will occur in the next quarter. The BOT signals will be monitored for changes to detect transmission problems and the signals will also be made available to experimenters as a proton BOT monitor.

Vacuum Improvements

The vacuum system fast valve has received considerable attention this quarter. After about a six-week debugging period in which we were plagued by noise problems, we are now at a point where the valve and electronics are becoming more reliable. The valve has closed on three occasions when the vacuum in Line EPB, Line C, or the SY deteriorated. Measurements with an interval timer indicate that the valve closes in 36 ms, substantially faster than originally reported. A proposal for a more complete high-voltage and trigger module is under way. It will incorporate all safeguards in the ready circuits of appropriate valves. This will guarantee that all spark plugs are operational before valves can be opened and that we are protected from slow vacuum leaks, vacuum ruptures, and loss of ac power.

The delivery of the 10-cm fast-closing VAT valve has been delayed until mid-November. Trigger and control electronics have been ordered for this valve to provide a system capable of producing a vacuum seal in <25 ms after the pressure rises to 1.3 Pa at the sensor. This valve and control system will be installed in the SY next quarter.

Magnet Assembly

Coils were manufactured for two small C magnets for Exp. 200. The coils were varnish-impregnated by the Zia Co. A locating jig was also made for the Exp. 197 magnet, to expedite $\int$ B-dℓ measurements on the C-12V24/12 magnet.

The new magnet assembly facilities still lack the overhead crane and brazing hood. However, work is proceeding on some smaller magnet improvement tasks such as the 150-mm-bore SY quadrupole magnets.

Magnet Measurement

Mapping the first EPICS spectrometer magnet occupied most of the period. Altogether, 36 maps were taken, giving over 400 000 magnetic field measurements. The maps had to be taken from both sides of the magnet because of the curvature of the beam trajectory. There is provision for overlapping the two sets of maps by the reference positions of three steel dowel pins fitted for this purpose to the pole tips.

All the above mapping, including setup and pin-finding, was accomplished in a two-month period by the two-technician measurement section with some help from the experimenters.

Harmonic content and gradient measurements were processed for four WNR quadrupoles (three 4Q11/5s and one 3Q11/4).

For the WNR bending magnet 1L-BM-01 (measured in July), the mapper data was used to calculate the $\int B \cdot d\ell$ and effective length along a particle's trajectory at the radius of curvature of the magnet.

Beam Line Physics Computations

The 840 computer program (1133) which calculates beam emittance at the end of the linac was modified to acquire, directly, the necessary quadrupole fields by reading the currents in the magnets.

Some calculations of the heating in the Line A-direct beam stop were done assuming a beam current of 330 μA and a Gaussian beam distribution on a graphite disk with the end (r = 10 cm) held at a constant temperature.

Processing of the H^- slit data (measured September 10, 1976) to determine the beam emittance was continued. The emittance at LX-ST-01 measured with emittance data at LX-WS-05 and LX-WS-07 agreed well with each other and with the value measured by a different method in Line A-direct. When transported back to the linac, the phase-space orientation compared reasonably well with the measurement made using the wire scanners in Line A-direct.

REFERENCES

1. E. W. Hoffman, Los Alamos Scientific Laboratory, unpublished data (MP-13/EWH/A-76-19), September 20, 1976.

2. O. van Dyck, Los Alamos Scientific Laboratory, unpublished data (MP-13/OVD/A76-13), September 9, 1976.

X. LARGE-SPECTROMETER SYSTEM

Energetic Pion Channel and Spectrometers

Spectrometer Dipoles

Assembly of EA-BM-06 was completed during the past quarter. This work proceeded reasonably well except for a vacuum problem which occurred when we attempted to install the NMR probe. Partial disassembly of the magnet and rework of the sealing surface were required in order to obtain a reliable vacuum seal.

The first dipole magnet, EA-BM-05, was tested and mapped at three fields. Preliminary analysis of the maps indicates that the field in the uniform field region is constant to ± 1 part in 10^4. No measurable effects of the pole-tip mounting bolts were found. Analysis of the maps with MAPFIT and MOTER is under way.

Spectrometer Frame

The new concrete floor in the EPICS area was ground to a flatness of ± 2 mm over most of the area. A small portion of the old 2.5-m floor, which will be needed in the 120 to 135° region, still requires some jackhammer work to level it. The spectrometer frame modifications were completed and the frame was installed. The air pads and drive system have been installed in preparation for the first tests of the system which should begin next week.

A contract for the rigging necessary to install the dipoles in the spectrometer frame was signed by ERDA; we are now preparing to negotiate for a starting date of December 13, 1976. In order to start this job on time, we are counting on delivery of the mounting brackets, being fabricated at the Univ. of Texas at Austin, during the last week of November.

Spectrometer Quadrupoles

Some rework of the spectrometer quadrupoles EA-QM-01 through EA-QM-03 was required. The modifications included an improved alignment system for the coils and field clamps and boring out the field clamp to give a circular hole. It is expected that these changes will eliminate most of the sextupole and octupole components of the field which were observed in measurements made a year ago.

Scattering Chamber and Target Mechanism

We have assembled and tested the small temporary scattering chamber and target mechanism. Although the system is leaktight and the mechanisms work smoothly, the window deflects under vacuum loading somewhat more than anticipated and comes in contact with the target ladder. A new window of either thicker Mylar or sailcloth-backed Mylar must be fabricated to cure this defect.

Channel Operations

The EPICS channel was used for three experiments during the past quarter with no major downtime reported. Experiment 246 (π^+ scattering from several targets at 50 MeV) was run in its entirety. Experiment 265 received an additional 200-h run and was completed as well.

Experiment 245, (π^-,n) on ^{3}He and ^{4}He, was set up and received approximately one-half of the approved running time. This experiment has substantial support from MP-10. During the past summer, a superfluid helium target was refurbished and debugged. All of the detectors were fabricated and tested at Los Alamos. These detectors include dE/dX and E plastic scintillators which have 0.3-ns resolving time and 10% pulse-height resolution for 50-MeV tritons. Two delay-line chambers are also included in the setup. This experiment is now in the final stages of data-taking and first results were reported at the October meetings of the American Physical Society.

Plans for Improvements of Channel

Three improvements to the EPICS channel are planned. First, an air-actuated beam plug has been designed to be installed near FJ04. This new beam plug will eliminate the requirement that FJ03 be closed before cave entry and will simplify operations.

Second, a new NMR drive mechanism has been designed and is now in fabrication. This mechanism will allow for replacement of the NMR probes without breaking vacuum and will also cause less wear and tear on the probe cables. More reliable operation of the NMR drives is expected after installation of the new drives, which will most likely occur in September 1977.

Third, two new ion chambers are being fabricated at the Univ. of Colorado. These ion chambers are larger than the existing set allowing them to be located 2 m downstream from the scattering target. In order to calibrate the new chambers and to improve our knowledge of the beam composition, an additional run of the tuneup experiment has been scheduled for February and March 1977. We hope to get data at several energies between 70 and 150 MeV, which was impossible in the earlier run. We also hope to improve on the quality of the data over the whole energy region available at EPICS. Detailed plans for this tuneup are being made at the present time. Suggestions and comments of the users are invited.

Computing for EPICS

A decision has been made to procure a 9-track tape drive for the EPICS computer. This tape drive will be switchable in density between 800 and 1600 bpi. This tape drive increases the information density on tapes written at EPICS by a factor of 4 over the existing 7-track unit.

During the summer, a study group was convened at LAMPF to consider the data-acquisition and data-analysis problems. This study group recommended that we increase use of PDP-11s for analysis of data tapes. MP-10 has made an agreement with the UCLA group to jointly purchase a PDP-11/55 for data analysis. This machine will be located in the HRS counting house and will be equipped with 128k of core, fast-floating-point 9-track tape drives, and a 50-megabyte Diva disk. Up to half the time on this machine will be available for EPICS work. Delivery of this machine is expected in March of 1977 and will be left in this location and configuration for one year. At that time it is hoped that both groups will have enough funds to allow the machine to fission and that a dedicated analysis machine will be available both for EPICS and HRS.

High-Resolution Proton Spectrometer

HRS Systems and Chambers

The TOF trigger and particle-identification system has been checked out and provides excellent particle-type separation for protons, deuterons, tritons, and pions. The only problem encountered with the TOF system is a rather large count rate on the order of $\sim 10^5$/s (average) for the back (S5-S6) scintillators when the beam current is $\sim$50 nA. We have tried several schemes which avoid the use of these detectors and they prove quite satisfactory.

The beam-monitoring system for relative and absolute determinations has been expanded to provide a variety of cross checks for beam-current determination.

The scattering chamber sliding-seal driving mechanism has been upgraded and we are now able to drive the curtain under vacuum loading.

The quality of beam from the accelerator is substantially better than advertised according to our observation of the dispersed beam-on-target. We consistently observed during the first part of Cycle 10 a spot 2-mm wide and 2-cm high (base width). Since the vertical dispersion on the target is 20 cm/percent $\Delta p/p$, this implies $\Delta p/p \approx \pm 0.05$ from the accelerator. Therefore, targets used for HRS experiments can be substantially smaller than expected and the possibility exists that QM13-14 will not be needed to transport the beam to the beam dump. If this latter condition proves to be true and QM13-14 can be removed, only one scattering chamber configuration will be needed for most experiments.

Line C

Most of the mechanical assembly of Line C was completed before the end of the last quarter. Initial study of the characteristics of the line indicated that a procedure needed to be developed to prepare beam in Line X for simultaneous input to Lines B and C, and to insure that the beam entered Line C along its optic axis. Phosphors designated as LCTV1, LCTV3, and LCTV4 were installed at the entrance to LC-BM-03, between LC-BM-04 and LC-BM-05, and at the focus after LC-BM-05. The procedure which was developed and which proves to be quite reproducible is the following: Using the Line X wire scanners, the beam is optimized at LX-WS-11 and LB-WS-01 and centered on LC-TV-01. Then LC-BM-03 is used to simultaneously center the beam on LC-TV-03 and LC-TV-04. If this is not possible, then LC-BM-03 is used to center the beam on LC-TV-03, and then LC-BM-05 is slightly adjusted to center the beam on LC-TV-04. At this point, LC-QM-01 and LC-QM-02 are varied to check steering at LC-TV-04. If the beam steers, then LX-SM-04Y (and possibly LC-SM-01Y) is adjusted to eliminate vertical steering and LC-BM-03 is adjusted to eliminate horizontal steering. With steering removed, LC-BM-04 and LC-BM-05 may or may not require slight adjustments to center the beam on LC-TV-03 and LC-TV-04, respectively. Between LC-BM-05 and the target, slight steering is required by LC-SM-05Y and possibly by LC-SM-06X. The above procedure has been used several times and provides an excellent non-steering beam to the target in Area C.

Using pencil beams prepared with LX-ST-01-5 and the Line C beam scanners it was demonstrated that there was indeed a focus after LC-QM-02, and that LC-BM-04-5 had a resolving power >15 000 (80 keV, FWHM, for the pencil beam).

In order to match the spectrometer optics to those of Line C, it is necessary to insure that at the target the beam is horizontally narrow, is focused and dispersed vertically, and the twister rotates x and y through 90°. Transport calculations were done to find linear combinations of Line C quadrupoles which only affect significantly the appropriate transport matrix elements. It was found that linear combinations of (1) LC-QM-01-02 affect essentially only the focus; (2) LC-QM-03, -09, -11 affect essentially only the dispersion; and (3) LC-QM-04, -05, -06 (LC-QM-04 and LC-QM-08 are in series and LC-QM-05 and LC-QM-09 are in series) affect essentially only the twist. Using the twist/linear combination and observing the beam on a Pilot B scintillator in the scattering chamber, the twist was adjusted to be 90°. It was found that the twister is extremely sensitive to adjustment of these quadrupoles. A 1% change in any of the twister quadrupoles would destroy the twist by as much as 45°. With the twist adjusted to 90°, variations of LC-BM-04-05 caused near-perfect vertical deflection of the beam on the scintillator. Using the dispersion/linear combination, it was possible to adjust the dispersion to 20 cm/percent of $\Delta p/p$. This dispersion was verified by changing the fields in LC-BM-04-05 and observing a vertical deflection of the beam on target by 20 cm/percent $\Delta B/B$. Because of the excellent emittance of the accelerator beam, adjustment of the focus/linear combination was not tried since visual obsevations on the scintillator would not be sufficient to insure that the beam was in fact focused. It was necessary to use the HRS to optimize this parameter.

Spectrometer Construction

Mechanical construction of the HRS has been completed and the system is operational. The first spectrum was obtained on August 21, 1976. The 500-keV resolution was attributed to multiple coulomb scattering in the thick CH_2 target and the various windows used to isolate the scattering chamber from the spectrometer, as well as improper matching of the Line C and HRS optics. With proper matching of the optics we obtained 85-keV (FWHM) resolution for p + ^{209}Bi elastic scattering at 25° laboratory scattering angle near the end of the quarter (see Fig. X-1). The resolution of the Line C-HRS energy-loss system was fine tuned in a rather straightforward way by observing the resolution of the elastic peak and only adjusting the Line C focus on target via the linear combination of LC-QM-01-02 and adjustment of the HRS quadrupole HS-QM-01. This resolution may be improved further by fine tuning of the twister and the beam line dispersion. When the resolution was on the order of 200-keV, correlations between focal plane position (x) and θ, y, and ϕ were searched for using cuts on these coordinates as determined by the wire counters near the focal plane and no correlations were found at the 200-keV level, except, of course, the kinematic correlation.

This procedure will be repeated again with the improved resolution in the near future. It is significant that the 85-keV-resolution spectrum was obtained in ~15 min with 50 nA of full phase-space beam-on-target and full HRS solid angle.

Time-of-Flight System

The TOF system provides the trigger to the HRS computer signaling that a valid event has occurred and also provides information as to particle type. This system has been checked out and works quite well except that for beam currents on the order of 50 nA the singles count rates for the large rear scintillators S5 and S6 approach 10^6/s (average). This rate is essentially independent of whether or not a target is present in the scattering chamber, and our initial investigations indicate that most of these events are due to a continuum background of slow neutrons. We have tried several alternate schemes to provide the master trigger and particle identification which do not involve use of S5-S6, and these schemes appear to be quite satisfactory. One such scheme involves using a fast "or" from the BNL wire counters in place of the S5-S6 coincidence requirement and TOF between scintillators S3-S4 and the rf with 80-ns chopping. Another technique which appears satisfactory for most experiments is to use a thin scintillator after the second wire counter near the focal plane and generate the event gate by requiring a coincidence between this scintillator and S3-S4. The flight path between this scintillator and

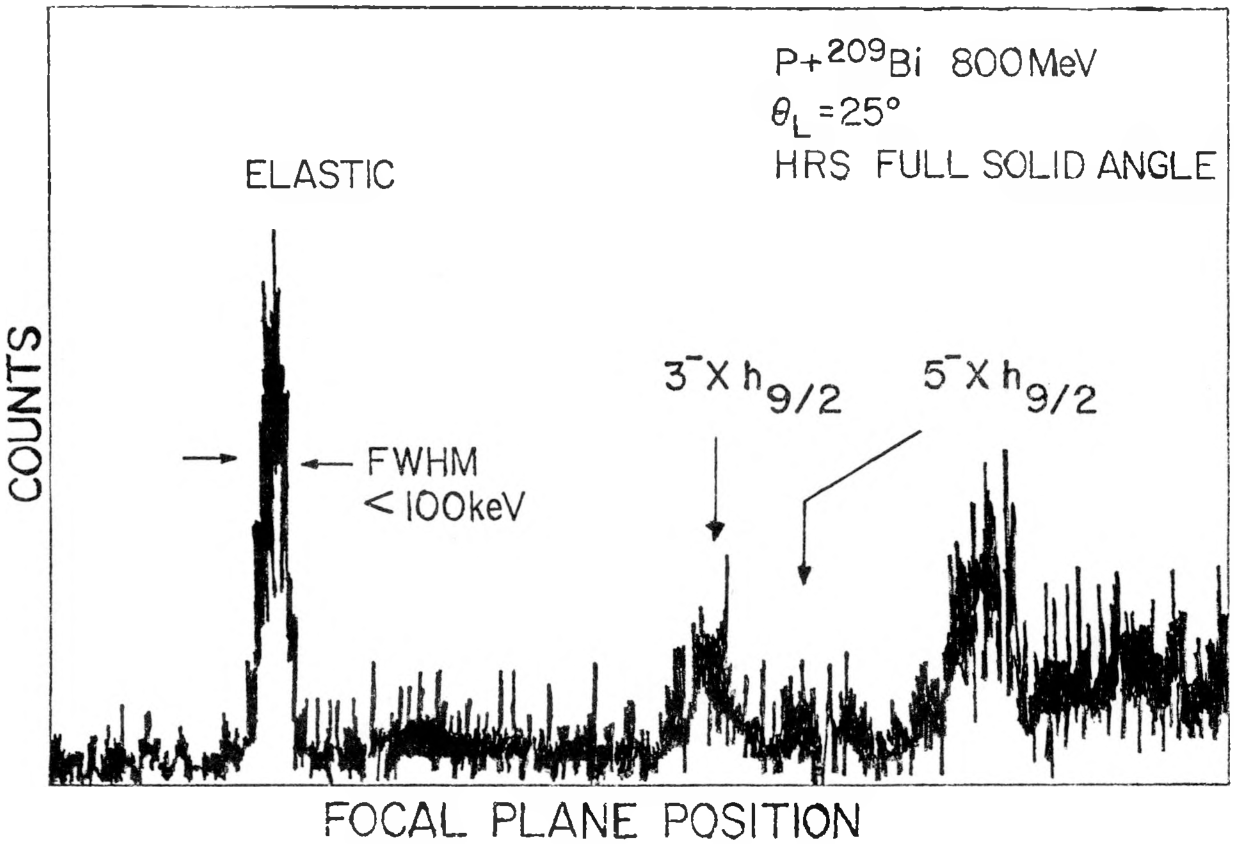

Fig. X-1.
Energy resolution obtained (85 keV FWHM) for p + ^{209}Bi elastic scattering at 25° laboratory scattering angle.

S3-S4 is ~2 m, and this distance is sufficient for particle-type identification via TOF. We have also demonstrated that dE/dX pulses in S3-S4 provide reasonable particle identification. We are presently discussing these and other alternatives for eliminating S5-S6 and should decide in favor of the most appropriate system in the near future.

Beam-Monitoring System

The results of any experiment depend critically upon knowledge of the beam current. Concern for having a number of independent techniques and cross checks to determine beam current has led to several additions to the Line C beam-monitoring system. Two ion chambers which operate at low pressure (1- to 100-mm Hg; Ar/CO_2 and He) have been installed inside the scattering chamber near the exit of the chamber. Two 4-detector counter telescopes have been installed around the scattering chamber to view the target at 45° and 129° with respect to the beam direction. Two large ion chambers are under construction for placement ~3 m after the scattering chamber. These additional beam-monitoring devices will supplement the toroid and split secondary emission monitor already in use. We are also considering the use of the water-filled beam dump as a Faraday cup.

Scattering Chamber

Initial problems with the ability to pull the sliding seal on the scattering chamber under vacuum loading have been solved with a beefing up of the curtain-drive mechanism. The electronics for coordinating the HRS movement with the curtain movement have been installed and the initial tests of changing scattering angle under vacuum indicate that the system operates as expected.

Vacuum System

Experience with the Line C and HRS vacuum systems has shown it desirable to operate the HRS and the scattering chamber at turbomolecular-pump rather than ion-pump vacuum. The TR between ion-pump vacuum and turbo-pump vacuum has been conveniently placed at the end of the twister where we have found that IP-06 and a turbo pump can coexist. In the future this transition will be done between LC-BM-04 and LC-BM-05.

XI. RESEARCH

Tests, Data Runs, and Analyses of Experiments

Studies of the Proton- and Pion-Induced Fission of Medium Mass Nuclides (Exp. 104) (Simon Fraser Univ.)

Extraction of the distributions in fission fragment mass and energy, from data on the distributions in tracklengths in mica exhibited by fragments from a given fissioning system, requires a knowledge of the tracklengths in mica for a range of ions of known mass and energy. Such calibration data have been obtained previously[1] in this laboratory, covering rather well the region of ion masses up to silver.

Analysis of preliminary fission fragment tracklength data obtained from our early experiments at LAMPF revealed, however, that improved calibration data would be needed in the mass region above silver. Much effort has been devoted in the time period covered by this report to the acquisition of such data, using an accelerated ^{127}I beam Rutherford-scattered off ^{197}Au target nuclei. As a result, there are now available new tracklength data for iodine ions in the fission fragment energy range, and also much improved data for gold ions of similar energies.

At the same time, scanning continued on micas from irradiations at LAMPF of 500- and 800-MeV protons incident on silver, gold, and uranium targets. The micas exposed in experiments conducted by the scattering array (or two-dimensional) technique are ~85% scanned. Scanning of micas exposed in sandwich (or three-dimensional) experiments is substantially less complete.

