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Compiled by

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GLOSSARY OF TERMS USED IN THIS REPORT

ADC – Analog Digital Converter
ADS – Analog Data System
APL – A Programming Language
ASCII – American Standard Code for Information Interchange
CCF – LASL Central Computer Facility
CCT – Color Character Terminal
CCR – Computer Control Room
CCTV – Closed Circuit Television
CIU – Console Interface Unit
CPU – Central Processing Unit
CRT – Cathode Ray Tube
cw – Continuous Wave
C-W – Cockcroft-Walton
DACT – Data-Acquisition and Control Terminal
DPM – Digital Panel Meter
DVM – Digital Volt Meter
EFB – Effective Field Boundary
EPA – Electron Prototype Accelerator
ETL – Equipment Test Laboratory
FET – Field-Effect Transistor
fh – Filament Hours
FWSS – Fast-Wire-Scanner System
hfs – Hyperfine Structure
hvh – High-Voltage Hours
IC – Integrated Circuit
ICR – Injector Control Room
IDS – Information Display System
IEC – International Electrotechnical Commission
IFA – Interface Amplifier
I/O – Input/Output
ISIC – Insertable-Strip Ion Chambers
IVR – Induction Volt Regulator
LAM – Look-at-Me Interrupt
LAMPF – Clinton P. Anderson Meson Physics Facility
LCF – Localized Current Fields
LED – Light-Emitting Diode
LEEP – LAMPF Electronics and Equipment Pool
LET – Linear-Energy Transfer
MBD – Microprogrammed Branch Driver
m.i. – Mineral Insulated
MIG – Metal Inert Gas
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
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
SSD – Serial System Driver
SY – Switchyard
TDC – Time-to-Digital Converter
TDI – Temperature-Difference Integrator
TIG – Tungsten Inert Gas
TOF – Time of Flight
TR – Transition Region
VSWR – Voltage Standing-Wave Ratio

Experimental Area

Primary beam lines in experimental area:

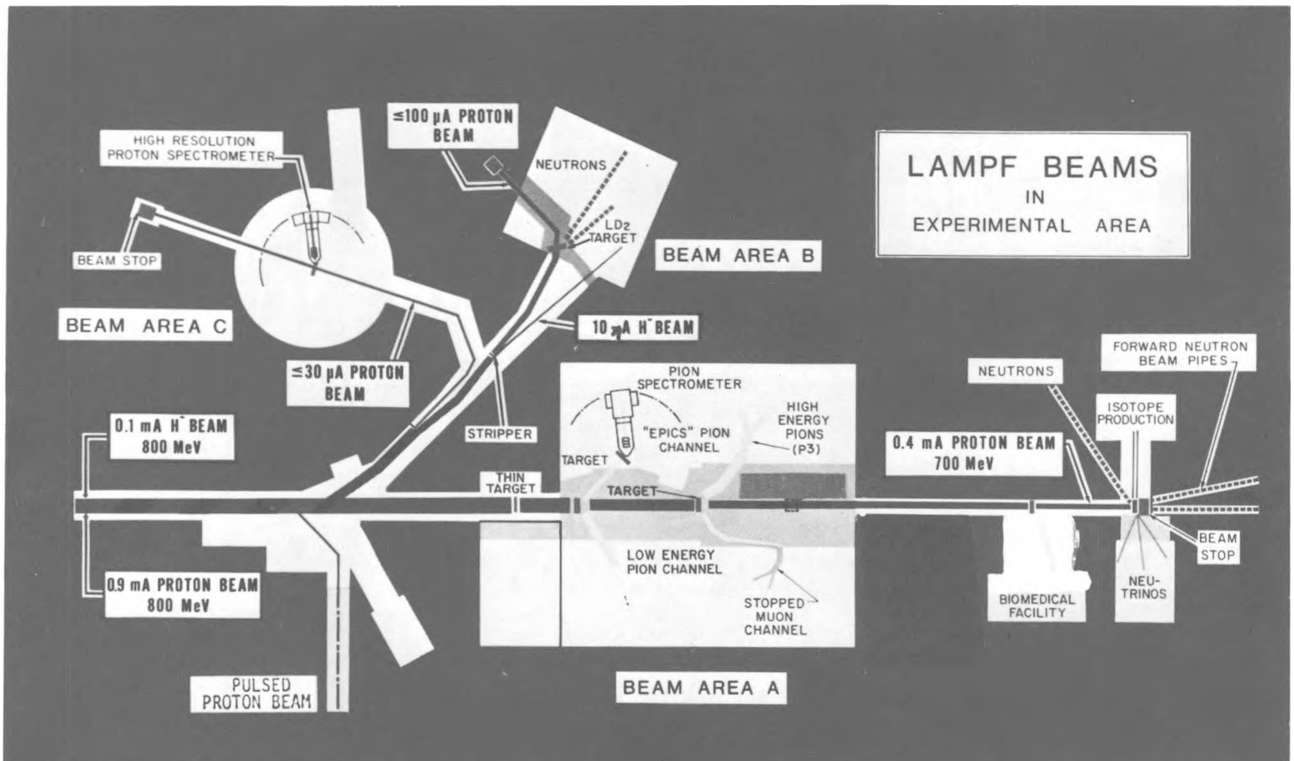
- Line A – Main Beam Line
- Line B – Nuclear Chemistry Facility
- Line C – High-Resolution Proton Spectrometer
- Line D – Weapons Neutron Research Facility

Experimental beams:

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

Beam Area C:
CCH – Area C Control and Counting House

HRS – High-Resolution Proton Spectrometer



Channel	Energy (MeV)	Beam
LOW ENERGY PION	0-300	$3\times10^9\pi^+$/SEC. OR $8\times10^8\pi^-$/SEC.
HIGH ENERGY PION (P3)	100-600	$10^{10}\pi^+$/SEC. OR $10^9\pi^-$/SEC.
EPICS PION BEAM	50-300	$4\times10^8\pi^+$/SEC. OR $10^8\pi^-$/SEC.
STOPPED MUON	0-165	$5\times10^7\mu^+$/SEC. OR $10^7\mu^-$/SEC.

Channel	Energy (MeV)	Beam
NEUTRONS (AREA B)	795	2×10^7 n/cm^2–SEC
NEUTRONS (BEAM STOP)	1-20	10^9 n/cm^2 – SEC. (INST.)
BIOMEDICAL	80-100	$2\times10^8\pi^-$/SEC.
NEUTRINOS	20-50	5×10^7 ν/cm^2 – SEC.

Channel intensities quoted above are full-open rates at maximum proton current and target thickness.

QUARTERLY REPORT ON THE MEDIUM-ENERGY PHYSICS PROGRAM

FOR THE PERIOD ENDING JANUARY 31, 1976

I. SUMMARY

Engineering Support

First priority in time and effort continued to be directed in support of the Experimental Area A program. Fabrication activities associated with this program are essentially complete.

Work in the Biomedical Area is continuing; extensive alignment support was provided in all of the experimental areas, and the engineering support necessary to effect the erection of the EPICS spectrometer was initiated.

Over 76 000 socket hours were accumulated on the accelerator in this quarter. Fourteen modulator/klystron units and twenty-seven switchtubes were replaced. Twenty-five more switchtubes were ordered and forty-five were reprocessed. Ten more klystrons were ordered and three were rebuilt.

Preparatory steps for rebuilding the electron prototype accelerator (scheduled for shipment to Yugoslavia) have begun. The equipment required to rebuild the accelerator is being assembled at the ETL. The accelerating sections and the 100-kW modulator have been moved to ETL for restoration to operating condition.

Experiment support has once again reached a significant level. Several experiments are on-line and several more are being readied for early installation.

Accelerator Support

The activities for this quarter are best characterized as a continuing search for more information on, and methods to improve, reliability.

A reliability study has been initiated based on information contained in the operations and maintenance reports. We hope to be able to use this ongoing analysis to pinpoint those units with high failure rates and long downtimes.

A preventive maintenance program for all rf systems was scheduled around the biweekly maintenance days.

Better system electrical drawings are being generated to aid in troubleshooting.

Modification of magnet power supplies has continued to achieve standardization, ease troubleshooting, and achieve better reliability.

The 201-MHz test stand is now available for 7835 gas checks and 4664 dc processing. When the stand becomes available for rf testing and processing, a spare stock of "known good" power tubes can be maintained. This should significantly cut 201-MHz downtime required for tube conditioning.

Mechanical support for HRS and vacuum support of efforts in Areas A and B have continued this quarter.

Equipment availability and beam availability have improved greatly since the shutdown. Equipment availability is near 90% and beam availability is near 80%.

Accelerator Systems Development

Analysis of 201-MHz linac bead-pull data was continued and documentation of the results began. An extensive experiment on the characteristics of the first tank at different field tilts was completed on the accelerator, and analysis was started. This work has led to increased understanding of how detailed dynamics calculations should be accomplished; extensions to PARMILA have been made.

Automation of the Δt procedures for checking and phasing the 805-MHz linac was successfully tested. This will improve the speed and consistency of tuning.

Experiments were completed on transverse matching, halo measurement using wire scanners and loss monitors, and beam position monitors.

Data-base development concentrated on improvements and extensions to the equipment reporting system and the Visitors Center system.

A number of instrumentation activities were conducted in preparation for more detailed investigation of transverse properties of the linac.

The EPICS separator was operated at design field, and the Biomed pion range shifter was tested for the first time as a closed-loop servomechanism.

Injector Systems

The H^+ injector was used for the first time for a production run at LAMPF. A proton beam of 25-μA average current was run for several shifts for a radiation-damage experiment. The H^- injector has been used for all other production runs.

Beam studies have been carried out in off-line operation of the H^+ injector to optimize operating conditions for high duty factor beams. Injector beams, which would provide several hundred microamperes of accelerated beam in the linac, have been run for several days with a fault rate of <0.5 arcs/h.

A modification was incorporated into the arc pulse modulator of the H^+ injector that permits the risetime of the arc current to be varied from 3 to 100 μs which in turn results in a similar risetime of the proton beam. This capability to vary the beam pulse risetime has already been used in linac development tests and may be useful in minimizing turn-on transients in the rf systems.

The H^- ion source was dismantled and several electrodes replaced after the fault rate on the extractor power supply became excessive. This source had run continuously for six months with no maintenance other than filament replacement. The cause of the extractor trips was due to spallation of the titanium electrodes because of hydrogen embrittlement.

The molybdenum insert anode aperture exhibited some melting damage after six months of operation but was still operative. It was, however, replaced and will be refurbished.

A prototype for a new high-power, transistorized arc pulse modulator was built and tested and is capable of 200-A/250-V operation at 6% duty factor. This unit was installed in the H^- injector and run for several hours at 6% duty factor, with no faults, and its performance easily exceeded that of the present SCR modulator. The lower impedance of the transistor drivers and the simplicity of its design should make a modulator of this design more reliable for ion source operation.

Design work and some mechanical assembly on existing hardware continues in the polarized ion injector program. Final fabrication is still being delayed by funding problems.

Electronic Instrumentation and Computer Systems

The intensive schedule of accelerator operations left little time for control computer development. The only significant addition to the hardware was a ROM bootstrap loader to initiate the loading of system software.

Development work continued on the information-exchange bus for the operator consoles and on the new master timing and distribution system.

Work began on the extension of the software and interface hardware required to control the polarized ion source from ICR and CCR.

The cause of a continual source of data-link errors between CCR and the satellite control computers was isolated and corrected.

The emphasis of software developments was on programs to aid operations. Two new programs were written to simplify control of the master timer during dual-beam operation. Work began on a series of programs to analyze the run-permit system for faults. A program to display the integrated beam current from the SY toroid current monitors was completed.

Numerous and significant changes were made to the controls and instrumentation along the primary and secondary beam lines. The harp system went through its final hardware and software tests. The EPICS α-particle test was successfully repeated to verify that the additions and modifications to the channel were operational. The regulator rack of controls for the trim windings for LCBM04 and 05 was completely rebuilt.

An intensive program of repairing and updating the LAMPF communications system was initiated.

Various pieces of the two new PDP-11/45s for LEEP began arriving in January. The Terminal computer was expanded with another 2-M word disk, 32k of core, and two dial-up phone lines.

The general data-acquisition program, Q, was converted to run under RSX-11D Version 6 and used successfully in the EPICS α-particle test.

A recent allotment of funds to LEEP made it possible to purchase several high-priority pieces of equipment.

Some long-standing analog instrumentation problems were attacked, with positive results.

Accelerator Operations

The accelerator was in continuous operation throughout the quarter for a total of 276 shifts. Of the total, 79 shifts were scheduled for accelerator development, 11 for maintenance, 14 for tuneup for production (research) beams, and 172 for research. Beam availability during research shifts averaged 74%.

Because upgrading of Experimental Area A was still in progress, research beams were limited to the beam switchyard, and Lines B and EPB. Beam currents to Lines B and EPB for experimental use totalled 740 μA-h. An additional 750 μA-h was delivered to the switchyard during one 36-h period for a radiation-damage experiment. Fourteen experiments received beam during the quarter.

Machine operation was more stable and reliable during this quarter than at any time in the past. The improvement can be attributed to the general upgrading of the machine during the recent shutdown, and the monitoring capabilities provided by the redundant phase-monitoring system and several new control computer programs. A major portion of the accelerator downtime occurred during machine startup following scheduled maintenance days.

Accelerator development activities concentrated on measurements needed for the eventual determination of the optimum field tilt for Tank 1 and the development of tuning procedures for dual-beam operation. Simultaneous operation at 100-μA H^+ and 3-μA H^- and single-beam operation at 165-μA H^+ at 800 MeV, to the switchyard beam stop, were attained without great difficulty. Problems associated with accelerating the high peak currents necessary for operation at 0.5- to 1-mA average currents were investigated. Wire scanners and beam-spill monitors were used to measure beam halos along the linac. Beam-position monitors were evaluated. Measurements of the adequacy of existing tank-resonance controllers were begun.

Installation and checkout of beam-current and spill monitors and personnel safety systems in Area A proceeded with difficulty due to electrical noise and damage to cables in the course of shield stacking.

Experimental Areas

Shutdown work dominated experimental area activities during this quarter. The PERT system was discontinued at the end of the quarter as the list of essential work activities remaining to be done before Areas A and A-East are ready for regular beam grew very short. Initial beam checkout of Area A was scheduled for February 14 and the beginning of the two-week cycle of main and secondary beam line checkout was set for March 6.

The five radioactive water-cooling systems have been checked out and placed in operation. Flow meters and remote manual valve operators have been installed. A new pump/heat exchanger for nonradioactive water is being installed in Area A. The resin systems have been upgraded and a nitrogen-tube trailer was added to the surge-tank pressurization systems.

Cryogenic targets for several experiments have been built, tested, and placed into service. One refrigerator has been repaired and a new cryogenic control console has been built.

Essentially all of the main beam components have been installed, but a number of items such as instrumentation, plumbing, and wiring still must be completed along Line A. Observation of the alignment of components at target cell A-1 while the Merrimac doors were moved revealed no relative displacements.

The secondary beam lines in Area A are ready for beam. Lines B and EPB are operating routinely. Support is being rendered for experiments in operation in Area B and in preparation in Area A.

The pion-production target systems at A-1 and A-2 have been installed and checked out for beam. The A-5 target system is being prepared for installation.

An order for a complete two-arm, force-reflecting servomanipulator system was placed. One arm will be delivered in December 1976, and the second in April 1977. A vehicle similar to Monitor will be used in conjunction with the new manipulator system. A one-arm, nonforce-reflecting system is on loan from the U.S. Navy for interim use while awaiting delivery of the new system.

Construction has started on a remote-handling mockup facility for training and development. Fixtures for removing and reinstalling steering magnets were built and tested.

Improvements to the closed-circuit TV and lighting systems on Monitor were carried out.

Shielding installation has reached the final stages of in-cell shield installation and Merrimac door completion. Operation of the A-1 doors resulted in accidental damage to portions of the LEP channel, causing about one week of repair work.

Beam Line Development

Preparation of Line A-South (in the beam SY) beam line magnets, beam diagnostic instrumentation, and vacuum systems are essentially completed, and the line is ready for first beam. Preparation of primary proton beam line magnets and beam diagnostic instrumentation for Area A are also essentially completed. Primary beam line magnets and beam diagnostic instrumentation for Area A-East are only slightly behind Area A in time.

Tunes of the Line A beam transport from the end of the linac to the A-6 beam stop have been calculated for a variety of target combinations in preparation for testing of beam diagnostic instrumentation, tuning of secondary beam lines, and production running of Line A.

Some improvements of the Lines X, B, and EPB wire scanners and TV phosphor systems have been made which reduce noise and/or increase reliability and convenience.

Procedures for tuning Lines X, B, and EPB were written, tested, and turned over to MP-2 operating crews, who now do the tuning and monitoring of H^- production beams for Area B.

A program to improve measurements of emittance and other transverse beam phase parameters has begun using switchyard wire-scanner data.

A reevaluation of experimental area vacuum systems has been undertaken with a view to finding ways of reducing the risk of vacuum accidents which may destroy Line A harps, targets, and other fragile beam line components.

Large-Spectrometer Systems

Energetic Pion Channel and Spectrometers

The EPICS-channel shielding was installed during the past quarter. In order to get tight-fitting shielding, it was necessary to rework a portion of the dc wiring and replace some conventional cable with water-cooled busses. The taut-wire system was installed and made operational. The separator was operated at full design voltage (300 kV), and enough information was obtained from this run to allow us to design a control system to make this a reliable, routine operation. The EPICS data-acquisition software was brought into routine operation for the first time and worked remarkably well. The detectors and beam monitors required for the channel tuneup are approximately 80% complete, and all tests to date have been successful. Work on the EPICS spectrometer has not progressed as rapidly as expected; however, two major decisions were taken. First, that the MP-Division engineering group (MP-8) will do the field engineering required for construction of the spectrometer; and second, that the existing lightweight floor in Area A will be replaced with a solid concrete foundation specifically designed to meet the spectrometer requirements. Our best estimate of the spectrometer completion date is now November 1 1976 with production data-taking occurring approximately January 1, 1977.

High-Resolution Proton Spectrometer

During November all magnetic measurements were completed on the spectrometer dipoles and they were prepared for rigging into the spectrometer frame. The rigging operation began in Area C during the last week of November. The first dipole (HS-BM-01) was installed by the end of December, and the second was installed by the last week in January. Strain gauge measurements of the relative motion between component parts of each dipole showed no measurable changes between the horizontal configuration on the floor of Area C and the final vertical configuration of the dipoles in the spectrometer frame.

Related work which was accomplished during this period includes: 1) installation of the cable bridge mounts on the wall and the top of the spectrometer; 2) installation of some of the jacking and hanging hardware for alignment of the dipoles; 3) installation of the spectrometer catwalk, elevator, and ground-level pivot-point platform; and 4) reinstallation of the beam line hardware which had to be removed for the rigging of the dipoles. The cable bridge has been moved into Area C for installing cable trays and cable prior to installation on the spectrometer frame. The last spectrometer power supply has been installed in the B/C equipment building and is now being modified for control from CCH. The spectrometer is currently ready to be moved to an angle of 30° in the laboratory after which optical alignment of the system will begin, together with installation of the water cooling to the magnets, etc.

Other work performed during this period includes: 1) completion of the taut-wire system upstream of the Line C shield wall; 2) tests of ISIC drive and control hardware; 3) layout of the spectrometer drive control and interlock system as well as partial fabrication; 4) installation of the rotating table and drive hardware together with their calibration; and 5) final assembly of the target rotation and elevation mechanism. The vacuum system for the scattering chamber was laid out and basic components have been acquired.

The various components for the last detector for the particle-identification system (PID) have been received and the detector is being assembled. The remote positioning and support hardware for the inner TOF detectors have been built and are being modified in the shops. Final modifications for the remotely controllable delays for the PID electronics have been checked out. Finally, the overall support structure and drive hardware for the outer TOF detectors have been built and are being tested.

Research

The group working on Exp. 2 (total cross sections of pions on nuclei) has reported an analysis of the total-cross-section data for ^{40}Ca and ^{48}Ca and for ^{13}C and ^{12}C, in the region of the first pion resonance. The direct results of the measurements give the total cross section of the several isotopes as a function of pion energy. In order to interpret the data in terms of nuclear matter and nuclear charge distributions, Kisslinger-type optical model calculations have been carried out, using measured pion-nucleon scattering amplitudes and charge distributions from electron-scattering experiments. The results show that, contrary to intuition, the neutron-proton radius difference changes little in going from ^{40}Ca to ^{48}Ca.

The reaction $\pi^- + T \rightarrow 3n + \gamma$ was studied using a converter for the γs and a pair-spectrometer. The γ-ray spectrum was carefully measured. Some conclusions of the experiment are (a) the bound trineutron is not seen; an upper limit to the branching ratio is 0.3%, (b) no evidence for a $T = 3/2$ (3n) resonance was found, (c) the absolute rate of the reaction was measured. A paper has been submitted to Phys. Rev. Lett. for publication.

The Rice-Houston groups have submitted for publication papers on measurements of the p-d reaction at 585 and 800 MeV; the 800-MeV portion of the work was done at LAMPF.

Four papers concerned with nuclear spectroscopy studies of proton-induced spallation products have been submitted for publication.

Data on the $\pi^+ d \rightarrow pp$ reaction have been analyzed and compared with theory. A preliminary report was presented as an invited paper at the Santa Fe conference last June.

A paper was published on the single-charge-exchange reaction (π^+,π^0) on nuclei, in the pion resonance region; ^7Li, ^{10}B, and ^{13}C were studied using activation methods. The excitation function from 70- to 250-MeV pion energy is rather flat. A companion paper gives a theoretical study of these reactions.

The CalTech-Wyoming group has completed analysis of muonic x rays in $_{67}Ho^{165}$, $_{73}Ta^{181}$, and $_{66}Dy^{161}$ (Exp. 166). The $(4f \rightarrow 3d)$ x rays were measured, and the hyperfine structure was used to extract electric quadrupole and hexadecapole moments of these nuclei. The results are of high precision and are consistent with those gotten by other methods. A paper will appear in Nucl. Phys.

A number of experiments were operated during the quarter in the EPB line. A search for direct lepton production in pp collisions was completed. An initial and quite successful test run was made of the thin target spallation experiment in Line B. The experiment on π production in pp reactions was run successfully. An initial study of proton-induced breakup of ^6Li and ^7Li was made. The technique features a germanium stack detector looking at one fragment and a conventional magnetic spectrometer looking at emitted protons at the angle corresponding to nearly elastic scattering from a nucleon in the lithium. The germanium stack clearly identified protons, deuterons, and tritons coming from the reactions off lithium.

Nuclear Chemistry

To the Nuclear Chemistry Laboratory counting rooms have been added a second γ-γ coincidence system and a new low-energy photon Ge(Li) detector. Hardware problems with two of the counting room CRT scope terminals have been encountered but are being resolved. Software development for the Data-Acquisition System is proceeding. Programs for controlling and reading the memory of a multichannel analyzer and for providing the computer with the master Time-of-Year output via a new CAMAC module have been developed.

The two containment boxes in the Nuclear Chemistry Hot Cell have had considerable preparatory work done on them and are essentially ready for high-level experiments.

Most of the efforts to bring the pneumatic "rabbit" system to operational status have been devoted to correcting mechanical deficiencies in several essential components. A special neutron irradiation station for the WNR facility has been designed.

The ISOBAR version of the VEGAS intranuclear cascade program has been revised so that the pion-nucleon isobar is formed only through the resonance region and the lifetime of the isobar is mass-dependent. This has resulted in improved agreement with the spectrum of protons observed at 90° from pions on nickel.

Practical Applications of LAMPF

Progress has been made in developing pion therapy beams by calculationally investigating the effects of scattering for improving beam flatness and properly handling the phase space of the contaminants. The Katz model of cell survival has been incorporated into the dose model code. The effects of collimators on the dose distributions are being studied. In order to assess the prediction of the dose model code, in the absence of experimental data, comparisons are being made with the ORNL Monte Carlo program.

The treatment-planning code is being modified to provide real-time planning capability and to allow specification of both static and scanning treatment beams. The planned system will provide the treatment planner with real-time communications to both the CCF for treatment-planning computations and to the Biomed computer for the manipulation and retrieval of patient data.

Neutron dose measurements were performed at the Univ. of California-Davis cyclotron to determine the parameters for an ion linear accelerator for neutron therapy. Depth-dose curves and microdosimetric spectra were obtained for both 35-MeV protons and 35-MeV deuterons on beryllium and lithium. The results show that the proton-produced neutron energy spectrum is somewhat harder than that produced by deuterons and that the ratio of peak dose per incident deuteron to peak dose per incident proton is about 6.

Other practical applications programs have involved computer studies of the feasibility of implementing proton radiography at LAMPF and of the calculational and prototype work on novel aspects of ion linacs. The latter program is aimed at size and cost reduction of linacs for medical purposes.

Management

Effective January 1, 1976, a new group was formed and designated MP-13, Beam Line Development Group. This group will develop the initial beam tuning and monitoring procedures for primary beam lines. The development of secondary beam lines will be shared with Groups MP-7 and MP-3. Group MP-13 will concentrate on beam line physics, instrumentation, and magnet engineering developments.

The ERDA financial plan for FY-76 authorizing programmatic budget allocation is not expected until late in February 1976. Barring unforeseen difficulties, the LAMPF operations budget should be $18.5M.

Total operating costs to date have exceeded the budget forecast by $50k, or ~0.1%. About 80% of the fiscal year capital equipment allocation has been obligated or costed. The average number of full-time equivalent employees chargeable to medium-energy-physics funding is 351, essentially as forecast.

Close control of the radiological safety aspects of work on the accelerator and in the experimental areas continued. Individual as well as total man-rem exposures were maintained at acceptable levels. Thirty-five operational plans for work involving radiation were submitted this quarter. The LAMPF Radiological Safety Procedures are being revised and updated.

Electrical Safety Committee inspection teams investigated the overall status of electrical safety at LAMPF. The purpose was to identify equipment and maintenance procedures and personnel practices that could present electrical hazards.

The main body of the PAC met at LASL on January 15-18, 1976 to hear new proposals, to review the old, and to establish priorities. Twenty-eight new proposals were heard with approval granted to fifteen. Two of the fifteen did not receive beam time allocations. Five deferred and resubmitted proposals were also approved.

Sixteen nuclear physics experiments and three accelerator development experiments have been completed at LAMPF. Schedules for the coming year are being prepared, based on the priorities recommended by the PAC.

The Ninth LAMPF Users Meeting was held at Los Alamos on November 10-11, 1975. There were 285 registrants for the meeting.

All LAMPF Working Groups held meetings on November 11.

The Board of Directors and Technical Advisory Panel met twice during this report period on November 12, 1975, and January 13, 1976.

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II. ENGINEERING SUPPORT

LAMPF Accelerator

Accelerator Support

Bending magnet TR-BM-06 developed a turn-to-turn short and new cast-epoxy coil sections were fabricated for replacement. The repaired magnet was then reinstalled and realigned. Three new beam-pipe assemblies for spare TR magnets were fabricated.

A total of 45 fabrication activities were completed in this quarter. Twenty of these activities were H_2 furnace-braze heats, mostly in support of Area A and the klystron-rebuild operation.

805-MHz RF System

The VA-862A klystrons have now accumulated more than 635 000 fh, and the L-5120 klystrons have more than 115 000 fh. One klystron, VA-862A, S/N 101, failed in the quarter. This klystron was seven years old and had 18 070 fh at failure. The average age of the VA-862As in service is ~12 000 fh and for the L-5120s the average is ~5600 fh. Ten additional VA-862A klystrons have been ordered, but delivery will not start until July 1976.

The 805-MHz portion of the accelerator accumulated 169 000 fh in the past calendar year. Forty-two switchtubes and nineteen modulators were replaced during the year. Nine of the modulators were replaced for malfunctions, the others for test and maintenance. The original klystrons and modulators are still in place and operating in half of the 44 active rf modules.

In the present quarter, 76 000 fh were accumulated, 14 modulators and klystrons were replaced (6 because of faults), and 27 switchtubes were replaced. The LPT-44 switchtubes have accumulated 740 000 fh, and 45 have been reprocessed in this quarter. Thirty-four have been returned to service, four were salvaged, and seven are being held for further processing. Twenty-five more LPT-44s have been ordered, and two have been received.

Klystron-Repair Facility

Two L-5120 klystrons (S/N 2016R2 and S/N 2014R1) were successfully rebuilt in the quarter, and a third (S/N 2009R1) is now in the bake-out oven. Three klystrons developed high-voltage problems during the quarter. One of these (S/N 2026R1) was high-voltage-processed and returned to service; the others are awaiting further tests and processing. One VA-862A, S/N 219, was severely damaged in operation following the failure of a mod-anode drive cable. The klystron then went into a cw mode and the noses of the input cavity melted. The klystron was repaired by reactivating the cathode and retuning the cavities. An external tuner was made to match the input cavity to 805 MHz again. Frequency shift measurements indicate that the melting of the nose cones increased the first cavity gap by 0.6 cm.

All orders to improve the klystron-rebuild facility have been placed, and some components, such as a fume hood, water heater, and a stainless-steel-parts cleaning station, have been received. The fabrication drawings for the stainless-steel rinse tanks have been reviewed, corrected, and returned to the vendor. The vacuum system on the bake-out oven has been redesigned to have an ion pump in parallel with the turbomolecular pump. Both pumps could be isolated from the system with valves. The improved system will have the turbo pump's high throughput and the ion pump's low ultimate pressure.

Experimental Lines

Area A

The alignment of Line A components, such as target boxes, harp boxes, magnets, collimators, and beam plugs, is now ~85% complete. Special fixtures were made which will be mounted on the target cell triplet magnets in A-1 and A-2. These will permit partial alignment checks of these components with a remote-controlled television camera.

Biomedical Beam Line

Assembly and testing of Slit No. 2 is nearing completion. Preliminary tests indicated a slight motion of the vertical jaws after the stepper motor was shut off. This was a result of its operating in the vertical plane instead of a gravity-balanced system of pairs of jaws such as used in Slit No. 1. Stepper motors with gear reducers were incorporated, which solved the problem of motion after turn-off. The stepper motors also lost counts when passing through a resonance period during ramp-up at turn-on. A permanent magnet flywheel damper was then incorporated and the system now seems to operate properly in all modes. One of the modules making up

Slit No. 2 is shown in Fig. II-1. Final assembly of Slit No. 2 is now in progress, including windows and dust covers.

The testing of the first slit (RT-SL-01) continued. The prototype drive shafts were designed, fabricated, and installed. The preliminary design of the final drive shafts is complete and some of the components have been ordered. The slit drawings are being updated to indicate the present configuration.

The A-5 target box and its collimators were aligned. The alignment work in the Biomedical area is now ~90% complete.

Energetic Pion Channel and Spectrometer

Several design-review meetings were held, and it was determined that the present floor will have to be rebuilt to support EPICS. Engineering studies were initiated to determine the best methods and techniques to install the spectrometer.

The fabrication of the trucks to lift and move the EPICS separator shield plug is now complete. The final assembly of these items will begin when the hydraulic cylinders, rollers, and shielding are delivered.

The shield plug was moved into position to check fit and would not close completely because of additions to the EPICS beam line. The plug is being modified to eliminate these interferences.

The design and drafting of the A-1 target-mechanism shield plug was completed early this quarter.

A new α-source assembly was aligned and marked for the EPICS channel.

Weapons Neutron Research Facility—Line D

Work is continuing on the steering magnets at a level geared to provide the units as they are needed. The total requirement has been increased from 20 to 24 magnets. Ten magnets have now been completed.

The four ion pumps required for the 122 m of tunnel vacuum system were modified and rebuilt using new pumping elements. The power supplies for these pumps were also modified to provide both start and run capability along with a two-out-of-four interlock logic.

The reference alignment monuments for that portion of Line D downstream of the waterfall to the experimental area were installed and positioned accurately.

A considerable amount of preliminary survey and layout work has been done in the experimental area.

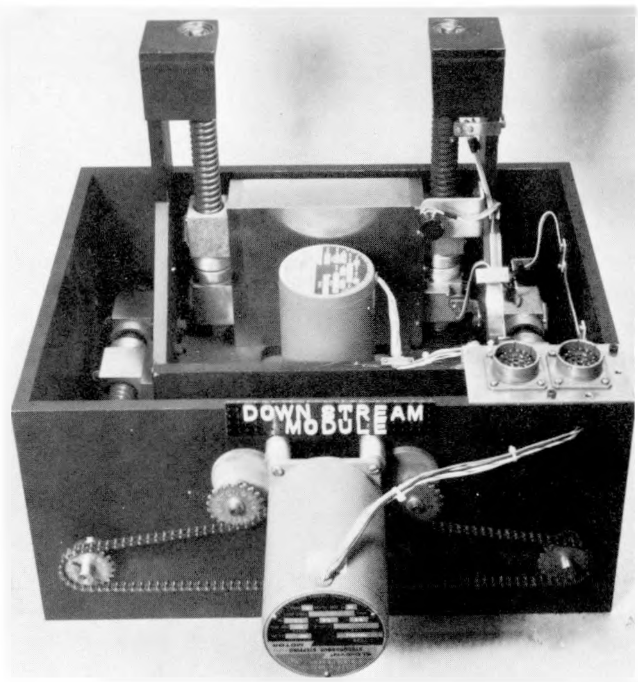


Fig. II-1.
Components of Biomed Slit No. 2.

The theoretical target point was established, and much data relating the flight tubes to this target point were obtained and recorded. The 30° line from Line D to the target area was laid out, and the pivot point for the target area was determined. Measurements from these layouts will enable final designs of support structures, mounts, collimators, etc., to proceed.

Several actuator assemblies were processed through the tooling dock. Precise measurements were made referencing the intersection of the cross wires to index surfaces on the actuators.

The fast-kicker modulator has been operated into the actual magnet at full operating current and low duty factor (which is limited by the available source power). The coils were adjusted to bring the pulse shape within design tolerances. Work is progressing on the documentation and final packaging of the control circuits.

Other Beam Line Support

Alignment monuments were placed on the second large HRS magnet. Both magnets have been indexed and are being installed into the supporting structure.

Alignment support was provided for several experiments in Line B.

Instrumentation

One carbon harp from Area A was destroyed when a 30-cm valve was opened in error thereby exposing the vacuum system abruptly to atmospheric air. A new harp was wound and some analysis performed on the shock loading of the harp wires. A shock tube has been designed and is being fabricated to permit experimental shock loading of carbon monofilaments, windows, and other beam line hardware.

The Class II current monitors for Area A and one current monitor each for Lines B and C were built and tested. The current-monitor system for the experimental area is now complete.

Design and detailed drawings have been completed for a low-momentum detector to be used in the SY area. Hardware components including 20-pin feedthroughs, vacuum valves, and special radiation-resistant plastic for high-voltage insulation are on order.

Three pneumatic actuators were completed for the beam line phosphor detector assembly.

Electron Prototype Accelerator

The long-lead items which are required for the assembly of the accelerator tanks are now on hand. The 12 tank sections and Model M (the graded-β tank) have been moved from the EPA building to the ETL in preparation for the rebuilding activities. The soldering oven and cooling-tube flat-milling machine have been moved from storage and put back into operational status.

Work is starting on the electronic system for the EPA. The 100-kW klystron and its modulator and control rack were moved to the ETL. There is a possibility of repairing the 100-kW klystron in the klystron-repair facility. Long-lead parts for the 100-kW and $1^1/_4$-MW modulators are being ordered. The pulse transformer for the small modulator has been fabricated.

Pion Generator for Medical Investigations (PIGMI)

A modest effort to explore the different materials and fabrication techniques for PIGMI accelerator tanks has been started.

A tracer lathe cam has been designed to produce prototype 1350-MHz, half-cell segments. Segments are now being machined from copper, steel, and aluminum to be used in joint development and copper-plating techniques. Joint designs using brazing, electron-beam welding, and heliarc welding techniques have been made for the various materials. Evaluation of the joint for each material will be made for vacuum integrity and electrical characteristics.

The limited space available in the small drift-tube linac designs being investigated would present difficult engineering problems if conventional magnet designs were adopted. Quadrupole magnet field requirements can be predicted with sufficient accuracy that the use of fixed-field magnets is possible. A low-level effort has been implemented to investigate the possibility of using permanent quadrupole magnets, eliminating the need for power supplies and water cooling.

A small, permanent quad magnet, with full circular poles, approximately the size required in the low-energy end of PIGMI (7-cm o.d., 0.8-cm bore radius, 1.5-cm long) was fabricated. Field gradients of 3 kG/cm were achieved. Preliminary harmonic measurements are promising, and those multipole errors associated with pole truncation, required on a conventional quadrupole magnet, are low or nonexistent.