Experimental Techniques and Results

A self-supporting gold target foil (184 μg/cm^2) was irradiated with 132-MeV ^{127}I ions from the Chalk River tandem accelerator in collaboration with Dr. David Ward of Chalk River National Lab. (CRNL). Freshly cleaved sheets of mica were arranged around the periphery of a 10-cm-radius scattering chamber, such that the scattered projectiles or target nuclei were incident on the mica surface at a known angle of 30°. After irradiation the mica was etched with 48% HF at 293°K for 20 min and scanned with a microscope under a total magnification of 1000x.

The length of the tracks arriving at precisely known angles to the beam direction was measured and histograms were constructed. A fitting of these histograms using the method of least squares was made by computer, in order to determine the most probable tracklength from a given data histogram. The function fitted[1] was a Gaussian with a tailing towards shorter tracklengths:

For $R < R_{max} - T^2$

$$P(R) = P_{max} \exp[T^2(2R - 2R_{max} + T^2)/2\rho^2]$$

For $R \geq R_{max} - T^2$

$$P(R) = P_{max} \exp[-(R - R_{max})^2/2\rho^2]$$

where P_{max} is the maximum height of the distribution

R_{max} is the corresponding tracklength value

ρ_{max} is the width of the Gaussian (ρ = FWHM/2.355) and

T_{max} is a tailing parameter

Figures XI-1 and XI-2 give some examples of the histograms and fitted curves. The number of tracks of a particular tracklength (in arbitrary units) is shown for gold (Fig. XI-1) and iodine (Fig. XI-2) at 57° to the beam direction.

For iodine, ρ was found to be (0.10 ± 0.02) mg/cm^2 and T = (0.13 ± 0.03) mg/cm^2.

In the case of gold, ρ = (0.13 ± 0.02) mg/cm^2 and T = (0.15 ± 0.07) mg/cm^2. We can compare these results with the values found previously by Blok *et al.*[1] For the same fitted function applied to all the ions studied, they determined ρ = (0.08 ± 0.01) mg/cm^2 and T = (0.077 ± 0.02) mg/cm^2. Given that the experimental conditions were completely different (different projectiles, energy, target, scattering chamber) and the scanning was carried out by a different person, we consider the present results to be in reasonable agreement with the previous values. Thus to a good approximation the range distributions of all the ions studied can still be represented by the same width and tailing parameters.

The tracklength values corresponding to the function maxima were then taken as the most probable tracklength values and corrected for the 30° angle of

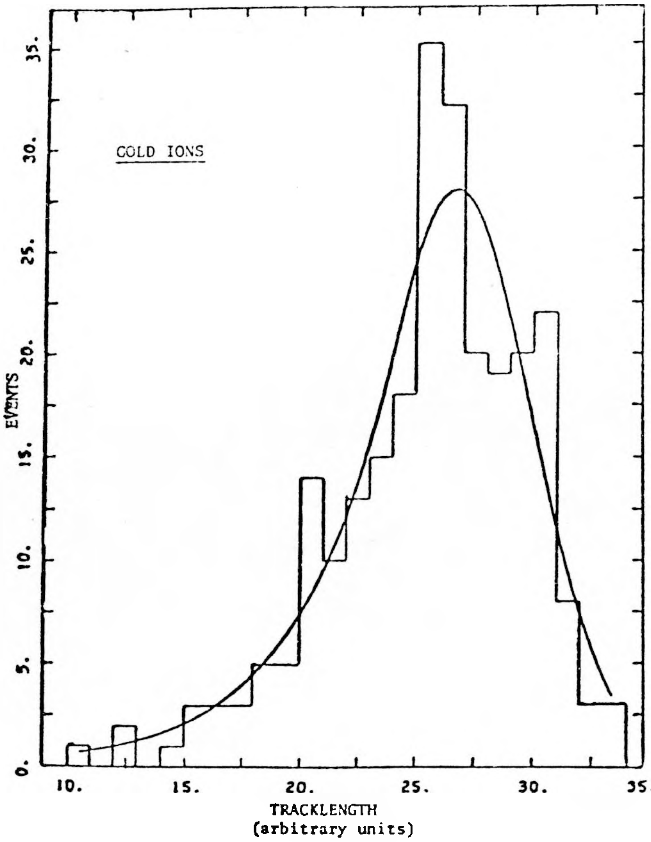

Fig. XI-1.
Comparison of histogram data and fitted curves for gold ions.

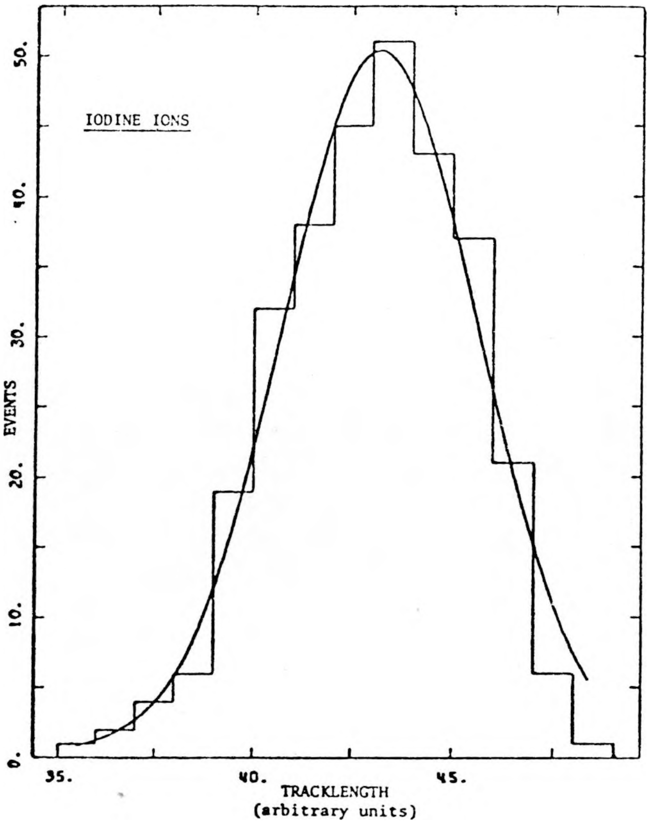

Fig. XI-2.
Comparison of histogram data and fitted curves for iodine ions.

incidence onto the mica. The energies of the scattered ions were calculated via the conventional Rutherford scattering formula, and were not corrected for iodine ion energy loss in the gold target. (The energy loss of an iodine ion going through the whole target and then scattered at backward angles is 4% at worst.)

The variation with energy of the most probable tracklength is plotted on Fig. XI-3 together with the previous data.[1] As one can see, the data for gold and iodine fall at the expected general location and follow the general pattern of the other curves determined by Blok *et al.*[1] We are planning to compare our results in detail with the same general function for most probable tracklength as a function of energy (shown by the solid curves) which was used by these authors. From a comparison of the previously calculated solid curve with the present data for gold ions, agreement is seen to be poor; parameter modification or a change in functional form may be necessary.

Parity Violation in p-He Scattering at 15 MeV (Exp. 137A) (LASL, Univ. of Illinois)

As part of a continuing program to search for the weak interaction in N-N scattering, we have followed up the improved limits on p-p and p-d scattering reported last quarter with a run on p-He scattering. The experiment involves a longitudinally polarized proton beam with rapidly reversing helicity incident on a gas target. By detecting scattered particles, we hope to detect a difference in the cross section for the two helicities of the order of 10^{-7} which would indicate a parity violation. Besides the basic problem of adequate statistics, the experiment

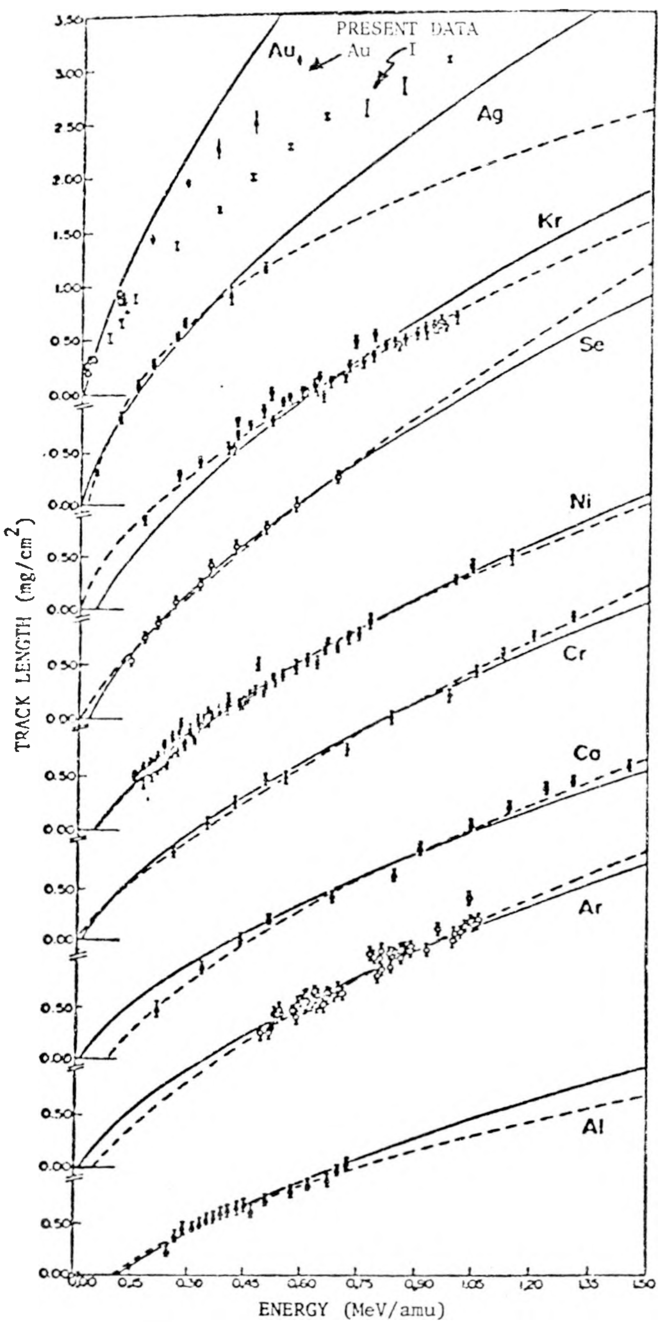

Fig. XI-3.
Energy dependence of the most probable track-length for various elements. Previous data are from Blok et al.[1]

demands sophisticated control of systematic errors. We have observed an asymmetry in p-He scattering of 8×10^{-7} but will need to make further study of our systematic errors before the result can be stated to be a parity violation.

In addition, our group is beginning to transfer the technology and expertise which we have developed to a similar experiment which is scheduled for LAMPF next spring.

Precision Measurement of the Decay Rate for the Dalitz Decay Mode of the π^0 Meson (Exp. 221)
(LASL, Arizona State Univ.)

During this period, Exp. 221 was set up in P³-West and two short test runs have been completed. The object of Exp. 221 is to measure the Dalitz decay branch ratio of the π^0 meson to an accuracy of 1%. The bulk of the effort in the test runs was aimed at reducing background rates and checking out the performance of the apparatus. Major revisions in the beam collimator walls, including using a larger opening and thicker collimator walls, reduced backgrounds substantially. In addition, a second hodoscope bank reduces the sensitivity to neutrons and soft photons.

Final revisions will be completed by the start of Cycle 10 and the data taking will occur in Cycles 10 and 11.

Study of the (π^-,n) and (π,πp) Reactions in ^{3,4}He and Other Nuclei by Detecting Recoiling Deuterons and Tritons (Exp. 245)
(LASL, New Mexico State Univ., Univ. of Virginia, Univ. of Texas at Austin, Florida A&M Univ.)

The experimental setup of this experiment consists of a plastic scintillator counter, a superfluid helium cryostat for liquid ^{3}He and ^{4}He targets, and a beam monitoring system. The experiment uses the pion beam of the EPICS channel and it is designed to be compatible with the arrangements for installing the EPICS spectrometer.

The detector for this experiment was specially constructed, and in the design we strived for large solid angle (100 msr and 35° acceptance in the reaction plane) and good performance with respect to E, ΔE, and TOF measurements. The design goals were well met giving, for instance, a resolution of ~4% or less in E, ~9% or less in ΔE, and ≈250 ps in TOF for

40-MeV deuterons. This allows for a clean identification of protons, deuterons, and tritons in the energy range $E_p \approx$ 30 to 150 MeV (somewhat higher energies for deuterons and tritons).

The cryostat was provided by the Univ. of Virginia group and rebuilt to fit this experiment. The target shells, for instance, had to be made larger (12.5 by 12.5 cm^2 in area and 0.65-cm thick) and can now take half the normal EPICS beam spot size.

Data on our experiment have been taken during October 1976 (Cycles 9 and 10), with some preliminary runs in September (Cycle 8). From the partial on-line analysis of the data, we know that the experiment is providing good quality data for the (π^-,n) reaction. From the achievements obtained, we project that the remaining beam time in Cycle 11 will enable us to accomplish the goals of this experiment. The goals were to provide the first comprehensive data on the (π,n) reaction, i.e., extended angular distributions ($\theta \approx$ 25 to 155°) at several incident energies covering the 3,3-resonance region (E_π = 50 to 300 MeV).

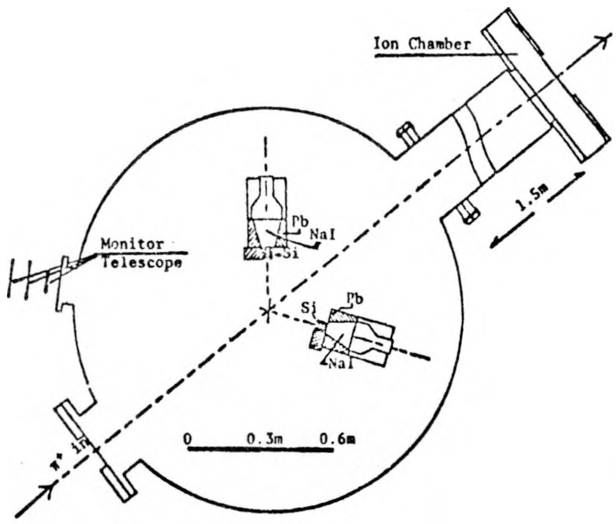

Fig. XI-4.
Schematic of experimental setup for Exp. 35.

Cluster Effects in Nuclear Pion Capture (Exp. 35)
(Univ. of Virginia, Florida State Univ.)

This experiment is a generalization of the $(\pi^+,2p)$ experiments that have been carried out by a number of investigators.[2] In a run just completed at LAMPF, π^+ of 100 MeV and 150 MeV penetrated targets of ^7Li, ^{12}C, and ^{181}Ta. The charged-particle pairs emitted by the target were identified according to the mass and charge of their constituents and their energy was measured. The beam from the LEP channel at LAMPF entered the 1.8-m SREL scattering chamber through a 0.1-mm Mylar window and was focused on a 2.5- by 10.0-cm target T, the inclination of which could be varied according to the position of the two particle identifiers (see Fig. XI-4). Each of these identifiers consisted of three 400-mm^2 silicon surface barrier detectors (0.2-mm, 0.5-mm, and 1.0-mm thick) followed by a cone-shaped 10-cm-thick NaI (T1) detector. The angle under which the identifiers viewed the target could be varied from 45°, with respect to the beam direction, to 130°. Most of our measurements were taken at angles of 60° and 98° respectively for the two detectors, corresponding to the two-body kinematics for the reaction $\pi^+ + {}^2H \rightarrow p + p$, for which the cross section for p,p (as well as for p,d and p,^{3}He) can be expected to be largest. The first run of the experiment has just been completed and the analysis of the data has begun. While it is too early to present conclusive results, the following qualitative observations were made:

1) The in-flight absorption of π^+ is strongly dominated by the $(\pi^+,2p)$ mechanism. This is in contrast to π^- absorption from rest where significant cluster effects were observed.[3,4]

2) Proton-deuteron events were observed with a cross section of ~10 to 15% of the 2p cross section. These events, however, seem to possess no well-defined kinematics making it appear that the deuterons were the result of neutron pickup by the outgoing protons from the $(\pi^+,2p)$ reaction. This is the first observation ever reported of the reaction $(\pi,p+d)$.

3) One of the aims of the experiment was to search for (p,^{3}He) pairs which are the charge conjugate of the (n,^{3}H) pairs found by Lee *et al.*[4] in the corresponding π^- absorption experiment. A few (p,^{3}He) pairs were found in ^7Li with a kinematics that indicates that they were the result of π^+ absorption in a nuclear α-cluster. In the other elements (carbon, tantalum), (p,^{3}He) events were extremely rare and showed no well-defined kinematic relationship between the proton and the ^{3}He.

4) We searched for the two-body break-up reaction $\pi^+ + {}^7Li \rightarrow {}^3He + {}^4He$ without finding any evidence for it.

5) We measured inclusive particle-production cross sections for protons, deuterons, tritons, ^3He and ^4He in ^7Li, ^{12}C, Ca, and ^{181}Ta at angles between 45° and 130°.

6) The most interesting result of our experiment was the observation that the knock-out reaction $(\pi^+, \pi^+ + p)$ in carbon leads to a well-defined final state of the residual nucleus. Figure XI-5 shows a scatter plot of the energies in the two arms of the spectrometer (T_1 vs T_2) when 100-MeV π^+ interact with a ^{12}C target.

This plot, in which the particles were not identified, is dominated by $(\pi^+,2p)$ events which cluster along the kinematic boundary and which fill the interior uniformly. In the lower left-hand corner, a band is visible which indicates that there are particle pairs which share a smaller but well-defined amount of energy. Figure XI-6 shows the events that remain if in one arm only pions and in the other only protons are accepted, indicating that the band is due to the reaction $\pi^+ + {}^{12}C \rightarrow \pi^+ + p + {}^{11}B$.

Since we consider the observation of this (π^+,π^+p) reaction the most significant result of our experiment, we are initially concentrating our efforts on the analysis of that part of our data that is pertinent to it.

Figure XI-7 shows the missing-mass distribution for the residual nucleus together with a level diagram of ^{11}B. Within the accuracy of our calibration, the residual nucleus can be in one or several of the particle stable states of ^{11}B.

Figure XI-8 shows the momentum distribution in the c.m. system of the residual nucleus indicating that a substantial momentum transfer takes place in the interaction.

Figure XI-9 shows a distribution of the recoil angles. Further analysis and interpretation of our results is being carried out in cooperation with Profs. J. Noble and H. J. Weber of the Univ. of Virginia.

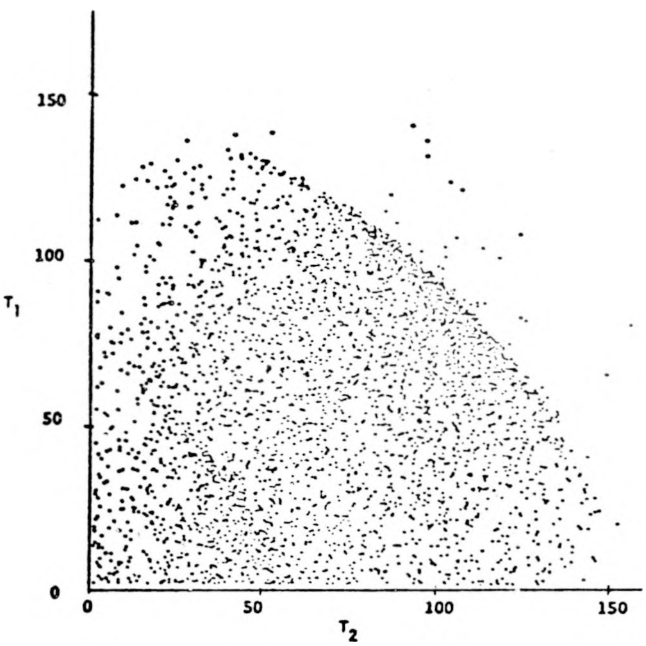

Fig. XI-5.
Scatter plot of the energies in the two arms of the spectrometer T_1 vs T_2 with no particle identification.

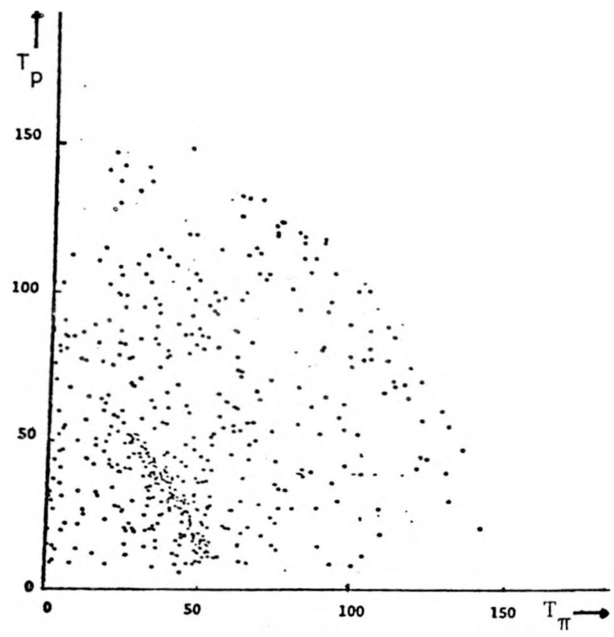

Fig. XI-6.
Scatter plot of energies of pion and proton events only.

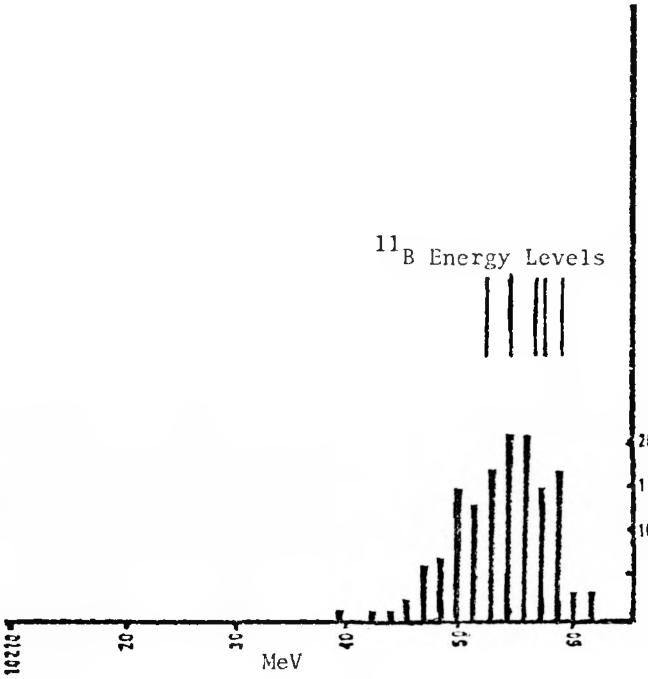

Fig. XI-7.
Missing-mass distribution for the residual nucleus, and the ^{11}B energy levels.

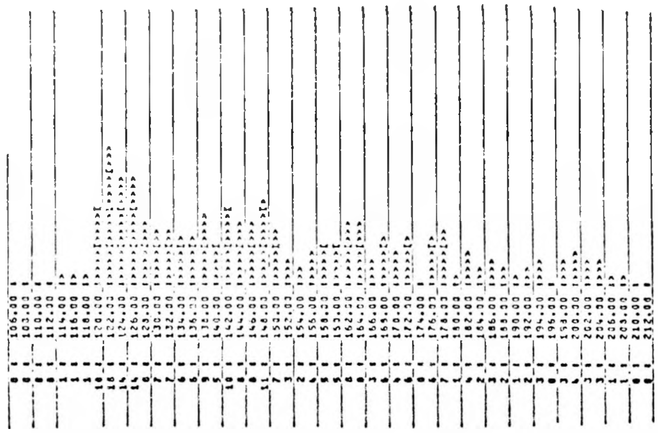

Fig. XI-8.
Recoil momentum distribution of the residual nucleus (MeV/c).

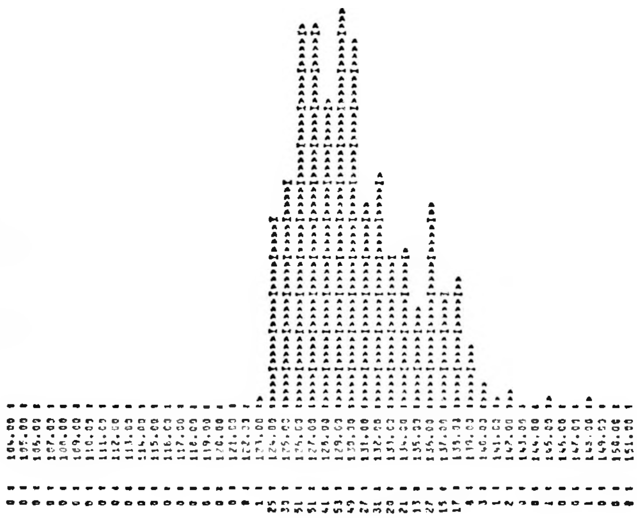

Fig. XI-9.
Angular distribution of recoil momenta in the c.m. frame.

An Investigation of the Reaction ($\pi^+,\pi^+ + p$) (Exp. 299) (Univ. of Virginia)

Monitoring of the Pion Flux

Beam Profile Monitoring

During our recent run of Exp. 35, we determined the beam profile and the centering of the beam on the target by moving the target across the beam by remote control and monitoring the count rate in our detectors.

While this method is completely adequate, it is rather time consuming and we plan to use one of the wire chamber beam profile monitors available at LAMPF for the original setup of the beam. During the experiment we will occasionally sweep the beam across the target by varying the current in the fourth bending magnet. This will allow us to check if the beam profile and the beam position have retained their optimal values.

Intensity Monitoring

The relative beam intensity will, as in Exp. 35, be monitored with a scattering monitor telescope viewing the target under a fixed backward angle and an ionization chamber several feet behind the target.

The absolute pion flux will be determined by calibrating the scattering monitor with a pion beam of intensity that has been reduced to the point where a scintillation counter telescope can be placed directly in the beam.

A Precision Measurement of the π^- - π^0 Mass Difference (Exp. 190) (Univ. of Virginia)

This experiment was accepted for a run at the LEP channel with the provision that its feasibility be demonstrated through a measurement of the background count rate in a detector of the design to be used in the experiment. We have in the meantime carried out such a measurement and report here its results:

Experimental Set-up and Procedure

As a detector we used a strip of plastic scintillator Pilot B of 50-cm length, 3.8-cm width, and 6-mm thickness that was viewed from either end by an EMI photomultiplier tube. The two tubes were used in coincidence with a time resolution of 9 ns. We calibrated the discriminators for the two phototubes with the known Compton edge of a ^{137}Cs source. This allowed us later, during the actual measurement, to set the discriminators to the desired threshold. We then mounted the counter assembly in the position in which it will be used during the actual experiment. In this position we measured the count rate as a function of the minimum accepted energy using the previously established calibration of the discriminators. We assumed that the measured count rate was all beam related and made no effort to gate our counters on except during the beam pulses. Our measured background rate constitutes, therefore, an upper limit that might be reduced somewhat through the use of a beam gate. During these measurements, the machine was running with a proton beam of 70 to 100 μA. The first half of the LEP channel was tuned for π^+ and the second for π^-. (A double-charge-exchange experiment was run at the time.) During the actual experiment, the channel will be set for π^-, which will result in a lower background rate since the main neutron background is expected to have come from protons that were stopped in the middle of the pion channel. (Our counter was mounted at the midchannel height of the LEP.)

Results and Conclusions

Figure XI-10 shows the background count rate measured as a function of the threshold energy under these conditions. We have in our original proposal estimated that the signal count rate in our experiment will be of the order of 2 counts/s in a 15- by 40-cm² detector.

The neutron energy to be measured is 420 keV; a threshold of 150 keV will give us adequate sensitivity and would, as Figure XI-10 shows, result in a background count rate of 500 counts/s in a detector of 190-cm² area. In the 600-cm² detector that we intend to use, the background rate will thus be ~1600 counts/s. These 1600 counts will, however, be evenly spread over the 5-ns interval between micropulses. Assuming a total width of 1.5 ns for the TOF distribution of the monoenergetic neutrons, 480 background events/s will be accumulated as background distributed over the line width. This is to be compared with two signal counts. After one 8-h shift, 58 000 signal counts and 1.4×10^7 background counts will have been accumulated in a time interval equal to the expected line width. The accuracy of the determination of the line center under these conditions can be estimated as follows:

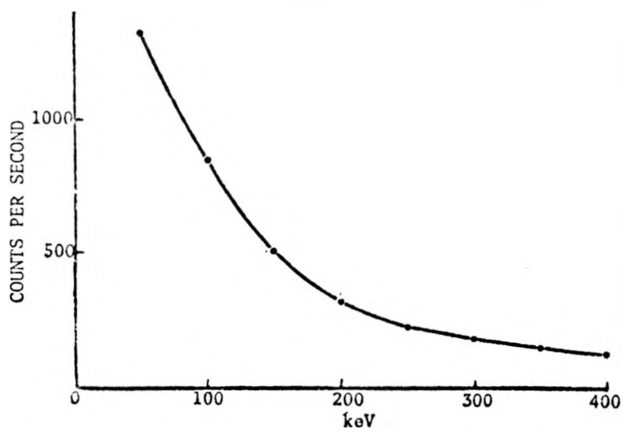

Fig. XI-10.
Background count rate as a function of threshold energy.

Let τ_i be the value of the TOF corresponding to a certain channel (bin) in the TOF distribution, and let n_i be the number of counts in this channel after background subtraction. The mean of the TOF distribution is then given by

$$<\tau> = \bar{\tau} = \Sigma n_i \tau_i / \Sigma n_i$$

The variance of this mean is given by

$$\Delta\bar{\tau} = \sqrt{\Sigma(\tau_i - \bar{\tau})^2 \Delta n_i^2 / \Sigma n_i}$$

where Δn_i is the uncertainty of the number of counts in the i-th channel. In our case the number of signal counts is small compared to the number of background counts so that the latter number — which is independent of i — determines the error margin $\Delta n_i = \Delta n$.

Using $N_s^2 = \sum_i^m n_i$ for the total number of signal counts (after background subtraction) and considering that $\Delta n^2 = \bar{\nu}$ is the average number of (background) counts per channel we get

$$\Delta\bar{\tau} = (\sqrt{\bar{\nu}}/N_s) \sqrt{\Sigma(\tau_i - \bar{\tau})^2} .$$

Assuming a Gaussian shape, we can express this in terms of the variance σ of the TOF distribution

$$\sigma = \sqrt{\sum_1^m (\tau_i - \bar{\tau})^2 / m}$$

$$\Delta\bar{\tau} = \sqrt{\bar{\nu}}/N_s \cdot \sigma \sqrt{m} = (\sqrt{\bar{\nu} m}/N_s)\sigma = \sqrt{N_b}/N_s)\sigma$$

where N_b is the total number of (background) counts under the line in the TOF distribution.

Putting in the numbers obtained above for an 8-h shift and assuming $\sigma = 0.75$ ns, we obtain

$$\Delta\bar{\tau} = (\sqrt{1.4 * 10^7}/58\,000) \cdot 0.75 \approx 0.05 \text{ ns} .$$

This estimate shows that the accuracy of our experiment is not likely to be limited by statistical but by systematic errors.

In view of the fact that a one-shift run in at least two positions of the counter assembly is needed, we are requesting a total of 20 shifts of prime time. This should be broken into several segments to allow for the study and elimination of systematical errors.

Studies of π^+ Scattering at 50 MeV from Light Nuclei (Exp. 246)
(Carnegie-Mellon Univ., LASL, Univ. of Virginia, Univ. of Colorado, New Mexico State Univ.)

Experiment 246 was successfully completed during beam time received on the EPICS channel in July and August. Angular distributions for elastically scattered 50-MeV π^+ were obtained for targets of ^6Li, ^7Li, ^{12}C, ^{13}C, ^{16}O, ^{28}Si, and ^{56}Fe in the angular range from 25 to 145°. Statistical accuracies of >5% were obtained for all cases with >3% statistics being achieved for the detailed comparisons of the carbon and lithium isotopes. We were also able to obtain angular distributions for scattering to the first excited (2^+) states for ^{12}C and ^{28}Si. Excitation of these states was apparent in the angular range of 30 to 145° for ^{12}C and 90 to 145° for ^{28}Si.

Although final analysis of the data is still in progress, a preliminary analysis shows that the prominent minimum, appearing at ~65° in our earlier measurements of elastic pion scattering from ^{12}C and attributed to an interference between the s- and p-waves, remains fixed in angle as the mass of the target nucleus is varied. As that mass increases, the diffraction minimum moves forward in angle reaching ~110° in the case of iron while the interference minimum becomes less prominent, being little more than a shoulder for iron.

Nuclear Resonance Effects in Pionic Atoms (Exp. 195)
(LASL, Univ. of Mississippi, National Res. Council of Canada)

Results for palladium are final and have now been published.[5] These establish, for the first time, the predicted repulsive nature of the zero-energy P-wave pion-nucleus interaction at high Z. Furthermore, our results imply that the width of the pionic 3p level (which is *not* directly observable) is significantly less than the value predicted by a phenomenological pion-nucleus potential.

Results for other elements are not quite final, but we can say the following:

1) For cadmium, the errors are reduced considerably from our earlier work.[6] The strong interaction width and shift of the mixed-in

state is directly observable in this case, and the agreement with theoretical prediction is very good.

2) For samarium, our results agree with prediction using the pionic 4d shift and width given by the phenomenological potential.
3) For titanium, *no* effect was seen. This implies that the shift and width of the pionic 1S level differ significantly from the values given by the phenomenological potential.

Our results should be incorporated in any future phenomenological potential fit to the pionic atom data.

Chemical Effects in the Capture of Negative Mesons in Matter (Exp. 60)
(LASL, Princeton Univ., Tech. Univ. of Munich, Washington State Univ.)

Experiment 60 will conclude with a final run on the SMC during Cycle 11. The principal target systems investigated this year include: 1) metal oxides — filling out the series studied in 1974; 2) pure metals — complementing the oxide series and comparing with kaonic atom data; 3) alkali halides — completing the series begun in 1974; 4) deuterated and normal water and polyethylene — testing for isotope effects; and 5) chloro- and hydrochlorocarbon compounds — differentiating between intra- and intermolecular hydrogen transfer of the captured muon.

Preliminary results of our data analysis indicate the following principal conclusions:

- An isotope effect is observed for both water and polyethylene: the relative intensities of the members of the Lyman series decreases with increasing energy for the deuterated targets.
- A comparison of the Lyman spectra of alkali-halides in aqueous solution with solid targets shows a much stronger enhancement of the higher members for the anion than for the cation as well as a relatively higher capture probability. These results might indicate hydrogen transfer from the polar water molecule to the anion together with shielding of the cation by oxygen in the water.
- The higher members of the Lyman series for the pure metal targets show a very strong dependence. For the transition elements of the fourth period, this dependence is qualitatively similar to such related properties as melting point, binding energy, and atomic volume; however, the correlation is not very strong.
- Very slight differences among the relative intensities of the chlorine Lyman series were observed for $C\,Cl_4$, $CH_2\,Cl_2$, and $C\,Cl_4 + C_8\,H_{18}$, due possibly to inter- and intramolecular effects of the hydrogen presence (transfer ?). These experiments will be repeated with fluorine compounds, which should show more significant effects, if present.

Study of the Photodetachment Spectrum of H^- in the Vicinity of 11 eV (Exp. 200)
(Univ. of New Mexico, LASL)

Experiment 200 uses colliding beams to search for a resonance. The beams are light from a nitrogen laser ($h\nu$ = 3.678 eV) and the 800-MeV H^- beam at LAMPF (γ = 1.853).

The very loosely bound H^- ion is broken up into a free electron and a hydrogen atom by photons when their energy exceeds 0.754 eV. A realistic calculation of the photodisintegration process in these 2-electron atoms is a challenging problem in "classical" quantum mechanics that has received considerable attention for more than a decade.[7] Activity in this field shows no sign of diminishing. Results from the application of some very sophisticated techniques to the problem have appeared during the last two years.[8,9] These calculations predict the occurrence of resonances in the photodisintegration cross section. A particularly prominent one is expected near 11 eV, just above the threshold of the channel leading to a free electron with the hydrogen atom left in its first excited state. This is classified as a "shape resonance," a phenomenon related to the serious delay suffered by the quantum mechanical wave of a free particle when it encounters, with just the right energy, a potential well that cannot bind it.

Just below this threshold, theories suggest the existence of a number of very narrow resonances, called Feshbach resonances.[8] These are generally thought to be too narrow to see in an experiment like ours. They arise from the formation of bound 2-electron state whose energy lies above the asymptotic state (free-electron, hydrogen atom in its ground state) but which decay only under the influence of perturbations.[10]

Generally, the various calculations, in the manner of variational methods, agree that the shape resonance will occur and what its energy will be, but the width and cross section, which depend upon the wave function itself, are not altogether settled.

Past experiments to look for the shape resonance have had mixed success. The resonance is clearly seen in electron scattering from hydrogen atoms,[11] but fails to be visible in the uv spectrum from an arc plasma.[12] It is suggested that local electric fields in the plasma quench the resonance by Stark-effect broadening.[13]

Figure XI-11 is a schematic diagram of the apparatus. The two beams intersect within a small scattering chamber. By varying the angle of intersection between them, the Doppler-shifted energy seen by the ion can be tuned from 1.8 to 11.5 eV. Photodetached electrons occupy nearly the same small phase space (<0.1 mr-mm) as the H^- beam and continue forward from the interaction region with the same velocity as the ions (β = 0.842). These electrons, which have an energy of 435 keV, are swept from the H^- beam by a magnetic field and brought to a solid-state detector.

Variation of the beam intersection angle is accomplished by a rotating mirror system. Mirror M1 accepts light from the entrance port of the vacuum chamber, M2 is located on the axis of rotation, and, finally, M3 directs the light into collision with the H^- beam. The laser and beam-forming optics are in a fixed position outside the vacuum. The mirror assembly is driven by a stepping motor through a 100:1 antibacklash gearbox. A 14-bit shaft angle encoder, coupled to the axle, telemeters the angle. A change of the least significant bit corresponds to a 0.384 mr or, near 11 eV, to a step of 1.5 meV. The assembly also has on it a bracket (not shown) with crossed wires that can be passed through the H^- beam so that a means internal to our apparatus of accurately surveying the geometry of the interaction region is available.

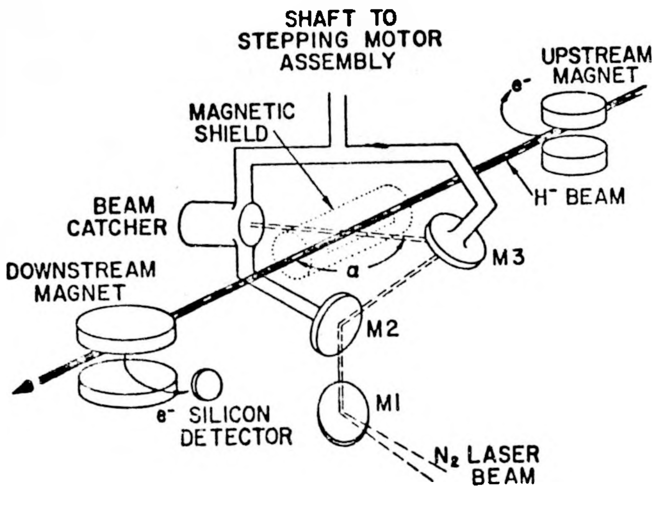

Fig. XI-11.
Schematic of colliding light beams apparatus used in Exp. 200.

The upstream magnet sweeps aside electrons stripped from H^- ions during their traversal of a long beam transport. The downstream magnet brings photodetached electrons to the detector, where they are identified both by their unique energy and their temporal relationship to the laser burst.

The interaction region is shielded from stray magnetic fields by the slotted Mu-metal cylinder. At the beam intersection point, the residual field is ~0.4 G, which at v = 0.856 c yields an electric field of 190 V/cm, considerably less than the field strength thought to be necessary to induce Stark-effect broadening of the shape resonance.[13]

The laser burst is so short and intense (~50 kW instantaneous) that quite often two or more electrons are detached (from different ions) during the same burst. The energy resolution of the detector enables us to correct the data for these occasions; peaks in the coincidence-gated pulse-height spectrum corresponding to the arrival of up to six electrons at once have been identified. However, this correction is rendered uncertain for some data points to the extent of 15% at the highest count rates owing to the statistics of the interaction between the two beams. The laser produces a burst of light 4 ns in duration, 60 times/s. The H^- beam usually arrives in pulses <1-ns long, separated by 40 ns (we were using the "chopped beam"). This microstructure is modulated by 500-μs beam gates repeated 120 times/s. The laser is adjusted to fire once sometime during every other beam gate, but the overlap of the two microstructures is left to chance. One expects a laser burst to overlap on H^- micropulse ~10% of the time. The multiplicity of electron events has been explicitly measured using the pulse-height spectra — but only for certain data points. For these points the correction is unambiguous, and the distribution of two and three electron events can be seen to obey Poisson statistics. Unfortunately, values of $\bar{n}$ (the average number of electrons) derived from 1) the multiplicity distribution and 2) one's expectation based on a 10% chance of overlap between the photon and H^- pulses, are found to disagree for certain data runs. The disagreement can be traced to variation in the H^- beam microstructure; occasionally two micropulses, 5 ns apart, appear at the basic 40-ns separation instead of only one. Therefore, those points at which no pulse-height spectrum was accumulated are displayed in Fig. XI-12 with increased error bars to indicate the additional uncertainty of a correction based on $\bar{n}$ alone.

Even after sweeping electrons from the H^- beam just upstream of the interaction region, gas stripping (at 10^{-5} Pa) within our apparatus produces an electron counting rate orders of magnitude greater than the photodetachment rate. The resulting accidental coincidence rate varies from 5% to 25% as we scan the cross section; accidentals have been subtracted at each data point.

The intensity of the laser light is continuously measured by allowing stray light to reach a photodiode. Pulses from this diode are digitized and the numbers are summed to provide an estimate of the integrated flux of photons during each data run. Periodic checks of the diode and "target empty" runs are made by inserting a calorimeter in the light beam. The H^- current is measured by stopping the beam in a Faraday cup.