The prototype magnets utilized poles of oriented material and were charged by the vendor. Ideally, the poles would be demagnetized, assembled in the yoke, then charged and stabilized after assembly. The technique, standard in the permanent-magnet industry, results in a system that is not subjected to open-circuit conditions and in higher gap fields and optimum pole uniformity.

Experiment Support

Temporary repair of the coils for the Ames "C" magnet is complete; the magnet is being prepared for Exps. 80 and 90. Both coil sections were grounded, which was probably caused by overheating. Disassembly and inspection also revealed turn-to-turn shorts. After repair of the shorted turns, the pancakes were baked to dry the insulation and then coated with glyptol to minimize moisture problems. The inner spools were anodized to enhance the ground insulation. The magnet was reassembled and thermal switches added to the conductor for high-temperature protection.

The chamber support, rotation pedestal, and movable instrument arm for Exp. 90 have been designed and fabricated at LASL and at vendors' shops. It is designed to fit on the pivot pedestal of the Kontiki spectrometer stand in P^3-east. This assembly is complete and is in storage awaiting the mounting date for this experiment.

The pole pieces and pole bodies of the Bicentennial magnet were inspected and measured for Exp. 29/54II. From these measurements, a machining template was made using the tooling dock. The template will be used to assure accurate pole contours. The design and drafting of the spectrometer stand are complete, and the last fabrication order has been submitted. The main base structure has been delivered, and assembly will continue in the ETL building as parts are received from vendors. All procured parts such as screwjacks, high-load tapered roller bearings, and high-strength steel bolts, are now on hand, thus allowing the stand to be assembled as the machined parts are delivered.

Field support and fabrication of beam-pipe components were furnished for Exp. 81. The field support consisted of modifying the magnet stand "Dinghy" for the users' experimental gear and the removal of the previous users' (Exp. 160/42) structure from both the existing 18D40 magnet and "Dinghy". The reconfiguration of the 18D40 magnet from "Picture Frame" to "C" was also carried out for Exp. 81.

A preliminary engineering design has been completed for the vertical- and horizontal-axis spectrometer frames that are being proposed for Exp. 181. A simple model of the vertical-axis frame has been made to illustrate the basic motions of the frame. Each frame provides four degrees of freedom for two detector assemblies weighing ~900 kg.

A target-support mechanism was completed in the prior quarter for use in Exp. 2. A modification of the cryogenic target mechanism was needed for Exp. 164. The design changes were made, and the necessary adapter parts are now being fabricated.

The scattering chamber for Exp. 176 was redesigned and fabricated. The scattering chamber, magnet chamber, ion chamber, and detector chamber for Exp. 179 were designed and fabricated.

The design and prototype fabrication were completed for a shutter mechanism for Exp.137B that will allow a 1-s exposure to occur on a detector from a radioactive source. Generally, the requirements were to allow a <0.1-s opening time, a 1.0-s exposure time, and <0.1-s closing time; also, to have sufficient reliability to operate $\sim 1 \times 10^6$ cycles. The key to the design life was to use an endurance model rotary solenoid rated at a 1×10^8 cycle life. During bench tests of the prototype, it was established that the opening requirement was met at 15 Vdc (~0.5 A) and the spring return of the solenoid was satisfactory for the closing time. Approximately 1×10^6 cycles were completed. The six shutter mechanisms are now being fabricated for the user. The prototype will be retained as a demonstration model for possible future application.

All of the scintillators for Exp. 31 have been placed on their stands and are now in position around the counter. The phototubes are being installed and checked out on the installed scintillators. The lead shielding has been received.

The support structure for the Exp. 179 scattering chamber was completely rebuilt and installed. The mechanical engineering effort is complete.

III. ACCELERATOR SUPPORT

General

The activities for this quarter are best characterized as a continuing search for more information on, and methods to improve, reliability.

A reliability study has been initiated based on information contained in the operations and maintenance reports. We hope to be able to use this ongoing analysis to pinpoint those units with high failure rates and long downtimes. In Table III-I are presented the data obtained.

A preventive maintenance program for all rf systems was scheduled around the biweekly maintenance days.

Better system electrical drawings are being generated to aid in troubleshooting.

Modification of magnet power supplies has continued to achieve standardization, ease troubleshooting, and achieve better reliability.

The 201-MHz test stand is now available for 7835 gas checks and 4664 dc processing. When the stand becomes available for rf testing and processing, a spare stock of "known good" power tubes can be maintained. This should significantly cut 201-MHz downtime required for tube conditioning.

Mechanical support for HRS and vacuum support of efforts in Areas A and B have continued this quarter.

Equipment availability and beam availability have improved greatly since the shutdown. Equipment availability is near 90% and beam availability is near 80%.

201-MHz RF System

An average of 1842 h was accumulated on each of the 201-MHz rf stands during the quarter.

No failures were experienced with any high-power tubes in the system. One 7835 now has 13 100 h of filament time and one 4664 has accumulated 4600 h of filament time without failing.

The reinstallation of the submicron filters in the cooling-water systems seems to have reduced the problem of precipitates from the water forming at certain critical points in the rf system and causing high leakage currents. In addition, no further problems have been experienced with the filament connectors on the 7835.

During the first part of the quarter, a 7835 output window failed. The failure was caused by large amounts of oil in the compressed air system. A considerable amount of time since then has been expended in cleaning cavities and windows that had become contaminated with oil. No further failures have occurred from oil, but oil is still being accumulated in the amplifiers.

Due to the problems with brush deterioration on the 7835 filament supply variable transformers (variac), the variac tanks have been relocated outside the filament supply cabinets. This will facilitate easier changeout of the variacs. The installation of new brushes has been scheduled after each 1400 h of running time.

A preventive maintenance program was generated for the 201-MHz systems during the quarter and scheduled around the biweekly maintenance days. It is hoped that this program will significantly improve the reliability of the systems.

The tank rf windows have now logged some 4000 h of running time with no failures. The window in

TABLE III-I

MAJOR SUBSYSTEM FAILURE HISTORY

Unit No.	Name	Section	No. of Failures/Quarter	No. of Failures/Week
135	PA-Mod	201-MHz rf	50	4.17
6711	Ion pump power supply	805 rf	38	3.17
125	IPA-2	201-MHz rf	30	2.5
1147	Klystron switch tube	805 rf	24	2.0
2001	Quad magnet power supply	805 rf	18	1.5
1111	IFA	Low-level rf	17	1.42
1183	pH control	Phase and amplitude	17	1.42

module 2 was inspected from the air side and showed no evidence of deterioration from heating. It was also leak checked and no evidence of vacuum leaks was found.

No failures were experienced with the 8871 hv cable and termination during the quarter. A marginal spacing situation was generated during the changeover to the 8871 cable, causing an occasional high-voltage flashover in the hv compartment of the 4616 amplifier. Relocation of some of the components in the compartment should remedy this problem.

Efforts to reduce the excessive voltage drop across the plate modulator for the 7835 were undertaken during the quarter. The loading on two of the 7835s was reduced in order to lower this voltage drop. Methods of increasing the drive to the modulator tubes continue to be investigated.

The 7835 that failed during the previous quarter was gas checked at the test stand and found to still have a good vacuum. Since two new 7835s were received during the quarter, it was decided to keep the tube at the test stand until the stand is completed and the tube can be rf tested.

A 4664 is being dc processed periodically at the test stand in the hopes of reducing the on-line processing time when the tube now in module 1 fails.

Preliminary design work has been completed on a unit which will automatically dc process a 4664 tube. When finished, this unit will not require an rf cavity, a cabinet, or a complete water system as is currently used.

Final checkout of the 4664-drive closed-loop controller was completed during the quarter. This retrofit included increasing the loading on the 4664. Upon completion and installation in its cabinet, the 4664 cavity will be checked out.

The 201-MHz test stand is now available for 7835 gas checks and 4664 dc processing. It can also be used for some low-level rf work. High-power rf is limited by the capacitor room installation, which is ~50% complete.

805-MHz RF System

Routine maintenance, periodic inspections, and preventive maintenance utilized the greater portion of this quarter.

Klystron modulator switch tubes have a rather high failure rate, primarily because many rebuilt tubes are in use. Since a tube which is starting to deteriorate can usually be detected in advance and replaced on a regular maintenance day, these tube failures result in very little accelerator downtime.

The two units in the 805-MHz system that have required the largest number of maintenance manhours are the ion pump power supply and the quad magnet power supply. The high failure rate of these units is caused primarily by design deficiencies, many of which have been remedied by LASL personnel. These two units were manufatured by the same vendor, and a memo has been directed to purchasing, outlining the history of these units and the problems encountered.

The total number of klystron crowbars for the second quarter of FY-76 was 188, or an average of two per day. This is 2.16 crowbars per 1000 h. The total crowbar rate has declined from the previous quarter.

Thirty system wiring diagrams, to be used as an aid in troubleshooting, have been completed and are located at the spare parts rack in each sector.

The 8871 hv cable under test at ETL has accumulated 7340 hvh.

Low-Level RF System

After an extensive study of 8501 tube failures in the 805-MHz source, it was determined that these tubes have been running at excessive temperatures. The overheating, which resulted in ceramic cracking, was caused by insufficient air flow around the lower section of the tube. The lower cavity has been redesigned to improve air flow, and new cavities are being fabricated.

A prototype 201-MHz solid state IFA has been completed and will be run in both the test stand and in Sector A for evaluation. At the completion of this evaluation, 12 of the units will be built. These units will replace existing 201-MHz IFAs. In addition, this unit will become available for replacement of tube-type 201-MHz amplifiers, of up to 50 W, in various other lower-level applications.

Parts for an 8501 amplifier to operate at 201 MHz have been fabricated and the cavities are being assembled. This amplifier will be evaluated at the test stand as a possible replacement for the 4616 now used in module 1 as a driver for the 4664.

Phase and Amplitude Control System

Work in support of normal accelerator operation by routine repair of malfunctioning phase and amplitude systems was continued during the quarter. In addition, preventive maintenance has been performed through routine monitoring of all 201- and 805-MHz rf control systems.

All 805-MHz manual trombones were disassembled and cleaned.

Support continued on the development of the new H^- buncher. Phase and amplitude control boards and their associated mounting bins, monitor panels, and interconnecting cables, for use with the buncher, have been provided.

The continuing problems encountered with phase subsystems have made apparent the fact that all of these units need the rather involved repair and rebuild program identified in the last progress report. This program will require approximately half the available time of the phase and amplitude section for the next year. Eight units have been completed at present and the repair program is being operated on a continuing basis as subsystems become available through failures.

Other projects in which the section is involved are as follows:

- Aid in development of the feedforward system.
- Parts procurement for additional phase monitor systems.
- Redundant phase monitor improvements in the 201/805-MHz areas.
- Fabrication of new source room control cards.
- Calibrations of rf permissive level.

Power Supplies

Modification of the LAMPF standard magnet power supplies has continued during this quarter. All power supplies which were purchased for use with external regulators fall into this category.

Only 16 supplies remain which have not yet been modified. These supplies are located as follows: three power supplies which drive Line B quadrupole magnets; three power supplies which drive Line EPB quadrupole magnets; six power supplies which drive Line A quadrupole magnets; four power supplies which drive experiment magnets.

The first dual-Acme power supply of the type used in the SMC has been modified to use the LAMPF standard regulator systems. These supplies were originally purchased with built-in, vendor-supplied regulators. The modified power supply is now being installed on the SMC power supply platform.

Checkout of the 18 power supplies for Line D is now complete and all of these units are operational.

Fabrication of the new by-pass shunt system for Lines A and X has been completed. The system is to be installed when machine downtime will permit.

The EPICS by-pass shunt system across BM01 through BM04 has been completed and is operational.

The mechanical design of the 2000-A reversing switches is being revamped in order to eliminate alignment and stress problems. When these problems have been corrected, more switches will be ordered and existing units will be replaced.

Beam Diagnostics

Routine maintenance was the major activity during the quarter. A wiring error which resulted in a plane reversal in the 5-2 wire-scanner signals was corrected, a loose bearing in the EM-2 bottom actuator was readjusted, and wire-scanner amplifiers were repaired and recalibrated.

Repairs were made to the position potentiometer signal amplifiers in two emittance chassis, the transition region sample-and-hold bias box, two shorted wires in harp No. 7, and the linear actuator drive modules.

It was determined that the EM-8 horizontal fixed-slit jaw did not travel into the beam line far enough to allow a proper emittance scan. This device and all devices mounted in the first beam box downstream of Tank 4 were removed so that spacer sizes and limit switches could be adjusted to obtain the proper travel.

During an attempt to tune the H^+ beam through the transport, it was found that only 80% transmission through the transport was achieved when the EM-2 emittance gear was put on axis. Since the accuracy of the EM-2 jaw-position measurements was questioned, the EM-2 right and top jaws were removed and remeasured. The original jaw-position measurements were found to be correct. The EM-2 collectors were also removed and inspected at this time, and found to be in good condition.

The procurement of spare parts and the updating of drawings were continued.

More checkout equipment is being fabricated so that it may be kept in each of the three beam diagnostics equipment cages.

Development activities during this quarter included the following:

1. Continued testing of the module 5 wire scanners revealed a problem with the timing of the pulse trains sent by the computer interface equipment to the stepping motor drive modules. This problem has been corrected.
2. New harp boards (ceramic board with carbon wire) were installed on harps 1 and 2. Testing of these new harps will be performed during the next quarter.
3. The design of a new sample-and-hold system using the fast wire-scanner amplifier was continued during this quarter. It appears that the wiring system associated with the present sample-and-hold system will be adequate. The spare sample-and-hold chassis with modified sample-and-hold boards has been installed in the transition

region racks and will be used to study the feasibility of higher-gain (2 μA in, 10 V out) amplifiers.

4. Tests are under way in an attempt to determine the source of noise in the transport sample-and-hold system. The problem appears to be associated with the bias box.
5. Operational tests were run on most of the linear actuators in the beam diagnostics system.
6. The design of a new checkout box which will simulate the beam current pulse was initiated.
7. A set of eight stepping motor driver cables of various lengths was fabricated for use in the checkout of stepping motor driven assemblies.

Almost all testing of beam diagnostics equipment requires the use of the central control computer. The limited availability of the computer on maintenance days is a serious problem which interferes to a great extent with the maintenance of the beam diagnostics equipment.

Vacuum Systems

With the exception of Areas A and B, vacuum support for the accelerator was light and routine. A few defective ion pumps on the 805 vacuum system were replaced, a few modules were let up to air for diagnostic device maintenance, two rf window spacers were replaced, and several leaks were found and repaired.

A great deal of work was spent in support of the reassembly of the main line and target cells in Area A. This support consisted primarily of fabrication, leak checking of components, and assistance with reassembly.

The vacuum section continued with moderate support in Area B this quarter. It involved the installation of new experiments, removal of completed experiments, and support of existing experiments. The fast valves in Lines B and EPB both failed and had to be removed, rebuilt, and reinstalled.

Mechanical Support

Mechanical work on the 201-MHz test stand has been completed. All water systems have been checked out and are operational. Keeping the resistivity of the demineralized water to an acceptable level for the 201-MHz test stand has proved to be a minor problem. Since the demineralized water system is shared with the klystron test stands, the introduction of different klystrons can deteriorate the system. It may, therefore, be necessary to add a separate, small demineralized water system for the sole purpose of cleaning klystrons and 7835 tubes prior to installation.

A new version of the 4664 amplifier cavity has been completed and is ready for testing.

Spare and modified hardware for use in beam diagnostics is ready for brazing and final machining.

Support for Group MP-10 is continuing. The new personnel platform is being installed as a part of the HRS magnet installation. As soon as this work is complete, final plumbing of the HRS magnets will be initiated. Design of a new elevator assembly for HRS has been finished and is out for bids.

IV. ACCELERATOR SYSTEMS DEVELOPMENT

Beam Dynamics

201-MHz Linac Field Distribution

The bulk of the bead-pull data from Tanks 1 and 2 has been processed for string signature removal and is ready for final analysis. The Tank 1 data for different head positions were studied using different fitting criteria, and show the expected pattern for this type of perturbation. A nominal cell-to-cell field-error pattern was obtained from an averaging of many runs for use in the PARMILA model. The general reproducibility of the data seems to be about 1%. Documentation of the bead-pull results began.

The experiment modeled using PARMILA during the last quarter was performed on the accelerator during November. This was a major experiment, performed in collaboration with the operations group; a great deal of information was obtained. The tank heads were set at six different positions. At each, the injection energy was varied from 720-780 keV, and various measurements of longitudinal and transverse emittance and acceptance properties were made.

Comparison of the experimental results with the PARMILA model began. Good agreement has not yet been attained, but significant progress in understanding and refinement of the dynamics calculations has been made. The effects on the dynamics of gap lengths, cell lengths, and relative fields that differ from design have been included, with measured data. A significant change in results occurred when transverse coupling effects, previously ignored, were included in calculating the longitudinal properties. Particles lost longitudinally in the first tanks are finally lost transversely due to over-focusing by the quads. In addition, off-axis particles experience higher average accelerating forces. Calculations are now being made using six-dimensional beam populations: lower amplitude cutoffs and changes in other features of acceptance and emittance are seen compared with the axial calculations normally used. Near cutoff, the transverse admittance actually demonstrates a hollow ellipsoid as the on-axis particles are no longer accelerated.

Transverse Matching—805-MHz Linac

The transverse-matching procedure consists of two parts: 1) a program that calculates the ellipse parameters from wire-scanner data; and 2) a program that calculates quad values that should give a matched condition. Difficulties with the first part were traced to doublet wiring changes which occurred during the shutdown. Successful matching was accomplished for simultaneously accelerated beams.

Δt Automation—805-MHz Linac

The Δt tune-up procedure has been partially automated. It is now possible to check Δt throughout the 805-MHz linac in ~45 min (~1 min per module). It is also possible to automatically set the phases in all modules in about the same length of time. The automatic rephasing procedure was tried in January, and the entire machine was rephased in an hour and a half. About half of this time was spent in manually adjusting either the phase or amplitude controls of some of the modules that went out of phase- or amplitude-lock at the new phase set points.

A program for automatically checking and adjusting the amplitudes of the modules is being written and will be checked out early in February. The goal of these automatic tune-up procedures is to provide both speed and consistency that would be unattainable without automation. This will aid both in operational aspects and in the investigation of phenomena involved in higher beam-intensity development.

Beam-Halo Analysis

Initial testing was done using the 805-linac wire scanners and loss monitors to probe the beam halo. Results were encouraging and testing of this method is continuing utilizing a wire-scanner drive code which plots loss-monitor output as well as wire-scanner currents.

New Linac Development

Design study work was accomplished on three linacs for practical applications. These include two proton linacs for pion and neutron therapy facilities and a deuteron linac to be used as a neutron generator in a radiation-damage facility. This work also included the extension of PARMILA to handle the alternating phase-focused structure.

Long-Term Stability Development

Applications in this area included use of the monitoring programs from the CCR, and analysis of data retrieved from the equipment-performance data base. Numerous individualized searches were made from this data base for concerned operations and maintenance personnel.

The Δt automation is expected to improve long-term stability by providing faster and more consistent tuneups.

Some further data were obtained on the effects of structure resonance and amplitude changes under both transient and steady-state conditions, using the Δt system to make measurements. This effort will continue during the next quarter.

Operations-Support Development

Operations/Maintenance Equipment Reporting Data Base

A review of the equipment reporting system by the ADC resulted in recommendations for several improvements. In order to clarify the distinction between loss of time to a scheduled activity (mission downtime) from time spent working on equipment which is in trouble but not necessarily influencing the scheduled activity, the equipment reporting forms will include only an "equipment downtime" block. Mission downtime will be assigned on a once-per-shift basis to 14 major categories of equipment, via the shift supervisor's report. The use in most cases of the individual unit designations for the equipment reports will still afford detailed investigation of performance over long periods of time using the data base. The general categories will not be used on the equipment reports unless the initiator cannot determine the actual problem.

New operator action cards have been ordered to conform to the adopted changes. The Daily Operations Report was rewritten to reflect the changes, to translate coded numbers to meaningful words, and to print the need for Immediate Service. New keypunching formats were chosen and IBM cards will be ordered.

The maintenance report has been redesigned and will be run separately from the operations report. The new report prints the original operations card, if one exists, preceding the maintenance card. This is accomplished by a PLI program that accesses the data base, inserts either operation or maintenance cards, retrieves operation card information for all entered maintenance cards and prints all the information for that report. Because S2K has no satisfactory error messages for improper inserts in PLI, these were built into the program and are written to a separate output file in such a way that the maintenance report remains reproducible for distribution. All computer files and indexes used for operator reference have been revised to reflect these changes and are in use.

A new data base has been defined on S2K which will store all 1976 information.

Retrievals of information stored in the 1975 data base have been made on a system basis and have been used by several MP personnel. In addition, interactive retrievals have been made for selected equipment.

Experimental Schedule Data Base

The system was transferred to the newly released version of S2K, and some minor maintenance was done to the programs.

Visitors Center Data Base

Time was spent in planning a new technical definition of the Visitors Center Data Base with the objective of saving disk storage and increasing usefulness. Requests have been made by and discussed with the Visitors Center supervisor about adding new data and improving consistency of already stored data. The systems analysis and programming approach phases were completed and preparatory programs for data manipulation were written. The proposed changes will not interrupt the use of the data base and will involve minimal changes in established procedures. All currently stored information can be machine read and transferred with no additional work by Visitors Center personnel.

Outside Contracts Data Base

Transfer to the new S2K version and final cleanup of programs were completed.

Users Group, Inc. Data Base

Additions were made to the data base definition to include information on technical interests and a more refined geographical classification of users. A number of production-type data-retrieval programs was completed. Transfer to the new S2K version was accomplished.

Bibliographic Data Base

Work was continued on this on-going data base. Past progress reports were completed, and abstracting of technical reports continues.

Diagnostic Equipment Development

Beam-Position Monitors

During this quarter a system definition was established for the beam-position monitors. Two types will be tested and compared. The first uses simple diode detectors. The final version of this approach was frozen after extensive testing and fabrication of the preproduction prototype were initiated. The second approach, using a heterodyne-receiver approach, was bench-tested, and fabrication of initial units for testing on the accelerator was initiated. Both systems use the same magnetic-loop pickups and rf cables, but utilize different electronics. A number of each will be installed along the machine for extended comparative testing and stability analysis.

Beam-position monitors were installed in the 201-MHz linac for evaluation of the horizontal beam oscillation and possible feedback control.

Feedforward System

The feedforward system was reactivated as tests at higher peak currents were resumed. Some improvements contemplated for the 805-MHz linac system were tried, but trouble with recovery from the variety of fault conditions that can happen was encountered. It was decided to return to the initial, very simple concept of feedforward in this area, with current-sensing at module 2. Work in the 201-MHz area will continue, since the beam-shaping processes in transport region and the first tank make scaling of a signal sensed at the injector mandatory.

Emittance, Wire-Scanner and Harp Hardware

Study of various problems continued. The thrust of this work is toward more reliable operation, and to make possible more detailed investigation of the transverse behavior and tuning of the machine.

Bead-Pull Apparatus

The FNAL 6800-based microprocessor crate has been set up and is working at LAMPF. It is envisioned that this will provide the central control for the new bead-pull apparatus. A debug panel and its software have been developed and are now in operation. Teletype interface and software are now working. A new MPU board has been designed which will facilitate Direct Memory Access (DMA) with the system.

Low-Momentum Component Detector (LMCD)

Mechanical engineering started on the design of a low-momentum component detector prototype for Line X. An amplifier circuit design for experimental area harp readout was adopted for the LMCD and the parts ordered. The ion pump has been procured and other long lead items ordered. All systems are scheduled for completion on the first of April when system tests will begin.

Δt Hardware

The solid-state-amplifier oscillations reported last quarter were diagnosed by the vendor to be caused when no rf input is present. They function satisfactorily when beam or calibration signal is present, and since the lifetime should not be affected, they were reinstalled. Several modifications to the system produced some progress in achieving the desired long-term stability of the system calibration.

Code Development

Beam Dynamics and Structure Codes

Extensions to PARMILA were continued to improve the capabilities for handling actual linacs with measured parameters, to handle the alternating phase-focused structure, and to improve documentation.

The powerful mathematical capabilities of APL were used extensively in the study of Tank 1.

Discussions on drift-tube structure codes, using geometrical calculations, resulted in plans for extending code development work, presently in progress at LBL, to LAMPF problems.

Control System Applications Programs

As mentioned above, major extensions to the Δt programs to allow automatic checking and set-up were completed.

Programs which communicate with the transport-emittance equipment were changed to allow their operation through module 0 instead of module 49. At that time, a timing problem with the module 0 RICE was diagnosed. A major modification to the emittance programs, which allows use of position feedback for position control rather than the open-loop motor-pulse technique, is being written for evaluation. This is an attempt to circumvent the problem of missed pulses at the motors.

The emittance programs have also been changed to make use of the changes in the routing of timing pulses at ICR. The programs will now select the proper timing for EM-2 or EM-5 and ask for the proper timing at EM-3. At present, EM-11 has access only to the H^+ timing.

Collaborative Programs

EPICS Beam Separator

During this quarter, the beam separator was operated at design field levels (3.4 MV/m and 400 G). While the system can operate at its design point, considerable effort on the part of the operator is required to reach it. This is caused by poor vacuum in the channel and inadequate control electronics. Steps have been taken to provide a large LN_2 trap close to the separator and to design a crossover control system to provide automatic conditioning during turn-on. Considerable effort went into determining a realistic transfer function that can simulate the voltage and current feedback signals from the C-W and Separator. This transfer function will be used for bench-development of the control electronics.

Biomed Pion Range Shifter

The range shifter was tested for the first time as a closed-loop servo using compressed gas as the energy source. This method is advantageous as it clearly reveals leaks and produces high compliance in the system so that static friction points can be located. Following initial tests, the unit was disassembled and interferences were removed to reduce stiction to the limit of the sliding seals in the cable cylinders. Various leaks were fixed and the unit was put into operation. Significantly better performance as a second-order servo was now achieved. Despite this progress, the general level of effort on the range shifter this quarter was low, so the obvious next step, hooking up the hydraulic power supply to provide a low-compliance servo, is still to be taken.

V. INJECTOR SYSTEMS

H^+ Injector

The three remaining defective diodes in the H^+ rectifier stack were replaced with new diodes in November; all diodes in this generator are now operating well within specifications. The final design for the bouncer control circuits (with improved spark protection) was also completed and installed on the H^+ Cockcroft-Walton generator in November. No component failure has occurred since it was installed and no further operating problems have been experienced with either the C-W rectifier stack or the bouncer.

High-power beam tests, over extended running periods, were then initiated on the H^+ injector. Particular attention was paid to obtaining proper operation of the beam-impingement/fast-protect systems and to studying the tuning of the ion source and high-voltage systems; extensive tests were made with various ion source configurations and operating conditions of the C-W generator. These tests have the established operating conditions for this injector needed to run high duty factor beams at low fault rates. Fault rates <0.5 arcs/h at 6% duty factor operation for beams with 12-mA peak current have been obtained in tests extending over several days of continuous operation under production-run conditions. Tests are still in progress to explore conditions required for low fault rates at higher peak currents.

In general, the problems associated with ion source tuning and the high-voltage generator operation are resolved, and the basic problem is now believed to be the question of proper conditioning and operation of the accelerating column. For example, it has been found that several shifts of operation are required to achieve low fault rates at high duty factor operation after opening the column up to air, even though high-voltage conditioning is achieved very quickly (several minutes) after pumpdown.

After these tests were completed, the H^+ injector was used for the first time to provide a production beam for LAMPF. A beam of 25-μA average current at 6% duty factor was provided at 800 MeV for 36 h. The injector was run with 8-mA analyzed proton current although the peak current to the linac was subsequently limited to 0.5 mA by the EM-2 jaws in the injector beam transport line. The injector fault rate during this run was 0.3 arcs/h. These injector operating conditions imply that accelerated beams in the linac up to 400-μA average current can now be achieved with this injector fault rate (assuming the same capture efficiency in the first tank of the linac).

The second wallplate capacitor system for the H^+ injector has been designed and is now being tested. This system will provide a redundant dome-voltage fast-protect channel and additional anode power supply protection to high-voltage faults.

Some problems have been encountered this quarter with DVM failure on the H^+ injector. Part of the failure rate may be due to the sparking environment, but since no definite pattern in component failure is apparent, the failure rate may be due in part to lifetime limit of the units. Some of these units have been in service for over eight years.

Some problems have also been encountered in beam damage to diagnostic equipment (emittance scanners) in the H^+ beam line. Evidence of beam impingement on the water-cooled apertures (discoloration and burning of copper surfaces) has also been observed, but no component failures on these units have been experienced and no significant melting damage has been seen.

H^- Injector

The H^- injector has continued to provide all production beams for LAMPF except for the first high-current H^+ beam which was run for a radiation damage experiment.

The H^- ion source was dismantled at the end of this quarter because of an increasing fault rate on the extractor power supply. Some spark damage was observed on the extractor electrode as shown in Fig. V-1. The cause of the extractor faults, however, was hydrogen embrittlement and subsequent spalling of both the extractor and charge-exchange canal electrodes. These electrodes were replaced with spare units. The molybdenum insert anode aperture was examined and exhibited some melting damage as shown in Fig. V-2. This unit was also replaced, although it was still deemed to be operative. The H^- ion source has been run continuously for over six months, and component lifetimes of this duration are reasonable for the operating conditions in this source.

The arc pulse modulator has continued to function with minimal component failures during this quarter. Further work on improving lifetime and reliability of this design has been deferred because of the success of a new transistor modulator. A prototype model (see Fig. V-3) was installed in the H^- injector and run for several hours at full beam power. This modulator design is much simpler and has much lower driving impedance than the present SCR model and its use is expected to make ion source operation more reliable.

The rf systems for the H^- prebuncher were installed, and initial checkout is now in progress.

Fig. V-1.
Spark damage to extractor electrode after six months of operation. The extractor aperture is 1 cm in diameter.

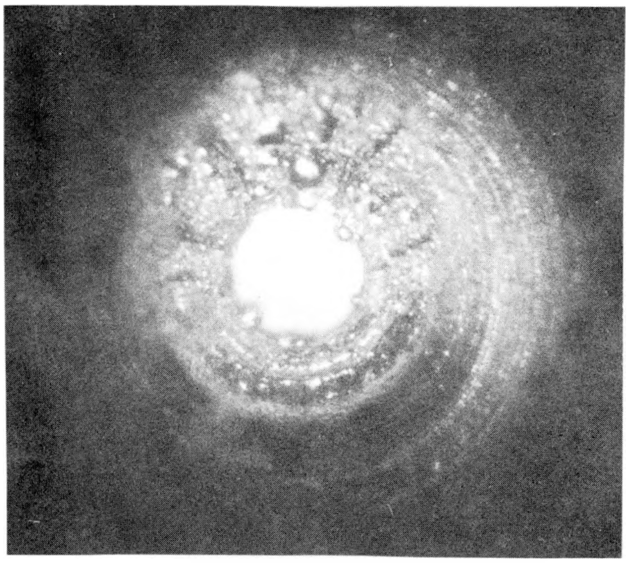


Fig. V-2.
Melting damage to molybdenum insert anode aperture after six months of operation. The anode aperture is 0.63 mm in diameter.

A cathode failure occurred on the H^- injector after only 300 h of operation. This failure was caused by the melting of the center tap wire, rather than destruction of the cathode material, which was probably caused by high peak current operation experienced this quarter. A new design of cathode using a larger center tap wire and thicker cathode gauze is now being tested.

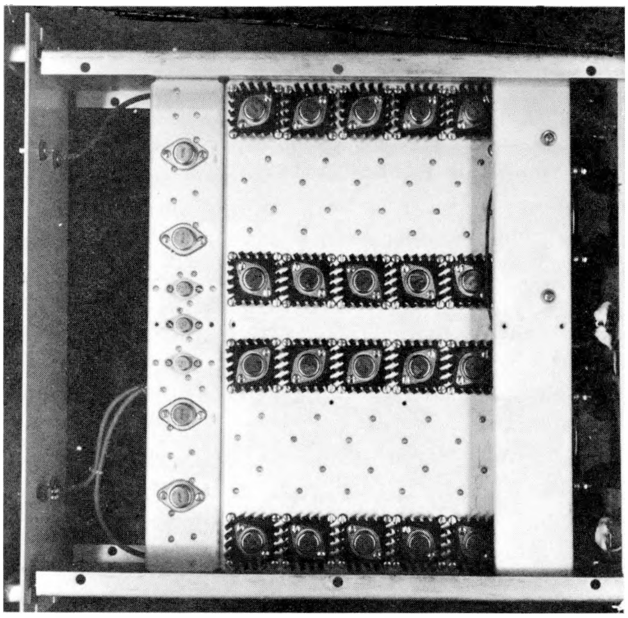


Fig. V-3.
Prototype model of a 250-V/200-A arc pulse modulator.

Ion pump failure on the H^- injector has increased this quarter with both pumps requiring overhaul. The cause of the higher failure rate has been the result of increased hydrogen flow required to provide the higher peak currents needed from the ion source with the limiting apertures now employed at the prebuncher and beam chopper. The mode of failure in these pumps has been electrical shorts produced by spallation of the center titanium rods in the ion pump elements. The use of stainless steel rods in these pumps is being investigated in an effort to obtain a greater lifetime for these pumps.

Polarized Ion Source

Assembly of the polarized ion source terminal is now completed. Installation of the 850-kV C-W power supply and the motor-generator set is under way. The accelerating column and ion pump manifold support stand have been installed in the dome.

The partially wired control racks have been received from the vendor. Modules are being installed and final wiring is under way.

Modifications to the duoplasmatron have been completed and this unit has now been installed in the H^- ion source test stand. The new cesium cell is ready for installation in the test stand; testing will begin as soon as the temperature controls and heaters are assembled.

The argon cell cryopumping system has been modified to use a liquified hydrogen heat exchanger system. It has been installed in the polarized source at P-9 Van de Graaff Laboratory where testing is being carried out.

Shop drawings have been completed for major source components except for the rapid-reversal region, the duoplasmatron-cesium cell vacuum housing, and the stand for the source. Funding problems have delayed further procurement and fabrication of ion source components.

The acrylic jacket was received from the vendor and has been sent out for machining of the end flanges. Most of the parts for the column are now on hand, with the notable exception being the accelerating tube electrodes. Procurement action for the remaining parts for the accelerating column will be initiated as soon as funding permits.

The status of the ion source components is shown in Table V-I. None of the components has undergone tests.

High-Intensity H^- Ion Source Program

Work continued this quarter to develop the hardware needed for operation of a surface ionization ion source, with primary emphasis being put on pulsed gas valves and a high-power transistor modulator.

Two methods of pulsing gas flow were investigated:

The first device consisted of a wheel rotating in a housing with small clearance. When a slot $9 \times 9\ mm^2$ in the wheel passes over a slot $1 \times 9\ mm^2$ in the housing, gas is allowed to flow through. The 10-cm-diam wheel was tested at 1800 rpm so that a gas-flow pulse with a rise and fall time of 140 μs and a

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	x	x	x	x	x	
Magnetic Lens	x	x				
Cesium Cell	(New Design Ready for Testing)					
Spin Filter	x	x	x			
Rapid-Reversal Region						
Argon Cell	x	x	x	x		
Focusing Lens	x	x				
Extraction Lens	x	x				
Accelerating Column	x	x	x			
Precessor Magnet	x	x				
Transport Quadrupoles	---	---	x	x		
Transport Diagnostic Equipment						
Ion Pumps	---	---	x	x		
Ion Source Stand	x					
Ion Source Gas Systems	x	x	x			
Injector Dome	x	x	x	x	x	
Injector C-W Power Supply	x	x	x	x		
Injector M-G Set	x	x	x	x		
Dome Wiring	x	x				
Ion Source Electronics	x	x	x	x		
NOVA Computer Program	x	x	x			
CCR Computer Program						
NOVA Interface						

pulse width of 1100 μs were expected; the measured values were 200 μs and 1100 μs. With a wheel-housing clearance of 0.4 mm the average leakage amounted to ~6% of the peak pulse. Later, this clearance was reduced to ~0.1 mm, and the leakage decreased to under 1%. A 7200-rpm rotary feedthrough unit is being procured to give this device 120-Hz capability; the design rise/fall times would then be reduced to 35 μs. No difficulty is anticipated with this unit as it is rated for 10 000 rpm continuous duty. A 6AH6 vacuum tube, operated as an ion gauge, was used to sense gas flow. The glass envelope was removed and the tube was placed near the outlet of the pulsed-gas device. In summary, the experiments showed this device to be a very workable gas pulser.