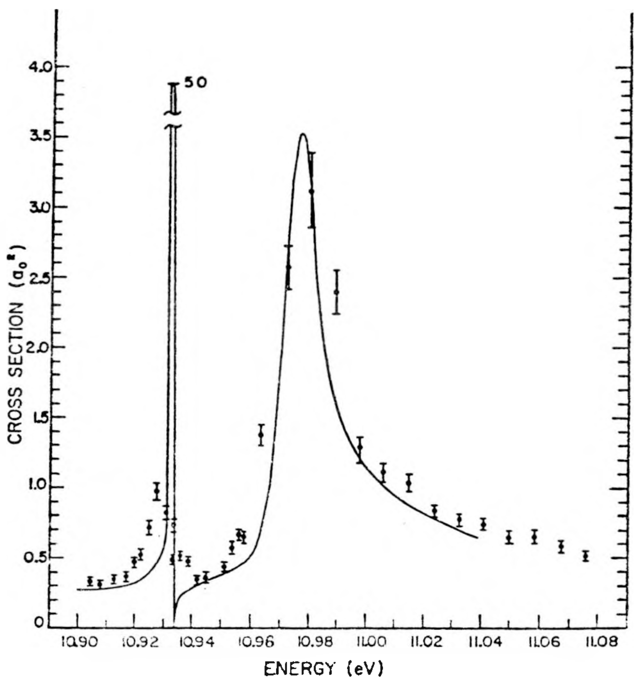

Fig. XI-12.
Comparison of data from Exp. 200 with published data.[9]

Figure XI-12 displays our data compared to the prediction of Reinhardt.[9] In this figure, the amplitude of our data is normalized to the low-energy continuum and the energy scale has been shifted by 33 meV but not dilated in order to align the low-energy peak with the Feshbach resonance. This shift is well within the error of our absolute energy calibration caused by uncertainty in the velocity of the H^- ions. The scale factor of the abscissa, which depends upon angle measurement, is relatively insensitive to variation in ion velocity.

The unexpected visibility of the sharp Feshbach resonance causes a representation of our experimental resolution function to appear in the raw data. This can be unfolded by quadrature from the shape-resonance spectrum to yield a measured width of 21 meV. Theoretical predictions have ranged from 27 to 14 meV.[8,9] The energy interval between the peaks is measured to be 47 meV, compared to 49 meV in, for example, Reinhardt's[9] prediction. With normalization at low energy, the data match the continuum at high energy. The Feshbach resonance has, to our knowledge, so far gone unreported. We regard these observations as persuasive evidence for the existence of these resonances in photoabsorption, but leave to future work the task of refining our preliminary measurement of cross sections and widths. The apparatus is also being modified to study the Stark-effect quenching of these structures. Calculations of the Stark broadening, which are just beginning,[13] provide a nice arena in which to test one's ability to predict the behavior of 2-electron atoms.

Theory

Calculations of the nuclear resonance effect for kaonic tin atoms were carried out. It was found that several tin isotopes are expected to show an effect, so that even in natural tin the 6→5 line is depressed. A recent experiment at Rutherford High Energy Lab.

(RHEL), carried out with LASL collaboration, compared ^{122}Sn with natural tin; the results are compatible with this calculation.

A calculation has been made of the effect of multiple coulomb scattering on the stopping of muons in inhomogeneous mixtures, following a suggestion by H. Daniel (Tech. Univ. of Munich) that this is an important effect. It was found that indeed for certain particle shapes and orientations, but independent of their size, the effect is very large; however, when one averages over the orientations of the particles, the effect is expected to become small though not negligible. To check this, a calculation for spherical particles was carried out. It shows the expected small effect.

Programming for Experiments

The analysis program for the parity experiment on the LASL Van de Graaff was modified to allow cuts to be made on scalers or DVMs before computing and punching means and errors. In this way, wild points are ignored and standard errors are reduced. A new program was written to combine means from several runs and produce correlations, overall means, and run-to-run time plots. Data from the September run were analyzed with this program.

An off-line analysis program for Exp. 221 was developed for use under DEC's operating system, RSX. This program decodes latches, ADCs, wire chamber TDCs, and scalers from data tapes, and prints event dumps and summary information on latches and scalars. It allows the user to write subroutines to compute other variables of interest for each event, and produces histograms and two-dimensional plots of any of these variables.

The program which summarizes LEEP requests from experiments was rewritten to use information from the S2K LEEP data base. (The old program used the GIRLS data base on the 7600.) For each item in LEEP, the program lists how many are in use and/or requested by the experiments of interest and compares these figures with the inventory.

Existing linear regression routines were modified and put together as an independent package of subroutines for use with data analysis or Monte Carlo codes. These routines differ from those in the CCF library in that cross products are accumulated as each event is processed, and the original data does not need to be saved for the final calculation of regression coefficients.

The General-Purpose Computing chapter of the LAMPF Users Handbook was rewritten to reflect CCF and LAMPF computing policies and procedures which have changed over the past two years.

REFERENCES

1. H. Blok, F. Hanappe, F. M. Kiely, B. D. Pate, and J. Péter, "Further Measurements of the Tracklengths of Heavy Ions in Mica," Nucl. Instrum. Meth. **119**, 307 (1974).
2. E. Arthur *et al.*, Phys. Rev. **C**11, 332 (1975).
3. P. P. Castleberry *et al.*, Phys. Lett. 34-B, 57 (1975).
4. D. Lee *et al.*, Nucl. Phys. **A**197, 106 (1972).
5. M. Leon, J. N. Bradbury, P.A.M. Gram, R. L. Hutson, M. E. Schillaci, C. K. Hargrove, and J. J. Reidy, "Observation of the Repulsive Nature of the P-Wave Pion-Nucleus Interaction at Large Z," Phys. Rev. Lett. **37**, 1135 (1976).
6. M. Leon, H. Daniel, and J. J. Reidy, "Observation of the E2 Nuclear Resonance Effect in Pionic Cadmium," Phys. Rev. Lett. **34**, 303 (1975).
7. J. Macek, Proc. Phys. Soc. Lond. **92**, 365 (1967).
8. C. D. Lin, Phys. Rev. Lett. **35**, 1150 (1975).
9. J. T. Broad and W. P. Reinhardt, to be published in Phys. Rev. A. (1976). We thank W. P. Reinhardt for discussing with us his results prior to publication.
10. R. G. Newton, ***Scattering Theory of Waves and Particles*** (McGraw-Hill, New York, 1966).
11. J. F. Williams and B. A. Willis, J. Phys. B, Atom. Moleic. Phys. **7**, L61 (1974).
12. W. R. Ott, J. Slater, J. Cooper, and G. Gieres, Phys. Rev. **A12**, 2009 (1975).
13. W. P. Reinhardt, private communication (1976).

XII. NUCLEAR CHEMISTRY

Nuclear Chemistry Laboratory

Counting Room Equipment

Fabrication has been completed and checkout partially completed on the control module and CAMAC interface for the new dual parameter Ge(Li)-Ge(Li) γ-γ coincidence system described previously. The heart of the system, a PDP-11/03-AA microcomputer, has been delivered and checked out. The rest of the required electronic components are on hand and the system is expected to be made operational during the next quarter.

The faulty Ge(Li) detector which was sent to a commercial firm for refurbishing has been returned and found to perform satisfactorily.

A master timer, which automatically updates itself via a receiver locked into the WWV radio station, has been ordered to drive the Time-of-Year slave clocks distributed throughout the laboratory.

Data-Acquisition System (DAS)

This quarter has seen heavy use of the PDP-11/40 for both data acquisition and further software development. The system has been used for Exps. 67 and 239 for automatic radioactivity counting, and for Exps. 111 and 150 for multichannel analyzer spectra recording, and for listing, plotting, and translating data tapes. The program to control a Canberra 8100 multichannel analyzer used with a 4-input mixer-router was extensively used for Exp. 150. The program to control the CAMAC scaler-timers had been considerably revised to accommodate several experiments. Some work has been done on installation of the new version of Program Q, but completion of the task has been delayed by the heavy use of the system for experiments. A Versatec Printer-Plotter has been ordered for the DAS to increase its efficiency and versatility.

Computer Programs

During this quarter the Beam Variation Correction (BVC) program, used for correcting for interrupted or nonuniform target irradiations, has been revised to increase its utility when run with a portable remote terminal. An HP-65 program has been written to evaluate the χ^2 function for nongrouped data. This was a necessary adjunct to the HP-65 library program (STAT 1-31A) since it is designed for use with grouped data only.

Pure-Water System

Installation of the air-free, reverse-osmosis/demineralizer water system has been completed. The system works well and provides very high purity water (resistivity >16 MΩ-cm) for the chemistry labs.

Pneumatic Rabbit System

Work has continued to the point of getting the branch of the rabbit system that runs from the Hot Cell to the Energetic Neutron Station at the A-6 beam stop into reliable operation. Many troubles were encountered, however. The original end-of-"snake" sensor switch failed, apparently due to shock damage to the boron nitride insulators. A replacement switch, built with alumina insulators, appears to be holding up well. A new, faster acting by-pass control valve in the Hot Cell was installed to replace a sluggish valve in order to insure proper logic operations. A time delay was installed on the in-terminal switch of the Hot Cell terminal in order to prevent resetting of the logic when the "rabbit" would bounce off the microswitch. A sonic proximity switch has been ordered to try out as a possible replacement for the microswitches that have been troublesome.

The devices for controlling and displaying the location of the end-of-the-"snake" or stopping location of the target carrier in the Energetic Neutron Station have been installed in the system control console. These devices enable the experimenter to remotely establish the location for target irradiation over a range of ~3000 mm, from a 135° position ahead of the beam stop to the 0° position behind the beam stop.

Components of the section of the WNR rabbit system that goes into the target crypt have been fabricated and are ready for assembly and bench-testing. These include the J-tube assembly, its drive mechanism, and the remotely removable head with its pneumatic locking device and radiation-resistant sensor switch.

Target Irradiation Facilities

The In-Air Target Box in the Nuclear Chemistry Cave at the end of proton Line B has suffered severe radiation damage during the past six months. This Lucite box, designed for low residual activation, has served us well as a proton station for on the order of 60 target irradiations for at least nine LAMPF experiments since early 1974. While gradual deterioration of the plastic has taken place from the start of its use, the intense, thick-target irradiations for Exp. 150 recently have caused extensive damage. An improved version of this targeting facility is being designed for fabrication in the near future. The plan is to install the new station during the December-January shutdown.

In order to continue obtaining pion irradiations on the P^3 channel for as many as six nuclear chemistry experiments during the rest of this year (while Exp. 90 is on P^3-East), and undoubtedly under future circumstances, a special targeting device has been designed, fabricated, and installed on the P^3-East output beam pipe. This device provides a thin-windowed target box to be inserted into the evacuated beam pipe such that targets, in air, can be irradiated in the focused pion beam.

Theoretical Support

The VEGAS Intranuclear Cascade Program

The treatment of stopped negative pions in nuclei is near completion. It is expected that cross sections of spallation products for stopped pions on copper will be available soon. Stopped pions on light nuclei are to be calculated as well. However, the evaporation code for light nuclei is inadequate because many mass excesses are missing since mass tables for light nuclei are generally not available. These mass tables are being updated by using mass excesses from the Garvey-Kelson[1] mass tables and, for nuclei not in these tables, by using those generated by the liquid drop model.[2] The latter are not expected to be precise for light nuclei, and hence not published, but should be adequate for the evaporation code.

The treatment of energetic pion reactions on nuclei with the VEGAS intranuclear cascade program has been improved in ways elaborated upon in previous progress reports. One manifestation of this improvement has been that much of the discrepancy between the measured and calculated proton spectrum at 90° for 235-MeV π^+ incident on nickel[3,4] has been removed. These spectra are compared in Fig. XII-1. The circles are the data,[3] and the solid histogram gives the calculated spectrum. The dashed histogram gives the spectrum due to pion absorption alone, which shows how sensitive this spectrum is to pion absorption. The shape and, roughly, the magnitude (to within 35%) agree for protons with energy <80 MeV. For more energetic protons, the measured spectrum falls off more rapidly than the calculated spectrum. However, a recently measured proton spectrum[5] for protons with energy >60 MeV for 220-MeV π^+ on ^{62}Ni indicates that the spectrum may not fall off this fast (squares in Fig. XII-1). Thus there may not be a severe discrepancy between the measured and calculated spectra even for these energetic protons.

The VEGAS intranuclear cascade code has been generalized to handle energetic heavy ion projectiles incident on nuclei. The projectile is treated simply: Fermi motion for the projectile nucleons is ignored and no cascades are allowed in the projectile. A calculation of ^{20}Ne at 250 MeV per nucleon impinging on uranium has been completed. The calculated

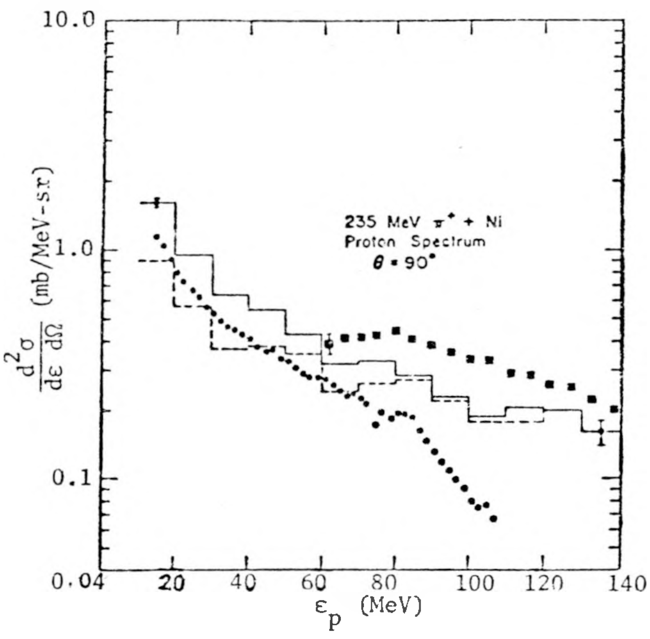

Fig. XII-1.
The proton spectrum for 235-MeV π^+ on nickel at 90°. The circles are the experimental data,[3] the solid histogram the result of an intranuclear cascade calculation,[4] and the dashed histogram the contribution to the calculated spectrum of pion absorption only. The squares constitute the more recently measured proton spectrum[5] for 220-MeV π^+ on ^{62}Ni.

proton spectrum for protons with intermediate energy ($\lesssim$150 MeV) are not expected to be affected much by the above simplifications. This proton spectrum at various angles is compared in Fig. XII-2 to the experimental proton spectrum[6] and that calculated in a relativistic 1-fluid hydrodynamical model.[7] The intranuclear cascade proton spectrum has roughly the right shape compared to the measured spectrum but is consistently lower in magnitude than both the experimental and hydrodynamical spectrum at all angles. At forward angles the discrepancy is the greatest, a factor of 3 to 6 times lower than the measured spectrum. This suggests that the heavy ion reaction is not solely a superposition of individual nucleon-nucleon collisions, and collective nuclear effects may be playing a role.

A compilation of reaction calculations using the VEGAS intranuclear cascade code is given in Table XII-I. The results of these calculations are stored on Hydraphotostore at the LASL Computing Center.

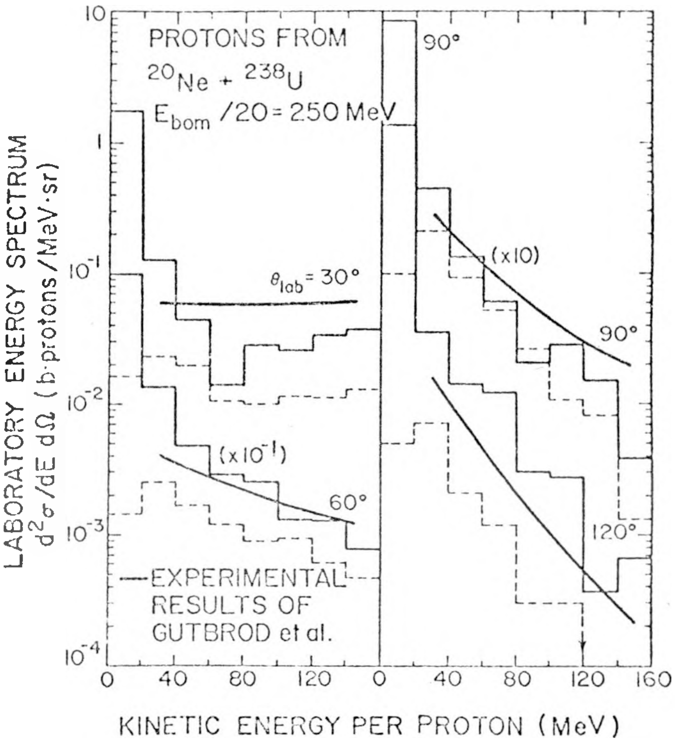

Fig. XII-2.

The proton spectrum for 5000-MeV ^{20}Ne colliding with ^{238}U. The solid line is the experimental spectrum,[6] the solid histogram is the calculated spectrum based on a relativistic 1-fluid hydrodynamical model,[7] and the dashed histogram is the calculated spectrum based on the VEGAS intranuclear cascade program.

TABLE XII-I

REACTIONS CALCULATED WITH THE VEGAS INTRANUCLEAR CASCADE PROGRAM

Projectile	Energy (MeV)	Target
p	500, 600, 630, 660, 700, 730	^{12}C
p	800	^{27}Al
p	800	$^{63,65}Cu$
p	50	^{64}Zn
p	177, 800	$^{90,96}Zr$
n	177	$^{90,96}Zr$
n,p	177	^{106}Ru
p	540	^{197}Au
$\pi^{\pm}$	100, 130, 180, 220	^{12}C
π^{+}	235	$^{24,25,26}Mg$
$\pi^{\pm}$	50, 100, 220, 300	^{27}Al
$\pi^{\pm}$	100, 200, 300	$^{28,29,30}Si$
π^{+}	235	$^{58,60}Ni$
$\pi^{\pm}$	100, 220	^{62}Ni
$\pi^{\pm}$	190	$^{63,65}Cu$
$\pi^{\pm}$	184	^{64}Zn
π^{+}	235	$^{107,109}Ag$
π^{-}	50	^{127}I
$\pi^{\pm}$	100	^{181}Ta
$\pi^{\pm}$	400	^{197}Au
^{20}Ne	5000	^{238}U

(p = proton, n = neutron.)

REFERENCES

1. G. T. Garvey, W. J. Gerace, R. L. Jaffe, I. Talmi, and I. Kelson, "Set of Nuclear-Mass Relations and Resultant Mass Tables," Rev. Mod. Phys. **41**, S1 (1969).

2. W. D. Meyers and W. J. Swiatecki, "Average Nuclear Properties," Ann. Phys. **55**, 395 (1969).

3. J. F. Amann, P. D. Barnes, M. Doss, S. A. Dytman, R. A. Eisenstein, J. Penkrot, and A. C. Thompson, "Particle-Emission Cross Sections for Pion Bombardment of Mg, Ni, and Ag at 235 MeV," Phys. Rev. Lett. **35**, 1066 (1975).

4. J. N. Ginocchio, submitted to Phys. Rev.

5. L. L. Rutledge, R. L. Burman, P. Gram, H. E. Jackson, S. B. Kaufman, L. Meyer-Schützmeister, R. P. Redwine, J. P. Schiffer, R. E. Segel, S. L. Tabor, S. E. Vigdor, J. N. Worthington, and M. A. Yates, "Proton Spectra from Pion-Induced Reactions," Bull. Am. Phys. Soc. **21**, 998 (1976).

6. H. H. Gutbrod, A. Sandoval, P. J. Johansen, A. M. Poskanzer, J. Gosset, W. G. Meyer, G. D. Westfall, and R. Stock, "Final State Interactions in the Production of Hydrogen and Helium Isotopes by Relativistic Heavy Ions on Uranium," Phys. Rev. Lett. **37**, 667 (1976).

7. A. A. Amsden, G. F. Bertsch, F. H. Harlow, and J. R. Nix, "Relativistic Hydrodynamic Theory of Heavy-Ion Collisions," Phys. Rev. Lett. **35**, 905 (1976).

XIII. 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.)

Pion Biomedical Program

Channel Operations

A new operating system for the biomed computer (RSX11-D, version 6.2) has been installed which makes the control system considerably more efficient. The handler for the magnet control/monitor function has been rewritten, and new surplus tape drives (IBM-729 Mod VI) have been obtained.

A mechanism and control logic for remotely inserting one of three wedges into the dispersion plane between BM-02 and BM-03 has been designed; installation should occur in mid-November. A new slab-target assembly has been installed which has a water-cooled stainless steel flange connection to the target mover. Although water cooling is not necessary at 100 μA of proton current, experience is needed in cooled targets for eventual operation above 200 μA. The new target also has the planes of pyrocarbon oriented transverse to the beam direction, which permits heat to be readily conducted to the large-area surfaces where radiative cooling is more efficient. The previous target, with planes oriented parallel to the beam direction, showed indications of high temperatures, delamination, and some disintegration.

The dynamic range shifter described in previous reports has performed with great reliability in a number of different experiments. The range shifter has been used successfully with several different beam tunes to produce isodose regions of up to 0.8 ℓ in volume, and with beam penetrations of between 10 and 27 g/cm^2. Using input from several radiobiology experiments, beams with large "isoeffect" volumes have also been produced. Range-shifter control is now possible through either an M6800 microprocessor or the biomed PDP-11/45 computer. This dual system provides added flexibility and ease of operation.

As a result of these successful experiments, it was decided to utilize the range shifter in the treatment of human head and neck tumors as part of the preclinical trials of pion radiotherapy. Several modifications have been planned to insure reproducibility and patient safety. New hardware and software are being designed which will provide the following features:

- hand-actuated brake for use in positioning the range shifter,
- computer monitoring of range-shifter motion to insure proper dose deliverance, and
- modification of the microprocessor memory (from EPROM to RAM) to allow modification of range-shifter motion for specific patient requirements.

Work has also begun on the design of a new range shifter which will be more compact yet more flexible than the present model. In addition, a PDP-11/03 microprocessor has been ordered which will provide more versatile control features.

Treatment Planning

The dose-model computer program BUCKET has been installed in the treatment planning code PIPLAN. This dose model first creates the dose distribution for a pencil beam. Final dose distributions are then obtained for real beams by adding pencil-beam distributions for individual particle trajectories recorded by MWPCs in the beam channel. In this way the actual phase space of the channel is duplicated. The model has also been upgraded in PIPLAN by the creation of separate pencil-beam libraries for pions, muons, and electrons.

Because both PIPLAN and BUCKET are large codes, it was necessary to "overlay" sections of PIPLAN as part of this installation. Since many useful features of BUCKET, such as stopping pion, LET, and "star product" distributions, could still not be included, the resolution of the pencil-beam libraries was reduced with a negligible loss in accuracy. The array space saved will be used for additional distributions of interest for microdosimetry and RBE studies.

New collimator and bolus models have been installed in PIPLAN. These models will enable the code to design treatment devices that can be fabricated easily using conventional methods. At present collimators and boluses are designed assuming a parallel-ray beam. These models will be upgraded to reflect the actual emittance of the treatment beams.

The dynamic range shifter in the beam channel is used to create dose distributions spread in depth during treatment. A range-shifter model has been installed in PIPLAN which uses a predefined function specifying the amount of range attenuation as a function of time. This function is generated independently for a particular beam tune by specifying the final depth-dose distribution desired. In the future this capability will be included in PIPLAN with the final depth-dose distribution tailored to the treatment volume of each patient.

To accommodate patient setup, additional geometry has been incorporated into the code to locate the patient and treatment volume in the beam channel and to independently move the peak dose distribution relative to the treatment volume. This is analogous to specifying the source-skin distance in x-ray therapy and using variable-energy x rays.

Specific dosimetry experiments were conducted to test PIPLAN dose predictions. Two such comparisons are shown in Fig. XIII-1. On the left is a

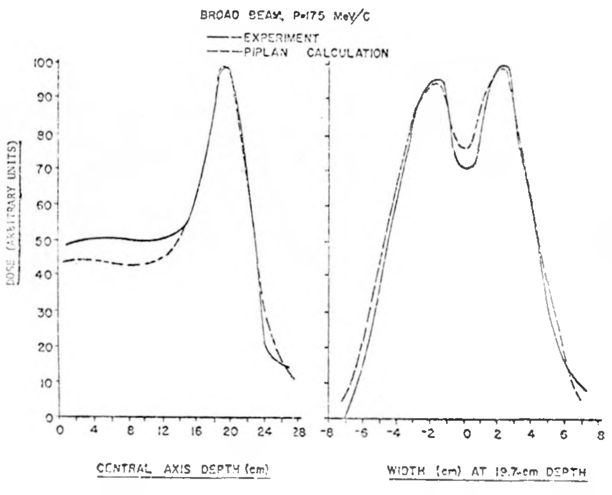

Fig. XIII-1.

Left: Depth-dose distribution in water phantom.

Right: Transverse dose distribution at 19.7-cm depth with 2-by 2-by 4-cm³ Teflon block centered at 14-cm depth.

depth-dose distribution in a uniform water phantom, showing the calculation to be slightly low in the plateau region. On the right is a transverse dose distribution at the normal peak-dose depth, but with a 2-by 2-by 4-cm^3 Teflon inhomogeneity centered at 14-cm depth. The calculation is somewhat high in the center. Additional experiments and calculations are being done to further test the code.

A collaborative effort has been established with Drs. Turner, Wright, and Hamm at ORNL to compare PIPLAN with their Monte Carlo program PION1. Both pencil beams and experimental results are being compared. Initial comparisons indicate some significant differences which are being investigated at this time. As mentioned above, the additional distributions being added in PIPLAN will greatly facilitate these comparisons and provide a better understanding of the effects of inhomogeneities.

Biomedical Experiments

Radiobiology with π^- (Exp. 236) (LASL)

Experiments have been performed to determine the RBE and OER for cells in culture exposed to both monoenergetic pions ($\Delta p/p$ = 2% rms) and broadened momentum (using the range shifter) beams. Cell survival as a function of dose has been studied as a function of depth for these various beams. Experiments using CHO, T-1, and V-79 cells, as well as the mouse skin system, have been performed. Some preliminary experiments on cell cycle stage sensitivity of CHO cells have also been performed.

In order to better understand the biological effects of pions and other high-LET particles, fundamental studies (experimental and theoretical) in radiobiology and radiological physics have been made. Some preliminary results have been obtained in the following areas:

- A dosimetry intercomparison between the LAMPF biomedical pion beam and the heavy ion beams at LBL-Bevatron has been made using a thimble-type tissue-equivalent ionization chamber. A detailed study of these data, including W-value corrections, stopping-power ratios, and kerma corrections, needs to be made before any final conclusions can be drawn.

- A new, high dose-rate ^{238}Pu alpha source has been built to study the effects of alpha particles on cells in culture.
- Theoretical investigations of the effect of radiation on cells have been made using the Katz model (single target, multihit) and the Kellerer-Rossi model (multitarget, single hit). Computer codes have been written to determine which model better fits the experimental data.

Study of ^{11}C and ^{13}N Production by π^- Irradiation of Carbon, Nitrogen, Oxygen, and Tissue for Radiotherapy Monitoring (Exp. 239) (LASL, Tel-Aviv Univ.)

The purpose of this research is to study the feasibility of using the β^+ activity of tissue as an *in vivo* pion-dose monitor or for imaging with a positron camera. The experimental work is now essentially complete. We have built lead collimators and chosen several 78-MeV beam tunes. An optimum combination was found with the use of a beam-profile monitor. Thick targets, consisting of many stacked slabs, were employed. Targets of graphite, boron nitride, water (in gelatin) and tissue-equivalent liquid were irradiated four or five times for 20 min each after each bombardment. Using shielded NaI detectors, a maximum of five slabs were counted.

Data processing is now under way. Preliminary results for ^{11}C activity in the water target are shown in Fig. XIII-2. There is a distinct peak in the ^{11}C activity which correlates very well with the position and width of the pion star dose. This result is quite encouraging in terms of an imaging application.

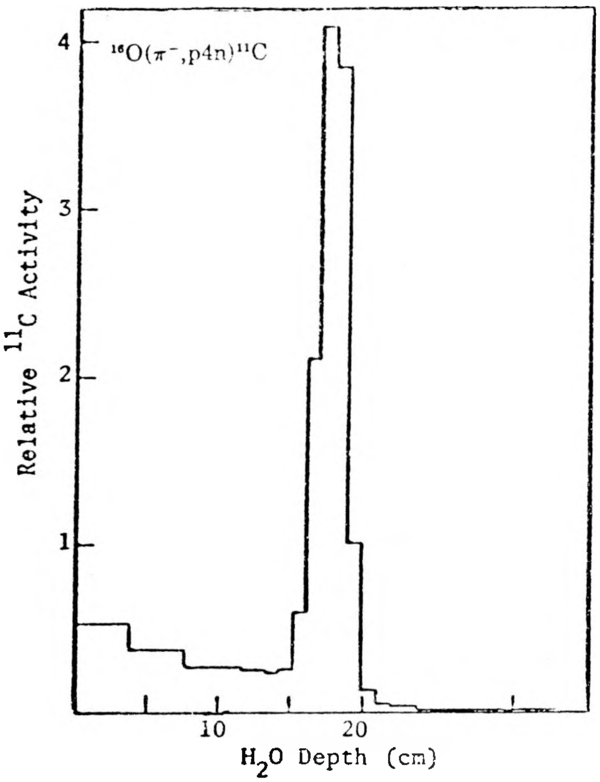

Fig. XIII-2.
Relative ^{11}C activity from water target at end of bombardment as a function of depth in the target (Exp. 239).

Biomed Beam Development (Exp. 270) (LASL)

A beam of approximate transverse dimensions 8 by 10 cm has been developed for radiotherapy on patients with deep-seated tumors. The initial tune was taken from a TRANSPORT beam calculation. Using MWPC data, derivatives of beam sizes and waist positions with respect to quadrupole magnet currents were determined experimentally. Adjustments were then made in the magnet currents for Q4 through Q8 to bring the beam to the desired size and phase-space orientation. Figure XIII-3 shows the uncollimated particle-flux distribution in the x-y plane perpendicular to the beam direction and at a location in the beam direction that corresponds to the maximum depth of the pions. Since the data are taken with MWPCs, no actual degrader is present. The numbers represent, as a power of 2, the relative numbers of particles through each square centimeter in the plane. The limits on the plot are ±20 cm in the x direction and ±15 cm in the y direction. The momentum spread of the beam is 2.1% rms $\Delta p/p$ at a central momentum of 163.4 MeV/c. For radiotherapy, the beam is spread in depth with the hydraulic range shifter. The 8- by 10-cm tune has also been optimized at a central momentum of 206 MeV/c for use on very deep tumors.

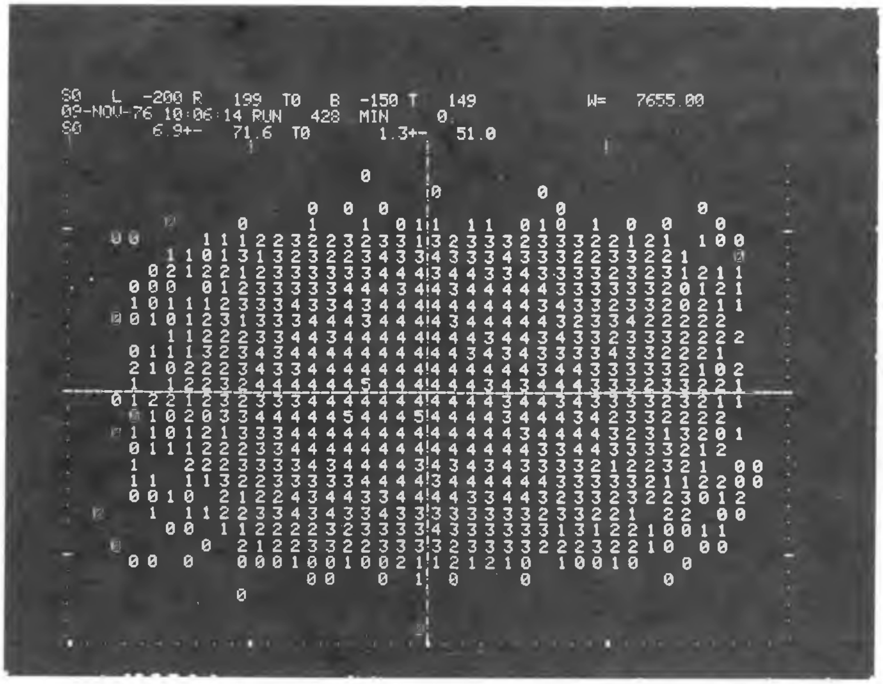

Fig. XIII-3.
Flux distribution in x-y plane at exit of channel. Scales ±20 cm in x, ±15 cm in y. Numbers are relative flux in powers of 2.

Early in this quarter the TOF system used for particle identification was operated. A 20- by 40- by 0.6-cm scintillator at the exit of the channel serves as a "start" signal. The "stop" signal comes from a similar 0.3-cm detector located just above the quadrupole magnet Q4. Measured contaminations at 163 MeV/c are 14% electrons and 9% muons. The TOF data are recorded along with each event measured with the MWPCs.

Beam tapes, as records of channel tunes, now include particle identification along with particle momentum and complete trajectory information. These data are the input to the treatment-planning code and represent the complexities of the beams without approximation.

Dosimetry (Exp. 271)
(Univ. of New Mexico, LASL)

In order to achieve the capability of treating larger and deeper seated tumors for the November/December patient-treatment cycle, extensive dosimetry measurements have been made on treatment beams with peak volumes of ~0.6 ℓ. Four new beam tunes developed through Exp. 270 have maximum penetration under treatment conditions of 10, 15, 21, and 27 g/cm^2. Cerrobend collimators are used to define reasonably flat beams in the plane perpendicular to the incident beam. Field sizes up to a 10- by 8-cm ellipse, as defined by the 80% dose level, are practical. A dynamic range shifter[1] is used to broaden the peak to give either a flat dose or flat equivalent-dose distribution. Figure XIII-4(a) and 4(b) are planar isodose distributions for the 15-g/cm^2 beam tune with a 9- by 7-cm elliptical collimator and with the range shifter programmed for an 8-cm flat dose profile in depth. This beam has a peak dose rate of 3.8 rads/min for 75 μA on target.

Collimation experiments which optimize collimator design using Cerrobend alloy are in progress, as are inhomogeneity experiments. Preliminary results using paraffin bolus to correct for geometrically simple air and Teflon inhomogeneities indicate that such a method might be adequate for shaping the pion beam penetration for individual patients.

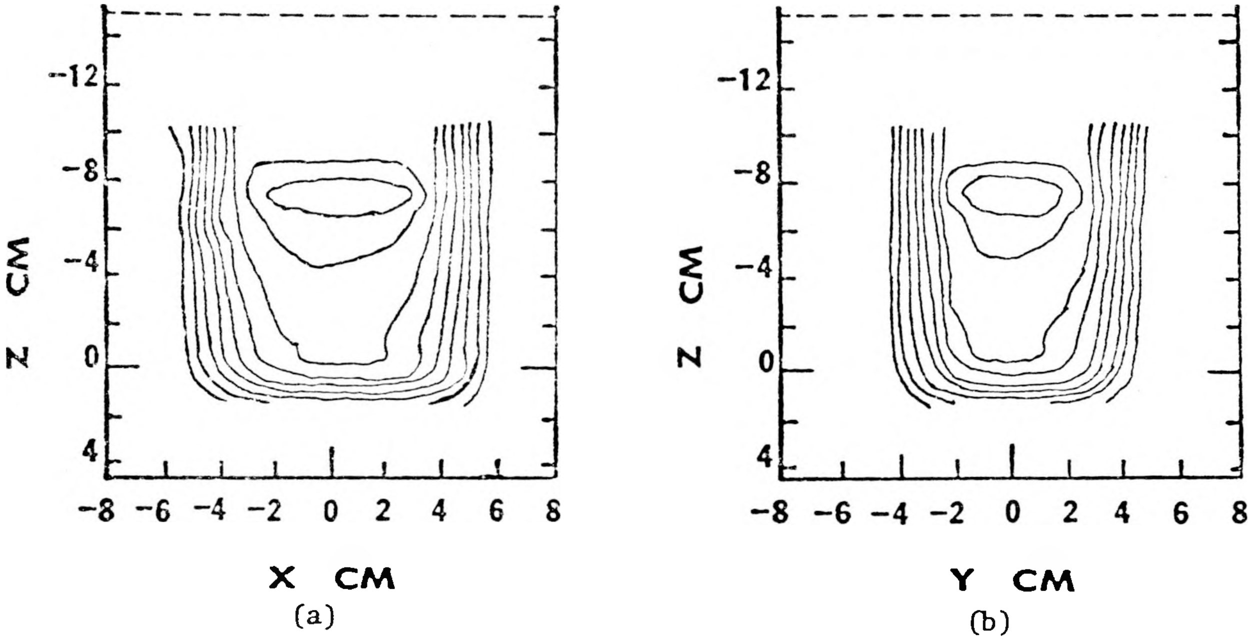

Fig. XIII-4(a) and (b)

Isodose distributions showing the 95, 90, 80, 70, 60, 50, 40, 30, and 20% contours for a π^- beam incident in the +z direction which has 15-g/cm² maximum penetration. The dose peak has been spread out via a dynamic range shifter, and the beam is collimated by a 9- by 7-cm elliptical collimator in order to achieve a uniform treatment volume.

(a) is an xz planar distribution, and (b) is a yz planar distribution. The z = 0 lies 15 cm below the surface of a water phantom.

The LET Characteristics of Therapeutic Pion Beams (Exp. 273)
(LASL)

It has been shown[2] that thick (~5000 μm) silicon detectors can separate electrons, muons, and pions, and the pion stars. For purposes of radiobiology and therapy, a more appropriate separation is into low-, medium-, and high-LET particles or doses. This has been accomplished using a 100-μm lithium-drifted detector as a probe. The whole electronic system was gated with the 1-in-10 low-intensity-pulse H^+ beam.

The 5- by 5-cm beam used with one of the recent patients was analyzed in this fashion. The experiment was repeated and the results were checked. The clinical evidence suggests that the location of the high-LET component is very important. In the case of the particular patient, three beams were overlapped for a 5-cm nodule in order to arrive at a more uniform distribution in the different LET components.

These measurements are being compared with the output from BUCKET using measurements of the particle phase space (Exp. 270). The results are very encouraging. The general behavior of the three LET components is qualitatively correct. Some adjustments need to be made in the total dose distribution and perhaps in the high-LET component.

A program is now being initiated in which the therapeutic beams will be characterized both in LET and biological effect. This should lead to a deeper understanding of the relationship of LET fraction to the survival curves.

Investigation of π^- Coulomb Capture and π^- Transfer in Tissue, Tissue-Equivalent Liquid, and Some Simple Compounds (Exp. 300) (LASL, Univ. of Munich, California State Univ. at Northridge)

Since accurate calculations of the high-LET dose during π^- radiotherapy depend on knowledge of the relative numbers of pions being captured by the various elemental constituents of tissue, it is important to determine the pion-capture behavior in tissue-like materials. In this experiment a number of targets were irradiated with the biomed π^- beam, and pionic-atom x-ray spectra were measured with an intrinsic germanium detector. Targets included frozen tissue, tissue-equivalent plastic, graphite, and others. The data analysis is in progress.

Practical Applications Experiments

Study of Muon Spin Relaxation in FCC Metals (Exp. 266) (Sandia, LASL, BNL)

Experiment 266 is a study of muon spin relaxation in FCC metals with the emphasis on determining the temperature dependence of the muon spin relaxation (or depolarization) rate. Such studies may illuminate the process of muon diffusion and trapping in metals and thus should prove useful for the study of defects in materials.

The experiment involves the stopping of polarized positive muons in a target and the subsequent measurement of the time structure of the muon decay by detecting the decay positrons. The duty cycle at LAMPF (6%) limits the average stopping rate of muons in the target since only one muon stop is permitted over several muon lifetimes. Because this class of experiments requires high statistical accuracy, studies to optimize the design parameters have been initiated with the goal of minimizing the counting time necessary to achieve a desired uncertainty in measured muon depolarization rate. Some of the parameters which enter these considerations are: the location and size of the positron detectors; the range of positron energies counted; the target thickness; the muon beam intensity; and the time-spectrum interval. Preliminary design parameters have been obtained from these studies.

Experiments such as this one are usually performed with an applied uniform magnetic field taken to be much larger than those dipole fields in the metal which give rise to the muon-spin depolarization. Therefore, the design of a Helmholtz coil pair capable of producing a field up to 100 G with a uniformity of 10^{-4} to 10^{-5} over a volume of 27 cm^3 has been undertaken and is near completion.

The data-acquisition system is also being planned with the emphasis on maximizing the data collection and processing rates. The time spectra will be collected in a Tennelec "PACE" ADC, which is capable of digitizing a pulse (regardless of amplitude) in 4.5 μs. The "PACE" ADC will be used with a PDP-11/45 computer via a CAMAC interface. The data-acquisition program "Q" developed at LASL will most likely be used.

Radiation Damage Effects of 800-MeV Protons (Exp. 269) (LASL, Univ. of Cincinnati)

Calculations using the nucleon-meson transport code (NMTC) indicate that damage effects produced by 800-MeV protons on metal samples are similar in many aspects to the effects produced by fusion-reactor neutron irradiations. The LAMPF primary proton beam could be used to generate damage in samples more rapidly than existing neutron sources. There was a recent opportunity to irradiate one set of samples in the LAMPF switchyard at high-current density (250 $\mu A\ cm^{-2}$). Three high-purity annealed aluminum samples were irradiated to a damage level of a few displacements per atom (dpa) in 30 h.

The objectives of the experiment were the following:

- to demonstrate the use of LAMPF for high-energy-proton irradiations,
- to create damage by high-energy protons in a real metal so that a comparison could be made to damage produced by neutrons,
- to create damage (voids) by heavy ions with concurrent gas production (as in fusion-reactor first walls), and
- to permit heavy-ion-irradiation damage in bulk material to be compared to that near a free surface (5000 to 20 000 Å from the

irradiated face, as in heavy-ion-beam simulation studies). The influence of high helium production concurrent with displacement damage would show whether the void nucleation rate varies greatly with helium production. Transmission microscopy comparing the midplane of the irradiated sheet to the surface regions would show whether surface image effects influence heavy-ion-irradiation results.