The second device was a commercially available piezoelectric gas valve. The advantages of this device over the rotating wheel are its small size, its mechanical simplicity, and its flexibility with regard to pulse width and repetition rate. Its main disadvantage is that the valve responds to a square turn on pulse by ringing at a frequency of ~1 kHz, as determined by the gas-flow measurement. The best observed risetime is ~400 μs and the lowest gas-flow variation due to the ringing is ±10%. This performance will be adequate for our use initially, and it may be possible to improve this operation with a suitably shaped drive pulse. No difficulty was experienced at 120-Hz pulse rate with a 1-ms pulse. The leak rate in the off state is evidently zero.

Development of a high-power transistorized arc pulse modulator continued this quarter with the construction of three breadboard units and the subsequent fabrication and testing of a 200-A/250-V prototype unit. This unit has run at 6% duty factor on a dummy load without fault and was subsequently installed in the H^- injector to power the H^- ion source. The arc current was limited to 40 A in this test because of the limited power-handling capabilities of the duoplasmatron in this injector. No faults in the modulator were experienced in this test. Construction of control circuits, crowbar circuits, and an internal pulse generator for this modulator is now in progress. Suitable input driver circuits are being considered that should permit amplitude modulation of the arc current during the beam macropulse. This system would then permit modulation of the beam-current pulse injected into the linac.

Injector Beam Development

Studies have been initiated this quarter to control the risetime of the proton beam-current pulse. The motivation for these studies has been to investigate the transient response of the rf controllers in the linac with a variable risetime beam. A system was designed employing a suitable inductor circuit in the arc pulse drive line which permits the beam risetime to be varied from 3 μs to over 100 μs. A beam-current pulse with a 120-μs risetime is shown in Fig. V-4. This variable risetime capability has already been used in beam studies of the feedforward system in the linac.

Another use of this technique has been to produce a triangular beam-current pulse. Tests have been conducted that verify there is no transverse motion in the injector beam as the beam current is ramped in this manner. Thus, this type of beam would be useful for checking the operation of the new beam-position monitors now being developed for the linac.

Plans are being formulated to move the ion source test stand to the basement of the Injector Building and to operate the stand at high voltage. The high-voltage cage for this test stand has already been completed. This facility will provide an off-line capability for carrying out beam studies and ion source delevoment (as well as providing a test stand for spare ion sources). It will have an analyzed proton beam and will operate the beam diagnostic equipment at ground potential.

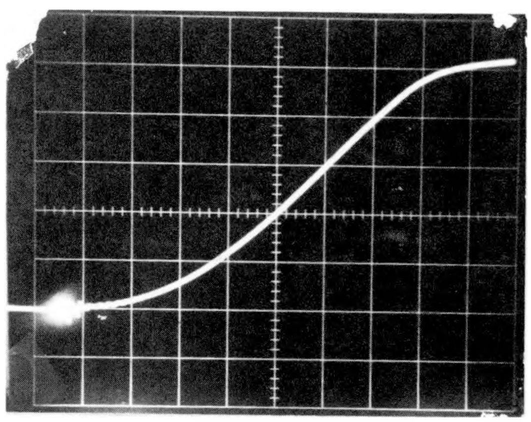


Fig. V-4.
Beam-current pulse with 10-mA peak current produced with a modified arc pulse modulator. The time scale is 20 μs/cm and the 10-90% risetime of this pulse is 120 μs.

VI. ELECTRONIC INSTRUMENTATION AND COMPUTER SYSTEMS

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

Computer Control System

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

Control Computer

The SEL-840MP was available throughout the quarter for accelerator development and operation. The intensive schedule of operations reduced maintenance periods to a minimum, thereby demanding greater ingenuity on the part of the maintenance staff in isolating and correcting problems. The task of maintaining a large computer system under a strict operating regime has been an effective teaching tool in the ongoing technician training conducted weekly by the staff.

The design fault in the SEL-840 interrupt system which had been diagnosed at the end of the last quarter was corrected during an accelerator maintenance period this quarter and has given no more trouble. The computer continues to suffer, however, from an intermittent failure which exhibits itself as a failure of an index loop instruction. A diagnostic program running under the normal, multitasking operating system shows the failure at reasonable frequency, but attempts to create a diagnostic in a simpler, stand-alone environment have not been successful to date.

A read-only memory bootstrap loader was added to the computer so that it is now impossible for any program bug or normal hardware fault to destroy the bootstrap code which initiates the loading of system software. The new device contains start-up codes for both the disk and card reader. The operator can restart the entire system by pressing a single button.

The logging printer failed late in the quarter. Fortunately, the troubles had come gradually and plans were well along for providing a replacement. A receive-only terminal has been ordered to replace the printer, with interfacing via a commercial CAMAC Teletype interface module. When the printer unit failed, the system software for the new terminal was already in an advanced state of checkout, and a spare teletype unit was pressed into service temporarily until the new terminal arrives.

Control Consoles

Development work continued on the CAMAC IEEE/ASCII interface bus system for the third console. This system will provide a standard and easily expanded method by which devices can be interfaced to computer-controlled consoles such as exist in CCR, HRS, WNR, and the Biomedical Facility.

The completed prototype microprocessor controller for the bus system awaits system software and extensive checkout with an automatic Bus Analyzer now under construction. The analyzer will allow simulation of any function and includes a 1024 × 8 RAM for message storage and retrieval.

A companion unit to the prototype controller is a microprocessor-implemented Function Button Panel. The panel wiring was nearing completion at the end of the quarter and will undergo checkout next quarter.

Work began on the modification of all storage-tube display scopes in CCR in order that a more effective technique of hard copy may be utilized. The incremental shaft encoders used on CCR Knob/Display Panels are being retrofitted with more reliable encoders.

Master Timer

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

A number of pc board designs and panel silkscreens were turned over to drafting for final layout. Design of the microprocessor control unit will continue through the next quarter.

Seven new timing distribution chassis were checked out, and two were installed in experimental areas where expanded capability was needed.

Interface Hardware

Work began on the extension of the software and interface hardware associated with controlling the polarized ion source. Injector control room console hardware and a complete list of data channels were detailed. Additions to the NOVA computer interface hardware will be installed during a down period following bench checkout.

A second SEL-840 CAMAC crate controller was constructed and will be checked out on the SEL-810A computer. The controller will be used in expanding the present CAMAC system on the control computer.

Interface design was initiated for a newly delivered keyboard/tape cassette terminal. This terminal will be used interchangeably with the laboratory PDP-11/05 and the microprocessor development system. In addition, the terminal is capable of modem communications with CCR for software development.

Communications between the central control computer and several satellite processors in remote areas of the facility are accomplished through CAMAC-based data-link modules. To increase the efficiency of communications by reducing the load on the control computer, a microcomputer is being incorporated in the data links.

Development of the microprocessor codes was held up last quarter owing to more pressing problems elsewhere in the accelerator. The design of a second-generation microprocessor controller, however, was completed. The new controller takes advantage of the latest integrated circuits available from INTEL for use with the 8080-A1 (faster version of the 8080) processor. Furthermore, the production version of the microprocessor data link will utilize printed circuit techniques, thereby reducing the module width from 4- to 2-wide and increasing the crate utilization factor by 2.

The cause of a continual source of data-link errors between CCR and the satellite control computers was isolated and corrected during the quarter. A design timing error present in all CAMAC single-crate controllers created the difficulty depending upon the transferred data pattern and overall module thermal loading. The manufacturer was advised of the problem and its solution.

Computer System Software

Aside from diagnostic and troubleshooting activities associated mostly with computer hardware faults, the effort devoted to systems software was modest. The activities which took place were mostly related to hardware changes such as the logging printer replacement cited earlier and the continuing development of remote consoles at HRS and WNR, necessary updates to certain modules to correct deficiencies discovered, and user requests.

The mode of access to the beam-transport-emittance instrumentation was changed, and corresponding software changes were made.

A new system call, "reserve slot and set access bit," was required to implement certain remote console functions and was added. Development of control console "knobs" for HRS continued. At the end of the reporting period, the PDP-11/45 software was operational, and the SEL-840 software was ready for checkout.

The debug program was modified to handle certain new system calls which subject programs can issue.

A program was written to set the contents of a disk file to an arbitrary constant.

A requirement arose for the magnetic tape software to handle tapes containing binary-coded decimal information, a commonly used format for exchange of information between dissimilar computers. The modifications to provide this capability are ready for final checkout.

Two programs were written to make it possible to support SEL-840 software on the LAMPF Terminal Computer. The commercial software available on the PDP-11 greatly facilitates the storage of programs and the management of changes in them. These two programs enable the exchange of ASCII-coded files between the two systems so that programmers on the SEL-840 can take advantage of this PDP-11 software. Important savings in the time of programmers and data analysts and in the accuracy of program changes should result from this capability.

Accelerator Application Programs

Software in support of the general operation of the accelerator continued to claim a significant effort.

The limitations of the present equipment for generating accelerator timing gates (the master timer) force frequent changes in the assignment of gates to various functions in order to accommodate different operational modes of the accelerator. In addition to modifying the standard master timer control display, which attempts to identify the various timer parameters in terms of their current functional use, two programs to permit more primitive access to the time registers were provided so that operators can record the current status and make changes with fewer mental gymnastics during intervals between hardware changes and the updating of the conventional control displays.

A program was written to generate a report listing the contents of the master file on the beam-line harps.

The magnet-setting program required extensive modification of some of its tables which describe beam line magnets. Work was completed on a new feature to permit an operator to use a knob to adjust the current through an unshunted magnet in series with a string of shunted magnets.

The rf-system monitor display was modified to permit the use of two VSWR counters in a module.

A program to permit operator control of the Line D beam plug was completed.

For some months (much of the time at a very modest level of effort), a scheme has been under development to use control vectors to permit more natural and powerful control interactions with the accelerator. A promising application and demonstration appears to be in the control of phase, position, and angle of the H^+ and H^- beams at entry to the 805-MHz section of the linac. The beams are divided and then merged again with magnets to give control over relative phase, position, and angle. The first attempt to provide a single incremental control for each quantity floundered on hardware difficulties connected with the pulse-motor controls and current readings. The attempt to implement this particular example is continuing as accelerator operations permit.

In order to speed the diagnosis of accelerator faults by operators, it would be helpful to have a program which could quickly survey and analyze the Run-Permit interlock string, take into account the mode in which the accelerator is operating, and indicate to the operators where the faults are. Very substantial progress was made in the past quarter toward such a program and the associated documentation of the Run-Permit interlocks. A file to contain the Run-Permit data, including provisions for describing alternate permissible configurations and taking into account accelerator operating modes, has been designed, along with programs to compare current hardware status to the information stored in the file and display discrepancies to the operators. Data for ~75% of the accelerator and beam lines have been entered into the file, and the operator interface programs are being written.

The program which displays the values of the toroid current monitors in the main beam lines was revised to conform to new hardware configurations, to do more accurate background and calibration measurements, and to permit the display of any six current monitors from Lines A or B or the SY at any given time. The associated PDP-11/10 program has been written to be compatible with the planned transmission monitor system which uses the same current monitors; it is ready for installation on the Area B and SY remote PDP-11/10s.

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

The controls and instrumentation in the SY continued to play their role last quarter in supplying beam to Area B. Controls for several new devices were added in anticipation of beam in Area A.

The controls for two turbo pumps located in the downstream portion of Line A in the SY were checked and made operational from Equipment Aisle A. The control circuit for the vacuum window, LASV05, was made operational from Equipment Aisle A and CCR. Wire installation books for the additional motors required for the Halo Scrapers were issued to the contractor. The control wiring for the LXTV02 phosphor was extended to operate a phosphor at the LAWS09 position. The shunt regulator on magnet LXBM02 was repaired along with several wire-scanner signal cables.

Area A

The main thrust of the effort in Area A was the installation and checkout of the wiring plant and instrumentation along Line A. A major portion of this effort went into the beam diagnostic equipment. Work orders were written for installation of harps, guard rings, current monitors, spill monitors, beam-on-target indicators, multiplexer control cables, and assorted hardware such as T-boxes, ducts, and conduits. This work is essentally complete. Controls for all harp multiplexers were tested and declared operational for beam into Area A. The harp display software was revised to conform with hardware changes and to incorporate revisions suggested by beam line tune-

Work on the thermocouple systems for monitoring the shielding and collimator temperatures is nearing completion. The electricians installed the thermocouples and thermoswitches on the shielding and collimators as far as the A-4/A-5 Target Area. The checkout of the sensors and inputs to the Run Permit kept pace with the installation of equipment.

Work on the controls for the A-1 and A-2 targets was completed. This work included the installation of the magnetic pickups that ensure the targets are spinning as required. Controls for the television camera monitoring the target were installed.

Software for the control of A-1 and A-2 targets was revised to conform with hardware changes made during the shutdown. In addition, a program was written to monitor the rotation of the A-1 target.

The wiring for the vacuum-controlled water valves was completed and tested up to the water valve locations. The Run-Permit inputs were verified. System checkout must await the installation of the water valves. The A-4 vacuum system was completed.

A bin of controls was installed for a semiportable water system in Area A. This system is similar to the X0 system in the SY except that the analog transducers are omitted.

Six of eleven RM-16 radiation monitors were installed and partially tested.

Work has begun on the Line A transmission monitor software which will form a part of the beam line protection system at high-intensity operation. Initially, beam transmission will be monitored between four successive pairs of current monitors by the Area-A PDP-11/10. If the beam transmission varies by more than a predetermined amount from the expected value, the PDP-11 will trip the Run-Permit interlock. While the PDP-11 performs the moment-to-moment checking, it must be supplied with calibration and background parameters and information on expected transmission fractions by the SEL-840. In addition, the 840 must display the faults so that operators can deal effectively with them when they occur.

EPICS

The work on the controls and instrumentation for EPICS was directed toward getting the system ready to receive beam. The α-particle test was successfully repeated as a verification that the additions and modifications to the channel were completed satisfactorily.

The work done on the EPICS rf separator included the installation of controls for the solenoid valves 1PSV02 and 1PSV03, the repair of the high-voltage cables, and the installation of computer controls for the leak detector.

In the regulator rack for the focus and steering magnets, several repairs were made and a fault detector was installed and put into operation.

The work completed in the EPICS counting house racks in preparation for the experimental program included the design and installation of delays for experiments, the replacement of a CAMAC crate and its I/0 cabling, the design of a rack blower package to cool the NIM bins (12), the relocation of power supplies and associated wiring, followed by a checkout of the power distribution system, and the modification of the NIM power distribution system to provide ±6-V-dc power.

Along the main line of EPICS, the H_t water cooling system was integrated into the main line interlocks, m.i. cabling and associated thermal switches were added where required, the cabling to the slit FJ1 was repaired and radiation hardened, new computer control cables were designed and fabricated for the magnet power supply, and a test rig for thermal switches was designed and sent out for construction.

A very large amount of time was devoted to working with the manufacturers of the EPICS large-capacity disk in an effort to bring it to a satisfactory level of operation.

The EPICS KS90 tape controller was received from the manufacturer after the installation of the latest engineering changes, and the magnetic tape handler for RSX-11D was modified.

SMC, LEP, and P^3

Miscellaneous support was given to the teams getting these channels ready for operation. The wiring of the P^3 collimator in the A-2 target box was completed and checked.

Beam-Stop Area

Wiring for the A-6 beam-stop controls was installed but no devices are available for connection.

Some wiring was installed for the controls in the RADIP area. A position counter/comparator for the stringers was completed.

The timing, patching, and current monitor cables to the neutrino trailer were installed.

Area B/C

The controls and instrumentation along Lines B and EPB continued to function to deliver beam to the experimenters. The following activities were coordinated with this primary purpose:

1) Remote computer control of the illumination to the TV phosphors was installed.

2) The control wiring for the nuclear chemistry rabbit system, trombone, and target was installed.

3) The regulator rack of controls for the trim windings for LCBM04 and LCBM05 was completely rebuilt. The maximum current for the center four windings of the H_t coils was changed from 250 A to 60 A. This allowed the multipole magnet, LCMU01, with its 12 windings of 60 A, to be added to the existing power supplies.

Engineering support was provided to several experiments during the quarter. Experiments 42, 241, and 192 were completed; 193 and 81 are in progress, and 179 is being mounted.

HRS

The control circuit for the new water system was designed during the quarter. The rack of controls was installed and an installation book was issued to the contractor for wiring the remote control of this system.

The control circuit for the spectrometer and scattering chamber was designed. This rack of controls is presently being fabricated.

The bin of controls required for HSBM02 was installed.

Communications

The LAMPF communications system includes in-erphone and paging services throughout the facility.

The performance of the communications system ias deteriorated over the past year, partly because of ts rapid expansion into the experimental area and artly because inadequate support was devoted to epair activities. To correct this situation, an inten-ive program of repairing and updating of the system vas initiated. Most of the interphone stations and peakers were tested and serviced. Thirty-six eadsets were repaired or replaced. To determine hat all reported failures had been corrected, a etrieval was made from the maintenance data base f all incomplete repair cards for the com-nunications system. This repair activity will con-inue until completed early next quarter.

A comprehensive study was begun to determine what actions should be taken on a long-term basis to bring the communications system to its full potential. Priorities will be assigned to the various tasks and work on the upgrading will begin next quarter. When the system is fully developed, consideration will be given to having the communications section of another LASL group take over the maintenance of the system.

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 purposes of acquiring and reducing data from nuclear physics experiments.

Experimental Area Computers

A short course on the PDP-11/45 operating system was prepared and given early in January. A primer prepared for use with the course provides a simple introduction for users of LAMPF data-acquisition computers.

The latest release of the RSX-11D operating system, which offers several improved features important to LAMPF operation, was installed and made operational on most of the PDP-11/45s.

Various components of two new PDP-11/45s for LEEP began arriving in January. A complete system contains various items of equipment from six different manufacturers. At the end of the quarter, the system still lacked disk drives, memory management hardware, and magnetic tape controllers. Installation has begun at the SMC and P^3-East.

Expansion of the Terminal Computer continued with the installation of a second dual-disk drive, bringing the total on-line disk capacity to ~6M words. A new core memory ordered for the computer was damaged in shipment and had to be returned to the manufacturer for repair. However, with the aid of some borrowed memory, the core size was increased to 96k by the end of the quarter.

This period saw the usage of the Terminal Computer grow dramatically although the number of experiments on line was small. Usage is limited at present by the capacity of the core memory to support simultaneous operation of several programs, disk capacity, and the limited number of user terminals available. The increase in disk and core capacity will permit more concurrent use by independent users. In order to improve the accessibility of the machine further, two telephone lines were ordered, along with modems and interfaces, so that any LASL time-sharing computer terminal capable of being connected to the dial-up telephone network will be able to connect to the computer.

A diagnostic and debug console for PDP-11s was ordered and received. This device monitors and records memory accesses on the PDP-11 Unibus. It is expected to speed up the diagnosis of certain types of hardware and software faults to a significant extent.

A Versatec printer-plotter with PDP-11 interface was received for LEEP and put into use.

A new nine-track magnetic tape unit was installed on the Neutrino Super-NOVA computer system. A hardware multiply/divide was installed on the magnet-mapper Super-NOVA.

Computer Maintenance

Negotiations for the maintenance of all non-DEC peripherals on the LAMPF data-acquisition computers were completed with the computer maintenance section of the LASL Electronics Division. The normal coverage is from 8:00 a.m. to 5:00 p.m. on weekdays, but a provision is included for 24-h/7-day service when the computer is attached to an experiment receiving beam. The maintenance contract also covers the computer equipment of LAMPF users while they are on site. However, users are expected to pay for services rendered. All service reports are logged in a data base which is used as a tool to monitor the effectiveness of the maintenance teams.

Data-Acquisition Software

All but two of the currently operational modules of the general data-acquisition program, Q, have been converted to run under RSX-11D Version 6. The remaining two modules, plotting and replay, should be converted shortly. The package is now running on several computers without these modules; a distribution disk and related documentation are in preparation.

A new feature added to Q is the ability to insert information generated by a PDP-11 program, perhaps from sources other than the CAMAC system, into the data stream being written on magnetic tape.

A number of additions were made to RSX-11D utility software during the quarter. A set of subroutines, compatible with previously existing DOS subroutines, was written to read and write magnetic tapes for exchange between machines equipped with DEC TU10 tape units and those equipped with IBM 729s and LBL controllers. The disk-dump utility program was modified so that it works with multiple disk-control units. A task and subroutines were written to give any program the ability to issue the same system commands a user can issue at a terminal. The assembly language macros for issuing subroutine calls were revised and made uniform on all RSX-11D systems at LAMPF.

The Tektronix 4010 plotting subroutines were converted for operation under the new release of RSX.

Some help was given to experimenters in converting data analysis software from DOS to RSX so that the analyses can be run on the Terminal Computer concurrently with other work. The process has proved simple and straightforward for programs written in FORTRAN.

Interface Hardware and Nuclear Instrumentation

A modification to the LAMPF CAMAC MBD was designed to allow the device to address 128k of PDP-11 memory. The change is being installed for checkout at the manufacturer's plant and will be installed in all other MBDs in the next quarter.

A remote capability was added to the BNL Versatec printer so that the printer can be used with the HRS PDP-11/45 or the BNL PDP-9 computers.

A new control card for the EPICS/HRS NMR probe multiplexer was checked out and installed in all NMR multiplexers. The new control card cures the problem of the gaussmeter losing lock during a CAMAC read operation.

A modification was made to the NOVA CAMAC crate controller so that the module passes dataway X along to the computer and is able to generate Initialize (Z), and Clear (C). Modifications to the BASIC software used with the controller were also made to take advantage of the improvements.

Work on the taut-wire magnet-position sensing systems for EPICS and HRS was completed except for continuing assistance to the users. A total of 3 master control units, 3 NIM bins, and 432 channels and sensors were constructed, tested, installed, and checked out. The EPICS taut-wire system was used successfully to measure floor motions associated with the closing of the A-1 target doors.

LAMPF Electronics and Equipment Pool

The pool is adequately stocked for cycle 2 through cycle 5 of the operation in Area A. A recent allotment of funds has allowed LEEP to process orders for some high-priority equipment.

An evaluation of disk packs and new CAMAC crate power supplies is under way in an effort to establish future sources for these items. Multichannel analyzer printout capability is being investigated for future procurement.

All LEEP inventory records will be shifted to the System 2000 data base through CCR. The purchase of a remote time-sharing terminal will greatly facilitate the maintenance of records in the future.

Special Instrumentation

Some long-standing analog instrumentation problems were attacked, with positive results, this quarter.

Magnet Shunt Amplifiers

The shunt amplifiers for the magnet power supplies in the experimental area show a propensity to drift with temperature. The source of the drift was traced to the common-mode rejection circuitry. A prototype circuit card to correct the problem was designed and built. In laboratory tests it exhibited a satisfactorily low drift rate when cycled over a wide temperature range. It has a common-mode rating of ±500 V and a common-mode rejection ratio of 10^8.

805-MHz Water Temperature Controllers

The water temperature controllers in the 805-MHz portion of the accelerator have proven to be reliable devices, somewhat prone to drift and difficult to adjust. These units were completely redesigned, but in such a way that no external wiring changes are required. The four variables used in controlling temperature were made completely independent in the new design. The prototype unit was tested and found to be very simple to adjust for optimal control. A water temperature signal is provided for the computer, scaled so the -10 V is 70°F (21°C) and +10 V is 90°F (32°C). The prototype unit was removed and some simple diagnostic circuits were installed. The unit will be reinstalled for further testing during the next maintenance day.

The source of the drift was identified in the rf power meter and eliminated by a redesign of the power head. A major advantage of the new design is that the number of the component parts was reduced from 30 to 8, promising increased reliability and reduced cost.

Sharing of LAMPF Technology

The design details of a CAMAC Serial System Driver Module were released to the ORNL Technical Information Service at the request of a commercial manufacturer who may choose to market the device.

Two members of the staff attended the NIM/CAMAC Dataway and Software Working Group meetings during the quarter.

Papers on the LAMPF microprocessor Data Link and CAMAC Serial Driver were presented at the annual Nuclear Science Symposium.

A seminar on operational amplifiers was presented to 100 staff members and technicians on the MP-Division staff as an effort in continuing education. A survey of interests in other topics is being conducted.

VII. ACCELERATOR OPERATIONS

General

The accelerator was in continuous operation throughout the quarter for a total of 276 shifts. Of the total, 79 shifts were scheduled for accelerator development, 11 for maintenance, 14 for tuneup for production (research) beams, and 172 for research. Beam availability during research shifts averaged 74%.

Experimental Program

Because upgrading of Experimental Area A was still in progress, research beams were limited to the beam switchyard and Lines B and EPB. Average proton beam currents ranged from 0.1 to 5 μA. Beam currents to Lines B and EPB for experimental use totalled 740 μA-h. An additional 750 μA-h was delivered to the switchyard during one 36-h period for a radiation-damage experiment.

Fourteen experiments received beam for a total of 215 eight-hour shifts. The beam supplied to each experiment is given in Table VII-I. This tabulation does not include parasite use of beam during production runs or the beam used in facility development or tuneup activities. An additional 45 μA-h spread over 35 shifts were used by Exp. 179 operating in parasite mode.

Accelerator Development

Measurements were made of Tank 1 acceptance vs proton energy and tank head position as part of an effort to determine the optimum field tilt for that tank.

Wire scanners and beam-spill monitors were used to measure beam halos along the linac. Routine use of this capability will require development of new control computer software.

Discovery of a miswired quadrupole doublet in module 6, resulting in field reversal, explained the transverse matching difficulties previously encountered in that region. A check of all other linac doublets revealed no other wiring errors.

Sensitivity of the six installed beam-position monitors proved adequate. Their long-term stability is still under study. Two prototypes are being developed for comparison, with the better of the two slated for eventual production and installation all along the linac.

Studies were made of the ability of the machine to accelerate high peak currents without exceeding phase and amplitude error tolerances. The practical limit, without anticipatory feedforward measures, is 2.5-mA peak, equivalent to 150-μA average at 6% duty factor. Installation of the feedforward capability is in progress. Effects of increasing the risetime of the pulse of protons are also under study.

Efforts to tune the machine for high-current operation continued. Single beam (H^+) average currents reached 156 μA in 30-s bursts. Dual beam capability of 100-μA H^+ and 3-μA H^- was demonstrated on several occasions. Two new vertical steering magnets are being readied for installation in the TR main line. The resulting capability for independent steering of H^+ and H^- beams in the TR (the side track already has vertical steering magnets) is expected to ease the tuning of simultaneous beams significantly.

Measurements were begun to determine whether possible deleterious effects on beam quality result

TABLE VII-I

QUARTERLY REPORT OF BEAM PROVIDED FOR EXPERIMENTS

Experiment	Channel	Shifts (8 h)	μA-h	Experiment	Channel	Shifts (8 h)	μA-h
42	EPB	70.0	----	192	EPB	10.0	----
81	EPB	13.0	----	193	AB Neutron	46.5	130
104	AB Nucchem	1.0 (2 runs)	6	205	AB Neutron	6.5	48
105	AB Nucchem	2.0 (4 runs)	52	241	EPB	41.5	----
106	AB Nucchem	1.0 (5 runs)	14	255	AB Neutron	5.0	86
111	AB Nucchem	0.5 (7 runs)	17	262	AB Neutron	2.5	16
123	AB Nucchem	1.0 (2 runs)	2	269	Beam SY	4.5	750
129	AB Neutron	15.0	330				

from variations in tank resonance conditions occurring within present control tolerances.

Operating Experience and Downtime Accounting

Machine operation was more stable and reliable during this quarter than at any time in the past. On each of the few occasions when beam quality deteriorated suddenly, the cause was found quickly and beam quality was restored without retuning. The improvement can be attributed to the general upgrading of the machine during the recent shutdown, and the monitoring capabilities provided by the redundant phase-monitoring system and several new control computer programs. The redundant phase-monitoring system is presently installed in modules 1-12 and work is in progress to extend it throughout the accelerator.

A summary of the machine downtime is given in Table VII-II. A major portion occurred during machine startup following scheduled maintenance days.

Accelerator Support

Difficulties were encountered in the installation and checkout of beam current and spill monitors and personnel safety systems in Area A: Area A has many sources of electrical noise at objectionable levels; many cables were damaged in the course of shield stacking. The current and spill monitors now appear to be in satisfactory condition. Installation and checkout of personnel safety systems will be completed soon after the cave shield blocks have been emplaced and doors installed.

The inoperative vector scopes were removed from the control room consoles and replaced by TV monitors and multitrace oscilloscopes.

A special short risetime toroid was built and installed in Line D at the top of the waterfall.

TABLE VII-II

QUARTERLY SUMMARY OF MACHINE DOWNTIME

Category	Downtime (h)	Percent of Total
201-MHz amplifiers and transmission lines	95	25.0
Magnets and magnet power supplies	55	14.0
805-MHz amplifier systems	47	12.0
Vacuum	41	11.0
Injectors	29	8.0
Computer control and data acquisition	21	6.0
Interlocks	15	4.0
Beam diagnostics	12	3.0
Reference source	8	2.0
Water	7	2.0
Timing	4	1.0
Beam stops, plugs, targets, strippers, scrapers	2	0.5
Miscellaneous (utilities, etc.)	50	11.5
Total	386	

VIII. EXPERIMENTAL AREAS

General

Continuation of shutdown work dominated all experimental area activities during this quarter. At the end of the quarter, the main beam line was nearly complete and ready for installation of instrumentation. The shielding effort was entering its final phases. The secondary beams were essentially readied for beam.

By the end of January 1976, there were less than 50 work activities remaining on the PERT network that were essential for beam operation in Area A. About 80 jobs were still to be accomplished at A-East. The PERT system, which was started in the fall of 1974 as a management tool for the Great Shutdown, was discontinued.

A target date of February 14 was set for the initial checkout run of beam in Area A. March 6 was selected as the scheduled date for the beginning of a two-week cycle of main and secondary beam checkout studies.

Facility Operations

Much effort has been expended in planning for an Experimental Area Operations Office. All attempts to obtain a facility have failed. Equipment has been purchased and software developed for monitoring the operations, but it is now obvious that the initial operations will be carried out with an incomplete, temporary facility.

The Experimental Area staff shop and tool crib are well equipped and in full operation to support the experiments and other activities in the area.

The exposed slopes of the switchyard and Area A-East shield cover have been covered with a concrete grout. This, along with the paving of part of the parking areas and roadway, has greatly reduced the dust and erosion problems.

Experimental Area Cooling-Water Systems

The major effort during this quarter was the installation and checkout of the cooling systems for the new beam line components in Lines A and A-East.

The five radioactive water systems operated continuously during this period. Bearings were replaced in the pump motor of system X05.

The installation of the valve cave flow meters is now complete. The units are being put into service after checkout.

Installation of the remote manual valve operators for the shielded valve caves is now complete.

The pump/heat exchanger package for the Area A nonradioactive water systems has been assembled. It is now being installed near the SMC. It will be used initially on Exps. 37 and 99.

Modifications are being made to the deionizer cave, which houses the resin tanks for the radioactive water systems. Pressure-reducing valves will be installed on the supply lines to protect the resin tanks. In addition, another resin tank was added to system X05 to accommodate its large volume.

A nitrogen-tube trailer was added to the surge-tank pressurization system. The system controls the pump-suction pressures for all five radioactive water systems. It will eliminate the operator time necessary to make the frequent change of the H-bottles used heretofore. The system will also reduce the risk of a system shutdown if a gas leak occurs. A single tube trailer will last from 9 to 12 months.

Cryogenics

Cryogenic hydrogen targets for Exps. 241, 81, and 201/56/129 were designed, built, and operated. Flasks for Exp. 99 have been built and tested. Construction of a target for Exp. 193 is nearly complete. A refrigerated tritium gas target of new design has been designed for Exp. 90. Modifications to the superfluid helium cryostat for Exps. 154/245/248 are in progress. The CTI 1022 refrigerator, which became oil contaminated, has been repaired and tested. A new control console for 10-W systems has been built, and a newly designed target pressure controller has been built and operated successfully.

Main Beam Line Installation

At target cell A-1 the vacuum system is complete and awaiting final leak check. A 0.12-mm-thick stainless window, welded to an insertable cone, was installed at the upstream end of the EPICS beam line. All thermal instrumentation has been installed and checked out.

At target cell A-2, the vacuum system is nearing completion. The target mechanism is installed and operating; the thermal instrumentation is installed and checked out.

The main beam line between target cells A-2 and A-5 is complete except for installation of harps. An isolation window will be installed at the A-4 location at a later date.

At target cell A-5 all the beam line hardware is complete and installed. The upper shield box and target/profile monitor vertical tubes were removed for water-cooled shielding installation. The in-cell shielding has been designed and fabricated.

At target cell A-6, the water-cooled shielding is fabricated. Hookup is approximately 50% complete. The beam stop has been assembled and its drive system has been operated, and will be installed upon completion of the plumbing and wiring. The installation of the thermal instrumentation is under way.

Alignment fixtures for components at target cells A-1 and A-2 have been installed, and all initial position measurements have been taken. The alignment system was monitored during the movement of the doors at A-1. No displacements of the target cell triplet or the first EPICS bending magnet relative to the profile monitor base were noted. However, the components tilted as much as seven arc-seconds as the doors were moved.

Secondary Beam Lines

During this quarter, the P^3, SMC, and LEP secondary beam lines have been made ready for the first beam after the Great Shutdown. Lines B and EPB have been kept in research operation and support has been rendered to experiments set up in those beam lines.

Significant accomplishments on the secondary beams were:

1. Repairs to LEP have been carried out following damage by the motion of the shielding door over target cell A-1. Damage was mainly to water manifolds, several bellows, the center absorber box, and the channel alignment. Repairs were made and the channel was completely realigned.
2. The NMRs and the NMR preamps for the LEP bending magnets have been repaired and the system is now operational.
3. The LEP canyon fill and the bulk shielding cover for LEP have been installed.
4. Minor additions to the P^3 and SMC canyon fill have been installed.
5. A new beam vacuum box for BM03 in SMC has been installed, and the magnet has been realigned. This box allows for a larger beam aperture for the SMC-East beam line, which is to be tested later this spring.
6. Two quadrupole magnets (20-cm and 30-cm diam) have been installed in SMC-East to allow preliminary tests of that beam line. Installation of power supplies and controls will start shortly.
7. All experimental cave rebuilding is complete for LEP, SMC (West, South, and East) and P^3-West; more work must be done to complete the P^3-East and the test channel caves. All cave gates have been installed and the installation and checkout of the personnel safety system are nearly complete.
8. Extensive testing of standard vacuum windows used in the secondary beam lines has been carried out. The following were tested: Kapton 0.12-mm thick by 20-cm diam; aluminum 0.12-mm thick by 30-cm diam; and Havar 0.033-mm thick by 20-cm diam. All burst at above 5-atm loading, and all withstood repeated cycling.
9. The vacuum isolation window in SMC has been removed. Remotely operable window guards for SMC exit windows have been designed and are being built.
10. Experimental engineering support is beginning to Exps. 2, 80, 90, and 164 in Area A.
11. Experiment 192 was dismantled; the Faraday cup was rebuilt and reinstalled, and the EPB beam stop was rebuilt.
12. Substantial support has been given to Exps. 81, 179, and 193 in Area B. A vacuum leak has been found in the Line B LD_2 target. A new current monitor has been installed in the Nuclear Chemistry Cave of Area B. The 0° neutron beam stop in Room BR has been moved outside for Exp. 193.

Polarized Proton Target Development

During the past quarter, work on the polarized proton target was deferred for a significant portion of time due to work in Area A and on Exp. 42.

The 500-ℓ/s liquid ^4He vacuum pump was delivered in October. It has been installed and tested on a temporary service basis in the ETL.

The cryostat has been remounted on a stand suitable for in-beam line service. It is being leak-checked and connected to the various pumps. A second condensation test using ^3He will commence after the cryostat is ready.