Preliminary electron transmission microscopy measurements showed that voids were produced on the midplane of the 0.254-mm-thick irradiated sheets. The irradiation temperature was ambient 293 K (0.31 Tm); the resulting void number density was $\sim 1 \times 10^{15}\ cm^{-3}$; the average void size was ~ 90 Å; and the calculated volume fraction was $\sim 0.05\%$. These results may be compared to studies of void formation in neutron-irradiated aluminum at about the same level of displacement damage. The void concentrations in aluminum are then $\sim 3.2 \times 10^{14}$ at an irradiation temperature of 328 K and 1.4×10^{13} at 398 K. Thus the high gas-production rate concurrent with the proton irradiation relative to the softer fission-reactor irradiation did not change the observed void density greatly. This is an important result to controlled thermonuclear technology since there has been speculation that high helium production per dpa could increase the void nucleation rate.

Proton irradiation using high-energy protons is really bulk heavy-ion irradiation with concurrent gas and impurity atom production. Experiments at LAMPF could be compared to experiments using heavy ions to show whether mechanical constraint and surface image forces influence heavy-ion simulation results. Continued effort on 800-MeV proton irradiations is planned as a strong, new fusion-reactor simulation technique.

Proton Axial Tomography (Exp. 286) (LASL)

The proton axial tomography experiment is tentatively scheduled to run in 1977 in the P^3-West area. Detector schemes are being assessed in terms of measurement accuracy and ultimate data-acquisition rate.

The earlier investigation of and modifications to the Moliere theory of multiple coulomb scattering have been represented in an experimentally useful form as a correction to the well-known Rossi formula. Figure XIII-5 shows this correction for multiple scattering in water as a function of thickness of material and the velocity of the incident particle divided by its charge. The correction is independent of the mass and charge of the incident particle provided θ_{rms} is small compared with 1 rad.

The inevitable errors in the projection measurements which are used in computerized tomography (CT) result in errors (noise) in the reconstructed two-dimensional density distribution. The power-spectral density of this noise indicates unusual properties which imply an anticorrelation of an error in one reconstruction bin with the errors in nearby bins. This suggests that image enhancement techniques may be effective in improving diagnostic reliability of CT reconstructions.

Technology Transfer

Collaboration with the Univ. of New Mexico Cancer Research and Treatment Center continues in an effort to develop techniques for localized heating of tumors. The most recent case of squamous cell carcinoma in the oral cavity shows no sign of tumor seven months after the last hyperthermia treatment, with the patient enjoying a weight gain of 25

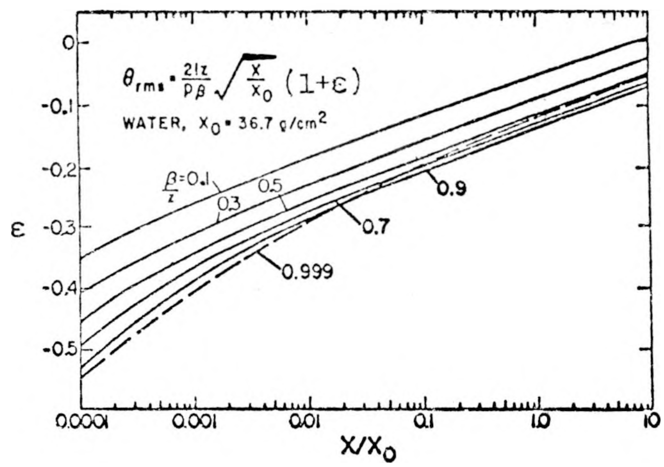

Fig. XIII-5.
Correction to Rossi multiple-scattering formula for effective rms polar angle determined from modified Moliere theory as a function of thickness in radiation lengths.

pounds.[3] Combination radiation-therapy hyperthermia treatments on animals continue at the same location, with encouraging results.[4]

Three portable LCF units, with a variety of rf probes, have been designed and tested for the treatment of cancer-eye in cattle. The most recently constructed unit is small enough to be worn on a belt during the treatment; all three units are powered by a standard 12.6-V automotive battery and are therefore useful in remote regions. Treatment results on this economically important tumor are encouraging; details are listed in Table XIII-1.

REFERENCES

1. H. I. Amols, D. J. Liska, and J. Halbig, "The Use of a Dynamic Range Shifter for Modifying the Depth-Dose Distributions of Negative Pions," (to be published).

2. C. Richman, "Characteristics of a Negative Pion Beam for the Irradiation of Superficial Nodules in Cancer Patients," Rad. Res. **66**, 453-71 (1976).

3. C. J. Sternhagen, P. W. Day, M. M. Kligerman, W. S. Edwards, R. C. Doberneck, F. S. Herzon, T. Powell, J. D. Doss, and G. F. O'Brien, "Preliminary Results Using Localized Current Field Hyperthermia in Oral Cavity Carcinomas," presented at the 18th Annual Meeting of the Am. Soc. of Therapeutic Radiologists, Atlanta, GA, October 1976.

4. P. W. Day, C. J. Sternhagen, J. D. Doss, and W. S. Edwards "Combination Radiation Therapy and Localized Current Field Hyperthermia of Spontaneous Malignant Neoplasms of Animals: A Preclinical Study," *ibid.*

TABLE XIII-I

TREATMENT RESULTS OF CANCER-EYE IN CATTLE

Summary of Treatment Results

Number of cattle treated	18
Number permanently lost to follow-up	3
Tumor treated and inspected at least four weeks later	53
Tumors treated too recently for four-week inspection	6

Of the 53 tumors treated and inspected:

Active[a]	3
Regressed[b]	23
In Remission[c]	27

Number of Treatments

The 53 tumors which have been treated and inspected have received a total of 75 treatments for the group, or $\sim 1^1/_2$ treatments for each tumor.

---

[a] "Active" is used here to describe a tumor which has not been substantially affected by the treatment.

[b] "Regressed" implies a small portion of the original tumor or suspicious scar tissue remains to be treated.

[c] "Remission" is used to describe the condition where the tumor appears to have disappeared completely; treatment is discontinued.

XIV. MANAGEMENT

A number of organizational changes have been implemented to be effective November 1. Ed Knapp has transferred to P-DO to become Alternate P-Division Leader. He will retain his role as Principal Investigator for the PIGMI project. As part of his responsibilities in P-Division, he will oversee the development and operation of WNR. This will help greatly in smoothing the way towards phasing WNR activities into the over-all operation of LAMPF.

Jim Bradbury has been appointed Group Leader of the Practical Applications Group, MP-3, a position previously held by Ed Knapp.

A new group, MP-14, has been organized to deal with our commitment to NCI for the development of PIGMI. The Group Leader is Don Swenson and his Alternate is Tom Boyd. Tom Boyd will be Acting Group Leader of the Engineering Support Group until January 1, 1977, at which time that position will be assumed by Ed Bush.

Budget and Personnel Levels

Operating costs during the 1976 transition period — July through September — were $4880k as projected. Funding for the first year of a three-year program to support the development of a pion generator for medical application (PIGMI) was authorized starting July 1976. Essentially all capital equipment funds for 1976T were either obligated or committed.

For FY 1977, operating funds are limited to $18 460k until Congress acts to authorize FY-77 funds (February or March 1977). Approximately 50% of the capital equipment allocation has been obligated or committed.

The average number of full-time-equivalent employees chargeable to the medium-energy physics program is 335, slightly less than forecast.

Experimental Program

From start-up of the accelerator through this report period, 48 experiments have been completed. These experiments are listed in Appendix A.

The LAMPF Scheduling Committee has completed a production run schedule through the summer of 1977 and it is given below. This schedule is based on the recommendations of the PAC. Some of the assumptions used in preparing the schedule are:

1. A three-week contingency period in May will be adequate for nonroutine maintenance.
2. The machine will be operated at 100-μA H^+ through next summer.
3. The machine will not be in production during January and September 1977 for budgetary reasons.
4. A 35-day cycle will be used of which the first 25 days are production. During the 25-day production period, there will be weekly 12-h interruptions for experimental area development or priority maintenance.

All of these assumptions will be reviewed periodically and, as necessary, the schedule will be revised.

Preparing a schedule for EPB, B, and C has been difficult. The polarized beam and polarized targets are not yet in operation. This schedule is based on best estimates. Starting dates for the cycles are:

Cycle 11	November 21, 1976
12	January 30, 1977
13	March 6, 1977
14	April 10, 1977
Contingency	May 15-June 5, 1977
15	June 5, 1977
16	July 10, 1977
17	August 14, 1977

The schedule, listed by channel, is as follows:

P^3

Cycle	West Exp. No.	West Shifts	East Exp. No.	East Shifts
11	221	21	90	26
	222	6	NC	7
12	222	26	93	24
			NC	20
13	222	34	201	16
			NC	20
14	222	34	201	16
			NC	20
	Contingency			
15	286	35	201	15
			NC	20
16	286	25	82*	25
			NC	20
17	?		82*	37
			NC	20

*Assumes PAC concurrence

Cycle	EPICS Exp. No.	EPICS Shifts	LEP Exp. No.	LEP Shifts
11	245	17	234	31
	133	30	Change over	3
			191	21
			Nucchem	5
12	130	55	50	70
13	130	10	29/54 (234?)*	32
	245	45	Change over	3
			191	18
			140 or 180	17
14	130	10	25*	70
	291*	45		
15	130	55	96	70
16	130	10	181	50
	9	45	247	20
17	18	28	144	57
	23	29		

*Will be run only if spectrometer is not ready.

*Assumes PAC concurrence on allocation of additional time.

SMC

Cycle	Exp. No.	Shifts	Cycle	Exp. No.	Shifts
11	37	10	14	206	12
	142	6		To be arranged	20
	7	12		292	10
	60	12		240	18
	173	20		288	10
12	292	5	15	268	42
	240	14		292	10
	292	5		288	10
	173	38		To be arranged	8
	266	8			
13	266	15	16	7	18
	288	10		To be arranged	52
	266	9			
	292	10	17	To be arranged	70
	To be arranged	17			
	206	9			

	B		EPB		C	
Cycle	**Exp. No.**	**Shifts**	**Exp. No.**	**Shifts**	**Exp. No.**	**Shifts**
11	262-4	34 (40 ns)	197	34 (40 ns)	Tune-up	53
	Nucl Chem	7		9 (no chop)	139	10
11/21-12/12		2	200	As available		
12	262-4*	63	Open		Dev.	9
					4	20
	Nucl Chem	7			15	30
					139	10
13	Open		27 II	24	Dev. (Unpol)	9
					Dev. (Pol)	24
					139 (Unpol)	30
	Nucl Chem	7				
14	Open		27 II	33	Dev. (Pol)	9
	Nucl Chem	7			XXX (Pol)	24
					5 (Unpol)	30
Contingency						
15	Open		27 II	33	Dev. (Pol)	9
	Nucl Chem	7			5 (Unpol)	30
					XXX (Pol)	24
16	65/66	63	194	63	Dev.	9
	Nucl Chem	7			?	54
17	65/66	51	137	51	Dev.	6
	Nucl Chem	6			?	45
Shutdown						

* = Assumes no problems with 80 ns chopped beam.
XXX = Elastic-Scattering Survey Using Polarized Protons (G. W. Hoffman, Spokesman).
? = Awaiting PAC meeting.

Safety

Radiological Safety

Individual and total man-rem exposures remained at acceptable levels. Excluding craft workers, 192 LAMPF-associated personnel received 31 man-rems during July, August, and September; the maximum individual exposure was 1.1 rems. Craft personnel were not included in this figure because many could have received exposures at areas other than LAMPF.

A four-hour Radiation-Safety Training Course was offered to 179 radiation workers by staff from Group H-1. This course included three hours of general radiological safety and one hour of specific LAMPF radiation problems. It was video-taped for those who missed the sessions and for new personnel.

Thirty-two operational plans for work involving radiation were reviewed and approved.

Detailed preparations were made for an experiment to be conducted in the P^3-East channel to measure the differential cross section for $\pi^{\pm}$ radiative, charge-exchange, and elastic scattering on the isospin doublet ^3H and ^3He. This experiment (No. 90) requires special safety considerations because of the large quantity (~55 000 Ci) of T_2 used as a target. To minimize possible hazards:

- An enclosure equipped with a forced exhaust system was constructed for the entire tritium apparatus, including the target cell. The exhaust duct is vented above the roof of Area A and contains tritium detectors to provide early leak indication. Tritium detectors were placed at selected occupied locations in the experimental areas.
- Detailed written procedures were developed that specify the operation of the T_2 target and refrigeration systems, area operational restrictions and regulations, personnel access and control, and physical surveillance. Emergency procedures cover situations involving potential or actual release of tritium.
- Personnel directly involved in the operation of the tritium apparatus were trained in the tritium gas-handling and refrigeration systems, operation of emergency generators, alarm and emergency procedures, and the use of Scott air packs and tritium monitors.

Site Access

Because of a lessening of physical control over access to TA-53, roadside signs were placed at the entrance to TA-53 instructing visitors to report to the LAMPF Visitors Center in the MP-Division Office Building during normal working hours (Central Control Room, other hours) and also at road entrances to the accelerator and experimental areas to define radiation-badge requirements.

Safety Procedures

Procedures were written for operation of the Personnel Safety Systems for Area B (EPB, Room BR, CNC-11 Cave, Line B, and EPB beam stop) and Area C.

The procedure for entering and exiting a sector capacitor room was revised.

Meetings

The following safety meetings were conducted this quarter: LAMPF Safety Committee, Group Safety Officers Committee, and Experimental Areas Safety Committee.

Safety Review of Experiments

Safety reviews were held for six experiments, in addition to Exp. 90 described above. No unusual safety problems were identified.

Safety review forms are sent routinely to experiment spokesmen.

Area A Evacuation Alarm

Recent tests of the present Area A evacuation alarm (variable-pitched siren) and fire alarm (slow-whoop siren) indicated a confusing similarity. Therefore, the present evacuation alarm will be replaced with one that has a sound of a stuttering Klaxon.

Inspections

Seven site inspections were conducted by the LAMPF Health & Safety Office this quarter. Also, a site-wide inspection of previously identified deficiencies was conducted. All deficiencies were reported to the appropriate groups for immediate corrective action.

Accidents

Twenty-two accidents resulting in injuries were reported this quarter. These were minor and consisted of lacerations, strains, and foreign bodies in the eyes. They did not result in any significant loss-of-work time.

LAMPF Users Group, Inc.

Liaison Office

The annual election of officers for the Board of Directors of the LAMPF Users Group, Inc. was conducted by mail ballots sent to 1011 members of the group on September 21, 1976. The Nominating Committee, consisting of Vernon W. Hughes, Chairman (Yale Univ.); Peter D. Barnes (Carnegie-Mellon Univ.); Bruce J. Dropesky (LASL); Sherman Frankel (Univ. of Pennsylvania); George J. Igo (UCLA); and Glen A. Rebka (Univ. of Wyoming), prepared a slate of candidates. Two additional candidates were placed on the ballot by petition. Following is the slate of candidates:

Chairman-Elect:

- John C. Allred (Univ. of Houston)
- Norton M. Hintz (Univ. of Minnesota)
- W. Kenneth McFarlane (Temple Univ.)

Members:

- Ed V. Hungerford (Univ. of Houston)
- Mahavir Jain (Texas A&M Univ.)
- Ralph Minehart (Univ. of Virginia)
- Glen A. Rebka, Jr. (Univ. of Wyoming)
- Benjamin Zeidman (ANL)

The two candidates for members of the Board receiving the most votes will replace Lewis Agnew (LASL) and John C. Allred (Univ. of Houston), who are completing their two-year terms of office. The deadline for the return of ballots to the Liaison Office is November 1, 1976, and the results of the balloting will be announced at the Tenth LAMPF Users Meeting.

Preparations for the Tenth LAMPF Users Meeting to be held in Los Alamos on November 8-9, 1976, are being made by Chairman David A. Lind (Univ. of Colorado) and the Liaison Office. Preliminary programs, reservation forms, and other meeting information were mailed to all members on September 21, 1976. The program will consist of a Welcome and Opening Remarks by Harold M. Agnew, Director of LASL; LAMPF Status Report by Louis Rosen, Director of LAMPF; and LAMPF Operations Report by Donald C. Hagerman, Chief of Operations for LAMPF. Invited talks are scheduled by James S. Kane, Director of the Division of Physical Research, ERDA, "Comments on the Future Role of Basic Research in ERDA"; John Domingo and Milan P. Locher, Swiss Institute for Nuclear Research (SIN), "Physics Research at SIN"; J. Krisch, Univ. of Michigan, "High-Energy Experiments with a Polarized Proton Beam and Target"; and T. D. Lee, Columbia Univ., "Nontopological Solitons." Reports on research at LAMPF will be given by Richard E. Mischke, LASL, "Particle Physics Research at LAMPF"; Robert A. Eisenstein, Carnegie-Mellon Univ., "Results of Nuclear Structure Research at LAMPF"; Edward A. Knapp, LASL, "Practical Applications of LAMPF"; and John F. Dicello, LASL, "Biomedical Results at LAMPF." The annual LAMPF Users Group report will be given by Chairman David A. Lind, who will also conduct the general business session. In addition, all Working Groups will hold meetings on the afternoon of November 9, except the HRS group which will meet on the evening of November 7.

The October issue of the LAMPF Users Group Newsletter was prepared and mailed to the members on October 15, 1976. The annual letter to the members, "Notice of Annual Meeting, Call for Nominations, and Amendments to the By-Laws," was 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 10. The newly elected officers of the Board of Directors for 1977 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 October 15, 1976:

Membership

Non-LASL	803
LASL	189
TOTAL	992

Fields of Interest

1. Nuclear and Particle Physics	748
2. Nuclear Chemistry	167
3. Biomedical Applications	355
4. Not Specified	6
5. Other (including administration, facilities, operations, coordination, theory, data acquisition, and miscellaneous applications)	380
6. Isotope Production	126
7. Radiation Damage	133
8. Weapons Neutron Research	101

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

Institutional Distribution

1. ***Membership by Institute***

LASL	189
Other National or Government Laboratories	107
U. S. Universities	398
Industry	50
Foreign	154
Hospitals and Medical Centers	94
TOTAL	992

2. ***Number of Institutions***

National or Government Laboratories	30
U. S. Universities	113
Industry	41
Foreign	76
Hospitals and Medical Centers	58
TOTAL	318

Regional Breakdown

East (PA, NJ, DE, Wash DC, MA, NY, CT, VT, RI, NH, ME)	138
Midwest (OH, MO, KS, IN, WI, MI, IL, ND, SD, NB, IA, MN)	131
South (MD, VA, TN, AR, WV, KY, NC SC, AL, MS, LA, GA, FL)	85
Southwest-Mountain (MT, ID, UT, WY, AZ, CO, NM, OK, TX)	169
Far West (AK, HI, NV, WA, OR, CA)	127
Foreign	153
LASL	189
TOTAL	992

LAMPF Program Advisory Committees

A new program and proposal review committee has been formed on the recommendation of the LAMPF Program Advisory Committee. The committee is called the Solid State Physics and Materials Science Committee and, as the name implies, its charter will cover the review of those programs so related.

The first meeting of the committee will be held on December 7, 1977. Present members are:

John H. Manley, Chairman, LASL Consultant
Thomas A. Tombrello, CIT
Brad L. Holian, LASL
Peter K. Haff, Yale Univ.
Allen N. Goland, BNL

LAMPF Visitors Center

Exclusive of the "casual" visitors this quarter, there were more than 248 research guests working on LAMPF-related problems or participating in experiments at LAMPF (see Appendix B), with 133 guests checking in and 107 checking out.

According to a survey conducted for the six-month period April 1 through September 30, 1976, $44 700 was spent from the medium-energy physics operating budget in experiment support of non-LASL research institutions using the "G" accounts established for use at LAMPF. In addition, an extimated $325 800 was expended in the form of salary fees, subsistence, honorariums, travel, etc., for short- and long-term visiting staff members, summer students, advisory committees, and consultants, seminar speakers and other visiting scientists (see Appendix C).

Tours

Organized tours of the LAMPF were conducted by LASL personnel for the following organizations:

8/ 2 – Ft. Bliss, TX Explorer Scouts
8/ 3 – Amer. Cancer Soc., Albuquerque, NM
8/ 5 – Texas Tech. Senior Elec. Engineering students
8/ 7 – LASL Families Tour
8/10 – Adams State College Chemistry teachers
8/11 – Regis College teachers
8/16 – Storage Ring Summer Study group
8/21 – U. S. Naval Reserve, Albuquerque, NM
9/11 – LASL Families Tour
9/13 – Wage & Salary officials from private industries
9/14 – California travel group
9/20 – Japanese delegation
9/24 – Delta Gamma Book Review Club, Albuquerque, NM
10/21 – Nuclear Target Society
10/22 – Ft. Lewis College biology class

APPENDIX A

PROPOSALS THAT ARE COMPLETE WITH SPOKESMEN AND INSTITUTE 76/11/19. 1

	PROP NO.	PROPOSAL TITLE	SPOKESMEN	INSTCD/GROUP
◆◆◆				
◆	2	TOTAL PION CROSS SECTIONS	JAKOBSON	UMT
◆	26	NEUTRON TIME-OF-FLIGHT EXPERIMENT AT BEA M STOP	VEESER	LASL
◆	28	STUDIES OF THE PI PLUS, PI ZERO REACTION	YAVIN	TELAVU
◆	34	ELASTIC SCATTERING OF PI+ OR - ON DEUTER ONS	MINEHART	UVA
◆	42	BREAK UP OF FEW NUCLEON SYSTEMS AND NUCL EI	COLE	USC
◆	44	RADIOBIOLOGY OF NEGATIVE PI MESONS, A PR ELIMINARY STUDY	CARLSON	UTXD
◆	79	CALIBRATION OF THE PION BEAM TRANSPORT S YSTEMS AND A PION BEAM MONITOR	PHILLIPS	RICE
◆	80	FORWARD ELASTIC SCATTERING OF PI PLUS AN D PI MINUS FROM 12C, 13C, 16 OXYGEN, 40C A, 208PB	PHILLIPS	RICE
◆	81	STUDY OF NEUTRON-PROTON AND PROTON-PROTO N COINCIDENCE SPECTRA FROM P+D GOING TO N+P+P REACTION	PHILLIPS	RICE
◆	84	QUALITY OF MESON RADIATION FIELDS	PHILLIPS	RICE
◆	99	MEASUREMENT OF THE CROSS SECTION FOR PI- + P GOING TO PI- + PI+ + N WITH A MAGNE TIC SPECTROMETER	REBKA	UWY
◆			GRAM	LASL
◆	102	EXCITATION FUNCTIONS AND ANGULAR DISTRIB UTION RECOIL STUDIES OF SIMPLE PION INDU CED NUCLEAR REACTIONS	MARKOWITZ	UCB
◆	121	PION INDUCED NUCLEAR REACTIONS	SEGEL	ANL/NWU
◆	124	MEASUREMENT OF THE NEUTRON ENERGY SPECTR UM IN P + P GOING TO N + PI+ + P	MC FARLANE	TEMPLE
◆			DIETERLE	UNM
◆	125	ELASTIC NEUTRON-PROTON BACK ANGLE DIFFER ENTIAL CROSS-SECTION MEASUREMENTS 300-80 0 MEV	DIETERLE	UNM
◆	128	WNR STORAGE RING STRIPPER EXPERIMENT	HAYWARD	LASL
◆	129	PION PRODUCTION IN NEUTRON PROTON COLLIS IONS	WOLFE	UNM
◆	130	EPICS TUNEUP PROPOSAL-PION CARBON SCATTE RING	THIESSEN	LASL
◆	143	STUDY OF THE RADIOBIOLOGICAL PROPERTIES OF NEGATIVE PIONS	KLIGERMAN	LASL
◆			KNAPP	LASL
◆	148	NEUTRINO ELECTRON ELASTIC SCATTERING AT LAMPF (A FEASIBILITY STUDY)	REINES	UCI
◆			CHEN	UCI
◆	153	INVESTIGATION OF NUCLEAR GAMMA-RAYS RESU LTING FROM IN-FLIGHT PION AND PROTON REA CTIONS	EISENSTEIN	CMU
◆	156	SURVEY OF QUASI-ELASTIC PION SCATTERING	SWENSON	ORSU
◆	162	STUDIES OF THE (PI+,PI ZERO) REACTION ON LIGHT ELEMENTS	YAVIN	TELAVU
◆			ALSTER	TELAVU

PROPOSALS THAT ARE COMPLETE WITH SPOKESMEN AND INSTITUTE
76/11/19.

	PROP NO.	PROPOSAL TITLE	SPOKESMEN	INSTCD/GROUP
◆◆◆				
◆	163	INVESTIGATION OF CHANGES IN CHARGE DISTRIBUTIONS FOR NUCLEI NEAR Z=28 BY ELECTRON SCATTERING AND MUONIC X-RAYS	PERKINS	LASL
◆			SHERA	LASL
◆	164	PION TOTAL CROSS SECTION MEASUREMENTS WITH AN ORIENTED 165-HO TARGET	FISHER	LOCKRES
◆			MARSHAK	NBS
◆	165	MUONIUM FORMATION IN HELIUM AND OTHER RARE GASES	HUGHES	YALE
◆	166	MUONIC X-RAYS AND NUCLEAR CHARGE DISTRIBUTIONS ELECTRIC QUADRUPOLE MOMENTS OF 67HO165 AND 73TA181	POWERS	CALTEC
◆	167	HEAVY FRAGMENT FORMATION FOLLOWING THE ABSORPTION OF NEGATIVE PIONS IN 12C	ZIOCK	UVA
◆	169	PROTON IRRADIATIONS FOR PROJECT JUMPER	ORTH	LASL
◆			SATTIZAHN	LASL
◆	170	STUDY OF REACTION 13C(PI+,PI ZERO)13N(GROUND STATE)	ALSTER	TELAVU
◆	175	SEARCH FOR THE FORMATION OF MUONIC HELIUM (ALPHA MU MINUS E)	HUGHES	YALE
◆	176	P-NUCLEUS TOTAL AND TOTAL REACTION CROSS SECTION MEASUREMENTS	ANDERSON	KENT-ST-U
◆	179	DIFFERENTIAL PRODUCTION CROSS SECTIONS OF MULTIPLY CHARGED FRAGMENTS IN PROTON AND PION INDUCED SPALLATION OF LIGHT NUCLEI	BOWMAN	LASL
◆	189	SEARCH FOR CONDENSED NUCLEAR STATES AND STUDY OF HIGH Q2 LOW NU NUCLEAR INTERACTIONS	VANDYCK	LASL
◆	192	MEASUREMENT OF THE EMITTANCE GROWTH IN H- STRIPPING	HAYWARD	LASL
◆	193	MEASUREMENT OF SMALL ANGLE NEUTRONS ELASTIC SCATTERING FROM PROTONS	DIETERLE	UNM
◆			MC FARLANE	TEMPLE
◆	198	EFFECTS OF PIONS ON DNA OF NONDIVIDING CELL SYSTEMS	POWERS	UCD
◆	207	MEASUREMENT OF NEUTRON SPECTRUM AND INTENSITY RESULTING FROM PI-MINUS CAPTURE IN WATER PHANTOM AND HUMAN TISSUE	ALLRED	UHOU
◆			BRADBURY	LASL
◆	209	PION INTERACTIONS IN NUCLEAR EMULSIONS	BRADBURY	LASL
◆			ALLRED	UHOU
◆	210	ISOTOPE PRODUCTION FACILITY IRRADIATION VANADIUM, MOLYBDENUM AND LANTHANUM TARGETS	OBRIEN	LASL
◆	211	NEUTRON IRRADIATION OF COPPER SINGLE CRYSTALS	GREEN	LASL
◆	214	PIONIC X-RAY ABSOLUTE YIELDS AS A FUNCTION OF Z	HARGROVE	LASL/NRCC
◆			LEON	LASL
◆	219	DOUBLE PION PRODUCTION IN PROTON-PROTON SCATTERING	BEVINGTON	CWRU

	PROP NO.	PROPOSAL TITLE	SPOKESMEN	INSTCD/GROUP
◆◆◆				
◆	241	DIRECT LEPTON PRODUCTION AT LAMPF ENERGI ES	HOFFMAN	LASL
◆			MISCHKE	LASL
◆	246	STUDIES OF PI-PLUS SCATTERING AT 50 MEV FROM LIGHT NUCLEI	EISENSTEIN	CMU
◆	255	MEASUREMENT OF (SIGMA (THETA)) FOR N/P E LASTIC SCATTERING AT 460 MEV	NORTHCLIFF E	TXAM
◆	265	STUDY OF PROMPT NUCLEAR DE-EXCITATION GA MMA RAYS FROM PION INTERACTIONS WITH 6,7 LI AND 12C	MORRIS	LASL
◆			BRAITHWAIT E	UTXA
◆	282	MEASUREMENT OF CROSS SECTIONS FOR PROTON -INDUCED FORMATION O F SPALLATION PRODUC TS IN COPPER BY ACTIVATION ANALYSIS	DONNERT	KSSTU

?

APPENDIX B

RESEARCH GUESTS AT LAMPF DURING PERIOD AUGUST 1, 1976 - OCTOBER 31, 1976

Douglas M. Alde . . . . Univ. of Illinois
John C. Allred . . . . Univ. of Houston
Jonas Alster . . . . .Tel-Aviv Univ.
James Amann . . . . Carnegie-Mellon Univ.
Daniel Ashery . . . . .Tel-Aviv Univ.
Norman Austern . . . . .Univ. of Pittsburgh
Helmut W. Baer . . .Case Western Reserve Univ.
Thomas J. Baird . . . . Rensselaer Poly. Inst.
Robert L. Barnard . . . . . . UNM Cancer Center
Stanley Bernsteen . . . . . Carnegie-Mellon Univ.
F. E. Bertrand . . . . . .Oak Ridge National Lab.
John L. Beveridge . . . . .TRIUMF
C. W. Bjork . . . . Univ. of Wyoming
Gary S. Blanpied . . . . Univ. of Texas
Felix H. Boehm . . . . . . California Inst. of Tech.
Joseph E. Bolger . . . . Univ. of Texas
C. A. Bordner . . . . Colorado College
Jonathan S. Boswell . . . . Univ. of Virginia
Richard L. Boudrie . . . . Univ. of Colorado
Kenneth Boyer . . . . Univ. of Texas
W. J. Braithwaite . . . . Univ. of Texas
Hubert Brandle . . . . .UC, Los Angeles
George A. Brooks . . . . .UC, Irvine
H. C. Bryant . . . . Univ. of New Mexico
Joseph J. Burgerjon . . . . .TRIUMF
G. R. Burleson . . . . . . New Mexico State Univ.
James R. Cadieux . . . . Univ. of Chicago
Elizabeth Cameron . . . . . .UNM Cancer Center
Roger D. Carlini . . . . Univ. of New Mexico
D. E. Casperson . . . . .Yale Univ.
John Chatten . . . . Telefactors, Inc.
Herbert H. Chen . . . . .UC, Irvine
Willie H. Christian . . . . Tuskegee Inst.
Terrance P. Cleary . . .Oak Ridge National Lab.
John M. Clement . . . . .Rice Univ.
Saadia Cochavi . . . . .Tel-Aviv Univ.
Robert K. Cole . . . Univ. of Southern California
Nicholas J. Colella . . . . .Temple Univ.
Bruce E. Collins . . . . Univ. of Houston
J. C. Comiso . . . . Univ. of Virginia
Andre Courtemanche . . . . Univ. of Virginia
Joseph N. Craig . . . . . . Carnegie-Mellon Univ.
Frank H. Cverna . . .Case Western Reserve Univ.
H. Daniel . . . . Technische Univ. München
Dietrich Dehnhard . . . . Univ. of Minnesota
Arthur B. Denison . . . . Univ. of Wyoming
Nick Depolo . . . . Univ. of Colorado
Michael J. Devereux . . New Mexico State Univ.
Satish Dhawan . . . . Yale Univ.
Kailash C. Dhingra . . . . . Univ. of New Mexico
Byron Dieterle . . . . Univ. of New Mexico
Nicholas J. Digiacomo . . . . . . Univ. of Colorado
Joey B. Donahue . . . . Univ. of New Mexico
Hermann J. Donnert . . . . . .Kansas State Univ.
Mohan Doss . . . . Carnegie-Mellon Univ.
William H. Dragoset . . . . .Rice Univ.
Steven A. Dytman . . . . . Carnegie-Mellon Univ.
T. E. Economou . . . . Univ. of Chicago
Patrick C. Egan . . . . .Yale Univ.
Robert A. Eisenstein . . . Carnegie-Mellon Univ.
John C. Fong . . . . .UC, Los Angeles
Sherman Frankel . . . . Univ. of Pennsylvania
William Frati . . . . Univ. of Pennsylvania
Rudolf Frei . . . . L. Hartmann, Switzerland
Stephen Friedland . . . . .Tel-Aviv Univ.
Nan J. Fullman . . . . .UNM Cancer Center
David R. Giebink . . . . Univ. of Texas
Shalev Gilad . . . . .Tel-Aviv Univ.
George Glass . . . . Texas A&M Univ.
Roy J. Glauber . . . . Harvard Univ.
Paul F. Glodis . . . . .UC, Los Angeles
Kazuo Gotow . . . . Virginia Poly. Inst.
Charles A. Goulding . . . . . Florida A&M Univ.
Steven J. Greene . . . . Univ. of Colorado
Mark B. Greenfield . . . . . . Florida A&M Univ.
Chilton B. Gregory . . . . . Univ. of New Mexico
Kurt F. Haden . . . . .UC, Los Angeles
Hosein M. Haghighi . . . . .UC, Los Angeles
Klaus Halbach . . . . . . Lawrence Berkeley Lab.
Robert L. Hall . . . . Univ. of Houston
Ann H. Hayes . . . . .UNM Cancer Center
Paul A. Heckert . . . . Univ. of New Mexico
Richard Helmer Idaho National Engineering Lab.
Herbert E. Henrikson . . California Inst. of Tech.
John C. Hiebert . . . . Texas A&M Univ.
Virgil L. Highland . . . . .Temple Univ.
John C. Hill . . . . Iowa State Univ.
Nathaniel W. Hill . . . .Oak Ridge National Lab.

John F. Hills . . . . Univ. of New Mexico
Norton M. Hintz . . . . Univ. of Minnesota
Martha V. Hoehn . . . . .Florida State Univ.
William J. Hoffert . . . . .Univ. of Indiana
Gerald W. Hoffmann . . . . Univ. of Texas
John F. Hoftiezer . . . . .Rice Univ.
Kenneth R. Hogstrom . . . .UNM Cancer Center
Roy J. Holt . . . . Argonne National Lab.
A. A. Hruschka . . . . .UC, Irvine
Vernon W. Hughes . . . . .Yale Univ.
Ed V. Hungerford . . . . Univ. of Houston
George J. Igo . . . . .UC, Los Angeles
Harvey Israel . . . . Private Consultant
Steven G. Iversen . . . . . . Northwestern Univ.
Richard J. Jacob . . . . Arizona State Univ.
Mahavir Jain . . . . Texas A&M Univ.
Mark J. Jakobson . . . . .Univ. of Montana
David A. Jenkins . . . . Virginia Poly. Inst.
R. H. Jeppesen . . . . .Univ. of Montana
K. F. Johnson . . . . .Temple Univ.
William Johnson . . . . Univ. of Rochester
David M. Judd . . . . .Rice Univ.
Herbert G. Juds . . . . .UC, Irvine
Jan Källne . . . . Univ. of Uppsala
Charles A. Kelsey . . . . . . .UNM Cancer Center
Arthur K. Kerman . Massachusetts Inst. of Tech.
Thomas R. King . . . . Univ. of Wyoming
H. B. Knowles . . . . . . Washington State Univ.
Thomas P. Kopera . . . . .Temple Univ.
Thomas Kozlowski . . .Brookhaven National Lab.
Kenneth S. Krane . . . . .Oregon State Univ.
J. J. Kraushaar . . . . .Univ. of Colorado
Ray Kunselman . . . . Univ. of Wyoming
Gary Kyle . . . . .Univ. of Minnesota
Jerome J. La Rosa . . . . Univ. of Chicago
Richard G. Lane . . . . .UNM Cancer Center
Phillip M. Lang . . . . Northwestern Univ.
John Lathrop . . . . .UC, Irvine
Alan G. Law . . . . Univ. of Regina
Chris P. Leavitt . . . . Univ. of New Mexico
Roger Liljestrand . . . . .Univ. of Texas
Stanley Livingston . . Los Alamos Scientific Lab.
Joseph W. Lo . . . . Univ. of Houston
Daniel C. Lu . . . . .Yale Univ.
Steven C. Luckstead . . Washington State Univ.
William Paul Madigan . . . . .Rice Univ.
Peter Majewski . . . . . . Washington State Univ.
D. J. Malbrough . . . . . Univ. of South Carolina
Fesseha Mariam . . . . .Yale Univ.
Thomas Marks, Jr. . . . Univ. of South Carolina
Nina Marsh . . . . .UNM Cancer Center
Nancy Matz . . . . .UC, Los Angeles
James S. McCarthy . . . . Univ. of Virginia
David K. McDaniels . . . . Univ. of Oregon
W. K. McFarlane . . . . .Temple Univ.
John A. McGill . . . . Univ. of Texas
Dorothy H. McGrath . . . . .UNM Cancer Center
Michael McNaughton Case Western Reserve Univ.
Claude A. Metzger . . . . CERN
Fred L. Milder . . . . Virginia Poly. Inst.
James P. Miller . . . . . California Inst. of Tech.
R. Russell Miller . . . . Univ. of Virginia
Ralph C. Minehart . . . . Univ. of Virginia
Murray Moinester . . . . Tel-Aviv Univ.
C. Fred Moore . . . . Univ. of Texas
C. L. Morris . . . . Univ. of Virginia
Edward Moy . . . . Univ. of New Mexico
Zvonko Mozetic . . . . J. Stefen Inst.
Donald W. Mueller . . . . Private Consultant
Scott Y. Nakamura . . . . UC, Irvine
Joseph B. Natowitz . . . . Texas A&M Univ.
Robert A. Naumann . . . . Princeton Univ.
B. M. K. Nefkens . . . . UC, Los Angeles
Peter Nemethy . . . . Yale Univ.
Charles Newsom . . . . Univ. of Texas
Andrew W. Obst . . . . Northwestern Univ.
Michael A. Oothoudt . . . . . .Univ. of Minnesota
Herbert Orth . . . . Univ. Heidelberg
Alden T. Oyer . . . . Univ. of Wyoming
Harry Palevsky . . . . .Brookhaven National Lab.
Alden E. Park . . . . Univ. of Colorado
C. L. Peacock, Jr. . . . . NASA
R. J. Peterson . . . . Univ. of Colorado
Robert F. Petry . . . . Univ. of Oklahoma
William W. Plumlee . . . . UC, Los Angeles
Norbert T. Porile . . . . Purdue Univ.
Richard J. Powers . . . . California Inst. of Tech.
Barry M. Preedom . . . . Univ. of South Carolina
Clifford Qualls . . . . Univ. of New Mexico
Glen A. Rebka . . . . Univ. of Wyoming
C. W. Reich . . . . Aerojet Nuclear Corp.
Louis P. Remsberg . . .Brookhaven National Lab.
Robert J. Ridge . . . . UC, Los Angeles
Peter J. Riley . . . . Univ. of Texas
Robert A. Ristinen . . . . Univ. of Colorado
Robert M. Rolfe . . . . UC, Los Angeles
Issac I. Rosen . . . . Univ. of New Mexico
Donald F. Rothfuss . . . Lawrence Berkeley Lab.
Frank H. Ruddy . . . . . Washington State Univ.
Ted D. Rupp . . . . Univ. of New Mexico

Marvin Sachs	Univ. of New Mexico
Oscar R. Sander	UC, Los Angeles
Mark A Schardt	Arizona State Univ.
Gerhard Schmidt	Princeton Univ.
Randy S. Schwartz	Temple Univ.
Ryoichi Seki	California State Univ.
Carol A. Selheimer	UNM Cancer Center
Kamal K. Seth	Northwestern Univ.
Yair Shamai	Tel-Aviv Univ.
Hasan Sharifian	Univ. of New Mexico
Tilak C. Sharma	Oregon State Univ.
Joseph D. Sherman	Carnegie-Mellon Univ.
D. G. Shirk	Iowa State Univ.
Frank T. Shively	Lawrence Berkeley Lab.
Ingo Sick	Univ. of Basel
Alfred R. Smith	UNM Cancer Center
Gregory Smith	Univ. of Colorado
Lester E. Smith	Univ. of Texas
John W. Somers	Univ. of New Mexico
Larry B. Sorensen	Univ. of Illinois
Paul Souder	Yale Univ.
Rolf M. Steffen	Purdue Univ.
Marcus D. Stevens	UNM Cancer Center
Richard J. Sutter	Brookhaven National Lab.
L. Wayne Swenson	Oregon State Univ.
Richard Talaga	Univ. of Chicago
Robert L. Tanner	Consultant
Willard Thomas	Univ. of New Mexico
Hossein Tootoonchi	Univ. of New Mexico
G. E. Tripard	Washington State Univ.
Anthony L. Turkevich	Univ. of Chicago
J. K. Valentine	Temple Univ.
Philip Varghese	Univ. of Oregon
Elizabeth Vine	Washington Univ.
Jean-Luc Vuilleumier	California Inst. of Tech.
E. A. Wadlinger	Univ. of Virginia
John D. Walecka	Stanford Univ.
John B. Walter	Univ. of Wyoming
K. H. Wang	Baylor Univ.
John E. Warren	Lakehead Univ.
W. R. Wharton	Carnegie-Mellon Univ.
Gordon R. White	UC, Los Angeles
James B. Whitenton	Univ. of Texas
Kay E. Whitner	Univ. of Virginia
R. Roy Whitney	Univ. of Virginia/NM State Univ.
Charles A. Whitten	UC, Los Angeles
Thorton J. Williams	Florida A&M Univ.
Suzanne Willis	Yale Univ.
Helen P. Wilson	Consultant
Nord F. Winnan	UC, Los Angeles
David Wolfe	Univ. of New Mexico
Y. Yamazaki	Florida State Univ.
Avivi I. Yavin	Tel-Aviv Univ.
Benjamin Zeidman	Argonne National Lab.
Hans J. Ziock	Univ. of Virginia
Klaus O. H. Ziock	Univ. of Virginia
Klaus P. Ziock	Univ. of Virginia
Gisbert zu Putlitz	Univ. of Heidelberg

APPENDIX C

LIST OF NON-LASL USERS OF LAMPF, AND VISITING SCIENTISTS AND EXPERIMENTAL TEAMS RECEIVING SUPPORT FROM MEDIUM-ENERGY PHYSICS PROGRAM FUNDS

Visiting Scientists, Seminar Speakers, User Assistants, Summer Assistants, etc.