Targets

The A-1 and A-2 pion-production target mechanisms have been installed and checked out for beam. The A-5 mechanism is being prepared for installation. The following targets will be mounted and available for immediate use at beam startup:

At A-1: 0.5-mm-thick graphite ($\rho = 1.73$ g/cm^3)
1-cm-thick graphite ($\rho = 1.73$ g/cm^3)
3-cm-thick graphite ($\rho = 1.73$ g/cm^3)

At A-2: 0.5-mm-thick graphite (ρ = 1.73 g/cm^3)
6-cm-thick graphite (ρ = 1.73 g/cm^3)
6-cm-thick Al_2O_3 ($\rho \cong$ 3.87 g/cm^3)

At A-5: 1-mm-vertical, 8-cm-long graphite (ρ = 1.73 g/cm^3)
1-mm-thick graphite (ρ = 1.73 g/cm^3)
8-cm-thick pyrolytic graphite (ρ = 2.2 g/cm^3)

Remote Handling

Six bids for a force-reflecting servomanipulator system were evaluated by the Experimental Area Development Committee. On December 2, the request to place an order for a complete two-arm system was initiated and the request was forwarded to ERDA on January 23, 1976. The first master and slave-arm system will probably be delivered by the middle of December. This will improve our remote-handling speed by ~30 X, compared to the PaR No. 3500 which is mounted on Monitor. The second system is due in April 1977, and at that time our remote-handling speed is expected to improve our present speed by ~60 X.

A second vehicle, very similar to Monitor but with improvements based on experience with Monitor to date, has been designed in concept. It will be called "Tele-arms," and will be used in conjunction with the force-reflecting servomanipulator system.

In view of the long delivery time for the force-reflecting servomanipulator, an interim solution, which would provide more capability than the existing PaR arm, was urgently sought. Arrangements have been made to borrow from the U.S. Navy for one year, a hydraulic servoarm made by the Remotion Co. In January an order was placed with the same company to supply additional equipment to give us a complete one-arm, nonforce-reflecting, servomanipulator system. Delivery is scheduled for March 1976. This system will improve our present remote-handling speed by about 6 X. The arm will be mounted as the right arm on Monitor with the PaR No. 3500 as the left arm.

Construction was started on a full-scale mock-up of a hypothetical target cell. The mock-up features assembly facilities for a steering magnet, a collimator, a harp box, and a quadrupole triplet with typical vacuum, water, and current connections. The components produced outside have already been received. The plywood target cell has been erected and the shop has completed about 80% of all welding and machining.

Special tooling fixtures designed to remove and reinstall a steering magnet, using Monitor and a crane, were tested in November. A fixture turns the magnet through 45°, to place it in a position that allows a second fixture to grab the magnet so it will open and can be lifted off the beam pipe. Some bolts have to be released with an impact wrench at the proper times. This fixture design differs from an earlier construction in that it utilizes the weight of the magnet to force it open, rather than an external force, for which most manipulators would be too weak.

The tests were successful and a procedure for removal and installation of a magnet was written up.

Monitor

November and December were devoted primarily to the installation of the stem unit carrying a closed-circuit TV camera and light. This involved disassembling the commercial light unit to mount the cable inside the retractable stem which was a tricky job since this was the first time it was done. It also involved the design and construction of a spring-loaded cable take-up drum and of a light-weight, remotely controllable pan and tilt mechanism for the TV camera, as well as the installation of the surplus carriage for the sideways movement of an automotive winch for "in-and-out" movement.

January was devoted primarily to installation of two boom cameras and remote controls for the harp unit and the hydraulic pump.

The automatic leveling motor burned out a second time and is now being replaced with an ac motor using electric braking.

Shielding

All major design work was finished for completion of final shielding in Areas A and A-East. Two known areas that will require further design and detailing are the upper level in-cell shield in the A-1 area and the steel shield that will be modified to accommodate the water-cooled shielding at the main beam stop.

At Target A-1, the in-cell shielding was installed up to the 3-m level. The bulk shielding up to the level of the Merrimac roadway was completed along with the canyon fill and covers for LEP and EPICS secondary lines.

The assembly of the large Merrimac doors that cover the A-1 target area was completed. The doors were filled and their operation was tested. In the initial movement of the doors, the south side of

Door 1C contacted the canyon fill alongside the LEP secondary line. The movement of this shielding displaced the two middle bending magnets and other nearby components of the LEP line. Correction of this damage required about one week of disassembly and reassembly of shielding and components of the LEP line.

At Target A-2, the bulk shielding around the target cell was completed and the in-cell shielding is complete up to the beam line elevation. The P^3 canyon fill and cover were completed during the previous quarter with only minor additions this quarter. The SMC canyon fill was completed and the channel cover installed. The frames for the large Merrimac doors were completed, including the removable bridge section above the A-2 target box. All four A-2 Merrimac doors were assembled and filled, and are ready for initial operations.

Mass shielding of Station A-3 has been completely installed, including the cover above the A-3 beam plug. Some additional fill will be placed in the service penetration to the A-3 equipment.

At Target A-5, the water-cooled shielding immediately around the target and nearby components has been fabricated and installed. Considerable shielding was added around the A-5 downstream proton line triplet and around the first bending magnet in the biomed line.

Some of the steel shielding at Station A-6, near the Line A beam stop, was removed and replaced with water-cooled shielding. The pieces removed are now to be trimmed to fit around the water-cooled plates and will be reinstalled. The neutrino shutter in the beam stop area was completed and is ready for testing. The A-6 shield doors have been assembled, including both steel and concrete battery plates.

Additional steel slabs have been purchased to complete the final fabrication work in the experimental areas.

IX. BEAM LINE DEVELOPMENT

Switchyard, Lines B and EPB

Procedures for tuning Lines X, B and EPB were written and tested. Several shifts of tuning time have been used for instruction and systemization of these operating procedures, and they have been used routinely by MP-2 operating crews since November 1975. Changes have been made to the wire scanner and magnet programs to improve operator interaction.

Guidelines and ground rules for experimental apparatus which will go into primary beam lines have been established. The guidelines deal with those aspects of experimental apparatus which may affect beam transport, tuning, or reliability of operations. A review of such experimental apparatus by cognizant beam line physicists and engineers has been set up.

Review and/or operations assistance have been provided for Exps. 179, 192, 205, and 269. For Exp. 269, a 25-μA-average H^+ was tuned to provide a small spot (2.7 mm FWHM) at the Line A-direct beam stop in order to provide beam densities of $\sim$350 μA/cm^2. This beam was run for about 32 h without damage to the 13-μm Havar exit window or the beam stop, and without causing vacuum leaks in the exit flanges.

Line A-South in the SY has been prepared for first beam into Area A. Preparations included installation of three wire scanners, one halo scrapper, and two toroids. The system of turbo pumps to provide differential pumping to make the transition from Area A vacuum to SY vacuum has been installed and checked out. Some problems still exist with the controls on one turbo pump. Shielding and vacuum plumbing for the thin-target region were also installed. A gate valve (LASV05) with a 13-μm Havar window has been installed to provide the capability of isolating the SY and Area A vacuum systems. This window will cause multiple scattering of the proton beam and increase the minimum achievable vertical spot size at A-1. Calculations indicate that the minimum vertical spot size at A-1 will be 4 mm FWHM.

Three new, two-position air-driven actuators with phosphors have been installed: one in Line A-direct, one at the Line B-EPB split, and one in EPB. The ribbons on several Line A and Line X wire scanners were changed to 50 μm $\times$ 2-mm nickel ribbons in order to reduce beam interactions with the wire material. Considerable effort was expended on reducing the noise on the Line B wire scanner and current monitor system. Not only were many ground loops traced down and eliminated, but in one case a motor drive cabling error was located. The wire scanners now operate much more reliably and produce useful beam profiles at 1-μA-average. The more severe noise problems in the Line B TV and current monitor systems have been cured.

Beam Measurements and Analysis

An informal report by O. van Dyck was given to the LAMPF Accelerator Development Comm. and the Experimental Area Development Comm. giving data taken (Fig. IX-1) on the SY wire scanners in which a satellite beam is progressively clipped off an H^- production beam by use of a Line A stripper. This and other measurements show that beam satellites are easily observable on the wire scanners, and that beam halos down to 10^{-3} or 10^{-4} of typical beam-core intensities can be measured.

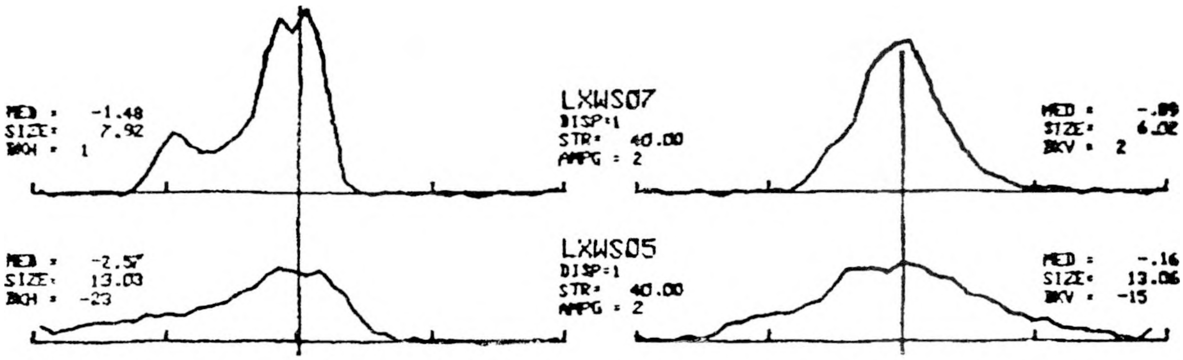
A program to improve measurements of emittance and other transverse beam phase space parameters has begun using the four wire scanners in Line A-direct and the last eight wire scanners in the linac. Some data have been taken for low-intensity (<2.0-mA-peak) H^+ beams.

In order to study wire scanner measurements for emittance calculations, two codes have been put on the SEL-840 computer. Program 1128 stores wire scanner data on a disk file, and Program 1132 dumps this disk file onto magnetic tape.

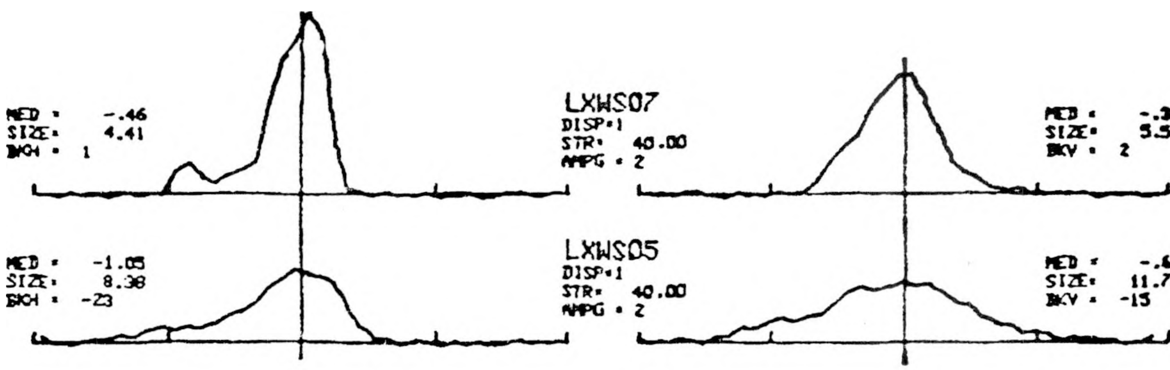
A code has been put on KRONOS file (so that it can be run from a portable keyboard terminal) which will read the magnetic tape (convert 24 bit words to 60 bit words), calculate the R-matrix elements between wire scanners, and estimate the beam matrix at a specified location. This code has options which allow either rms or percentile spot-size calculations, and either a least square fit to the data or a nonlinear optimization which constrains the correlation parameter to absolute values less than unity.

Beam Transport Calculations

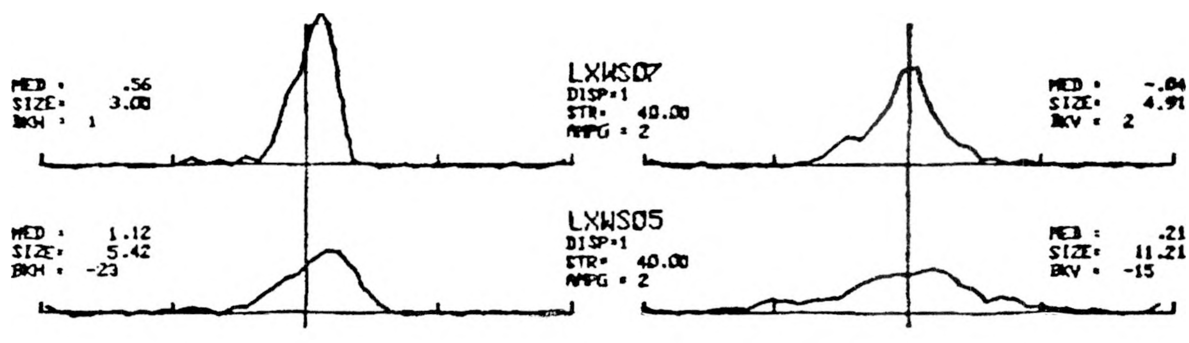
Work on a standard tune for Line A from the end of the linac to the A-6 beam stop using K. Crandall's matched "linac beam of π/30 mr-cm emittance" as input has been completed. This tune assumes targets of 30-mm graphite at A-1, 60-mm graphite at A-2, and 80-mm pyrolitic graphite at A-5. The beam constraints used as well as the philosophy behind



(a) LA-ST-IX open



(b) LA-ST-IX at 12-mm width



(c) LA-ST-IX at 6-mm width

Fig. IX-1.
Clipping satellite beam with stripper. The double-peaked H^- beam in (a) would produce double beam spots for LB/EP experimenters, and also might not clear all of the beam transport aperture. Rather than shut down for a retune of the accelerator, the satellite beam was clipped off with the SY stripping equipment. The profiles in (b) and (c) show the progressive elimination of the undesired beam component as LA-ST-1X is closed down. Note also that the width of the X-profile at LX-WS-07 establishes an upper limit of 0.2% FWHM of the beam momentum bite; LB and EP experimenters should be aware that this analysis of the beam energy composition can be made at any time.

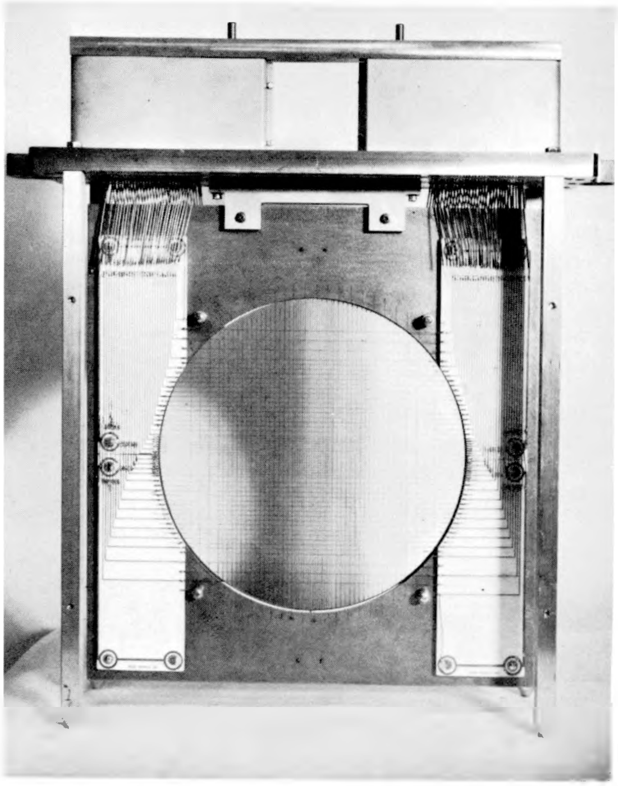


Fig. IX-2(a).
Large (33 cm) harp, downstream view, with circular hv ring removed.

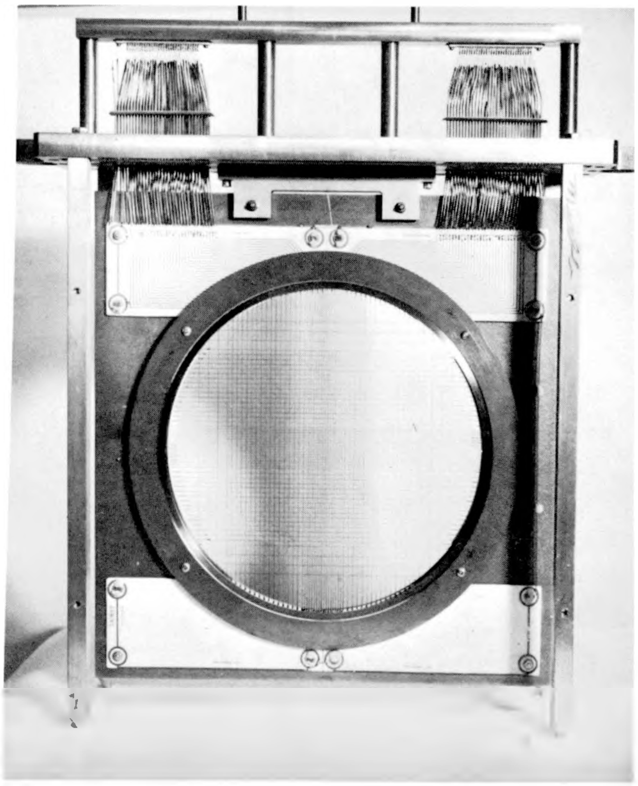


Fig. IX-2(b).
Large (33 cm) harp, upstream view (x coordinates), with feedthrough covers exposed.

these constraints have been documented in an internal report by R. Macek/A. Aldridge.

Additional tunes for the Area A beam transport system have been calculated for a variety of target combinations in preparation for testing of diagnostics, tuning of secondary beam lines, and production-running of experiments. Tunes have been obtained for: (a) all targets removed from the beam line, (b) a thin target (0.5 mm of graphite) at A-1 and standard targets elsewhere, and (c) 60 mm of Al_2O_3 at A-2 with standard targets elsewhere. Effort is proceeding to find a solution for thin targets (0.5 mm of graphite) at all locations which will allow standard spot sizes to be achieved.

Calculations are in progress for tunes of the SMC for all three output legs including the new section (SMC-East) which takes off from BM3.

Instrumentation Development

Line A Harps

The entire harp system was assembled this quarter, although serious problems arose concerning the reliability of the mineral-insulated feedthroughs. Each feedthrough in all 10 harp lids was measured for leakage resistance a number of times during construction. Repairs of defective feedthroughs took about two months to accomplish. The problem appears to have been caused by improperly made beads on the feedthroughs. Once more, care was taken in assembly; the failure rate dropped from 30% to ~5%. All Area A harps are now installed and checked out with the voltage tester, and the harps that are to be installed in A-4, A-5, and A-6 are finished. This installation will not be done until the main beam line vacuum system is installed and checked out. Figures IX-2(a),(b) are photographs of both sides of an assembled harp, ready for installation in the harp boxes.

A parallel effort in all of Areas A and A-East was the checkout and repair of all of the harp cables. Continuity and resistance measurements revealed that ~10% of the cables were in need of repair by MP-1. These repairs have now been completed.

Preliminary tests of the installed harp system are now in progress and indications are that the system will work as well or better than anticipated. Figure IX-3 is a typical harp output after the voltage pulser test was applied. In this test, the clearing field wires are pulsed with a voltage step. The pulse charges the capacity between the clearing field wires and the signal wires and thus provides a test signal. The shape is due to the different capacitances of each wire. The places where the trace drops to the base line indicate a bad cable or wire. It is clear that this test is a very easy and convenient measure of wire continuity. The harp program was run in the repetitive mode so that each picture is actually 50-100 traces. The width of the trace is a measure of the noise of the system. In this particular case, the noise is ~ ±1 ADC count at a MUX gain of 25. Additional noise from SCR spikes is expected when the magnets are turned on.

The vulnerability of harps to damage from vacuum accidents was amply demonstrated with the harp at A-3. That section of the beam line was under vacuum and the valve at A-4 was accidentally opened. The rush of air broke most of the harp wires. This incident served to stimulate the development of a number of vacuum system improvements described later.

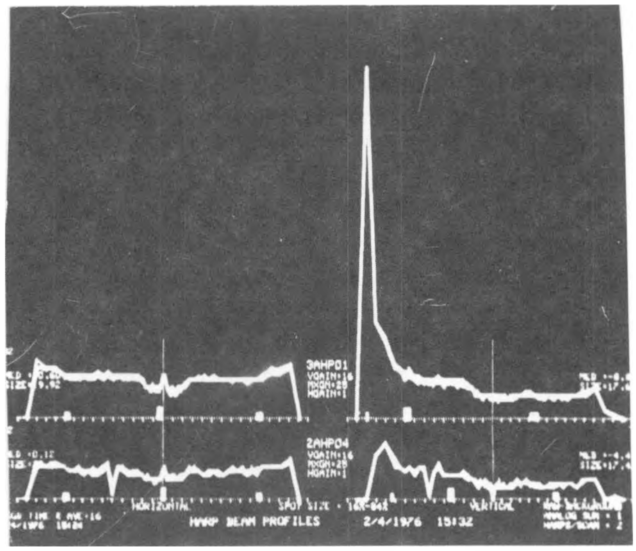


Fig. IX-3.
Sample harp spectra when the voltage test is applied. Two nonconnected wires are evident in the lower traces.

TV Phosphors

In an attempt to decrease radiation damage, two cameras were equipped with 150-mm lenses and mounted 2-3 m away from the beam line, under magnetite shielding, near the Line A beam stop, where camera lifetime has been ~50 μA-h. One camera had direct view of the beam stop and lasted ~400 μA-h. The other camera, viewing the Line A-direct insertable phosphor, is still functioning. Experimental arrangements of alumina phosphors and mirrors are being tried out to improve phosphor lifetime, reduce image blooming and vidicon burn-out, and increase camera lifetime.

Three new, two-position air-driven actuators with phosphors have been installed. One is installed in Line A-direct, one at the Line B-EPB split, and one in EPB.

Magnet-Current Measurement

The problems in the magnet current measurement system, particularly problems with inaccurate and noisy data, have been reviewed. Among the improvements to date are the recalibrations that have been made to the shunt amplifiers in the SY magnets and bypasses. Excessive noise in the RICE ADS magnet-current data has been removed with proper location of a simple common-mode filter.

Further tests on the shunt and shunt amplifier revealed that inadequate temperature stability might give ~0.25% drift in each (shunt and amplifier) just from diurnal 10°C changes in ambient temperature.

A trial installation of a transductor and a forced-air-cooled shunt was completed and tested, showing more satisfactory performance. Tests are under way on a new shunt amplifier circuit. Several digital panel meters are installed for evaluation as possible augmentation or replacement of the RICE ADS or SY DVM systems for measurement of the magnet shunt voltage.

Instrumentation Coordination

A considerable effort was made to coordinate the installation of cable conduits, T boxes, cables, and transducers for toroids, beam-on-target monitors, SEM guard rings, spill monitors, and thermocouples for Areas A and A-East. The locations were specified for spill monitors. Coordination was provided for software developments needed to read out data for the harps, toroids, magnet currents, and transmission monitor.

Documentation of Instrumentation

Block diagrams are being prepared for the major switchyard and experimental area instrumentation and control systems. These will become part of system descriptions which will be generally available. Up-to-date instrumentation roadmaps have been prepared for the SY and Lines B and EPB. The roadmap for Areas A and A-East instrumentation is near completion.

Magnets

All magnet hardware, including the radiation-hardened wiring, has been installed and checked out in Area A. The steering magnets are arranged for remote removal from the beam pipe, and the triplet quadrupoles are now units independent of other devices, such as harps, to facilitate their replacement. Some difficulty has been experienced in maintaining reasonable insulation resistance on hardware such as temperature switches. This is believed to be due to the dirty construction environment in the experimental area.

Ceramics

Considerable effort has gone into the search for better materials, especially for beam line instruments. Ceramics are mandatory for electrical insulation in the radiation environment of the LAMPF target cells, and early versions of some of the instruments use relatively impure ceramics (e.g., 85% purity alumina in harps) because of the procurement and fabrication problems associated with purer dense aluminas. Some of the fabrication techniques used to bring electrical signals out of the vacuum in the beam pipe are also very labor-intensive (sealing individual m.i. cables of 1.5 mm o.d.) and have a high failure rate. Alternatives that could be purchased on the open market are being sought.

Magnet Measurements and Analysis

Magnet measurements and analysis have continued with effort concentrated on the quadrupoles for WNR, steering magnets for Line A, and the EPB spectrometer dipole. The 1.5-m mapper has been returned from MP-10, and is being refitted for compatibility with the MP-13 Super-NOVA system. The 3-m mapper will be required cantilevered from one end for EPICS spectrometer mapping, and a new coil holder will be installed. A test magnet, ZOZOBRA, has been reconditioned to permit mapper testing, and a high-field ^{7}Li NMR probe has been added to the gaussmeter complement.

Vacuum System Improvements

The discovery that harp wires are broken by the rush of air from a vacuum accident has prompted a reevaluation of the experimental area vacuum system, particularly with regard to windows, valves, and operational procedures. When Area A becomes operational, all experimental area vacuum systems will be joined in one connected system. An accident in one can produce a high velocity rush of air in all.

There are over 30 windows in the system. Criteria are being established for the design and testing of these windows. For the near future, relatively conservative criteria have been established as follows:

1. Window design will be tested to destruction. A successful design shall rupture above 5-atm load.
2. Each window to be installed will be tested at 3-atm load for 5 cycles of loading and unloading in the direction of normal use.
3. Windows that flex in both directions will be tested by flexing in both directions for several cycles.

A shock tube facility is being constructed for a program of tests and study of problems related to vacuum accidents. These include measurements of the velocity of propagation of the harp-breaking disturbance, response time of fast valve triggers, tests of new harp wire materials, and certain vacuum window tests.

A Vacuum Task Force has been formed to formulate and oversee experimental area vacuum improvements including tests at the shock tube facility. Membership is R. A. Macek, Chairman, R. Kandarian, J. J. Burgerjon, J. A. Bridge, R. D. Werbeck, D. L. Grisham and J. D. Little.

X. LARGE-SPECTROMETER SYSTEMS

Energetic Pion Channel and Spectrometers

Completion of Channel—Installation of Shielding

Most of the effort available in the last quarter was spent on installation of shielding around the beam line, installation and debugging of the taut-wire system, and modifications to the vacuum system needed to pump the channel with a pump-out port on top of the shielding. The installation of the channel shielding required cutting and fitting of a large number of small lead and steel pieces. Shortly after we started the job, it was discovered that the plans were inadequate and it was necessary to remove a portion of the large air cooled dc cables powering the magnets and replace them with water-cooled m.i. busses. After changing the cabling, it was possible to get a good, tight, shielding job done.

The taut-wire system was installed and debugged. This was a tedious, difficult job since it was discovered that if the stretched wire contacted any of the sensors, the system would not work and it had to be disassembled to find the short. This problem caused us to abandon the two long wires which were to be stretched down the full length of the channel. Three shorter wires interconnecting the several magnets were installed and are now working. With this system, it is possible to detect most motions of the beam-line components, but since the sensors do not detect a rotation about the axis of the sensor, it is not possible to determine completely the motions of the magnets. During the first month of reliable operation, it was determined that movements of the target cell A-1 shield doors cause 0.4- to 0.8-mm relative motions of components which are elastic. Stability during the course of a day is much better, perhaps as good as 0.1 mm. Further studies are required to understand the effects of these motions on the beam optics.

The turbomolecular vacuum pump that pumps the separator was moved to its final location on top of the shielding. In order to connect this to the beam line, and to increase the reliability of the system, substantial rework of the interconnecting plumbing was required. As of this writing, the changes have been made but some leaks exist and must be found and corrected.

Particle Separator

Final installation of the separator was completed with the addition of several new high-voltage components and a motor-driven needle valve for controlling a nitrogen gas leak into the area of the electrodes. The separator door removal was successfully tested. This procedure is part of the routine maintenance.

System testing began in December, and the design goal of 300 kV was achieved. Conditioning to 280 kV was done at the best possible vacuum (5×10^{-5} torr). Raising the pressure to 5×10^{-4} torr by admitting N_2 gas allowed the voltage to rise to 315 kV. Tests to 285 kV were made with the full magnetic field.

While these tests prove the separator is capable of operating at its design levels, several conditions exist which prevent routine sustained operation at high voltages. First, deconditioning sets in very quickly, causing sparking and gradual loss of voltage capability. This is thought to be due to contamination of the electrodes by residual vapors in the vacuum. Second, the existing controls for the C-W power supply are not able to cope with the variety of fault conditions which can occur. In particular, the voltage regulator increases the drive signal during a spark, which pumps more power into the spark and could damage the power supply or the electrodes. In addition, when a spark occurs with the magnet on and the gas being bled in, a glow discharge can be set up which draws considerable power and remains until the magnet is turned off. Considerable effort went into determining a realistic transfer function that can be used to simulate the voltage and current feedback signals from the C-W system. This information will be used to design and benchtest a control system with a voltage/current-crossover characteristic which should make a substantial improvement in the separator performance.

Channel Operating Controls

Computer control of the dynamic shunts for magnet BM-01-4 has been tested. Extensive tests of the shunts were performed, and some problems corrected. The field vs current characteristics of each magnet were determined, and these data were used to develop a procedure for setting the main power supply current and each shunt current to obtain a desired field. This procedure gives average fields which can be reproduced to ~0.1%, and magnet-to-magnet variations of ~0.03%. A single computer program for magnet turn-on is being developed from this procedure.

Data-Acquisition Software

The basic means of data acquisition on the EPICS computer is a CAMAC data-acquisition package, the software of which is generally referred to as program Q, and has only recently been upgraded for Version 6 of RSX-11D. These data-acquisition programs have been in use for nearly three months with Version 4 of RSX-11D; however, several changes were required in order to be compatible with the newer and superior Version 6, which has only been in use since the flexibility in the amount and type of data received from CAMAC hardware. A special compiler is included in the Q program package that accepts as input a very simple user-written code that allows for as many as 32 priority ordered events types, each of which may cause any variety of CAMAC operations to be performed. The output of this compiler then generates two files, the first of which will form a buffer in the PDP-11/45 and direct data analysis that is to be performed for each event. The second output file is code that gets loaded into the MBD which does the actual data acquisition. In the Q package there are programs included to initialize and load the MBD, cause data to be automatically written to magnetic tape, create histograms from the analyzed data, and suspend or terminate the acceptance of data. The advantage of having such a versatile data-acquisition system is to allow for any possible hardware configurations that might be needed for experiments; Q then can be considered as the computer interface to users' experimental hardware.

A code for data-acquisition control and subsequent data manipulation has been written which complements the Q programs by providing a user interface to data acquired by Q and is called WORKER. The WORKER package is an interpreter which gives users on-line control of a teletype display, random access to linear files, algebraic manipulation of linear data arrays using FORTRAN-like statements, line-printer output of data, etc. WORKER permits on-line evaluation of spectra generated by Q which lets the user set logical tests on an event word string to restrict requirements for the acceptability of data. FORTRAN-like algebraic combinations of up to eight data arrays originating from a 56 536-word disk data file or from the Q-generated histograms may be displayed and manipulated. A text file can be written by the RSX-11D text editor to describe end-of-run sequences and may be executed by computer control through the use of WORKER. Thus, automatic data acquisition can be achieved for many runs where the experiment can be prescribed in advance, e.g., an angular distribution, excitation function, etc. The WORKER command language includes numerical constants, sets of system-defined names (e.g., SCALE, PI, etc.) and any user-defined synonyms for general variables. WORKER can display the results of any algebraic expression in order to monitor variables, or to act as a calculator. The software package WORKER has been operational for two weeks under RSX-11D Version 6, and has been successfully linked with a Q analyzer for approximately one week.

A code was written that incorporates both Q and WORKER, and which is now in use checking the three helical wire chambers that are to be used on all the initial EPICS channel experiments. This software not only is essential to the checkout of the wire chambers but allows checkout of both Q and WORKER as well. This three-wire chamber-analysis code is so far the most complicated ever used with Q, requiring 24 data words to be read from CAMAC hardware registers. It is planned to use this computer code to acquire the data required for the EPICS alpha test which is to be performed to determine the channel resolution. As each piece of hardware to be used on the initial experiments becomes available for testing, additions will be made in the present three-wire chamber code so that it will grow into the final experimental version.

A dot-plot analysis package has been written and tested. This program allows the user to display and manipulate two-dimensional data in dot-plot form. The program can perform least-squares fits to points input by the user, using any of three curves or two closed figures.

A peak-fitting task has been written which performs a least-squares fit to a peak in a histogram. The fitting function is a two-component Gaussian on a quadratic background. This task is initiated by a command from WORKER, and can receive histogram data from the computer memory or the disk. This program is currently being tested.

Helical Multiwire Proportional Counters

Multiwire proportional counters with wire-wound cathodes have been developed recently by a Univ. of Virginia/LASL collaboration. This design has been used in the development of the two-dimensional position-sensitive detectors intended for instrumenting the EPICS spectrometer.

Short detectors of this design have yielded position resolution as good as 250 μm; however, when long detectors (~40 cm) are constructed, attenuation and its corresponding dispersion worsen this position resolution.

We have constructed a prototype 60-cm detector with a cathode comprised of copper-clad aluminum ribbon whose cross section is a rectangle 13 μm × 710 μm, helically wound with a 1-mm spacing. Initial tests have yielded a position resolution of 250 μm over most of the useful length of the detector, worsening to a position resolution of 330 μm only at the very edges. Estimates of ^{55}Fe-source width and multiple-scattering effects suggest the intrinsic position resolution is better than 200 μm.

The position resolution of this device compares favorably with a 40-cm detector with a wire-wound cathode, where the latter is wound with the same pitch and has a wire diameter of 76 μm. In order to understand the origin of the advantages of the helically-wound ribbon counters, one should note the ratio of cross-sectional areas favors the ribbon device by a factor of 2 and the ratio of surface areas favors the ribbon device by a factor of 6. The latter is significant due to "skin effects" which are important in the propagation of fast risetime signals. Thus, the attenuation-dispersion properties of the helically-wound ribbon counter are superior to those of its wire-wound predecessors.

Although the prototype detector gave superior resolution compared with the wire-wound devices, it evidences some difficulties associated with the ribbon windings being mechanically twisted through small angles. As an example of these difficulties, the prototype detector had a small residual counting rate which was attributed to breakdown along the slightly twisted strips.

Three changes were proposed to reduce the twisting of the ribbon: 1) new ribbon stock was ordered with care in specifying that the edges do not overlap; 2) a constant-tension friction brake and pulley system has been built (by P-9); and 3) a new frame has been built with two offset glass-rod supports at each side. Each pair of glass rods is ~10 cm apart so that each ribbon in the helix is forced to lie flat at each side, contributing to the stability against twisting. A revised prototype detector is now under construction.

Ion Chambers

We have assembled an ion chamber box and have carried out preliminary tests on its structural stability and electrical integrity.

The 30.5 × 63.5 × 14.0-cm outside case of the ion chamber has been constructed from 0.6-cm aluminum stock. A 15.2 × 45.7-cm windowhole, for permitting pion-beam transmission, was cut asymmetrically from the front and back surfaces of the case and each hole was fitted with a 0.75-mm aluminum window, clamped onto an 0-ring surface to render it gas tight.

The inner portion of the ion chamber box has been constructed as follows: a (near ground) signal plane of 24-hardened aluminum foil is suspended at the symmetric center of the box. It is insulated from a 1.5-mm aluminum frame which is grounded to the case. The signal plane, which is connected to the integrator, is suspended between two high-voltage planes constructed from 6-μm aluminized Mylar, each held at a separation distance of ~4 cm from the signal plane.

The deflection of the outside 0.75-mm aluminum windows was measured to be a linear function of small pressure changes, when the box was over-pressured at ~30% above atmospheric pressure. The windows bowed out 48 μm for each 1% of atmospheric increase in gas pressure. However, a difficulty was encountered in that the front and back cover plates were found to bow out a nontrivial amount, and due to the asymmetry in the windowholes, the amount of bowing out of the cover plate varies with the transverse position across the window. As a consequence, these cover plates will be replaced by plates machined from 1.28-cm aluminum stock.

A gas mixture of 10% carbon dioxide and 90% argon has been obtained from the LASL Liquid- and Compressed-Gas Facility, where the mixing ratio is known to >1%.

A differential pressure meter has been installed for continuous monitoring of the gas overpressure referenced to the barometric pressure. Also, the box is equipped with separate input and output needle valves.

For several weeks the original ion chamber held a gas overpressure of 30% above atmospheric, with negligible change.

Once the new cover plates are installed, the ion chamber will be checked for stability and for agreement with estimated gas multiplication, using a ^{90}Sr source. Ultimately the new chamber will be calibrated using single-pion counting, and compared for reference with a continuously integrated output from a phototube connected to a light-scintillating material placed in the pion beam. This device is presently under construction at the ANL.

Spectrometer

The major accomplishment on the EPICS spectrometer was the reorganization of the field engineering effort devoted to this project. The LAMPF engineering group, MP-8, will take over responsibility for field engineering of the spectrometer construction. This will enable us to effectively use the talents of several engineers with expertise in heavy assembly work, and will make it easier to obtain support group help when required.

The first result of this new engineering effort is a decision to abandon the earlier plan to patch up the existing lightweight floor in the EPICS area and to replace it with a substantial (60-cm-thick) concrete foundation specifically designed for the spectrometer and air pads.

A second decision taken was to abandon the plan for using Merrimac for installation of the magnets in the spectrometer frame. Instead, we will use the same method as was used for the successful erection of the HRS spectrometer.

The detector frame for the EPICS spectrometer was redesigned in late August and engineering drawings were completed in late September. The majority of the components were machined at The Univ. of Texas and are now on hand at LASL. The present design of the detector frame is a considerable improvement over the earlier design as it allows the various counters to be positioned with greater flexibility and a higher reliability. The positioning can be made better than the position resolution of the helical wire counter (~0.25 mm). The detector frame components are being assembled in the ETL.

Use of the EPICS Channel During Spectrometer Assembly

Careful consideration was given to the question of how to make use of the EPICS beam line during construction of the spectrometer. It was decided that spectrometer construction would have first priority, channel tuneup second priority, and experiments using the beam line would receive third priority during this period. Within these ground rules, we found that it will be possible to erect a small cave at the end of the channel and use it while constructing the magnets, erecting the frame, and measuring and testing the magnets. When we are ready for rigging, the small cave will be torn down and the spectrometer frame will be installed. The final large cave will be installed around the area. During this phase, experiments can be run on nights and weekends on a noninterfering basis. Only when the spectrometer is ready to run and the scattering chamber is ready to install will experiments be shut down. There will, of course, be a six-week interruption of all work in the area for installation of the concrete foundation. With this plan, approximately two-thirds of the beam time can be used for experiments during the spectrometer construction.

Experiments 156, 245, 246, and 265 have been approved for running during the spectrometer construction on a noninterfering basis. Experiment 133, which was approved previously for running during this period, requested that its running time be scheduled after October 1, 1976, for funding reasons.

High-Resolution Proton Spectrometer

Two major milestones were accomplished during this report period: optimization of the spectrometer dipole fields between 4 and 14 kG, and transfer of the magnets from horizontal positions on the floor of Area C to their vertical positions in the spectrometer frame. The field measurement and optimization results obtained for HS-BM-02 were comparable to those reported last quarter for HS-BM-01 in both the uniform and fringing field regions. This particular work consisted of shimming the central field region and machining and shimming the nosepieces at entrance and exit of the magnet as described in the previous quarterly report.

The transfer of the magnets to the spectrometer frame involved a number of operations. Preparation of the magnets for the rigging consisted of: 1) testing fixtures for load capacity; 2) fitting and installing different hardware including alignment fixtures and standoffs for protection of the vacuum envelop; 3) leak-testing the vacuum envelop; 4) moving the magnets into position for the rolling and lifting operation; and 5) adding transductors at various points along the mating surfaces of each of the magnets to measure relative motion during the lifting operation. There were, of course, a number of other jobs such as completely clearing the experimental area of beam line magnets wherever possible and protecting the equipment which could not be readily moved. The H_t coils and manifolds were completed and leak checked on both magnets prior to lifting in such a way that they did not interfere with the installation operation. This phase was completed in late November at which time full access to the area was given to the riggers.

The initial rigging work consisted of moving various hardware, including a 27-metric-ton crane, into the area and drilling holes in the floor for the foundation of the jacking tower which would be built around the spectrometer frame. The tower was used for rolling the magnets from the horizontal to the vertical position, placing them on a rotary table to orient to proper alignments, and lifting the magnets above the midlevel frame members and placing them into position in the structure. Prior survey of the frame permitted proper location of the magnets to an estimated ±0.5 cm or better which should simplify the final alignment operation. Figures X-1 through 4 show the various installation stages. The overall operation proceeded very well and without serious incident. There was no measurable motion between any of the various component parts of the dipoles between the horizontal position (shown in Fig. X-1) and the final vertical configuration (shown in Fig. X-4). Figure X-5 shows the final system at a location of ~160° in the laboratory.

Beam Line and Area C

Related work which was carried out during this period includes the installation of the cable bridge mounts on the wall of Area C and at the top of the spectrometer frame. The cable bridge itself has been moved into the area where installation of the cable and trays is ready to begin. The last power supply for HS-BM-02 has been installed in the B/C equipment building where modifications and interfacing to CCR and CCH have begun. The basic spectrometer catwalk and elevator have been installed so that work on the various levels of the frame can begin such as installation of electronics racks, vacuum pipe, water cooling, and power and instrumentation cabling. The pivot-point platform at ground level which allows access to the scattering chamber and protects the water supply hoses to the spectrometer has also been installed. All of the beam line hardware which had to be removed for the rigging has been reinstalled and is now ready for final alignment. Installation of the remaining jacking and alignment hardware required for final alignment of the spectrometer is now under way. The spectrometer is presently ready to be moved to an angle of 30° in the laboratory where the optical alignment of the system will be carried out and where the first experimental spectrum will be taken with HRS.

Other work accomplished during this period includes the completion of the taut-wire system upstream of the Line C shield wall. The long-term stability of this system has been measured to be better than ±0.1 mm in the vertical direction and ±0.025 mm in the horizontal with the difference presumably due to temperature effects on the support members attached to the ceiling. The remaining downstream portion of this system is fully designed and partially fabricated and installed. Three ISICs which go in Line C have been built and the drive control and readout have been partially tested.

Layout of the spectrometer position control and interlock system has been completed which disallows access to Area C or motion of the spectrometer until the first isolation valves upstream and downstream of the scattering chamber have been closed, together with the spectrometer isolation valve. The remainder of this system includes the direction controls for the takeup and feedout reels for the sliding curtain, the rod and plunger controls for the curtain, and a variety of bumper and air interlocks.

The scattering chamber rotating table and drive mechanism have been installed and the encoder readout calibrated in terms of scattering angle. There appears to be no measurable backlash in the system as measured by approaching a desired angle from either direction. The target elevation and rotation mechanism has been assembled and is ready for installation. The vacuum system for the scattering chamber has been laid out and essentially all basic components have been acquired.

All components for the fourth and last detector for the outer TOF system of the particle-identification setup (PID) have been received. The remote-positioning and support hardware for the inner counter system have been built and are being modified in the shops. Final modifications for the remotely controllable delays for the PID electronics have been checked out, with rather nice results. The basic system which has been checked out consists of a two-wide CAMAC module which allows selection of from 1 to 16 independent delay units as well as its delay setting from 0-101 ns either from its front panel, by the computer, or locally at the delay unit. Two outputs of either polarity are available for each input and there is a width adjustment of ±1 ns for the outputs to allow the user to maintain good integrity on the pulse widths. NIM logic levels having a FWHM down to 6 ns can be passed with a width variation of $< \pm 1$ ns at a 50-MHz instantaneous rate.

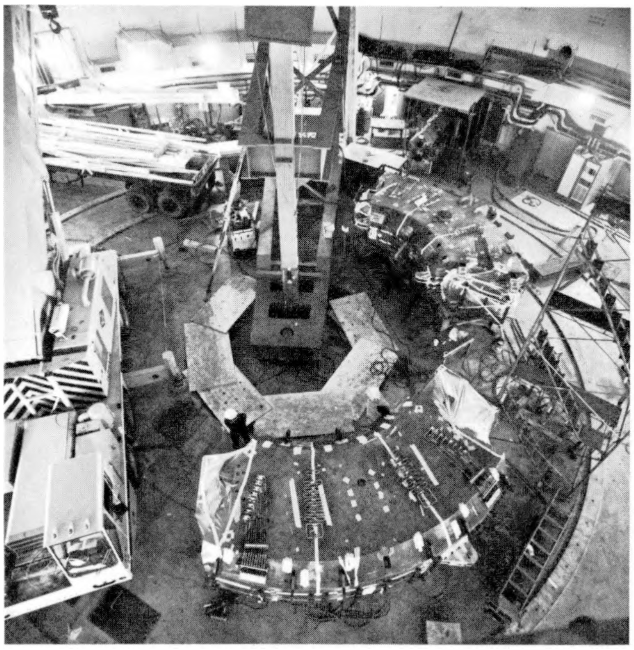


Fig. X-1.
Top view of the two HRS dipoles prior to setting up the jacking tower.

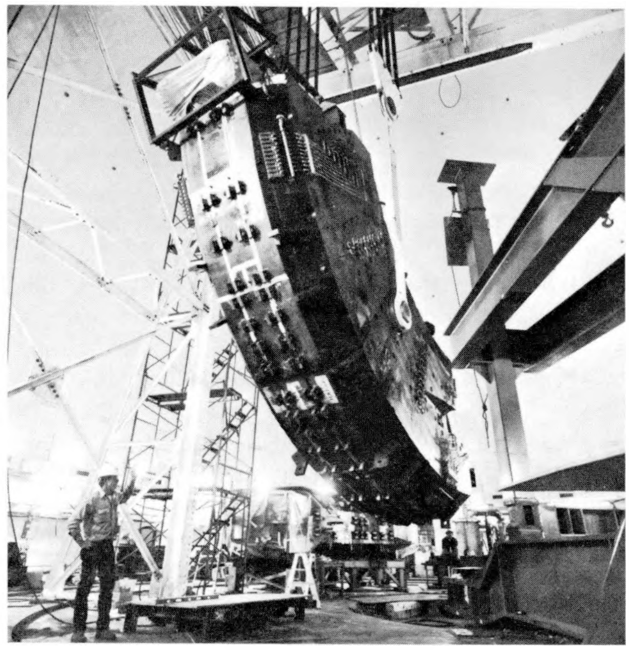


Fig. X-3.
Initial lifting operation of the first dipole as viewed from the floor.

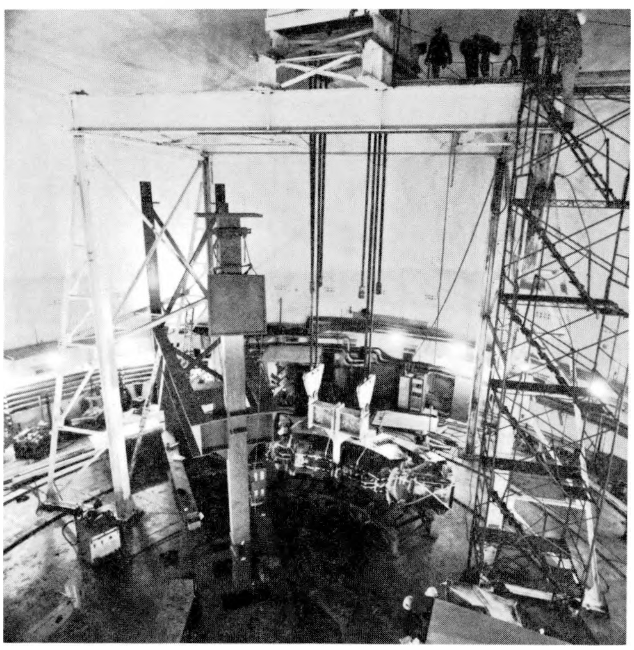


Fig. X-2.
Initial rolling operation of the first dipole showing the jacking tower and the spectrometer frame with its top level removed.

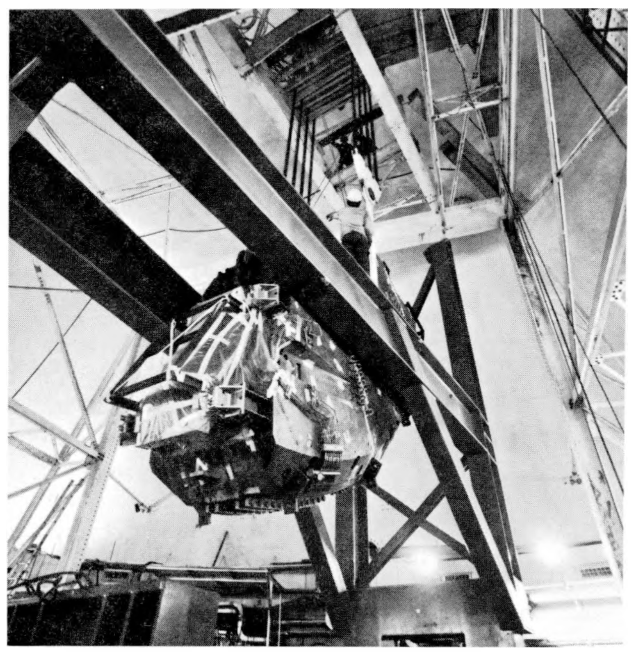


Fig. X-4.
Installation of the first dipole in the frame as viewed from below.

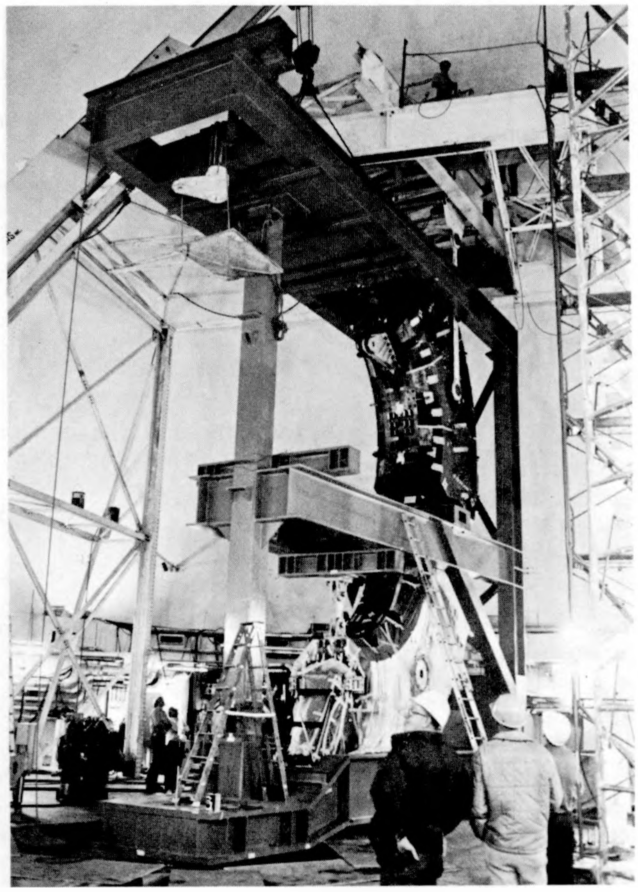


Fig. X-5.
Final stages of the installation of the second 122-metric-ton dipole into position in the spectrometer frame.

XI. RESEARCH

Tests, Data Runs, and Analyses of Experiments

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

The experiment to measure pion-nucleus total cross sections is being readied for a second data-taking run. As the Great Shutdown comes to a close, the experimental apparatus is being mounted on the floor at LEP. The equipment, described in previous progress reports, has been constructed.

A set of data-analysis programs has been written which will allow for fast-turnaround reduction of the raw data. This feedback system is desirable for monitoring the experiment. Its features include calculation of the target energies and the geometrical and pion-decay corrections, extrapolation to zero solid angle, and a comparison to optical model predictions. The programs reside on the CDC6600 KRONOS disk and are executed by the use of a remote terminal in the LEP counting house. A limited amount of data can be transferred between the data-acquisition computer (PDP-11) and the terminal via paper tape. To minimize the commands which must be learned by non-LASL personnel, all programs are executed by procedure files, which are lists of internally stored computer system instructions.

The total cross-section data on neighboring isotopes has been analyzed to extract relative rms radii of neutron distributions. The idea of determining neutron rms radii with pions stems from the isospin coupling of the π-nucleon system through the (3-3) resonance. By comparing isotopes of the same element, many experimental and theoretical uncertainties are reduced; since a neutron excess outside a core is more strongly coupled to the π^- than the π^+, obtaining the same radii with both projectiles is a built-in systematic check of the technique.

The curves in Fig. XI-1 show predictions for the difference between the total cross section for ^{48}Ca and ^{40}Ca as a function of pion kinetic energy for several values of the difference in the rms radii of the neutrons and protons in ^{48}Ca. The calculations were performed using the Kisslinger optical model and parameters derived from free π-nucleon phase shifts. The proton radii for ^{40}Ca and ^{48}Ca are taken from electron scattering, and the neutron and proton radii of ^{40}Ca are taken as equal.

Where the absorption is strongest, atop the (3-3) resonance, the cross sections seem quite insensitive to the details of the model. The Laplacian and Kisslinger models, with parameters derived from free π-N phase shifts, give very similar values for the cross-section differences at 175 MeV. In the ^{13}C-^{12}C system, the results are also the same when parameters derived from fits to elastic scattering are used. At energies away from the strong absorption region, the model dependence of the cross-section differences grows.

Data from the upcoming experiment will improve the errors considerably, but even at this state the results are interesting. The preliminary values for differences of rms neutron and proton radii are: ^{13}C, 0.25 ± 0.15 F; ^{18}O, 0.20 ± 0.15 F; and ^{48}Ca, 0.00 ± 0.15 F.

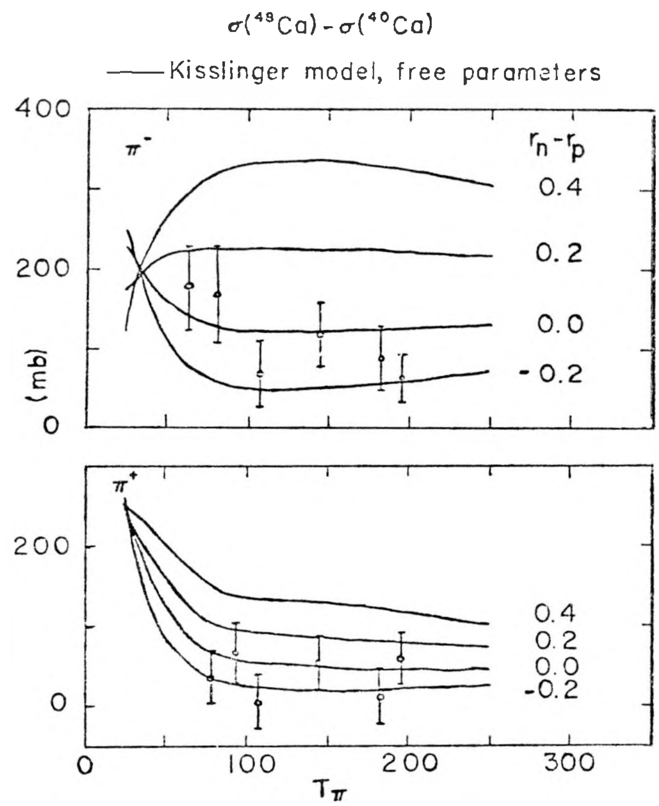


Fig. XI-1.
The π^- and π^+ total cross-section differences between ^{48}Ca and ^{40}Ca. The curves are from the Kisslinger optical model using parameters taken from free π-nucleon phase shifts. The quantities r_n and r_p are the rms radii of the neutron and proton matter distributions in ^{48}Ca.

A Neutrino Experiment to Test Muon Conservation (Exp. 31)
(Yale Univ., Saclay, LASL, SIN, National Research Council of Canada)

The installation of scintillators, 2.55-m × 60-cm × 2.5-cm, is now complete. These counters are used for cosmic-ray anticoincidence and completely surround the water Cerenkov detector. Phototubes have been mounted and tested on all of the scintillators, and tuning is in progress.

The gain of the water Cerenkov detector has been measured at intervals over the past three months, and has been found to be constant to within 5%.

Software development for the on-line 16k SuperNOVA computer is continuing, and the disk operating system should be functional within the next few weeks. A nine-track magnetic tape unit was received and installed during December.

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

The data-taking phase of Exp. 42 was completed during January 1976. Measurements of the (p,pd) and (p,pt) reactions at angles corresponding to quasi-free scattering were made on isotopically enriched targets of ^{6}Li and ^{7}Li, using a magnetic spectrometer to detect the protons and an eight-element intrinsic germanium counter array to detect the heavy particles (i.e., d or t). Measurements of the p-p, p-d, and p-t elastic-scattering reactions were also made at the same angles as in the lithium reactions. In order to facilitate corrections for multiple scattering and nuclear reactions, further p-p and p-d elastic-scattering measurements were made at angles where the protons and deuterons stop in the last element of the germanium array.

Preliminary on-line and off-line-data analyses revealed the following results:

- The germanium stack performed quite well. Satisfactory particle separation was achieved, and losses due to multiple scattering and nuclear reaction processes were readily discernible. Figure XI-2 shows a ΔE vs E plot for protons on a titanium tritide target. Figure XI-3 shows a plot of the number of particles vs the particle-identification parameter.
- The magnetic spectrometer showed a momentum resolution of $(\Delta p/p) = 2\%$ or less. The helical wire chambers adequately handled counting rates up to 150 000 counts/s. The five chambers were operated almost continuously for five weeks without significant malfunctions.
- Information about the (p,2p) reaction on the lithium targets can also be extracted from the data, although the measurements were not made at the quasi-free scattering angles.
- Our p-p elastic-scattering results seem to agree with the published data.

Detailed analyses of our measured results are now in progress.

Radiative Pion Capture in Light Nuclei (Exp. 50)
(LBL, LASL, Case Western Reserve Univ., Univ. of Zürich)

The first phase of the experiment, measurement of the photon spectrum in π^- capture on tritium, has been analyzed and submitted for publication to Phys. Rev. Lett. A schematic layout of the apparatus (A) is shown in Fig. XI-4. One of the major difficulties encountered in the experiment was the large number of events originating in the target-cell walls and vacuum jacket of the LT_2 target [Fig. XI-5(a)]. Since time limitations permitted only one, short, target-empty run, the shape of this spectrum was poorly determined. To overcome this ambiguity in the analysis, the spectrum of type 304 stainless steel was measured by two members of the Exp. 50 collaboration at SIN using the Lausanne-Munich-Zürich pair spectrometer. This spectrum is shown in Fig. XI-5(b). Small subtractions were also required for the 1.0% ^{1}H and 2.79% ^{2}H content in the target and for the π^- stopping in the small beam-defining counter in front of the LT target [Fig. XI-5(b)]. The subtracted ^{3}H spectrum [Fig. XI-5(c)] contained 1064 events.

The major results of the experiment are:

1) The absence of bound tri-neutron. The upper limit on the measured branching ratio is 0.3%, which contrasts strongly with the 6.6 ± 0.8% branching ratio for forming the triton in the $\pi^- \, ^3He \rightarrow \, ^3H\gamma$ reaction.[1]

2) No strong evidence for existence of I = 3/2 resonances in the (3n) system was found. This does not support the interpretation of the $^3He(\pi^-,\pi^+)3n$ results by Sperinde *et al.*[2] The measured photon spectrum is well described by the theoretical spectrum $d\lambda_\gamma(y)/dE_\gamma$ of Phillips and Roig[3] [Fig. XI-5(c)]. The integrated theoretical rate is $\lambda_\alpha(1s) = 2 \times 10^{13}$/s. The nonradiative capture rate is calculated with the 2-N absorption model, giving $\lambda_n(\pi^- t \rightarrow 3n) = (1.0 \pm 0.3) \times 10^{15}$/s. The resultant 1s-state branching ratio $\lambda_\gamma/(\lambda_\gamma + \lambda_n) = 6.5 \pm 2.0\%$ is in fair agreement with our measured radiative branching ratio $R_\gamma = 4.5 \pm 0.8\%$.

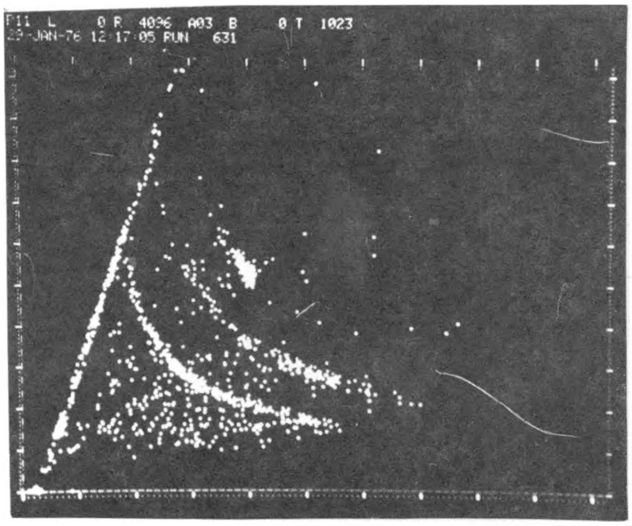


Fig. XI-2.
Plot of ΔE vs E for protons on a titanium tritide target.

- *Vertical axis = ΔE is the energy loss in the first element of the germanium array (scale: 10 MeV/major division).*
- *Horizontal axis = E is the energy loss in the germanium array (scale: 40 MeV/major division).*
- *The particles are protons, deuterons, and tritons progressing from lower left to upper right.*
- *The protons and deuterons, as well as the scattered tritons, are from titanium (p,p$\substack{p\\d\\t}$) reactions whereas the triton cluster is the 157-MeV triton elastically scattered by 800-MeV protons. (θ_p = 40° lab, θ_t = −59.2° lab).*

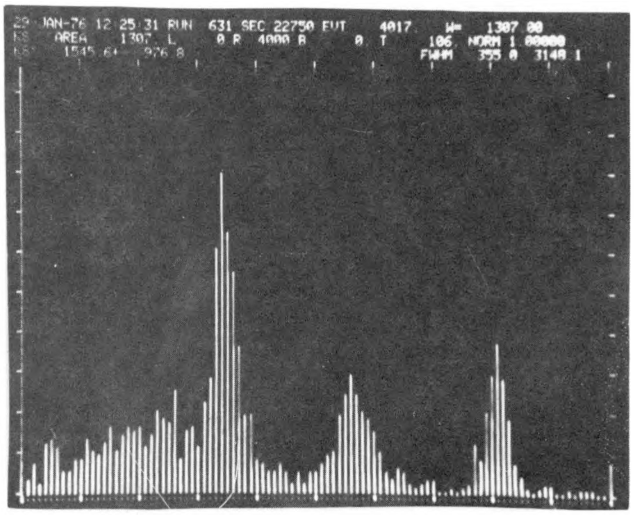


Fig. XI-3.
Plot of number of particles vs particle-identification parameter of p-p and p-d, and p-t elastic-scattering measurements on a titanium tritite target.

- *Vertical axis: number of particles.*
- *Horizontal axis: particle identification parameter calculated from the range-energy relationship in the germanium array.*
- *The peaks are protons, deuterons and tritons, progressing from left to right. All other parameters are identical to Fig. XI-2.*

3) The ^3H strong absorption level width $\Gamma_a(1s)$ = 1.02 eV was deduced. The "experimental" total widths obtained from $\lambda_a(1s) = \lambda_\gamma(1s,\text{theory})/R_\gamma$ (experiment) are listed in Table XI-I for ^1H, ^2H, ^3H, and ^3He. The λ_γ (1s) capture rates were calculated in the IA, considered accurate to <12% (Refs. 4,5). The extracted 1s-level width of 1.02 eV is seen to be much smaller than the 37 eV for ^3He and the 3.67 eV for ^3H obtained[6] from the phenomenological extrapolation of data on heavier nuclei.

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

Experiment 80 determines the forward elastic-scattering amplitude of $\pi^\pm$ from ^{12}C, ^{16}O, and ^{40}Ca. This is accomplished by measuring the small-angle elastic scattering, using a magnetic spectrometer, and the total cross section in a transmission experiment. Previous Progress Reports give the details of the small-angle results.

The total cross sections were measured for π^+ on ^{12}C and ^{40}Ca at 205, 175, and 145 MeV. The experimental setup is shown in Fig. XI-6. The number of pions transmitted through the target was measured as a function of angle, determined by the MWPCs x_4 through x_6. The total cross section can then be determined in a manner similar to standard methods using circular transmission counters.

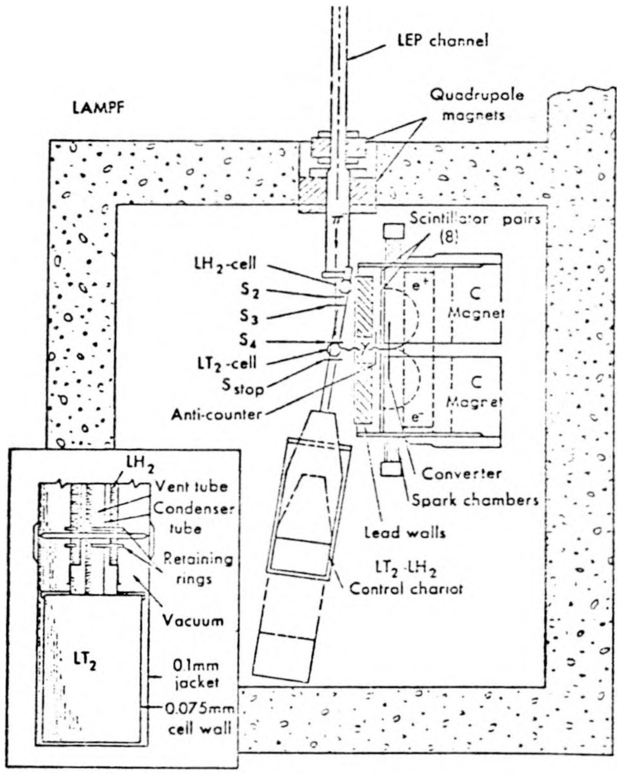


Fig. XI-4.
Schematic of setup at LEP showing pair spectrometer and LT_2 target. Insert shows cross section of target obtained from x-ray radiograph.

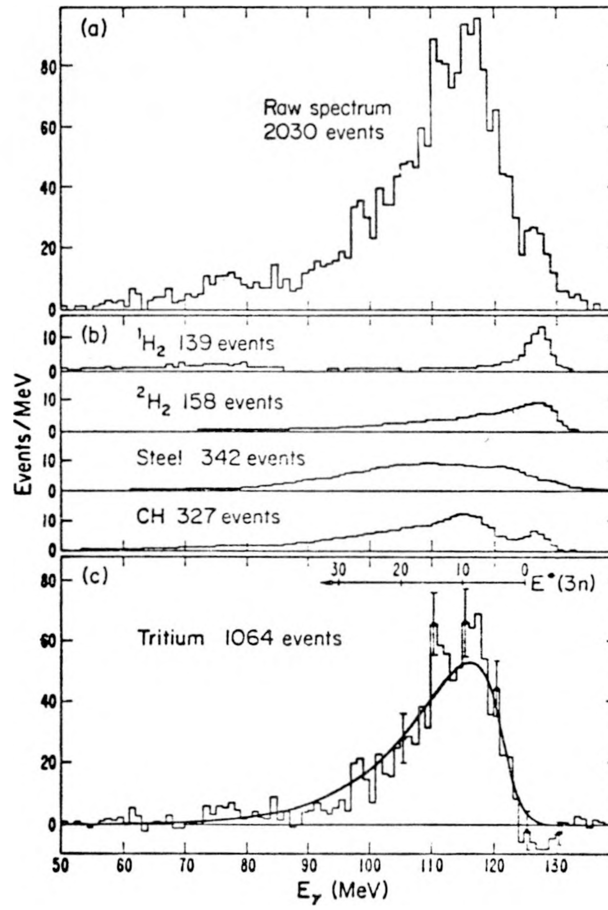


Fig. XI-5.
(a) Raw photon spectrum obtained from tritium target cell.
(b) Background spectra for LH_2, LD_2, steel (from SIN exposure) and polystyrene.
(c) Spectrum from reaction $\pi^- t \rightarrow nnn\gamma$ after subtraction of (b) from (a). Solid curve is theoretical spectrum of Phillips and Roig,[3] folded with acceptance and instrumental line shape and normalized to total number of photons.

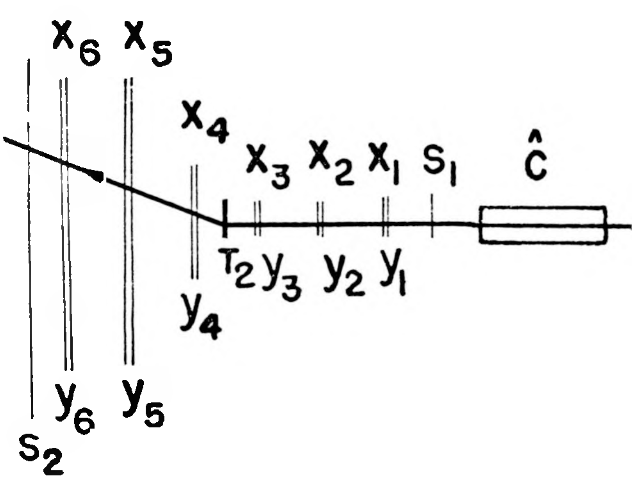


Fig. XI-6.
Experimental layout.
$\hat{C}$: CO_2 Cerenkov Detector
S_1, S_2: Trigger scintillators
x_1, y_1 through x_6, y_6: Two-dimensional MWPCs.
T_2: Target

The data can be used to determine the differential cross sections for each target for laboratory angles from 8° to 20°. These data are inferior to the small-angle data described earlier because they contain inelastic events. Nevertheless, at small angles the inelastic cross section is expected to be small, and these data should reproduce the small-angle results. Figure XI-7 shows the small angle data from π^+-^{40}Ca at 205 MeV, and the differential cross section obtained from the total cross-section measurements. The solid curve is a fit to the small-angle data (see LA-6195-PR). The dashed curve is the solid curve

TABLE XI-I

RADIATIVE PION CAPTURE BRANCHING RATIOS AND 1S-LEVEL WIDTHS FOR THE ISOTOPES OF HYDROGEN AND HELIUM-3

Isotope	Reaction	Radiative Capture, Branching Ratio (%)	Radiative Capture, 1s Width (theory) (eV)	Total 1s-Level Width[a] (eV)
^1H	$\pi^- p \rightarrow n\gamma$	39.5 ± 0.3[b]	0.248 ± 0.003	0.63 ± 0.01
^2H	$\pi^- d \rightarrow nn\gamma$	24.7 ± 0.7[c]	0.192 ± 0.019[d]	0.78 ± 0.08
^3H	$\pi^- t \rightarrow nnn\gamma$	4.5 ± 0.8[e]	0.046[f]	1.02 ± 0.18
^3He	$\pi^- {}^3He \rightarrow t\gamma$	6.6 ± 0.8[g]	2.44[h]	37.00 ± 4.50

[a] Obtained from the theoretical radiative capture rate and the experimental branching ratios. The error reflects the experimental uncertainty.

[b] V. Cocconi *et al.*, Nuovo Cimento **22**, 494 (1961).

[c] J. Ryan, Phys. Rev. **130**, 1554 (1963).

[d] Obtained from $\lambda(\pi^- d \rightarrow nn\gamma)/\lambda(\pi^- p \rightarrow n\gamma) = 0.775 \pm 0.078$ (Ref. 5) and hydrogen rate given above.

[e] This experiment.

[f] Ref. 3.

[g] Ref. 1.

[h] Ref. 4.

multiplied by 0.85. Thus there is a 15% difference in the normalization of the two sets of data. The source of this discrepancy is being investigated.

Study of Neutron-Proton and Proton-Proton Coincidence Spectra from the p + d → n + p + p Reaction (Exp. 81)
(Rice Univ., Univ. of Houston)

The analysis of the existing data has been completed, and the results were reported in previous Progress Reports. These results are also available in the following publications.

1) "Kinematically-Complete Study of Pion Production by the Reaction $^1H(p,\pi^+ p)n$ at 800 MeV," J. Hudomalj-Gabitzsch, T. R. 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, Phys. Lett. **60B**, 275 (1976).

2) "Quasi-Free Scattering in Proton-Induced Deuteron Breakup at 585 and 800 MeV," R. D. Felder, T. R. Witten, T. M. Williams, M. Furic, G. S. Mutchler, N. D. Gabitzsch, J. Hudomalj-Gabitzsch, J. M. Clement, G. C. Phillips, E. V. Hungerford, L. Y. Lee, M. Warneke, B. W. Mayes, and J. C. Allred, to be published in Nucl. Phys.

3) "Final-State Interaction in Deuteron Breakup by Protons at 800 and 585 MeV," T. R. Witten, R. D. Felder, T. M. Williams, M. Furic, J. Hudomalj-Gabitzsch, D. Mann, G. S. Mutchler, N. D. Gabitzsch, J. Clement, G. C. Phillips, M. Warneke, E. V. Hungerford, B. Mayes, L. Y. Lee, and J. C. Allred; submitted to Nucl. Phys. A.