Name	Outside Affiliation	Name	Outside Affiliation
Jacob, R.	Arizona State Univ.	Schardt, M.	Arizona State Univ.
Seki, R.	California State Univ.	Thaler, R.	Case Western Res. Univ.
Glauber, R.	Harvard Univ.	Donnert, H.	Kansas State Univ.
Feshbach H.	MIT	Kerman, A.	MIT
Lomon, E.	MIT	Whitney, R.	Univ. of Virginia/ New Mexico State Univ.
Burleson, G.	New Mexico State Univ.	Devereux, M.	New Mexico State Univ.
Verbeck, S.	New Mexico State Univ.	Taylor, C.	Norfolk State Univ.
Iversen, S.	Northwestern Univ.	Lang, P.	Northwestern Univ.
Obst, A.	Northwestern Univ.	Baird, T.	Rensselaer Polytech. Univ.
Ernst, D.	Texas A&M Univ.	Christian, W.	Tuskegee Inst.
Oillataguerre, P.	UC, Los Angeles	Greene, S.	Univ. of Colorado
Allred, J.	Univ. of Houston	Alde, D.	Univ. of Illinois
Frauenfelder, H.	Univ. of Illinois	Hoffert, W.	Univ. of Indiana
Rickey, M.	Univ. of Indiana	Gluckstern, R.	Univ. of Maryland
Anderson, H.	Univ. of Chicago	Austern, N.	Univ. of Pittsburgh
Malbrough, D.	Univ. of South Carolina	Preedom, B.	Univ. of South Carolina
Blanpied, G.	Univ. of Texas	Bolger, J.	Univ. of Texas
Boyer, K.	Univ. of Texas	Hoffman, G.	Univ. of Texas
Liljestrand, R.	Univ. of Texas	Moore, C.	Univ. of Texas
Whitenton, J.	Univ. of Texas	Morris, C.	Univ. of Virginia
Luckstead, S.	Washington State Univ.	Hughes, V.	Yale Univ.
Willis, S.	Yale Univ.	Friar, J.	Brown Univ.
Bethe, H.	Cornell Univ.	Sevgen, A.	MIT
Todd, P.	Penn. State Univ.	Powers, R.	California Inst. Tech.
Smith, E.	Univ. of Texas	Long, M.	Univ. of Montana
Garcia, M.	New Mexico State Univ.	Elliot, S.	New Mexico State Univ.
Martinez, L.	New Mexico State Univ.	Chacon, D.	New Mexico State Univ.
Maestas, A.	New Mexico State Univ.	Salazar, E.	New Mexico State Univ.
Sena, K.	New Mexico State Univ.	Ortiz, E.	New Mexico Tech. Voc.
Parra, J.	New Mexico Tech. Voc.	Johnson, M.	New Mexico Tech. Voc.
Alarid, C.	New Mexico Tech. Voc.	Heller, P.	Indiana Univ.
Nance, R.	Univ. of New Mexico	Waterbury, R.	New Mexico State Univ.
Esposito, M.	New Mexico State Univ.	Wechsler, P.	Univ. of Wyoming
Baldwin, G.	Univ. of Michigan	Bohanan, R.	Univ. of New Mexico (NAPCOE)
Levine, H.	MIT	Esquibel, C.	Highlands Univ.
Easley, G.	Univ. of New Mexico	Richardson, S.	Univ. of New Mexico
Sweet, D.	UC, Davis	Valencia, J.	Univ. of New Mexico
Taylor, J.	Univ. of New Mexico	Klosterbuer, S.	Univ. of South Dakota
Naranjo, L.	Univ. of New Mexico (NAPCOE)	Laubacher, D.	New Mexico State Univ.
Cverna, F.	Case Western Res. Univ.	Evans, R.	NM Inst. Mining & Tech.
Hickman, M.	NM Inst. Mining & Tech.	Simons, S.	New Mexico State Univ.
Fireman, E.	Smithsonian Inst.	Rojas, T.	Chapman College
Vier, A.	UC, San Diego	Renfro, J.	Univ. of New Mexico

Vigil, D.	Univ. of New Mexico	Zaider, M.	Univ. of New Mexico
Heffner, R.	Univ. of Washington	Moir, D.	Arizona State Univ.
Redwine, R.	Northwestern Univ.	Scheidegger, K.	New Mexico State Univ.
Sanchez, A.	Highlands Univ.	Vigil, B.	Highlands Univ.
Coulter, A.	Univ. of Alabama	Law, A.	Univ. of Regina
Metzger, C.	CERN	Naumann, R.	Princeton Univ.
Minh, D.	SLAC	Johns, H.	Ontario Cancer
Triftshauser, W.	Univ. of Munchen	Sanders, G.	Princeton Univ.
Ingram, Q.	SIN	Sadrozinski, H.	Princeton Univ.
Kunz, P.	Stanford Univ.	Plattner, R.	Univ. of Basel
Takahashi, S.	Univ. of Hamamatsu	Burks, J.	Univ. of Colorado Med.
Mackenzie,	Univ. of Guelph	Keister, B.	Carnegie-Mellon Univ.
Combley, F.	Univ. of Sheffield	Adler, S.	Princeton Univ.
Cramer, J.	Univ. of Washington	Grodzins, L.	MIT
Henley, E.	Univ. of Washington	Huizenga, J.	Univ. of Rochester
Morgan, I.	Columbia Scientific Ind.	Siegel, R.	Univ. of Virginia
Steiner, H.	UC, Berkeley	Turkevich, A.	Univ. of Chicago
Walecka, J.	Stanford Univ.	Fearing, H.	Univ. of British Columbia
Mayer, B.	Univ. of Houston	Peterson, R.	Univ. of Colorado
Caretto, A.	Carnegie-Mellon Univ.	Lind, D.	Univ. of Colorado
Garvey, G.	Princeton Univ.	Harvey, B.	UC, Berkeley
Vogt, E.	Univ. of British Columbia	Kozlowski, T.	BNL
Dragoset, W.	Rice Univ.	Felder, R.	Rice Univ.
Williams, T.	Rice Univ.	Ridge, R.	UC, Los Angeles
Rolf, R.	UC, Los Angeles	Braithwaite, W.	Univ. of Texas
Johnson, K.	Temple Univ.	Holt, R.	ANL
Jackson, H.	ANL	Kaufman, S.	ANL
Meyer, L.	ANL	Nardi, B.	ANL
Schiffer, J.	ANL	Steinberg, E.	ANL
Tabor, S.	ANL	Vigdor, S.	ANL
Worthington, J.	ANL	Zeidman, B.	ANL
Wang, K.	Baylor Univ.	Chasman, R.	BNL
Espensen, B.	BNL	Evans, J.	BNL
Galvin, J.	BNL	Palevsky, H.	BNL
Remsberg, L.	BNL	Sutter, R.	BNL
Boehm, F.	California Inst. of Tech.	Hahn,A.	California Inst. of Tech.
Marrs, R.	California Inst. of Tech.	Miller, J.	California Inst. of Tech.
Barnard, R.	UNM Cancer Center	Cameron, E.	UNM Cancer Center
Crawford, D.	UNM Cancer Center	Fullman, N.	UNM Cancer Center
Hayes, A.	UNM Cancer Center	Hogstrom, K.	UNM Cancer Center
Kelsey, C.	UNM Cancer Center	Lane R.	UNM Cancer Center
Marsh, N.	UNM Cancer Center	Selheimer, C.	UNM Cancer Center
Smith, A.	UNM Cancer Center	Stevens, M.	UNM Cancer Center
Amann, J.	Carnegie-Mellon Univ.	Bernsteen, S.	Carnegie-Mellon Univ.
Clark, J.	Carnegie-Mellon Univ.	Craig, J.	Carnegie-Mellon Univ.
Doss, M.	Carnegie-Mellon Univ.	Dytman, S.	Carnegie-Mellon Univ.
Eisenstein, R.	Carnegie-Mellon Univ.	Karol, P.	Carnegie-MellonUniv.
Marlow, D.	Carnegie-Mellon Univ.	Sherman, J.	Carnegie-Mellon Univ.
Wharton, W.	Carnegie-Mellon Univ.	Baer, H.	Case Western Res. Univ.
Bevington, P.R.	Case Western Res. Univ.	McNaughton, M.	Case Western Res. Univ.
Willard, H.	Case Western Res. Univ.	Barnes, P.	Carnegie-Mellon Univ.
Bordner, C.	Colorado College	Duclos, J.	Saclay
Kalbach, C.	Duke Univ.	Greenfield, M.	Florida A&M
Williams, T.	Florida A&M	Hoehn, M.	Florida State Univ.
Wagner, L.	Florida State Univ.	Yamazaki, Y.	Florida State Univ.

Hill, J.	Iowa State Univ.	Shirk, D.	Iowa State Univ.
Anderson, B.	Kent State Univ.	Warren, J.	Lake Head Univ.
Poskanzer, A.	LBL	Shively, F.	LBL
Bloom, S.	LLL	Browne, J.	LLL
Becker, J.	Lockheed	Fisher, J.	Lockheed
Watson, B.	Lockheed	Crane, T.	Yale Univ.
Yates, M.	Carnegie-Mellon Univ.	Marshak, H.	NBS
Hargrove, C.	National Res. Council of Canada	Rutledge, L.	Northwestern Univ.
Segel, R.	Northwestern Univ.	Seth, K.	Northwestern Univ.
Bertrand, F.	ORNL	Cleary, T.	ORNL
Gross, E.	ORNL	Hill, N.	ORNL
Ludeman, C.	ORNL	Plasil, F.	ORNL
Krane, K.	Oregon State Univ.	Sharma, T.	Oregon State Univ.
Swenson, L.	Oregon State Univ.	Naumann, R.	Princeton Univ.
Schmidt, G.	Princeton Univ.	Biswas, S.	Purdue Univ.
Fortney, D.	Purdue Univ.	Klonk, H.	Purdue Univ.
Porile, N.	Purdue Univ.	Steffen, R.	Purdue Univ.
Church, L.	Reed College	Buchanan, J.	Rice Univ.
Clement, J.	Rice Univ.	Gabitzsch, J.	Rice Univ.
Haftiezer, J.	Rice Univ.	Judd, D.	Rice Univ.
Madigan, W.	Rice Univ.	Mutchler, G.	Rice Univ.
Phillips, G.	Rice Univ.	Williams, T.	Rice Univ.
Goldstone, J.	State Univ. of New York	Alster, J.	Tel-Aviv Univ.
Ashery, D.	Tel-Aviv Univ.	Friedland, S.	Tel-Aviv Univ.
Gilad, S.	Tel-Aviv Univ.	Moinester, M.	Tel-Aviv Univ.
Shamai, Y.	Tel-Aviv Univ.	Yavin, A.	Tel-Aviv Univ.
Auerbach, L.	Temple Univ.	Colella, N.	Temple Univ.
Highland, V.	Temple Univ.	Kopera, T.	Temple Univ.
McFarlane, K.	Temple Univ.	Schwartz, R.	Temple Univ.
Valentine, J.	Temple Univ.	Glass, G.	Texas A&M
Jain, M.	Texas A&M	Natowitz, J.	Texas A&M
Northcliffe, L.	Texas A&M	Collier, J.	Tulane Univ.
Orth, H.	Univ. of Heidelberg	ZuPulitz, G.	Univ. of Heidelberg
Meyer, H.	Univ. of Basel	Reist, H.	Univ. of Bern
Goulding, C.	Univ. of British Columbia	King, N.	UC, Davis
Brooks, G.	UC, Irvine	Chen, H.	UC, Irvine
Iyer, R.	UC, Irvine	Lathrop, J.	UC, Irvine
Nakamura, S.	UC, Irvine	Smith, W.	UC, Irvine
Brandle, H.	UC, Los Angeles	Fong,J.	UC, Los Angeles
Glodis, P.	UC, Los Angeles	Haden, K.	UC, Los Angeles
Hazhighi, H.	UC, Los Angeles	Igo, G.	UC, Los Angeles
Kostoulas, I.	UC, Los Angeles	Matz, N.	UC, Los Angeles
Nefkens, B.	UC, Los Angeles	Plumlee, W.	UC, Los Angeles
Sander, O.	UC, Los Angeles	White, G.	UC, Los Angeles
Winnan, N.	UC, Los Angeles	Cadie, J.	Univ. of Chicago
Economou, T.	Univ. of Chicago	La Rosa, J.	Univ. of Chicago
Swallow, E.	Univ. of Chicago	Talaga, R.	Univ. of Chicago
Boudrie, R.	Univ. of Colorado	Depolo, N.	Univ. of Colorado
Digiacomo, J.	Univ. of Colorado	Kraushaar, J.	Univ. of Colorado
Park, A.	Univ. of Colorado	Ristinen, R.	Univ. of Colorado
Smith, G.	Univ. of Colorado	Bart, S.	Univ. of Houston
Hungerford, E.	Univ. of Houston	Kallcor, J.	Univ. of Houston
Koester, K.	Univ. of Houston	Lee, L.	Univ. of Houston
Lo, J.	Univ. of Houston	Pinsky, L.	Univ. of Houston

Thomasson, J.	Univ. of Houston	Warneke, M.	Univ. of Houston
Sorensen, L.	Univ. of Illinois	Dehnhard, D.	Univ. of Minnesota
Hintz, N.	Univ. of Minnesota	Kyle, G.	Univ. of Minnesota
Oothoudt, M.	Univ. of Minnesota	Reidy, J.	Univ. of Mississippi
Jakobson, M.	Univ. of Montana	Jeppesen, R.	Univ. of Montana
Bhave, D.	Univ. of New Mexico	Bryant, H.	Univ. of New Mexico
Carline, R.	Univ. of New Mexico	Dhingra, K.	Univ. of New Mexico
Dieterle, B.	Univ. of New Mexico	Donahue, J.	Univ. of New Mexico
Glatzmaier, G.	Univ. of New Mexico	Heckert, P.	Univ. of New Mexico
Hills, J.	Univ. of New Mexico	Leavitt, C.	Univ. of New Mexico
Moy, E.	Univ. of New Mexico	Rosen, I.	Univ. of New Mexico
Rupp, T.	Univ. of New Mexico	Sach, M.	Univ. of New Mexico
Sharifian, H.	Univ. of New Mexico	Thomas, W.	Univ. of New Mexico
Tootoonchi, H.	Univ. of New Mexico	Wolfe, D.	Univ. of New Mexico
Petry, R.	Univ. of Oklahoma	McDaniels, J.	Univ. of Oregon
Varghese, P.	Univ. of Oregon	Frankel, S.	Univ. of Pennsylvania
Selove, W.	Univ. of Penn.	Johnson, W.	Univ. of Rochester
Schroeder, W.	Univ. of Rochester	Cohenca, J.	Univ. of Sao Paulo
Darden, C.	Univ. of South Carolina	Edge, R.	Univ. of South Carolina
Marks, T.	Univ. of South Carolina	Cole, R.	Univ. of Southern California
Waddell, C.	Univ. of Southern California	Giebink, D.	Univ. of Texas
McGill, J.	Univ. of Texas	Newsom, C.	Univ. of Texas
Riley, P.	Univ. of Texas	Vullemier, J.	California Inst. of Tech.
Bosewell, J.	Univ. of Virginia	Bube, E.	Univ. of Virginia
Comiso, J.	Univ. of Virginia	Courtemanche, J.	Univ. of Virginia
McCarthy, J.	Univ. of Virginia	Miller, R.	Univ. of Virginia
Wadlinger, E.	Univ. of Virginia	Whitner, K.	Univ. of Virginia
Ziock, H.	Univ. of Virginia	Ziock, K.O.H.	Univ. of Virginia
Ziock, K.P.	Univ. of Virginia	Chiang, D.	Univ. of Washington
Halpern, I.	Univ. of Washington	Knutson, L.	Univ. of Washington
Weitkamp, W.	Univ. of Washington	Erwin, A.	Univ. of Wisconsin
Bjork, C.	Univ. of Wisconsin	Dennison, A.	Univ. of Wyoming
King, T.	Univ. of Wyoming	Kunselman, R.	Univ. of Wyoming
Le Compte, M.	Univ. of Wyoming	Oyer, A.	Univ. of Wyoming
Rebka, G.	Univ. of Wyoming	Roberson, P.	Univ. of Wyoming
Walter, J.	Univ. of Wyoming	Gotow, K.	Virginia Polytech. Inst.
Jenkins, D.	Virginia Polytech. Inst.	Lam, W.	Virginia Polytech. Inst.
Milder, F.	Virginia Polytech. Inst.	Knowles, H.	Washington State Univ.
Majewski, P.	Washington State Univ.	Ruddy, F.	Washington State Univ.
Tripard, G.	Washington State Univ.	Vine, E.	Wahington State Univ.
Broughton, R.	Yale Univ.	Casperson, D.	Yale Univ.
Egan, P.	Yale Univ.	Lu, D.	Yale Univ.
Mariam,F.	Yale Univ.	Nemethy, P.	Yale Univ.
Souder, P.	Yale Univ.	Trudell, A.	Yale Univ.
Daniel, H.	Univ. of Munchen	Burgerjon, J.	TRIUMF
Walwecka, J.	Stanford Univ.	Källne, J.	Univ. of Uppsala
Cochavi, S.	Tel-Aviv Univ.	Gilad, S.	Tel-Aviv Univ.
Bolton, R.	Univ. of New Mexico	Buchen, J.	Univ. of New Mexico
Hwang, L.	UC, Santa Barbara	Neher, P.	UC, Santa Barbara

Institutions Using "G" Accounts

Name	Experiments
Baylor Univ.	Exp. 111
California Inst. of Tech.	Exps.11, 12, 166, 173, 801, 161, 246
Carnegie-Mellon Univ.	Exps. 140, 180, 191, 123, 246
Case Western Reserve Univ.	Exps. 176, 50
Catholic Univ.	Exp.254
College of William and Mary	Exps. 166, 62, 12
Colorado College	Exp. 99
Florida A&M Univ.	Exps. 62, 93, 156
Florida State Univ.	Exps. 156, 93, 62, 35
George Mason Univ.	Exp. 62
Iowa State Univ.	Exp.62
Kent State Univ.	Exp. 80, 81, 176
M. D. Anderson	Exp. 161A
Massachusetts Inst. of Tech.	Exp.99
New Mexico State Univ.	Exps. 164, 2, 173
Northwestern Univ.	Exps. 53, 121
Oregon State Univ.	Exps. 93, 156
Purdue Univ.	Exps. 243, 53
Rice Univ.	Exps. 84, 80,81
Stanford Univ.	Exp. 164
State Univ. of New York at Buffalo	Exp. 123
Temple Univ.	Exps. 164, 124, 189, 2
Texas A&M	Exps. 111, 86, 125, 129, 205, 62
Univ. of California, Davis	Exp.176
Univ. of California, Berkeley	Exp.
Univ, of Chicago	Exps. 121, 150
Univ. of California, Irvine	Exps. 174, 148
Univ. of California, Los Angeles	Exps. 4, 90, 15
Univ. of California, Santa Barbara	Exp. 42
Univ. of Colorado	Exp. 246
Univ. of Houston	Exps. 80, 81, 84
Univ. of Minnesota	Exp. 15
Univ. of Montana	Exp. 164, 2
Univ. of New Mexico	Exps. 129, 200, 125, 124,
Univ. of Oklahoma	Exp.111
Univ. of Oregon	Exp. 156
Univ. of Rochester	Exp. 142
Univ. of Southern California	Exp. 42
Univ. of South Carolina	Exps. 234, 131, 29, 54
Univ. of Texas at Austin	Exps. 205, 99, 276
Utah State Univ.	Exps. 93, 62
Univ. of Virginia	Exps. 156, 28, 99, 90, 246, 35
Univ. of Washington	Exps. 140, 180, 191, 164, 2
Univ. of Wyoming	Exps. 12, 99, 173, 122, 166
Univ. of Pennsylvania	Exp. 189
Virginia State College	Exp. 62
Virginia Polytech Inst. and State Univ.	Exps. 234, 93, 131
Washington Univ.	Exp. 84
Yale Univ.	Exps. 31, 801, 29, 54

☆ U.S. GOVERNMENT PRINTING OFFICE 1977—777-018/15