Mechanism of (π,πN) Reactions on Complex Nuclei (Exp. 93)
(Virginia Polytech. Inst. and State Univ., Utah State Univ., Florida State Univ., LASL)

Experiment 93 is now scheduled to run within six months. The scattering chamber we will use has

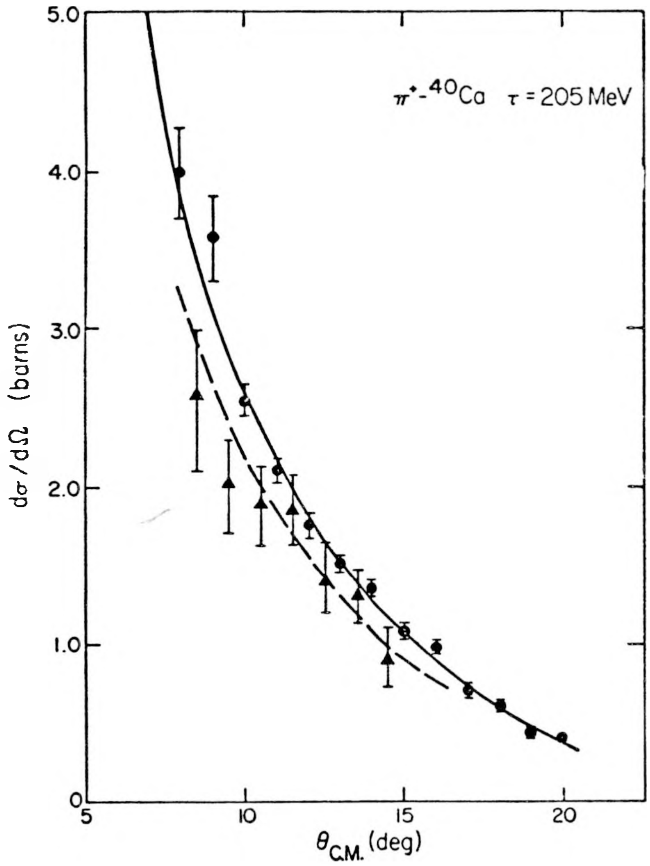


Fig. XI-7.
Differential cross section vs angle. The circles are the small-angle elastic-scattering data taken with a magnetic spectrometer. The triangles are data from the total cross-section measurement (see text). The solid curve is a least-squares fit to the small-angle data. The dashed line is the solid curve × 0.85.

been leak-tested. A target ladder and hat are under construction. A trolley to position the solid-state detector telescope inside the chamber has been designed. Together, these devices will allow us to select targets and set the telescope angle and target angle from outside the chamber.

Two of three wire planes and two of three large scintillators have been finished and tested. During the past months, the ΔE-E solid-state telescope was tested at the Florida State Univ. tandem Van de Graaff. Excellent particle identification was achieved. Most of the data-acquisition programs have been written, but have not yet been tried with the particular apparatus we will use.

An engineering review for Exp. 93 is scheduled next quarter.

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

Preparation for our next run includes several items of new apparatus, which are being constructed. Among these are a scattered-particle beam-monitoring telescope and a low-mass ion chamber. The modifications of the shaping amplifiers referred to last quarter have been completed. Satisfactory tests have been performed with these amplifiers, and a production prototype of the new preamplifiers has been completed.

Programming work has been started to implement a new logic scheme which uses a PDP-11/20 to categorize events. The CAMAC equipment necessary to interface between the computer and the experiment electronics is on hand.

The pursuit of an explanation for some minor experimental effects noticeable in our ^{12}C scattering data is nearly concluded. Final versions of the cross sections will soon be ready for release.

Nuclear Spectroscopy Studies of Proton-Induced Spallation Products (Exp. 105)
(LASL, Idaho National Engineering Lab.)

Our experiments in this quarter were concentrated on several neutron-deficient rare-earth nuclides, produced by 800-MeV bombardment of tantalum. Individual spallation-product activities were isolated for off-line study with an isotope separator, in combination with standard radiochemical procedures. The γ-ray spectrum of each source was then recorded with high-resolution Ge(Li) detectors. In favorable cases, γ-γ coincidence data were also obtained. The principal activities studied were ^{147}Tb(1.7 h), ^{148}Tb(70 min), ^{150}Tb(3.1 h), ^{151}Tb(17.6 h), ^{152}Tb(17.6 h), and ^{147}Gd(38 h). The nuclide ^{147}Tb lies 12 mass units away from the stability line. The data are still being analyzed.

Several papers[7-9,12] describing experiments done in previous quarters have been completed. Their titles, along with a brief summary of results, are as follows:

Decay of ^{128}Ba.[7] Twelve γ-ray transitions have been assigned to the ^{128}Ba decay (only one was known previously), and all have been placed in a level scheme with excited states in ^{128}Cs at 187, 215, 229, 273, 317, 359, and 375 keV. The data suggest that all of these excited states, with the possible exception of the 187-keV state, have $I^\pi = 0$ or 1.

^{134}Ba Level Scheme, as Observed in the Decay of ^{134}La.[8] Ninety-nine γ rays have been identified with the $^{134}La \rightarrow {}^{134}Ba$ decay, and a level scheme is proposed that involves 41 excited states. For many of these states, the spin and parity have been deduced from γ-transition multipolarities and the log *ft* values. An interesting grouping of excited 0^+ states is observed between 2 and 3 MeV. The B(EO)/B(E2) ratios associated with the deexcitation of some of these 0^+ states are unusually large.

Gamma-Ray Emission from ^{134}Ce, and Levels in ^{134}La.[9] By using an on-line chemical-separation technique, we have identified 32 γ rays, ranging in energy up to 355 keV, that are associated with this decay. No γ rays had previously been reported. Our proposed level scheme for odd-odd ^{134}La involves 10 excited states, ranging in energy up to 355 keV. It follows that the previously reported[10] Q_β-value of 110_{-30}^{+90} keV is incorrect. Further details are given in Ref. 11.

Half-Lives of ^{134}La and $^{132\text{-}135}$Ce.[12] Measurements on isotopically separated spallation-product activities, produced by 800-MeV bombardment of praseodymium metal, have yielded the following half-lives: ^{134}La, (6.45 ± 0.16) min; ^{132}Ce, (3.51 ± 0.11) h; ^{133}Ce, (4.93 ± 0.39) h; ^{134}Ce, (75.9 ± 0.9) h; and ^{135}Ce, (17.76 ± 0.31) h. Some of these values differ significantly from previous results.

Two other papers, one describing the $^{131}Ba \rightarrow {}^{131}Cs$ decay and one describing the $^{128}Cs \rightarrow {}^{128}Xe$ decay, are being prepared for publication.

Neutron-Proton Charge-Exchange Cross Sections at 647 MeV (Exp. 125)

(Texas A&M, LASL, Univ. of New Mexico, Univ. of Texas)

The final results for the n-p charge-exchange cross sections at 647 MeV, in the angular range 145° < $\theta_{c.m.} \leq 180°$, have been obtained and submitted for publication in Phys. Rev. Lett.[13] The neutron beam was generated from the ^{2}H(p,n)pp reactions at 0° by collimating neutrons to a half angle of 0.1°. The neutron beam was incident on a liquid hydrogen target and the reaction-charged particles were detected in a MWPC spectrometer to a momentum accuracy of ~0.5%. Particle separation was obtained from measurement of momentum and TOF.

Data were analyzed by numerical integration of particle trajectories. Only events within the empirically determined acceptance of the spectrometer were used in the analysis. The discreteness of particle coordinates from MWPCs caused artificial discontinuities which were removed by randomly redistributing hit wire positions. The multiple hits in MWPC planes were analyzed by considering all possible trajectories. Events with a missing x or y coordinate (~0.3%) were also analyzed.

The relative normalization of individual runs was provided by both the proton beam integrator and the neutron beam monitor, which were consistent to 1.6%. Background subtraction for each run was made from the corresponding LH_2 empty run. The absolute normalization was obtained by simultaneously detecting deuterons from the pn $\rightarrow$ dπ^0 reaction. Knowledge of the cross section for this process is thought to be known to 7%. Figure XI-8 shows our measurements at 647 MeV along with the previous measurements of Dubna,[14] PPA,[15] and Saclay[16] groups around this energy. Our results fall between Dubna and PPA values. They are in reasonable agreement with the Saclay results for angles <175°, but differ in the shape of the extreme backward peak. This shape is conveniently parameterized by $d\sigma/du = \alpha_1 \exp(\beta_1 u) + \alpha_2 \exp(\beta_2 u)$, where u is the square of the crossed 4-momentum transfer. A least-square fit to the data, shown in Fig. XI-9, gives α_1 = 47.5 ± 0.3, β_1 = 162.5 ± 4.5, α_2 = 47.9 ± 0.2, and β_2 = 6.8 ± 0.1 with χ^2 = 0.92. The values for the Saclay data are α_1 = 38.5 ± 1.2, β_1 = 119.1 ± 6.1, α_2 = 45.7 ± 0.5, and β_2 = 7.73 ± 0.2 with χ^2 = 1.85.

The plausibility of the shape of backward peak for n-p CEX scattering can be tested by the pole-extrapolation method of Chew[17] to extract the π-N coupling constant. This method gave f^2 = 0.073 ± 0.003 for our data, which agrees with LLL phase-shift analysis. The same method did not yield a

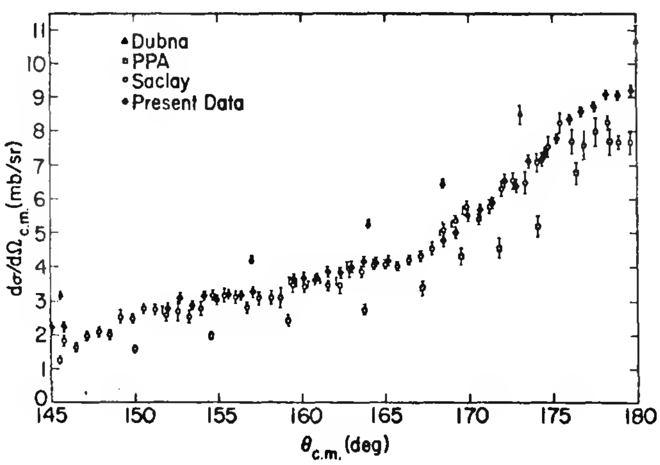


Fig. XI-8.
$d\sigma/d\Omega$ for n-p CEX; Dubna (630 MeV, Ref. 14); PPA (649 MeV, Ref. 15); Saclay (649 MeV, Ref. 16); present experiment (647 MeV).

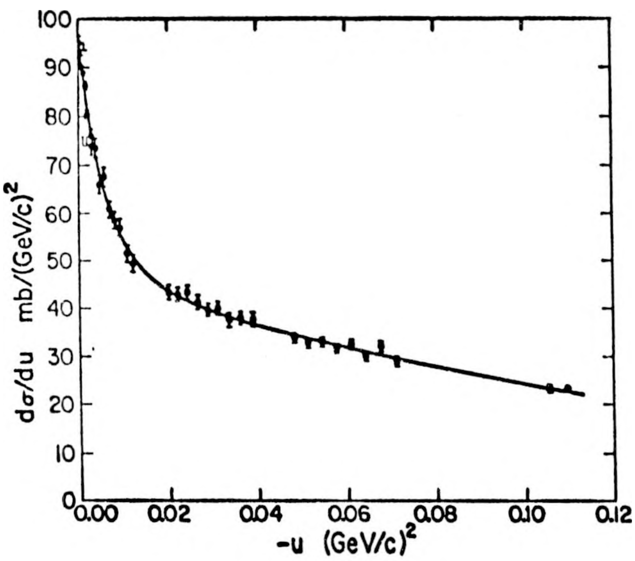


Fig. XI-9.
Double exponential fit to dσ/du for present data.

reasonable f² for the Saclay data unless data for $\theta_{c.m.} > 176°$ were excluded.

In conclusion, the validity of our results is supported by the high internal consistency of the data and the good value for f². The complete data ($51° < \theta_{c.m.} \leq 180°$) are being prepared for publication.

The $\pi^+ d \rightarrow pp$ Reaction at 40-60 MeV (Exp. 131)
(Univ. of South Carolina, ORNL, Virginia Polytech. Inst. and State Univ., LASL)

We present data for the $\pi^+ + d \rightarrow p + p$ reaction at pion energies of 40, 50, and 60 MeV. Because of the large momentum mismatch in this reaction (i.e., $p_\pi \sim 100$ MeV/c, $p_p \sim 400$ MeV/c each), the protons must obtain their momentum from their mutual interaction and thus the cross sections are quite sensitive to the high-momentum components of the deuteron wave function. Therefore, this reaction should provide a sensitive measure of the D-state probability of the deuteron. However, since a reaction is involved, one needs a model for the reaction mechanism.

Goplen, Gibbs, and Lomon (GGL) have studied this problem[18] and have shown that this reaction is sensitive to the D-state of the deuteron. They also showed the dominance of a reaction mechanism that allows the pion to scatter from one nucleon to another (off-momentum-shell) before it is absorbed. Parameters (α_ℓ) which relate to the specific off-shell behavior of the interaction have been determined by studying the $\pi^+ + d \rightarrow p + p$ reaction, $\pi + d$ elastic scattering, and $\pi + {}^{12}C$ elastic scattering. While only the very-low-energy calculations are sensitive to values between 0 and ∞ for α_0 (the s-wave parameter), the calculations are very sensitive to α_1, with the data requiring α_1 (the p-wave parameter) to be ~ 300-400 MeV/c in order not to require significant changes in other parameters thought to be better known.

The data were taken using the LEP Channel. A deuterated polyethylene target was used and the protons were detected in coincidence in plastic scintillators. The absolute normalization of the angular distributions was achieved by using an in-beam monitor at low-beam intensity to calibrate a relative monitor that viewed coincident protons resulting from (π,2p) reactions in the target. This (π,2p) monitor was then used to determine absolute cross sections for data taken at high beam intensity.

The system used to detect the protons resulting from the pion absorption consisted of one (dE/dx)-E telescope and one large solid-angle conjugate detector placed at an angle corresponding to 180° rotation from the telescope in the center of mass. Four detector systems were used simultaneously with the (dE/dx)-E telescopes placed ~25 cm from the target. Thus each detector system had a solid angle of ~4.4 msr with an uncertainty of ±0.012 msr.

Results of a least-squares fit to the data (including all correlated and uncorrelated errors) are presented in Table XI-II. The data were fit with the functional form $C_0 + C_2 \cos^2 \theta_{c.m.}$ as expected from s- and p-waves in the π-d system and with the form $C_0 + C_2 \cos^2 \theta_{c.m.} + C_4 \cos^4 \theta_{c.m.}$ to determine if there were any measured deviations from the simple $\cos^2 \theta_{c.m.}$ dependence. No significant deviation is observed. It should be noted that the integrated cross sections obtained by using the fit parameters exhibit an energy dependence stronger than has been noted before. When these cross sections are compared with the calculations of GGL, there is agreement in magnitude with the 50-MeV data whereas the calculations are too high by ~30% at 40 MeV and too low by ~10% at 60 MeV.

In order to compare measured and calculated relative angular distributions, the ratio of the cross section at 90° to difference between the 0° and 90° cross sections is plotted in Fig. XI-10 as a function of pion momentum. The calculations have the s-wave off-shell parameter α_0 = 500 MeV/c and the p-wave off-shell parameter α_1 = 340 MeV/c. Three different deuteron wave functions were used. Two of them use the Boundary Condition Model (BCM) of Lomon and Feshbach, and one was derived from the Hamada-Johnson (HJ) potential. The HJ wave

TABLE XI-II

LEAST-SQUARES FIT TO $(d\sigma/d\Omega) = A + B\cos^2\theta_{c.m.} + C\cos^4\theta_{c.m.}$

T_π (MeV)	A (mb)	B (mb)	C (mb)	$2\pi\int(d\sigma/d\Omega)d\Omega$ (mb)	χ^2/N
40	0.310 ± 0.011	1.017 ± 0.023	0	4.077 ± 0.091	34/9
40	0.319 ± 0.011	0.897 ± 0.048	0.170 ± 0.059	4.099 ± 0.091	25/8
50	0.486 ± 0.018	1.777 ± 0.036	0	6.78 ± 0.10	13/9
50	0.497 ± 0.019	1.643 ± 0.091	0.17 ± 0.10	6.77 ± 0.10	11/8
60	0.552 ± 0.013	2.016 ± 0.039	0	7.69 ± 0.14	24/7
60	0.565 ± 0.014	1.812 ± 0.093	0.28 ± 0.12	7.70 ± 0.14	18/6

function has 6.96% D-state whereas the two BCM wave functions were chosen to have 7.57% and 4.56%. From the figure it is apparent that this model predicts that the relative angular distributions are quite sensitive to the percentage D-state and that within this model the data require $P_D \approx 4\%$.

The angular distribution measured at 50 MeV is shown in Fig. XI-11. Also shown are the calculated angular distributions described above. The calculation using the HJ wave function and that using the 7.57% BCM wave function are essentially parallel, while both have a quite different slope from the calculation using the 4.56% BCM wave function. This fact is interpreted to mean that the $\pi^+ + d \rightarrow p + p$ angular distribution is very sensitive to the exact form of the radial wave function.

To summarize, the $\pi^+ + d \rightarrow p + p$ reaction appears to be quite sensitive to the high-momentum components of the deuteron wave function. The predictions of one model for this reaction display such a sensitivity. Within this model, variations in the deuteron wave function show that the present data require a deuteron D-state probability of ~4% without a great dependence on the exact form of the radial wave function. The sensitivity of the calculated angular distributions to the exact form of this or any other model remains to be investigated.

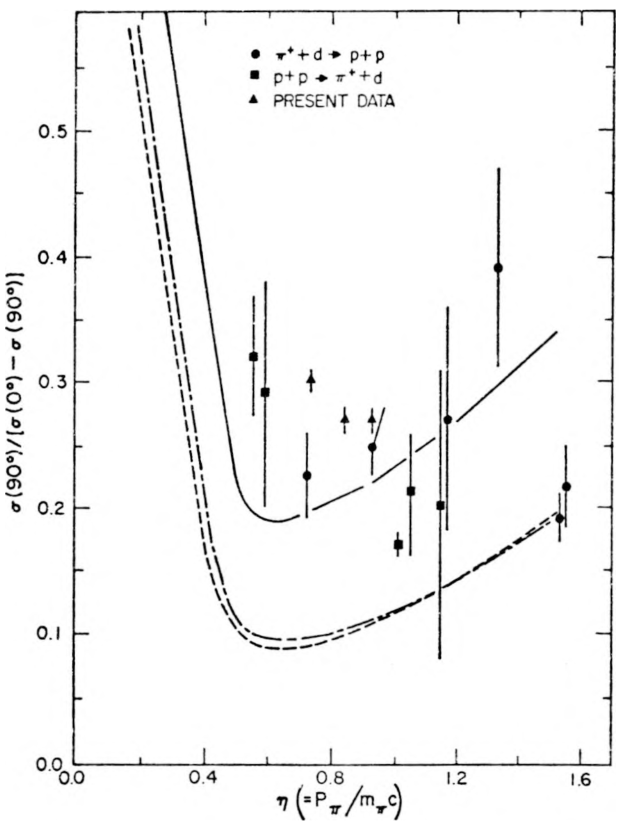


Fig. XI-10.
Relative angular distributions as a function of pion momentum. The curves are calculated using (a) solid: BCM wave function with P_D = 4.56%; (b) dashed: BCM wave function with P_D = 7.57%; and (c) dot-dashed: HJ wave function.

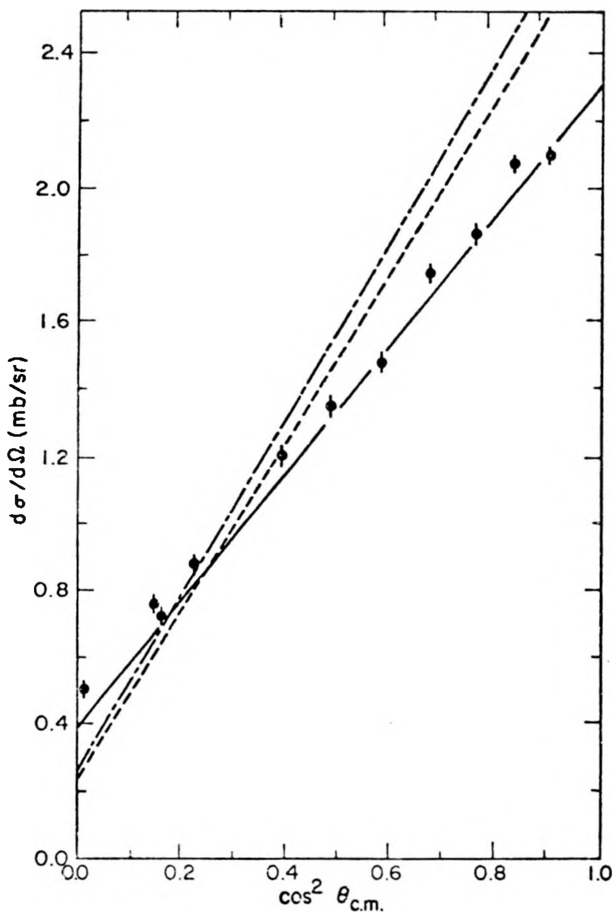


Fig. XI-11.
Angular distribution for an incident pion energy of 50 MeV. The curves are calculated using (a) solid: BCM wave function with P_D = *4.56%; (b) dashed: BCM wave function with* P_D = *7.57%; and (c) dot-dashed; HJ wave function.*

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

The spectrometer for Exp. 132/160 was used in Exp. 42, and that part of the data which involved (p,p), (p,d) and (p,t) elastic scattering was used to test its momentum resolution. Preliminary results showed it to have at least 2% momentum resolution sufficient for the experiment. More detailed analyses of these results are now in progress.

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

The cross sections for the reaction (π^+,π^0) on ^{7}Li, ^{10}B, and ^{13}C were measured over the energy range of 70 to 250 MeV by activation methods. The excitation functions were found to be flat, with cross sections of about 2.5 mb for ^{7}Li, 0.4 mb for ^{10}B, and 1.0 mb for ^{13}C.

The analysis of the experiment was completed and the results are presented in Phys. Rev. Lett. **36**, 82 (1976).

Muonic X Rays and Nuclear Charge Distributions and Electric Quadrupole Moments of $_{67}$Ho^{165}, $_{73}$Ta^{181}, and $_{66}$Dy^{161} (Exp. 166)
(California Inst. of Tech., Univ. of Wyoming, Coll. of William and Mary)

We have completed the analysis of the muonic 4f → 3d transitions in holmium, dysprosium, and tantalum. The hfs of these transitions has been used to determine the electric quadrupole (E2) and hexadecapole moments (E4) of these nuclei.

A summary of our results and a comparison with other techniques is given in Table XI-III. In general, there is good agreement with coulomb excitation work although our accuracy is generally three times greater. This agreement is a remarkable check of the rotational model for these nuclei since the coulomb excitation work is sensitive to dynamic quadrupole moment effects whereas the muonic x-ray work is sensitive to static quadrupole moment effects. There is poor agreement with spectroscopic techniques — such as atomic beam and optical techniques — because in no case have the Sternheimer effects been taken into account in the interpretation of these

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

TABLE XI-III

NUCLEAR CHARGE MOMENTS

	Q_0(eb) Other Techniques	Q_0(eb) This Experiment	H_0(eb^2)
$_{66}Dy^{161}$	3.8 ± 0.8 [a]	6.95 ± 0.08	0.93 ± 0.41
	7.38 ± 0.22[b]		
	7.61 ± 0.66[c]		
	8.0 ± 2.0 [d]		
	6.6 ± 1.1 [e]		
$_{67}Ho^{165}$	7.44 ± 0.24[f]	7.44 ± 0.07	0.45 ± 0.18
	5.85 ± 0.13[e]		
	7.62 ± 0.12[b]		
	7.4 ± 0.4 [g]		
$_{73}Ta^{181}$	6.16 ± 0.46[c]	6.99 ± 0.07	−0.30 ± 0.38
	8.4 ± 2.1 [h]		
	6.95 ± 0.27[d]		
	7.08 ± 0.25[b]		

[a] hfs (paramagnetic resonance)
[b] coulomb excitation: inelastic scattering
[c] from the half-life of the first rotational state
[d] coulomb excitation: γ-yield
[e] hfs (atomic beam)
[f] pionic x rays
[g] giant resonance
[h] hfs (optical)

data. Earlier (less precise) muonic x-ray determinations exist, but in general many theoretical corrections, such as nuclear polarization, have been neglected, making the interpretation of these data incomplete.

No comparable data for the E4 moments currently exist. Coulomb excitation work in adjacent even-even nuclei indicates the trend suggested by our data, and most theoretical nuclear calculations predict that the hexadecapole moment should change sign around Z = 72.

A complete discussion of the analysis of the muonic x-ray determination of the nuclear charge parameters of ^{165}Ho will appear in Nucl. Phys. Work is proceeding on the analysis of the absolute transition energies of the K and L transitions in ^{161}Dy and ^{181}Ta in order to allow a similar determination of the radial charge parameters.

Search for Condensed Nuclear States and Study of High-Momentum Transfer and Low-Energy Transfer Nuclear Interactions (Exp. 189) (Univ. of Pennsylvania, Temple Univ., LASL)

The analysis of the measurement of the energetic portion of backward p, d, and t production in proton-nucleus collisions has been completed and the results presented in two journal articles.

One article sets upper limits for the proportion of "supercondensed" nuclei in various samples (e.g., observation of recoil of the incident proton without loss of energy) in the range of 10^{-7} to 10^{-8} per normal nucleus.

The second article presents the measured p, d, and t spectra, noting the interest in observing protons rebounding with up to half the incident beam energy and in the fact that the backscatter cross section per target nucleon rises with atomic

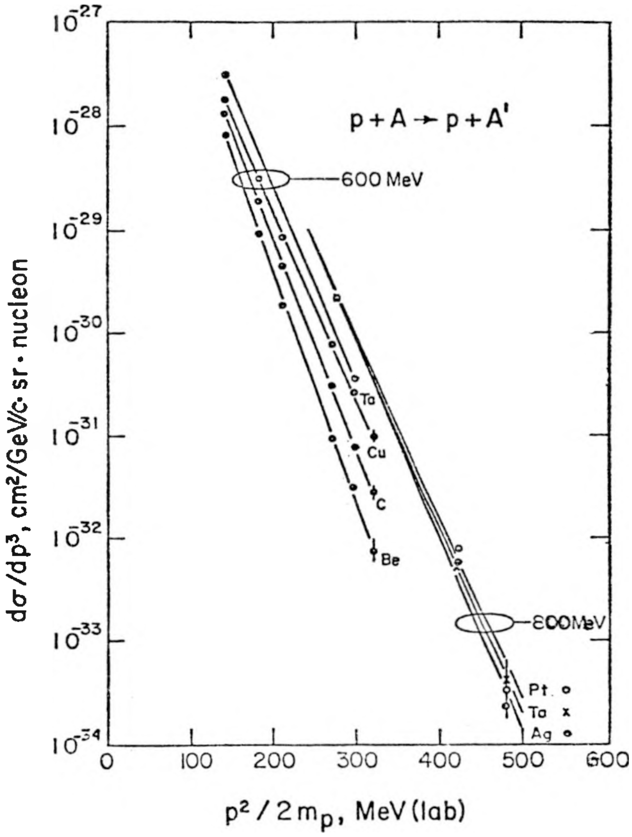

Fig. XI-12.
Cross Section for 180° production of protons in $p + A \rightarrow p + A'$ at 600- and 800-MeV beam energies. The cross section is normalized per unit target nucleon. *(Note that the abscissa, $p^2/2M_p$, is greater than the correct relativistic kinetic energy by 90 MeV at 500 MeV on the graph.)*

number of the target nucleus. Figure XI-12 shows the proton spectrum. The deuteron and triton spectra are similar, but are shifted toward lower energies and with flatter slopes.

The interpretation of these data invites one to weigh the merits of a nuclear-clustering model vs an extended Fermi-motion model vs a conventional nuclear-cascade model.

Experiment to Observe Nuclear Resonance Effects in Pionic Atoms (Exp. 195/214) (LASL, National Research Council of Canada, Univ. of Mississippi)

The electronic logic and counters have been assembled and tested. The magnetic tape drive for the pulse-height analyzer has proved troublesome, but it

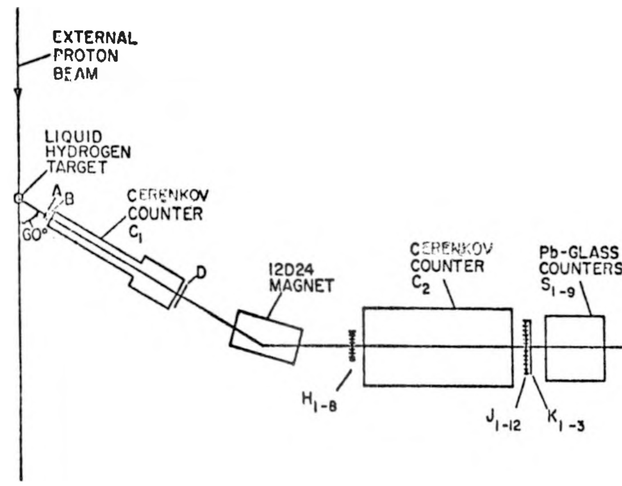

Fig. XI-13.
Plan view of apparatus.

is working properly at the moment. Modifications to a teletype are being performed so that a reserve readout device will be available.

The counter stand and sample holders are built. Several shelves, absorbers, sample holders, and a collimator are under construction. Cables have been acquired.

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

Design of the scattering chamber, magnets, and magnet vacuum chamber is complete. Construction of parts of this apparatus has begun. The design of the goniometer, which is the most critical part of the equipment, is nearly developed.

A power supply for the laser is in operation. The optical system to go with the 50-kW laser is being procured.

Direct Lepton Production at LAMPF Energies (Exp. 241) (LASL, Temple Univ.)

The data-taking for Exp. 241 has been completed and the analysis is proceeding. Positron yields from p-p collisions at 800 and 256 MeV have been measured with a single-arm spectrometer, shown in Fig. XI-13, in the EPB. The apparatus had excellent electron identification and moderate momentum resolution. The electron detection efficiency for each of the two threshold Cerenkov counters was >96%,

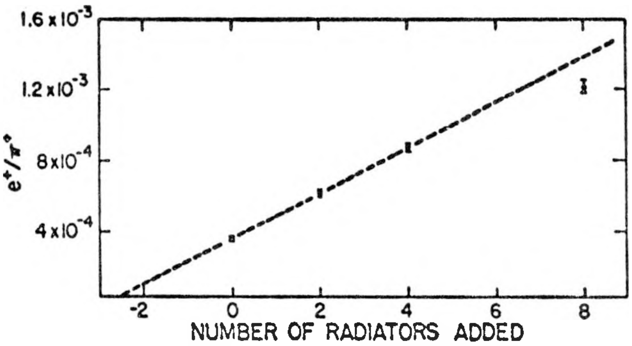

Fig. XI-14.
Ratio of positron to pion yields as a function of the number of radiators added before energy loss and radiative corrections are applied.

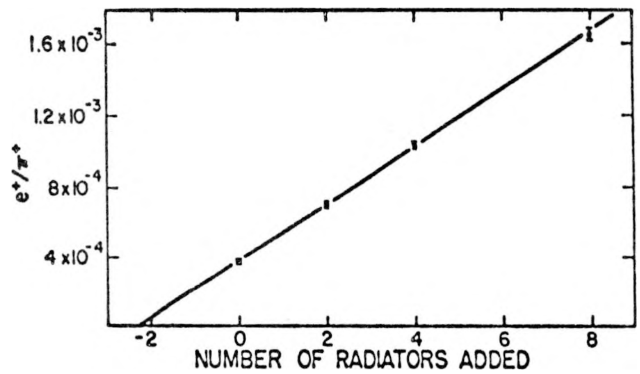

Fig. XI-15.
Ratio of positron to pion yields as a function of the number of radiators added after energy loss and radiative corrections are applied.

while the efficiency for detecting pions was $<10^{-3}$ for C_1 and $<2 \times 10^{-4}$ for C_2. Counters A, B, and D defined the solid angle, while the H and J hodoscope banks were used to measure the momentum of the particle traversing the spectrometer. The lead-glass counters gave independent confirmation of the electron-pion discrimination.

The bulk of the positrons observed in the 800-MeV data result from π^0 decay, either $\pi^0 \rightarrow e^+e^-\gamma$ (Dalitz decay) or $\pi^0 \rightarrow \gamma\gamma$ with one of the photons producing an (e^+e^-) pair in the target. Since the aim of the experiment is to search for e^+ yields which are not due to π^0 decay (i.e., direct leptons), it is necessary to subtract those positrons which result from π^0 decay from the total yield. In order to perform this subtraction, data were collected with differing amounts of radiator added between the target and the A counter to increase the e^+ yield from $\pi^0 \rightarrow \gamma\gamma$. Figure XI-14 shows the ratio of e^+ to π^+ yields as a function of the number of 0.3069-g/cm^2 Mylar radiators added. This ratio is not linear due to the ionization and radiative energy losses suffered by the positrons. Figure XI-15 shows the same ratio corrected for these energy losses. If this curve is extrapolated to ~ -1.1 radiators added, the positrons resulting from pair production in the target are removed. Since the positron spectrum from Dalitz decay is quite similar to the spectrum of positrons resulting from the pair production of photons from π^0 decay, an additional extrapolation will remove these positrons. Preliminary studies suggest an extrapolation of an additional ~ -1.2 radiators, although more Monte Carlo studies are required to accurately determine this number. The data in Fig. XI-15 show that the direct e^+ yields are small, but no quantitative statement can be made until the analysis is complete. An extrapolation of the existing high-energy data down to the kinematic region spanned by this experiment predicts an invariant cross section $E\, d^3\sigma/dp^3$ which corresponds to $e^+/\pi^+ \simeq 1 \times 10^{-4}$. It thus appears that Exp. 241 will be able to determine whether or not direct leptons are produced in 800-MeV p-p collisions.

Data were also collected at 256 MeV, well below pion-production threshold. At this energy the chief backgrounds are from neutral pions produced in the nuclei in the target walls, and from nucleon-nucleon bremsstrahlung. A preliminary analysis of this data indicates an ultimate sensitivity at the level $d\sigma/d\Omega \sim 0.5$ nb/sr for positron production with $E_{e^+} > 70$ MeV. A photon spectrum at 108° in the laboratory was also measured with a cross section $100 \text{ nb/sr} \leq d\sigma/d\Omega \leq 200$ nb/sr for $E_\gamma > 45$ MeV.

General Research Projects

Line A Guard Rings

The nine-quadrant secondary-emission monitors (QSEM) for Line A have been installed and checked for shorts. All are ready for beam. These guard rings will be used as part of the fast-protect system in Line A to prevent collimator burnout in case of beam-steering problems. A prototype of the system which will be used to amplify the signals from each of the quadrants referenced to their own ground has been built and will be tested on the QSEM downstream of the A2 target (2AGRO2) as soon as beam goes through Area A.

Beam-on-Target Monitors

Beam-on-target ion chambers and collimators are now installed in A-1 and A-2 target cells.

Theory

By modifying the electron-meson scattering function which appears in the Fuzzy Fermi-Teller Model, we have been able to fit the variations of kaonic x-ray yield (Wiegand and Godfrey, 1974). The resultant model has been tested on measured pionic yields (Kunselman, 1969). The agreement is fairly good, but better data are needed; these should be provided by Exp. 214. Agreement with muonic data (Kessler *et al.*, 1967) is poorer.

A computer code has been written for solving the fully quantum-mechanical coupled-channel problem presented by Stark-mixing in mesonic hydrogen. Experiment 206 at LAMPF and a number of experiments at other laboratories will attempt to measure x rays whose yields depend critically on this Stark-mixing process.

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XII. NUCLEAR CHEMISTRY

Nuclear Chemistry Laboratory

Counting Room Equipment

During this quarter, the components have been assembled for a second γ-γ coincidence counting system consisting of a pair of 76- × 76-mm NaI(Tl) detectors. This is in anticipation of the large number of positron-emitting samples that will result from phase two of Exp. 67 and from the new Exp. 239 when beam delivery to the pion channels is resumed.

A new lithium-drifted germanium planar detector of the low-energy photon type (16-mm diam × 4.75-mm thick) with a 0.025-mm beryllium window and a resolution of 520 eV at 122 keV has been added to the array of γ-spectrometers.

Data-Acquisition System (DAS)

This quarter was marked with several hardware problems. One of the counting room CRT scope terminals was sent back to the factory for repairs and has been returned in good condition. Another CRT unit became inoperative and will require factory repair.

Software development for the DAS is proceeding. A program for controlling a Canberra 8100 Multichannel Analyzer and reading its memory data into the computer has been developed. The CAMAC module to read the laboratory master Time-of-Year clock has been built and checked out. Routines to supply the time information to other programs have been written.

Computer Programs

The standard form of data output from our multichannel pulse-height analyzers is magnetic tape. In order to apply our gamma spectrum analysis code, GAMANAL, a translation of the tape information is necessary. The codes for performing this translation and for listing the data on a line printer have been available, but recently a set of written instructions has been prepared to enable the outside user, who may be unfamiliar with the CCF system, to use these programs.

A programmable, hand-held calculator, the HP-65, is also available to users in the Nuclear Chemistry Laboratory. This calculator has a full complement of mathematical and statistical programs for data analysis, as well as several LASL-prepared special-purpose programs.

Nuclear Chemistry Hot Cell

Substantial progress has been made in preparing the stainless steel containment boxes in the Area A hot cell for high-level nuclear chemistry experiments. The wet chemistry box has been completely sealed, except for a HEPA filter on the air inlet and an air duct to an external blower which will provide negative pressure inside the box. A 10.2-cm PVC pipe conducts the exhaust air from the box to the main air plenum below the hot cells. A transfer cart, operating through an air-locked curved tunnel, has been installed for delivery of chemicals, glassware, etc., from the operating gallery to the interior of the chemistry box. There is also a connecting tunnel between the two containment boxes for transfer of irradiated materials to the chemistry box for processing. Vacuum and pressurized air manifolds, and ac power strips (110- and 280-V ac) with individual outlets, controlled via the manipulators, have been installed. Modest supplies of water and radioactive waste storage systems have also been included.

Pneumatic "Rabbit" System

Further efforts were made to bring the pneumatic "rabbit" system to operational status. It was recognized that important mechanical deficiencies existed in the system and corrective measures are being taken. The main 9-position diverter was removed from the hot cell for shop modifications needed to insure precise alignment of the tubes when various routes are selected by the control system. New, larger diameter air cylinders have been obtained to replace the original inadequate cylinders for operating the main air shifters. All four receiving terminals have been removed to have the microswitch detectors, which signal the arrival of a "rabbit" carrier, replaced by a more positive and failproof sensor.

Design was completed on the special (3.8-cm-diam) neutron irradiation station to be installed in the target tank of the WNR facility. This station will be utilized in conjunction with the CNC-11 laboratory trailer to be located adjacent to the WNR building.

Theoretical Support

In the original version of the VEGAS intranuclear cascade program[1] a pion interacting with a nucleon in a nucleus forms an isobar (excited nucleon with angular momentum and isospin 3/2) with a mass which conserves energy and momentum. The resulting isobar travels through the nucleus until it decays or is absorbed by another nucleon. The decay probability is proportional to the lifetime of the isobar which has been assumed to be a constant independent of the mass of the isobar.

The program has been revised so that the isobar is formed only through the resonant part of the pion-nucleon cross section. The resonant cross section is fitted to a relativistic Breit-Wigner form with a mass-dependent width.[2] This mass-dependent width implies a mass-dependent isobar lifetime which can vary substantially over the (3,3) resonance thereby changing the isobar path through the nucleus. The effect of these changes on pion-induced reactions in nuclei is being investigated. The mass-dependent lifetime has been shown to improve the spectrum of protons emitted at 90° in pion-induced reactions on nickel so that the spectrum agrees with the measured spectrum[3] for protons emitted with energies below 100 MeV.

The isobar absorption mechanism on two nucleons is now in the process of being improved to take into account the form factor at the pion-nucleon vertex. This will have effects on pion-induced reactions, including the proton spectrum at 90° mentioned above.

A time analysis of the VEGAS program was made and it showed that 58% of the computer time was spent in six of the fifty-one subprograms of the code. From this it was concluded that it may be possible to cut the computing time by ~35% by streamlining these six subprograms.

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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.)

Biomedical Channel Development

The effective lengths of the beam-shaping quadrupoles were estimated more accurately by using the results of field measurements. The agreement of the pion beam-shape calculations with observations has been improved.

As a result of additional programming it is now possible to use the measured pion coordinates at the entrance to the beam-shaping program as input to beam-shape calculations. In the past it was necessary to use pion coordinates chosen randomly from a distribution that only approximated the beam characteristics.

Initial work has been done to study the effectiveness of using scattering foils as a technique for flattening the pion flux distribution at the patient position. Figure XIII-1 shows the flattening effect of using a scattering foil intercepting the central portion of a Gaussian-shaped beam at a point 110 cm above the patient. A 9-cm-wide collimator was placed 2 cm above the patient. The abscissa of the figure is 15-cm long.

A 0- to 5-kV pulser has been designed and tested for operation of the MWPCs in the Biomedical Channel to allow data accumulation during periodic low-intensity beam pulses. Logic circuitry associated with the high-voltage pulser initiates the voltage ramp (−1 kV/ms) with the arrival of a precursor pulse from CCR. An operating level of about −4500 V is attained at approximately 3 ms before the beginning of the "low-level" beam pulse. Turn-off begins with the end of the beam gate, and voltage should drop to about −2500 V before the next (higher level) beam pulse appears. Initial tests indicate the relatively slow rise-time pulses cause no serious effects on the MWPC preamplifiers. Other tests with an electron source indicate that the preamplifiers are operating normally during the flat top of the pulse. Tests under actual beam conditions

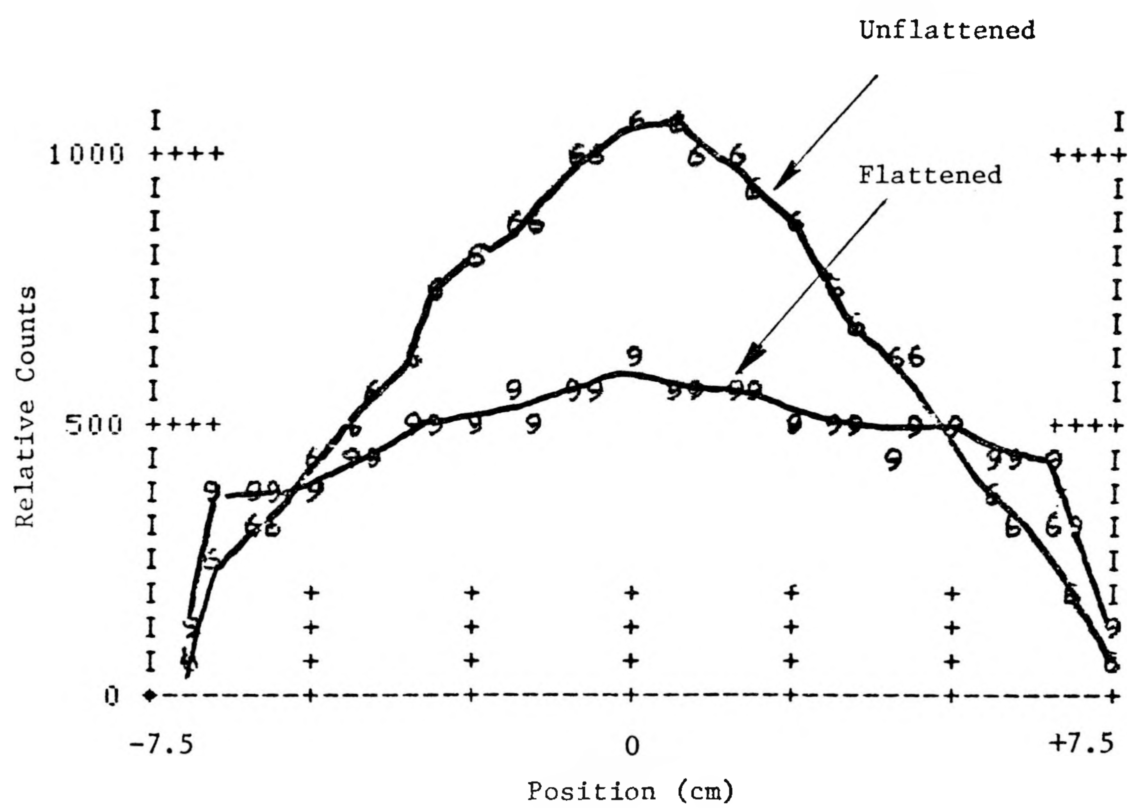

Fig. XIII-1.
X Profile of unflattened and flattened pion beams.

are required to prove that the system is actually working in a satisfactory manner.

Dose Model Calculations

The program BUCKET described in the previous progress report is now fully operational, and numerous calculational runs have been made; comparisons with experimental data have been made whenever possible. Based on those comparisons, several modifications have been made in the code.

Two versions of BUCKET now exist. The calculational procedures are essentially identical in the two versions, the main differences being in the input subroutines. Version 1 has been written specifically to accept and analyze phase-space data for the "biology tune" obtained last year on the Biomed Channel. Version 2 has more general input specifications and can accept input from punched cards, magnetic tape, or more commonly photostore files containing information for any arbitrary tune. Provisions have also been included in Version 2 to accept tunes which have been altered by scattering foils and bolus material. Input files consist of ray information, with each line of input furnishing information on ray position, angle, and momentum. Files may represent experimental data from MWPCs, or calculated data from other computer codes (such as PIFLUX).

The basic calculational aspects of the code have been described in the previous progress report, although several modifications have since been made to improve the versatility, running time, and overall performance of the code. For example, BUCKET is now capable of treating pions, muons, and electrons separately, with the different phase spaces of the three particles being properly accounted for. The Katz model of cell survival[1] has also been incorporated into the code, and output graphs, tables, and histograms now provide three-dimensional information on cell survival. Several attempts have been made to try to include the effects of collimators on the dose distributions. This is a difficult problem if multiple scattering and secondary charged particle fluences are to be handled properly, and several attempts were made before reasonable agreement with experiment could be obtained.

In addition to total dose and cell survival, the code also provides information on the spatial distribution of the various components of the dose, including star dose, proton and neutron dose, and ionization dose. Extensive calculations have been made for the "biology tune" using Version 1 of BUCKET, and agreement with experiment is very good for all calculated quantities.

Calculations have also been made using Version 2 for several computer-generated tunes, including one broad (8×10 cm^2) therapy tune. Comparison with experiment for this and other tunes awaits resumption of operation at the Biomed Channel. In order to assess the results of BUCKET without corresponding experimental data, work has started on implementing Monte Carlo computer codes for calculating dose distributions from pions (as opposed to the purely analytical approach used in BUCKET). In particular we have obtained a copy of the program PION-1,[2] and in collaboration with H. Wright and R. Hamm of ORNL have made the modifications necessary to run this code on the LASL computers. A preliminary version is presently running, and work is under way to make the additional changes necessary to adapt this code to our specific needs.

Treatment-Planning Program

Software

Modifications of the PIPLAN code are being investigated to provide real-time planning capabilities and to allow specification of both static and scanning treatment beams. The present dose model is being tested against the Monte Carlo results obtained for static beams at ORNL with PION-1.

Hardware

Data links between the Biomed facility and the CCF have been defined, equipment has been specified, and initial equipment purchases have been requested. The system will provide the planner with real-time communications to both the CCF for treatment planning and to the Biomed computer for manipulation and retrieval of patient data. The system can be duplicated easily at the Univ. of New Mexico Cancer Research and Treatment Center, and, when DECNET is implemented between the Biomed and the Univ. of New Mexico Cancer Research and Treatment Center computers, it will provide a treatment-planning network to expedite patient-related logistics.

Practical Applications Experiments

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

Preparations for further muonic x-ray measurements to be done this spring have been made by obtaining samples of normal dog liver and dog liver tumor. These were provided by Edward Gillette of Colorado State Univ. An arrangement was also made to obtain samples of human tissue from the Univ. of New Mexico School of Medicine.

Neutron Dose Measurements

In order to determine the feasibility of an ion linear accelerator for neutron therapy, experiments were performed at the isochronous cyclotron of the Univ. of California-Davis. These measurements were part of a collaborative series of measurements performed by the FNAL, the Univ. of California-Davis, the Naval Research Laboratory, and LASL. Some preliminary results are given here.

Depth-dose curves were measured in a water phantom, 50 × 41 × 40 cm, with a 0.1 cm^3 EGG TE plastic ionization chamber filled with air. For purposes of comparison, some data for ^{9}Be(d,n) and ^{7}Li(d,n) were repeated with a TE gas of 64.4% CH_4, 32.5% CO_2, and 3.1% N_2 in the chamber.

The front surface of the phantom was positioned 66 cm from the end of a steel collimator (152-cm long with a 5.7 × 7.0-cm aperture) which corresponds to a target-to-surface distance of 351 cm.

Build-up curves were measured with an EGG extrapolation chamber embedded in a block of TE plastic with the front surface of the system in the same position as the front surface of the water phantom.

Microdosimetric spectra were obtained with a 2.5-cm-diam Rossi-type spherical proportional counter constructed of A150 TE plastic. The chamber, in addition, was embedded in a cylinder of TE plastic, 5 cm in diameter, in order to obtain electron equilibrium. The proportional gas consisted of 55.0% C_3H_8 (propane), 39.6% CO_2, and 5.4% N_2.

Neutron spectra [N(E) vs E] were obtained by a TOF method.

Clinical considerations dictate that a depth-dose curve for neutrons be at least as favorable as that for ^{60}Co γ rays. Figure XIII-2 shows a comparison of the absolute dose per incident particle at an SSD of 351 cm. The corresponding build-up curves are shown in Fig. XIII-3. Data for ^{60}Co are also shown for comparison. The absorbed doses for the build-up curves are somewhat less than for the data obtained in the water phantom because of less scattering material in back of, and surrounding, the extrapolation chamber.

The depth-dose curves for the four cases are only slightly different beyond the first g/cm^2 of depth and are very similar to that for ^{60}Co. The ratio of the peak dose per incident deuteron for ^{9}Be(d,n) to the dose per incident proton for ^{9}Be(p,n) is 6.1. The proton-produced neutrons reach maximum dose somewhat more slowly, which is characteristic of a harder neutron spectrum as compared to that produced by deuterons.

The fact that the proton-induced neutron spectrum is somewhat harder than that produced by deuterons is substantiated by the microdosimetric and the TOF spectra. Table XIII-I lists the dose mean lineal energies, $\bar{y}_d$, for the spectra.

Figures XIII-4-7 show the microdosimetric distributions for neutrons from 35-MeV protons and deuterons on beryllium and lithium. First of all, one can estimate the photon contribution to the dose. These are tabulated in Table XIII-I, along with the

TABLE XIII-I

MICRODOSIMETRIC DATA FOR NEUTRON SPECTRA

Reaction	y_d (keV/μm)	1 - D(158) (y > 158 keV)	Estimated Photon Contribution (%)
^{9}Be(d,n)	80	0.13	4
^{7}Li(d,n)	75	0.12	3
^{9}Be(p,n)	68	0.10	6
^{7}Li(p,n)	69	0.10	7

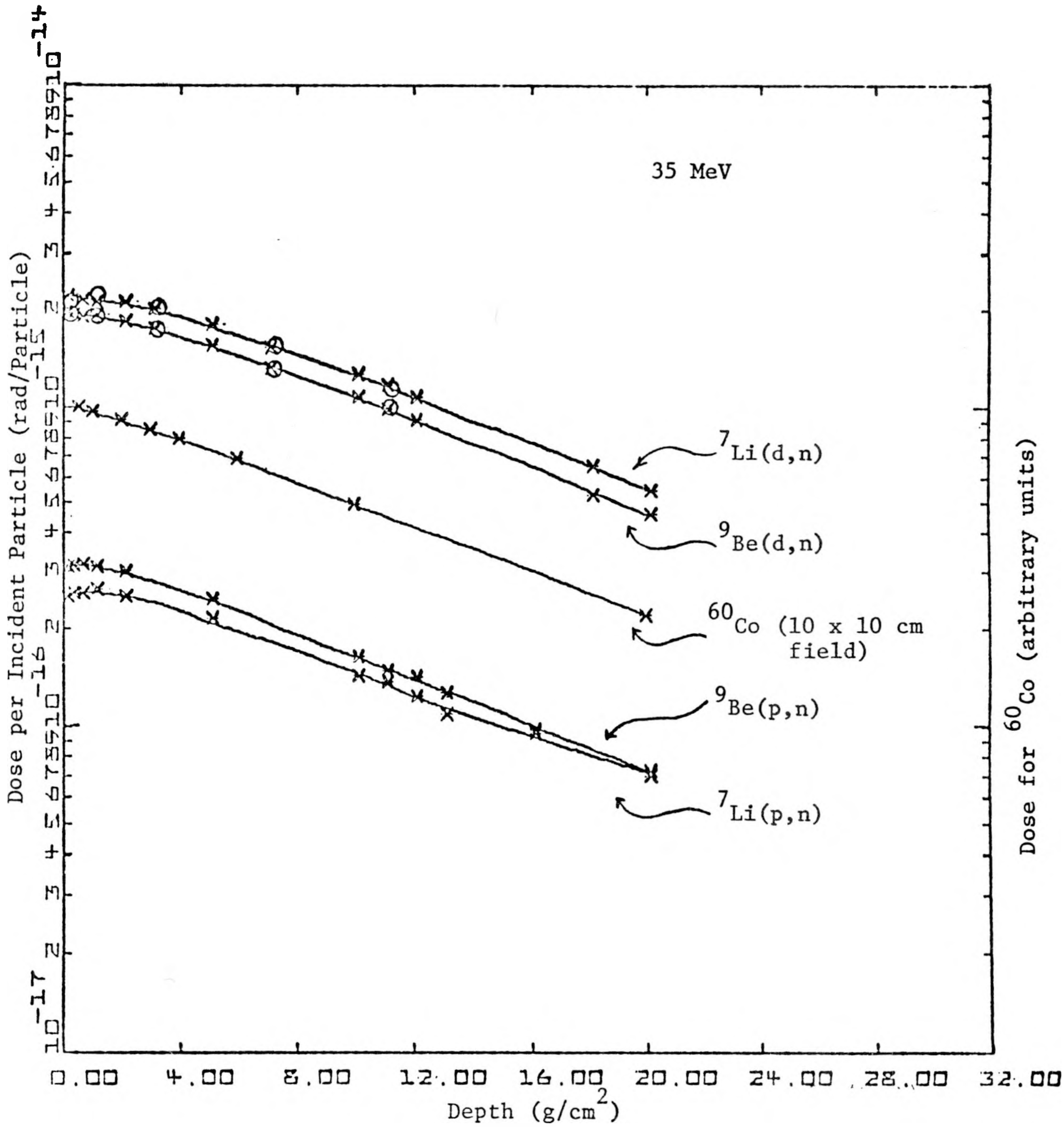

Fig. XIII-2.
The absolute dose per incident proton or deuteron on beryllium or lithium as a function of depth in a water phantom. The corresponding curve for ^{60}Co has been included for comparison.

dose mean lineal energies, $\bar{y}_d$, and the fraction of dose from events having a lineal energy >158 keV/μm.

The major difference in the distributions seems to be that for (p,n) reactions, a larger fraction of the dose is contributed by recoil protons of higher LET. These events probably are a result of the larger component of low-energy neutrons produced by ^{9}Be(p,n) and ^{7}Li(p,n) reactions. It could be possible to reduce the number of lower energy neutrons by a judicious choice of target thickness, for example. This would produce a spectrum with a larger component of

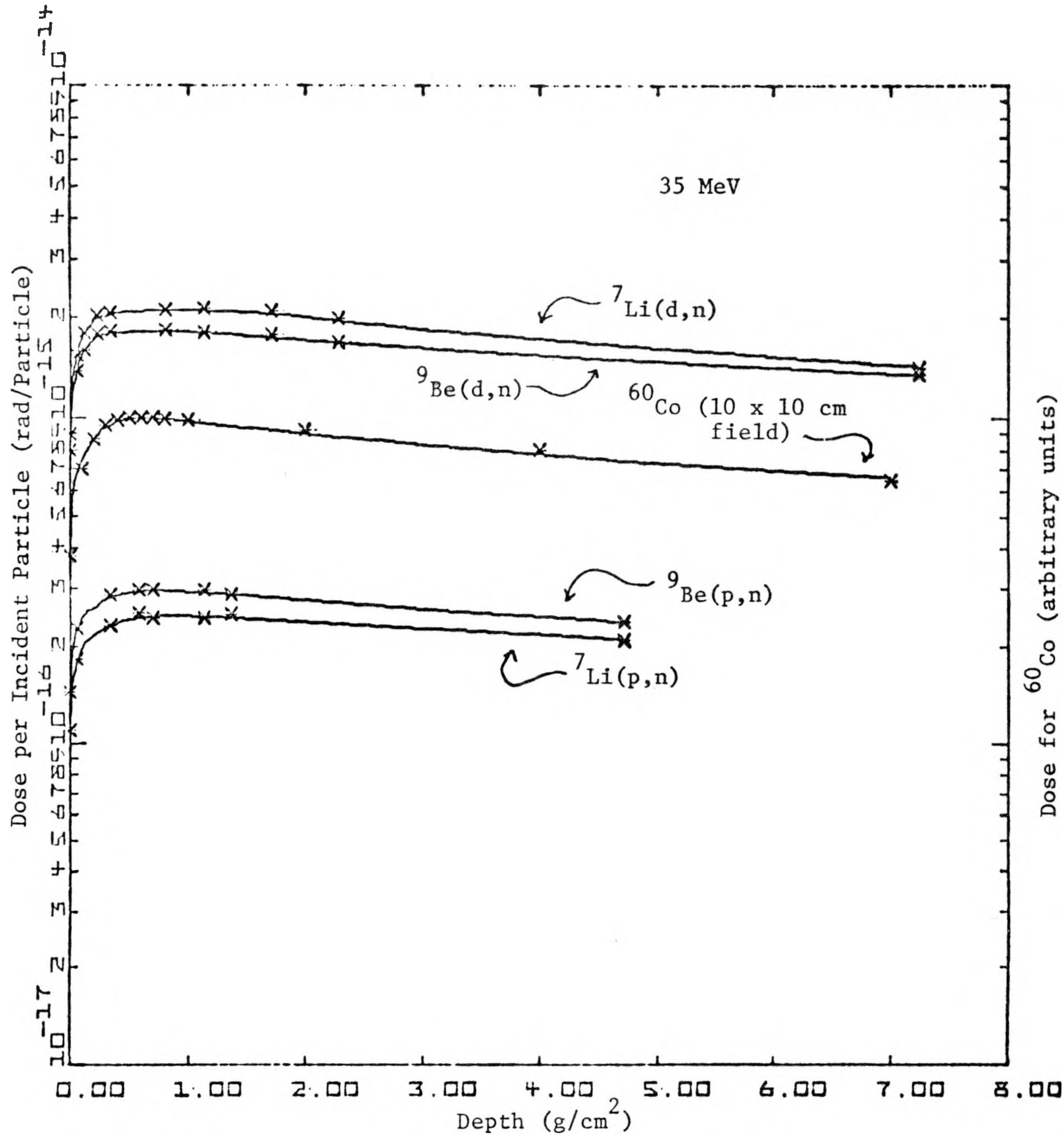

Fig. XIII-3.
The absolute dose per incident proton or deuteron on beryllium or lithium as a function of depth in a water phantom. The corresponding curve for ^{60}Co has been included for comparison.

alpha particles and heavy ions. It would also tend to produce recoil protons of lower mean LET.

Proton Radiography

A new program has been undertaken to determine the feasibility of implementing proton radiography at LAMPF in the form of a proton axial tomography (PAT) system. It is hoped that such a system would be useful in the pion therapy program by defining the spatial position and extent of tumors and the pion energies required to stop the pions precisely in the tumor. In PAT, the two-dimensional density distribution in a section of a specimen is reconstructed from the integrated density ($\int\rho dx$) distributions

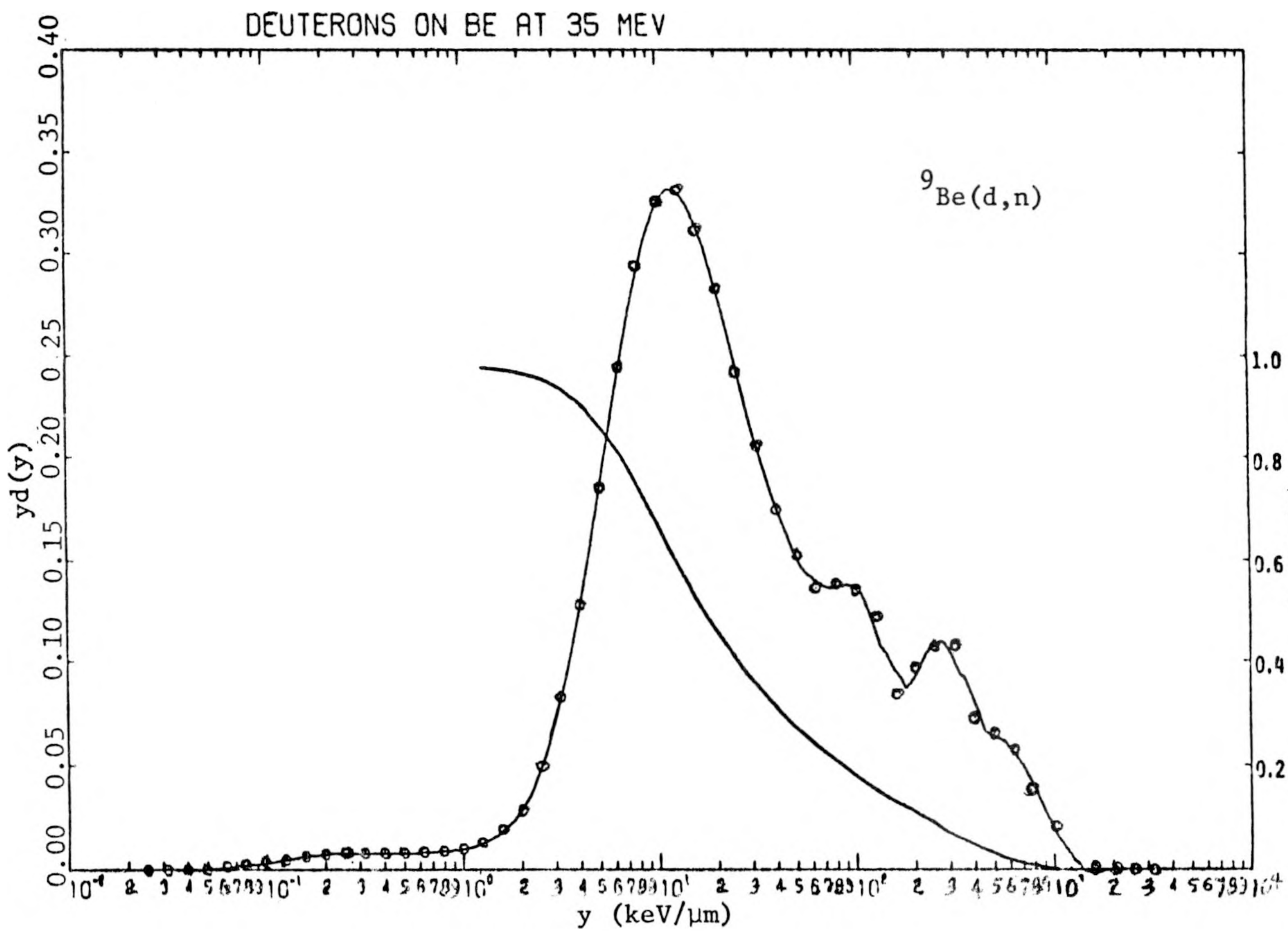

Fig. XIII-4.
Microdosimetric distribution of deuterons on beryllium at 35 MeV. The circles are the differential dose per logarithm interval of lineal energy, yd(y) vs lineal energy, y. The solid line with no symbols is the fraction of the dose in excess of a given lineal energy, 1 - D(y), vs lineal energy.

taken through that section at various angles. The integrated densities are obtained by measuring the energy lost by protons which traverse the specimen. Computer codes have been developed which simulate the experimental data that would be obtained in several PAT configurations. The aims of the computer simulation are: 1) to understand the intrinsic limitations implied by the use of protons to make these measurements, and 2) to determine the best experimental set-up to implement these measurements at LAMPF.

A program has been implemented on the CDC-7600 to reconstruct two-dimensional density distributions from the simulated proton data. The two reconstruction algorithms presently employed are being characterized in terms of their noise amplification factors, the minimum number of views required for meaningful reconstruction, and possible artifacts.

Technology Transfer

LCF Heat Therapy for Cancer

Dr. Phillip Day, Univ. of New Mexico School of Medicine, has prepared the following tabulation on spontaneous animal tumors treated with LCF heating in collaboration with LASL:

TABLE XIII-II

RESPONSE OF SPONTANEOUSLY OCCURRING NEOPLASMS TO LCF HYPERTHERMIA

Neoplasm	No. of Cases	Results S	TR	R	U
Squamous Cell Carcinoma	5	1	4	-	-
Mast Cell Sarcoma	4	3	-	-	1[a]
Perianal Adenoma	2	1	-	1	-
Fibrosarcoma	2	-	1	1	-
Basal Cell Sarcoma	1	1	-	-	-
Fibromatosis	1	-	1	-	-
Epulis	1	-	1	-	-
Ameloblastoma	1	-	-	1	-
Chondrosarcoma	1	-	-	1	

S = Satisfactory (regression without regrowth to date—6 to 24 months).
TR = Temporary regression (regression of treated area for 1 to 3 months).
R = Resistant (neoplasm resistant to treatment, or developed resistance after first treatment).
U = Unsatisfactory treatment (no regression).
[a]Severe damage to normal tissue due to improper electrode configuration.

Not included in the tabulation are nine equine sarcoids, eight of which have been in apparent complete regression for periods ranging from a few months to more than two years.

The LCF technique has been adopted by the Radiation Oncology Department at the Univ. of Arizona, Arizona Medical Center, and is being used there in combination with radiation therapy on spontaneous animal tumors. Initial results are, as expected, more impressive than treatments with heat alone. Therapists at the Univ. of Arizona also feel that the results that they are seeing are more beneficial than radiation therapy alone would be, but they do not have radiation controls at this date. Drawings for improved control circuitry have been supplied recently to the Univ. of Arizona group by LASL, and collaboration continues at a modest level between the two groups.

Organ Preservation Studies

Tissue-warming techniques that are similar to the LCF method for heating tumor tissue are being applied to the problem of rapid, uniform warming of frozen organs.

Advanced Accelerator Development

Development continues on an array of alternating phase-focused (APF) linac structures. A more elaborate computer simulation code has been prepared which accommodates particle dynamics studies in the six-dimensional phase space, includes all significant coupling terms, and has provisions for space-charge forces. The mechanical design of a model of the APF structure has been conceived which has all the features necessary to support cavity field measurements on a number of APF structures.

Plans to incorporate a microprocessor into the data-collection process for the bead perturbation (field) measurement are well under way. The resulting system should produce quality data at high speed in a format easily interpreted by the user.

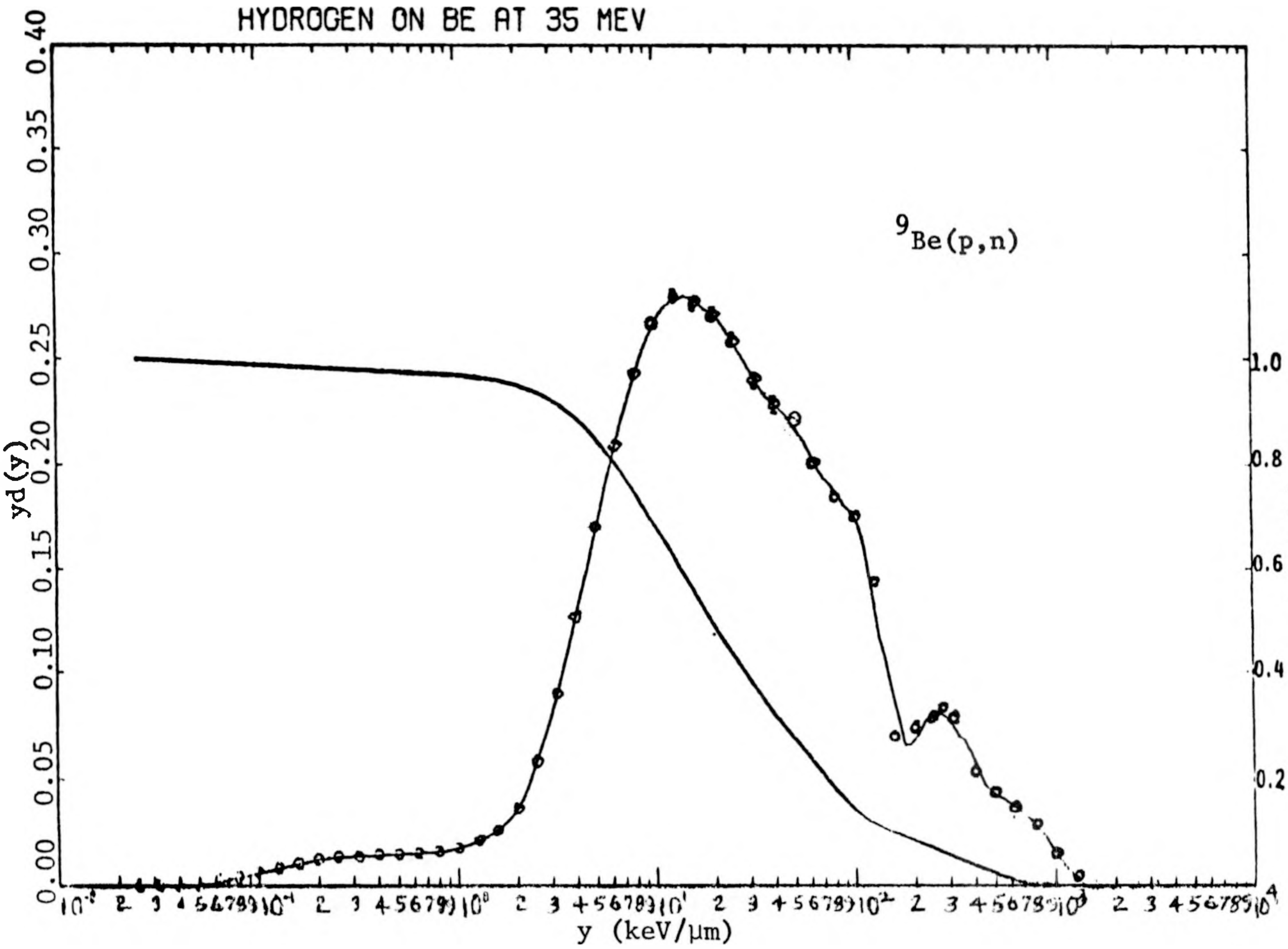

Fig. XIII-5.
Microdosimetric distribution of hydrogen on beryllium at 35 MeV. The circles are the differential dose per logarithm interval of lineal energy, yd(y) vs lineal energy, y. The solid line with no symbols is the fraction of the dose in excess of a given lineal energy, 1 - D(y), vs lineal energy.

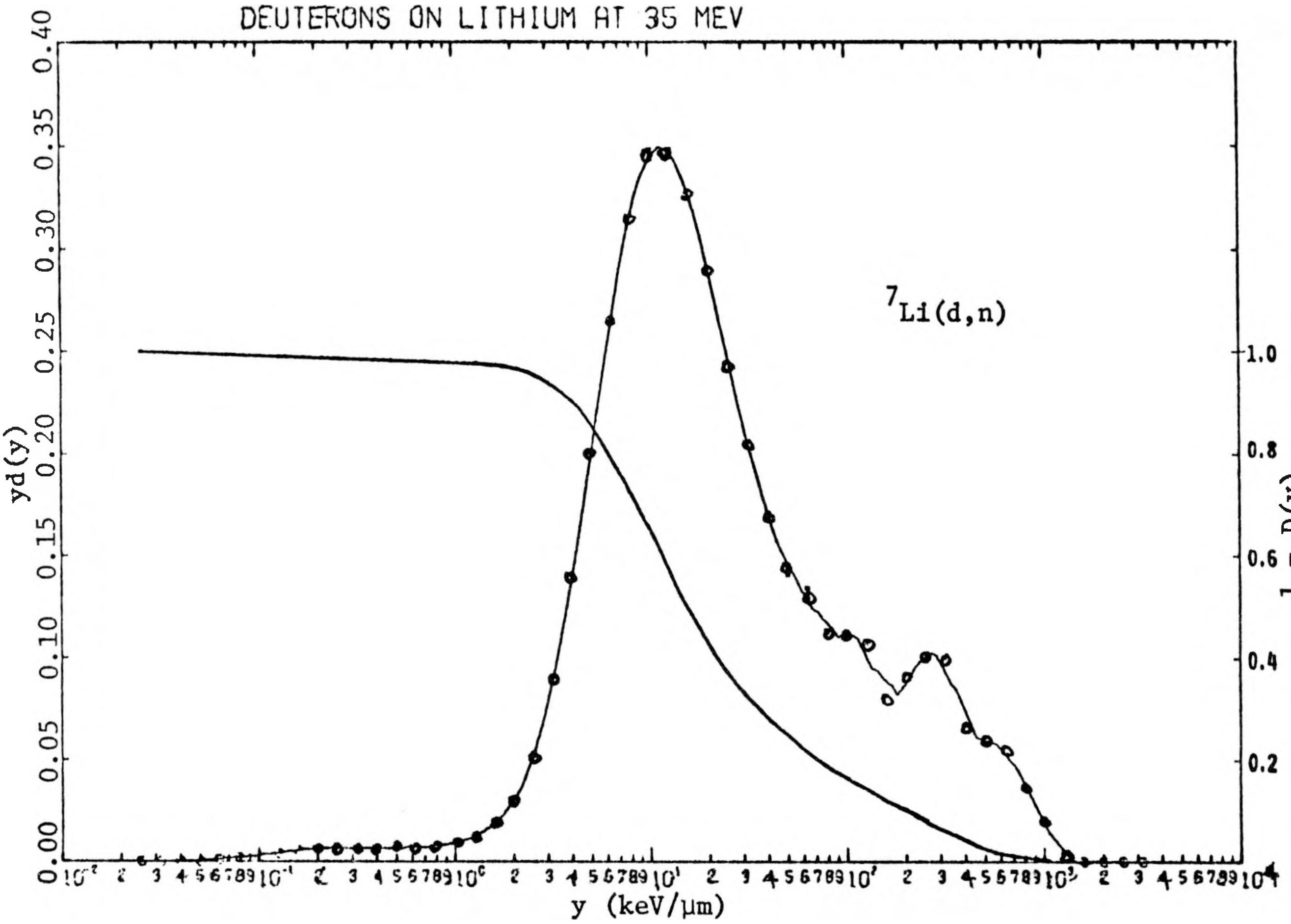

Fig. XIII-6.
Microdosimetric distribution of dueterons on lithium at 35 MeV. The circles are the differential dose per logarithm interval of lineal energy, yd(y) vs lineal energy, y. The solid line with no symbols is the fraction of the dose in excess of a given lineal energy, 1 - D(y), vs lineal energy.

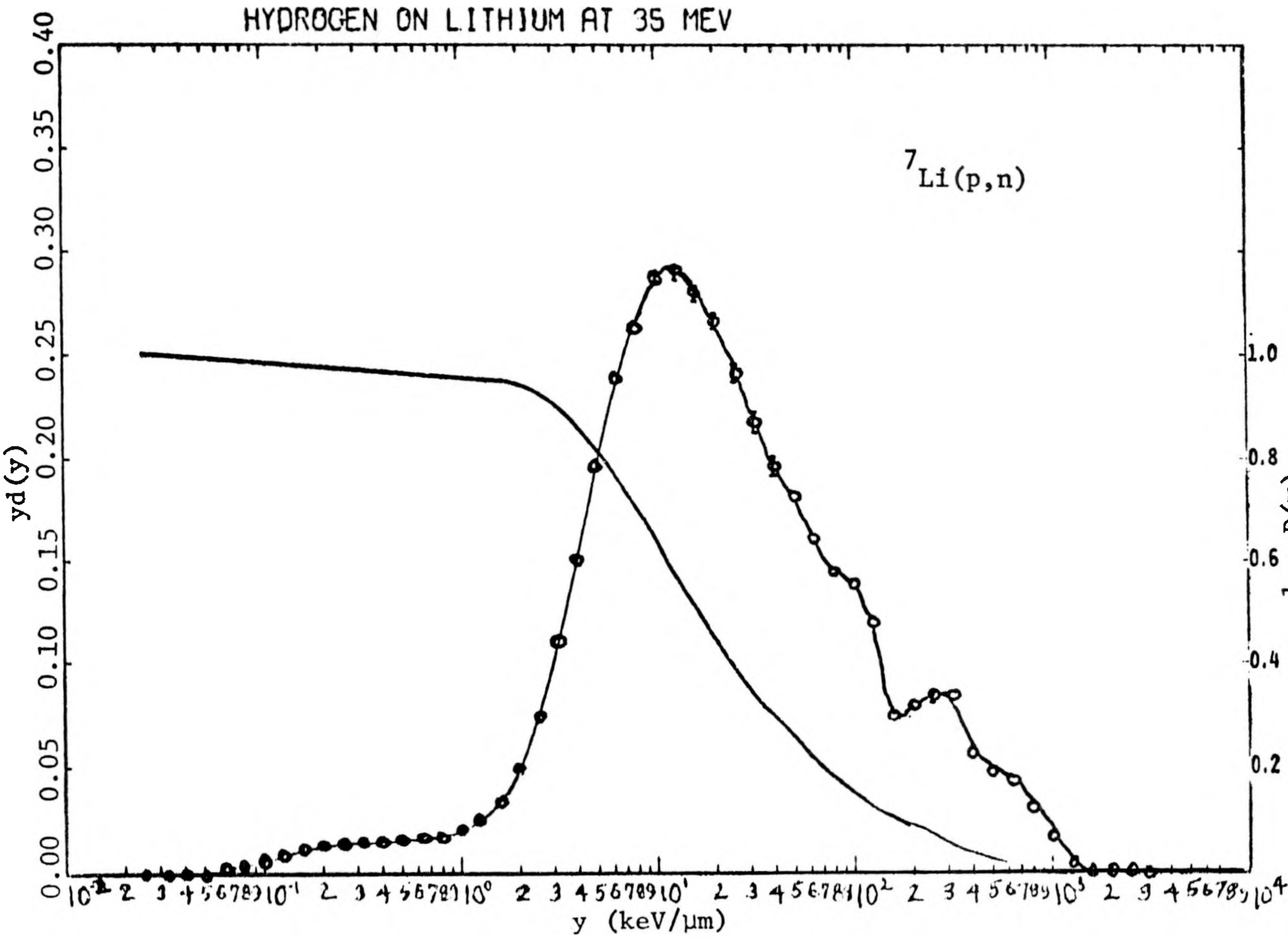

Fig. XIII-7.
Microdosimetric distribution of hydrogen on lithium at 35 MeV. The circles are the differential dose per logarithm interval of lineal energy, yd(y) vs lineal energy, y. The solid line with no symbols is the fraction of the dose in excess of a given lineal energy, 1 - D(y), vs lineal energy.

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XIV. MANAGEMENT

Effective January 1, 1976, a new group was formed and designated MP-13, Beam Line Development Group. This group will develop the initial beam-tuning and monitoring procedures for primary beam lines. The development of secondary beam lines will be shared with Groups MP-7 and MP-3. Group MP-13 will concentrate on beam line physics, instrumentation, and magnet engineering developments.

Budget and Personnel Levels

The ERDA financial plan for FY-76 authorizing programmatic budget allocation is not expected until late in February 1976. Barring unforeseen difficulties, the LAMPF operations budget should be $18.5M.

Total operating costs to date have exceeded the budget forecast by $50k, or ~0.1%. About 80% of the fiscal year capital equipment allocation has been obligated or costed. The average number of full-time equivalent employees chargeable to medium-energy-physics funding is 351, essentially as forecast.

Safety

Radiological Safety

Close control of the radiological safety aspects of work on the accelerator and in the experimental areas continued. Individual as well as total man-rem exposures were maintained at acceptable levels. Excluding crafts workers, 277 LAMPF-associated personnel received 45.3 man-rem during October, November, and December. The maximum individual exposure was 1.6 rem. Crafts personnel were not included in this quarter's figure because many received exposures at areas other than LAMPF.

Thirty-five operational plans for work involving radiation were submitted this quarter.

A radiological safety procedure was prepared which specified responsibilities of crafts workers and LAMPF Engineering and Health Physics personnel in planning and performing construction work.

The LAMPF Radiological Safety Procedures are being revised and updated.

Electrical Safety

Electrical Safety Committee inspection teams investigated the overall status of electrical safety at LAMPF. The purpose was to identify equipment and maintenance procedures and personnel practices that could present electrical hazards. These investigations revealed numerous minor deficiencies (e.g.: frayed cables, power cables lying on the floor), and lists of these were forwarded to the appropriate groups for correction. Several items were identified that require further study by the Committee; they include interlock design features on ion source development equipment and power supplies.

Fire Protection

An ad hoc committee was formed to review the status of fire and smoke protective facilities for the accelerator and experimental areas. The Committee made several recommendations, the most significant of which included providing automatic closure of the doors between the 805 sectors, sealing certain fire and smoke passageways, and providing a fire alarm annunciation system in the CCR. The recommendations were reviewed and approved by the LAMPF Safety Committee.

Safety Analysis

Work began on two types of safety analysis. Both employ parts of the new ERDA-wide MORT (Management Oversight and Risk Tree) safety program. The *Master Priority Safety Problem List* is a method which should help identify major problem areas or subjects. All group leaders and other responsible people throughout LAMPF are being interviewed currently. From these interviews, a report covering potential personnel and equipment safety problems will be prepared. The *MORT Occupancy-Use Readiness Tree* is being used to analyze the Merrimac remote-handling system as a means to help ensure that the process is operationally ready. By using the formal analysis process (objective tree), oversights and omissions are less likely to occur. The analysis in its present form will be completed soon.

Safety Committee Meetings

The following safety committee meetings were held during the quarter, in addition to those mentioned above:

LAMPF Safety Committee (2): Major topics discussed were lock and tag procedures, personnel radiation exposures, scheduling of division-wide safety meetings, adherence to safety rules, fire protection, and electrical safety.

Group Safety Officers Committee (2): Principal items covered were their inspections and reports, division and group safety meetings, storage space, walking and working surfaces, bicycle maintenance, and adherence to safety rules.

Experimental Areas Safety Committee: Primary items discussed were experimental area alarm systems, ladders and stairway problems, gas-bottle storage racks, vehicle parking, and methods to improve crane operations.

LAMPF Hydrogen and Cryogenic Safety Committee: The Committee met to review Exp. 90, which can use hydrogen, ^{3}He, or tritium as a target gas. The Committee made specific recommendations relating to pressure testing, documented stress analyses, pressure-relieving devices, a proper enclosure and ventilation system for the target equipment, and operating procedures.

Training

One division-wide safety meeting was held this quarter. After a brief reminder of current safety topics, a formal talk on "Radiation in Perspective" was presented. The talk covered the various types of radiations at LAMPF, their discoveries and how they were named, their properties and biological effects, and methods for minimizing the biological hazards.

Safety Bulletin

A LAMPF Health and Safety Bulletin was issued to all LAMPF-associated personnel. It discussed disposal of radioactive material, fire and evacuation alarms, locations of first-aid kits, working alone regulations, and site tours.

Accidents

Twelve accidents resulting in injuries were reported this quarter. These injuries were minor and consisted of lacerations, sprains, abrasions, and foreign bodies in the eye. None resulted in any significant loss-of-work time.

Program Advisory Committee

The main body of the PAC met at LASL on January 15-18, 1976 to hear new proposals, to review the old, and to establish priorities. Twenty-eight new proposals were heard with approval granted to fifteen. Two of the fifteen did not receive beam time allocations. Five deferred and resubmitted proposals were also approved.

The PAC is composed of the following members, with Louis Rosen serving as Chairman, D. E. Nagle, Alternate Chairman, and D. R. F. Cochran, Secretary:

Stephen L. Adler	Ira L. Morgan
George I. Bell	Raymond K. Sheline
Robert L. Burman	Robert T. Siegel
George A. Cowan	Herbert M. Steiner
Gerald T. Garvey	Anthony Turkevich
Lee Grodzins	Erich W. Vogt
Bernard G. Harvey	John D. Walecka
Ernest M. Henley	Joseph Weneser
John R. Huizenga	

D. F. Measday, W. E. Powers, M.D., T. A. Tombrello, Gerhart Friedlander, Isaac Halpern, J. M. Eisenberg, and H. E. Frauenfelder completed their terms as of January 1976. Their contributions to the LAMPF effort are greatly appreciated.

Sixteen nuclear physics experiments and three accelerator development experiments have been completed at LAMPF. Schedules for the coming year are being prepared, based on the priorities recommended by the PAC.

The following proposals were approved for beam time, in accordance with the recommendations of the PAC:

154 "Elastic Scattering of π^+ and π^- from the Helium Isotopes"
J. S. McCarthy and R. C. Minehart, Spokesmen

197 "Investigation of the Charged Symmetric Reactions $p + d \rightarrow {}^3He + \pi^0$ and $p + d \rightarrow {}^3H + \pi^+$"
E. V. Hungerford, Spokesman

219 "Double Pion Production in Proton-Proton Scattering"
P. R. Bevington, Spokesman

231 "Selectivity in π^+ vs π^- Inelastic Excitation of Odd-A Nuclei"
W. J. Braithwaite and C. F. Moore, Spokesmen

240 "Isotope and Isotone Shifts in the $1f_{7/2}$ Shell"
E. B. Shera and H. D. Wohlfahrt, Spokesmen

243 **"Recoil Studies of Deep Spallation and Fragmentation Products from the Interaction of 800 MeV Protons with Heavy Elements"**
N. T. Porile, Spokesman

245 **"Study of the (π^-,n) and $(\pi,\pi p)$ Reactions in $^{3,4}He$ and Heavier Nuclei by Detecting Recoiling Tritons or Deuterons"**
J. Källne and H. A. Thiessen, Spokesmen

246 **"Studies of π^+ Scattering at 50 MeV from Light Nuclei"**
R. A. Eisenstein, Spokesman

247 **"Distributions of Products from Interactions of Stopped π^- with Several Medium- and Heavy-Mass Nuclei"**
C. J. Orth, Spokesman

249 **"The (p,π^+) Reaction on ^4He with 800 MeV Protons"**
R. Ridge and C. A. Whitten, Jr., Spokesmen

251 **"Neutron Irradiation of Copper Tensile Specimens"**
J. B. Mitchell and D. M. Parkin, Spokesmen

253 **"Neutron Irradiation of Metal Samples for Use in Positron Annihilation Studies of Defects"**
A. N. Goland and D. M. Parkin, Spokesmen

254 **"Feasibility Study for the Measurement of the Inelastic Neutrino Scattering Cross Section in ^{39}K"**
E. L. Fireman, Spokesman

255 **"Measurement of $\sigma(\theta)$ for n-p Elastic Scattering at 460 MeV"**
L. C. Northcliffe, Spokesman

262 **"Test of Isospin Invariance in the Reaction $np \rightarrow d\pi^0$"**
B. E. Bonner, Spokesman

263 **"Measurement of the Energy and Angular Variation of the np Charge Exchange Cross Section"**
B. E. Bonner, Spokesman

264 **"Measurement of the Energy Variation of the nD Elastic Differential Cross Section Near 180°"**
B. E. Bonner, Spokesman

265 **"Study of Prompt Nuclear De-excitation Gamma Rays from Pion Interactions with $^{6,7}Li$ and ^{12}C"**
C. L. Morris and W. J. Braithwaite, Spokesmen

266 **"Trapping of Positive Muons at Defects in Metals"**
W. B. Gauster, Spokesman

267 **"Preparation of Radioisotopes for Medicine and the Physical Sciences Using the LAMPF Isotope Production Facility"**
H. A. O'Brien, Jr., Spokesman

268 **"Measurement of the Ground State Hyperfine Structure Interval of the Muonic Helium Atom $(\alpha\mu^- e^-)$"**
P. A. Souder and V. W. Hughes, Spokesmen

The next meeting of the PAC will take place during the week of August 15-21, 1976. New proposals, updates, and added requests for beam time must be submitted by July 2, 1976.

Biomedical Program Advisory Committee (BPAC)

The Biomedical Program Advisory Committee was formed and its first meeting as a separate entity was held at LASL on January 12, 1976. This committee will report its recommendations to the Director of LAMPF. The membership is composed of:

Edward A. Knapp, LASL, Chairman
Max L. M. Boone, M.D., Univ. of Arizona School of Medicine
Edward L. Gillette
Kenneth M. Crowe
Lawrence Lanzl
Paul Todd

The next BPAC meeting has tentatively been scheduled for one day during the week of August 8. Deadline for submission of proposals for beam time is June 25, 1976.

The following proposals were recommended for approval of beam time:

151 "An Investigation of Pion Dosimetry by Passive Particle Detectors"
H. B. Knowles, Spokesman

171 "Study of Negative Pion Beams by Means of Plastic Nuclear Track Detectors"
E. V. Benton, Spokesman

239 "Study of ^{11}C and ^{13}N Production by π^- Irradiation of C, N, O, and Tissue for Radiotherapy Monitoring"
L. F. Mausner and S. S. S. Friedland, Spokesmen

242 "Survival of Synchronized Cultured Human Kidney T-1 Cells Exposed to Stopping Pions and X-Rays at Various Times After Mitosis"
P. Todd, Spokesman

244 "Systems Development for Efficient Utilization of Hi Purity Germanium Mosaic Detectors for Tumor Localization"
A. B. Brill, Spokesman

270 "Therapy Beam Development — Channel Tuning"
M. A. Paciotti, Spokesman

271 "Therapy Beam Development — Dosimetry"
A. Smith, Spokesman

272 "Therapy Beam Development — Microdosimetry"
J. F. Dicello, Spokesman

273 "Therapy Beam Development — LET Measurements"
C. Richman, Spokesman

274 "Pion Radiobiology"
J. Yukas, Spokesman

275 "Pion Clinical Trials"
M. M. Kligerman, Spokesman

LAMPF Users Group, Inc.

Liaison Office

The Ninth LAMPF Users Meeting was held at Los Alamos on November 10-11, 1975. There were 285 registrants for the meeting.

The meeting was opened with a welcome by LASL Director Harold M. Agnew, followed by the LAMPF Status Report by Louis Rosen, Director of LAMPF. Donald C. Hagerman (LASL) gave a report on the status of the accelerator, and Lewis E. Agnew (LASL) reported on the status of the experimental areas. The annual report was given by Chairman of the Board of Directors Herbert L. Anderson of the Univ. of Chicago. The election results of officers on the Board of Directors was given by Chairman of the Nominating Committee Mark J. Jakobson, Univ. of Montana. The officers for 1976 and their terms of office are as follows:

Chairman: David A. Lind, Univ. of Colorado (two-year term, first year to be served as Chairman)
Chairman-Elect: Harvey B. Willard, Case Western Reserve Univ. (three-year term, second year to be served as Chairman)
Board Members: Lewis E. Agnew, LASL (one year remaining of a two-year term); John C. Allred, Univ. of Houston (one year remaining of a two-year term); Herbert L. Anderson, Univ. of Chicago (one-year term as past Chairman); Barry M. Preedom, Univ. of South Carolina (two-year term); and Paul Todd, Pennsylvania State Univ. (two-year term)
Secretary-Treasurer: Donald R.F. Cochran, LASL (appointed office)

The meeting featured addresses by Luis W. Alvarez, LBL, "Scientific Detective Work"; Daniel R. Miller, Acting Director of Physical Research, ERDA, "The ERDA Approach to Nuclear Research"; Edward C. Creutz, Assistant Director for Mathematics and Physical Sciences and Engineering, NSF, "National Science Foundation Support of Nuclear Science"; Stanley Brodsky, SLAC, "The Impact of Quantum Electrodynamics"; and William Bertozzi, MIT, "Inelastic Electron Scattering; Nuclear Structure."

The following reports on results of research at LAMPF were given: "Chemical Effects Accompanying Muon Capture; Survey and Recent Experimental Results," Robert A. Naumann, Princeton Univ., and Jere D. Knight, LASL; "Human Pion Radiobiology," Morton M. Kligerman, M.D., Univ. of New Mexico Cancer Research and Treatment Center, and LASL; "Pion Nuclear Total Cross Sections," Martin Cooper, LASL; and "Direct Lepton Production," Richard F. Mischke, LASL.

All LAMPF Working Groups held meetings on November 11.

Board of Directors and Technical Advisory Panel

The Board of Directors and Technical Advisory Panel met twice during this report period on November 12, 1975, and January 13, 1976. Summaries of the minutes of these meetings are given below:

Board of Directors Meeting, November 12, 1975. Chairman Herbert L. Anderson called the meeting to order. The date for the Tenth LAMPF Users meeting is November 8-9, 1976.

The Board made nominations for the Program Advisory Committee to the LAMPF Director.

Chairman Anderson reported on the LAMPF Policy Board meeting (LPB) held on November 11, 1975, and the concern about the LAMPF budget as it will emerge from Congress. The Board agreed with the suggestions of the LPB that users be contacted and urged to write letters to key congressmen, committeemen, and agency heads concerning the LAMPF appropriations.

There was a discussion of the fund drive being held by LASL Director Harold M. Agnew for the construction of a University House at LASL. Present plans call for meeting rooms, recreation rooms, and a reading library, but no sleeping quarters. The site will be close to the new National Resources Study Center. It is expected that the LAMPF users will play an active role in the fund drive. It was agreed that the LAMPF Users Group should support this effort since the idea originated with the Board of Directors, and LAMPF visitors will be the largest users of such a facility.

The Board discussed what could be done to improve the quality of life for students and faculty visiting LAMPF for extended periods. It was recommended that a member of the MP-Division staff be appointed as an ombudsman to be responsible for establishing more of a university atmosphere for students at LAMPF by promoting seminars, classes, and general exchange between LASL staff, students, and visiting faculty members.

Medical insurance for LAMPF users who are not covered by their home institutions received much discussion. The LAMPF Users Group will actively pursue, through LASL and private sectors, the proper coverage at an affordable price for users. Louis Rosen made several proposals, one of which the Board urges MP Division to pursue: Budget for ERDA funds to be transferred to the LAMPF Users Group, Inc., to cover all costs for medical insurance for students with no other coverage.

Hillard H. Howard (LASL) explained that the Zia taxi service is now available to users through the use of tickets authorized by the user at the time of usage. The cost is charged against the user account (G or U) on a monthly basis. The LAMPF Visitors Center dispenses the tickets.

TAP Meeting, November 12, 1975. The first order of business was to hear reports from the Working Group representatives:

Allen Goland (BNL) reported for the Radiation Damage Working Group and stated that the RADIP channel is ready for 100-μA protons. This facility represents LASL's first effort in the field of radiation damage on a large scale. It is hoped to simulate fission reactor damage and fusion reactor damage. Recently, the idea of using the proton beam for fission and fusion reactor damage studies was presented by Louis Rosen. Calculations are now under way and show some promise.

A report on the Muon Working Group was given by Felix Boehm (California Inst. of Tech.). Magnets are being installed in the east leg of the SMC and measurements will be made on spot size, contamination, and shielding. It is felt that there needs to be some type of "exotic" muon channel at LAMPF since the east beam will not be pure enough for some experiments. Long-range plans call for the development of a new channel.

Bill Bonner (LASL) reported for the Nucleon Physics Laboratory (NPL) Working Group. The Working Group heard a report from Hillard Howard on Lines B and EPB. One area of concern is the radiation levels. It was recommended that the beam in Line B be shut off whenever the LD_2 target is inserted or removed, thereby reducing unnecessary irradiation of the target flanges and the cave. The NPL Working Group also heard a report from Richard Bentley (LASL) on chopped beam operation, the effect of which should be studied by the EPB experimenters. It is hoped that the average intensity could be kept the same.

Richard J. Sutter (BNL), substituting for Robert E. Chrien (BNL), reported for the HRS Working Group. Work on mounting the dipoles will begin in December; the magnetic field work is about finished; the field integral at constant radius is good to 1 part in 10^4 which gives an expected resolution of $\pm 10^{-4}$. Magnet erection will be closely monitored, and NMR measurements made before and after. Area C will be ready to accept beam in the spring. The first round of experiments needs only low resolution; the second round will need 100- to 200-keV resolution, which should be ready in the fall. There is need for additional MP-1 work on the data-acquisition program Q, especially buffering data in the MBD. The shield door is still an economic problem.

The EPICS Working Group report was given by Robert A. Eisenstein (Carnegie-Mellon Univ.). The channel is assembled and working; the particle tests show the channel meets the specifications of 2 parts in 10^4; separator work is continuing. There are shielding problems that will require some rewiring and special design for incorporation of the taut-wire systems. The spectrometer has been delayed until completion of the channel; the schedule now calls for erection of the spectrometer to begin in mid-July.

Paul Todd reported for the Biomedical Working Group, stating that the shutdown work included some shielding and magnet movement in the main beam line. The pion channel is now complete, including the helium bags and ion chamber and their gas systems. The momentum slits can be set by remote control; the computer-control and magnet-control systems are such that the channel can be tuned for the desired momentum and momentum bite from the control room. The liquid range shifter, which will allow two methods of range control (wedge and liquid), has been constructed but not tested with the liquid. Analysis of previous data shows that the dynamics of the channel are now understood. Future developments include a good model for distribution in phase space, folding in biological factors in the dose calculations (bone, air, etc.), and having a "swept" beam capability. The computerized control of treatment planning and control is still to be done. The stopping pion visualization work is being done.

W. Kenneth McFarlane (Temple Univ.) reported for the P^3 Working Group. The channel is ready for beam, but the tuning of the channel is a problem. The beam momentum is apparently 2 to 3% lower than predicted, and there may be a magnet calibration problem. A request was made that the LAMPF Scheduling Committee not charge P^3 experiments if the time is used to develop a tune for the channel which will be generally useful and documented for other users; this type of approach would be better than a full-blown tuneup exercise.

Robert A. Naumann (Princeton Univ.) reported for the Nuclear Chemistry Working Group, stating that the counting room systems are about ready, the pneumatic tube rabbit system is being tested, and there are no major problems to be reported.

The Neutrino Working Group report was given by Peter Nemethy (Yale Univ.). The University of California-Irvine group reported on the direct measurement of the neutron flux at Berkeley, which agreed to within 30% (low) of the Monte Carlo calculations. The BNL group reported that there is still no explanation of the solar neutrino anomaly. The schedule is the same as that proposed at the March TAP meeting, but moved back by the Great Shutdown. Background studies will be made during the spring at low-intensity operation. In late spring or early summer, the final shielding will be placed. Neutrino experiments will probably begin in December 1976.

Michael Saltmarsh (Hollifield National Lab.), reporting for the LEP Working Group, stated that the status of the channel looks good and will be ready for first beam. Grounding and climate control in the shack remain chronic problems. There is still a need for an operation handbook for users. There are two new major pieces of equipment being constructed: the bicentennial magnet spectrometer and the π^0 spectrometer. A second low-energy pion channel is needed. (The New Facilities Subcommittee report deals with this in detail.) There is a need for documentation and modification of existing data-acquisition programs for general use.

Harold S. Butler (LASL) met with the TAP to report on the Computer Working Group and discuss computer problems. The major problem is with maintenance for users' computers. The ERDA contract with LASL prohibits MP Division from paying for the maintenance of non-LASL computers. The user must be charged through his university account for costs of the maintenance. Since this was discovered late in the fiscal year, it puts a real burden on users' budgets because they were not expecting to pay for the maintenance, and most groups do not have liquid funds to cover these costs.

After discussion, it was recommended by the TAP that steps should be taken, if necessary at users' expense, to ensure that on-line experiments receive the highest priority with regard to 24-h, 7-day/week computer maintenance. It was requested that Rosen ask for some variance in ERDA's contract with LASL to allow maintenance of users' computers on scheduled experiments for at least this fiscal year, or that Rosen give support for budget supplements to users' contracts to cover this cost.

Thomas M. Putnam (LASL) reported on storage space for users' equipment. The biggest problem is with large items and combustibles which cannot be stored in corridors in the sector building, because of safety regulations. Instead, valuable lab space is being used for storage. The earliest there will be additional storage is next summer, although a search is under way for additional vans. The best short-term solution is for users to buy and bring their own portable storage sheds.

Stanley E. Sobottka (Univ. of Virginia) presented the report of the New Facilities Subcommittee. The discussion dealt mainly with the advisability of including a new target cell with the Area-A north-side expansion, and the need for a new low-energy pion channel.

The TAP recommends that when the cost and design studies for a new low-energy pion channel are done, a new muon channel and staging area north of Area A should be included. The TAP will address the priority of this project after more study.

McFarlane reported on the LEEP Subcommittee meeting. There appears to be a 5% shortage of NIM and CAMAC equipment and we will be short one computer when Area A comes on. The LAMPF Scheduling Committee will have to resolve the computer problem. The TAP adopted the recommendation that the responsibility of MP-1 for user support in computer software be defined. There should be a formal mechanism for user input to computer software decision, either through a TAP subcommittee or through the proposal mechanism. In addition, the TAP deplores the growing tendency to separate equipment pools inside LAMPF. The maximum amount of LAMPF funds should go to expanding a common equipment pool. In view of the fact that equipment will fall short of the experimenters' needs when Area A comes on, all equipment of general use within the lab should be available to scheduled experiments at that time and in the future, and not be isolated in separate pools accessible only to a few users. It is suggested that a new internal LAMPF committee be charged with the responsibility of assuming the task of providing the greatest possible amount of equipment in a common pool for use by all concerned in meeting the lab's mission. The TAP's own subcommittee has the responsibility of studying the inclusion of outside users' equipment in the LEEP.

Board of Directors Meeting, January 13, 1976. The first item of business after Chairman David A. Lind called the meeting to order was to appoint Donald R.F. Cochran (LASL) as the Secretary/Treasurer for 1976, and Hillard H. Howard (LASL) was appointed Liaison Officer for 1976. The following appointments were made to the TAP:

- Albert A. Caretto (Carnegie-Mellon Univ.), Nuclear Chemistry
- Edward R. Flynn (LASL), HRS
- George Glass (Texas A&M Univ.), NPL
- Robert J. Peterson (Univ. of Colorado), EPICS (one-year term to complete R. A. Eisenstein's two-year term)
- Richard J. Powers (California Inst. of Tech.), Muon Experiments
- Bill W. Mayes, II (Univ. of Houston), Experimental Facilities
- Peter Nemethy (Yale Univ.), Neutrino Facilities

Paul Todd is now serving a dual role as Board member and TAP representative. He will ask the Biomedical Working Group for a replacement nominee on the TAP. The date of the next TAP meeting was scheduled for July 27, 1976.

The Board appointed Raymond Kunselman (Univ. of Wyoming, currently at LASL) to serve as the LAMPF Users Group Safety Representative.

A list of names was prepared from which to form a nominating committee for the next general election and submitted to Vernon W. Hughes (Yale Univ.), Chairman of the 1976 Nominating Committee.

After a discussion of the 1976 annual meeting, the Board made appointments for various responsibilities.

The Board appointed J. Allred, Harvey B. Willard, and H. Howard to a committee to establish the duties of a "Dean of Students" at LAMPF. In the interim, they are to begin fulfilling that role by instituting short courses and a lecture/seminar series. Progress will be reported to the Board.

H. M. Agnew asked the Board to consider the makeup and duties of the LAMPF Policy Board, which reports to him, suggesting that some changes should be made and soliciting recommendations from the LAMPF Users Group, Inc. Harvey Willard was appointed to begin discourse with H. Agnew and present his findings to the Users Board of Directors as a base for possible recommendations to the Director of LASL.

TAP Meeting, January 13, 1976. The TAP heard from several members of the LAMPF management concerning various programs at LAMPF: LAMPF Director L. Rosen reported on the FY-76 and FY-76A budgets; D. Hagerman reported on the status of the accelerator and proposed operating schedule; L. Agnew reported on the experimental areas; H. A. Thiessen (LASL) reported on the HRS and EPICS channels; and D. Cochran reported on mounting new experiments and the neutrino facilities. H. Butler reported on the resolution of the computer maintenance problem, which was presented at the November meeting, and discussed other aspects of computer support for users. His report included the information that a maintenance contract for non-LASL computers, was arranged with the maintenance charges to be made against the appropriate users' accounts. After hearing these reports, the TAP discussed the main points to be considered in recommending the priority for expenditures. The following recommendations were made:

First Priority: Accelerator improvements should be made as needed to achieve reliable 100-μA operation.

Second Priority: Shutdowns are disruptive and should be avoided whenever possible since "machines are made to run."

Third Priority: The EPICS spectrometer should be brought into operation along the lines and according to the timetable proposed by Thiessen, giving him whatever budget flexibility that may develop.

Fourth Priority: The neutrino program should complete the next step in incremental shielding needed for the neutron background studies.

Fifth Priority: New experiments should be mounted as presently scheduled by the LAMPF Scheduling Committee.

Sixth Priority: The SMC-East studies should be continued as proposed by L. Agnew

Seventh Priority: A polarized target should be built within MP Division.

Eighth Priority: Funds for the purchase of health insurance for users at LAMPF should be provided where it is impossible for university contractors to accomplish coverage.

Ninth Priority: G-accounts should continue to be provided to approved experiments if funds are available.

Tenth Priority: Support should be given to user software needs. Neglect of the small-computer owners is evident.

The TAP supports the idea that some time be made available for exploratory experiments.

The TAP recommends that if a shutdown is necessary, the month of September is preferred.

The proceedings of the Ninth LAMPF Users Group meeting will be sent out as a part of the January 1976 newsletter, which has gone to the printers. The Newsletter will be mailed in February.

The second notice for 1976 membership renewals were mailed in January. The minutes of both the November 12, 1975, and the January 13, 1976, TAP and Board of Directors meetings were prepared and copies sent to members.

LAMPF Visitors Center

In the previous quarter, it was reported that leases had been obtained for 100 apartments owned by the Los Alamos Medical Center (LAMC). The number of apartments actually obtained is 11, and, unfortunately, the housing shortage still exists and remains a problem of major concern to LASL officials. These apartments have had an occupancy rate of 57% for the current report period. Reservations are now being made for the summer months, based on the scheduling of beam time for experiments, for the 20 LASL-operated kitchenette apartments and the other apartments which are leased by LASL for assignment on a priority basis.

In addition to visitors on conducted tours, about 200 "casual" visitors, including representatives from 9 foreign countries, were received at MP Division. There were 176 visitors at LAMPF to participate in the research programs, with 97 visitors received and 82 checked out during this report period. In Appendix A are listed the research guests at LAMPF for this quarter.

Meetings and Tours

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

- 11/ 4 – Legislators from Western States
- 11/ 4 – Attendees of ERDA Statistical Symposium
- 11/ 5 – Naval officers, 8th Naval Dist.
- 11/ 6 – Army officers, Ft. Bliss, TX
- 11/ 8 – Texas Boy Scouts
- 11/14 – Tucson, AZ High School Students
- 11/14 – Univ. of New Mexico Radiopharmacy Students
- 11/17 – Students of the St. Vincent Hospital School of Practical Nursing
- 11/18 – Flowing Wells, AZ High School Students
- 11/21 – Oklahoma State Univ. Radiation and Nuclear Technology Students
- 11/22 – New Mexico Academy of General Dentistry
- 11/24 – Univ. of Colorado Nuclear Engineering Students
- 12/ 1 – Eastern New Mexico Graduating Class of Nuclear Engineers
- 12/ 5 – Univ. of New Mexico Radiobiology Students
- 12/ 6 – LASL Family Tour
- 12/20 – LASL Family Tour
- 1/ 3 – LASL Family Tour
- 1/23 – Fusion Power Coordinating Committee

APPENDIX A

RESEARCH GUESTS AT LAMPF DURING PERIOD NOVEMBER 1, 1975 - JANUARY 31, 1976

John C. Allred .... Univ. of Houston
James F. Amann .... Carnegie-Mellon Univ.
Bryon D. Anderson Case Western Reserve Univ.
Herbert Anderson .... Univ. of Chicago
Wendell A. Anderson ..... UNM Cancer Center
George W. Atkinson .. UNM School of Medicine
Leonard B. Auerbach .... Temple Univ.
Helmut W. Baer .. Case Western Reserve Univ.
Thomas J. Baird .... Rensselaer Poly. Inst.
Howard I. Balshem .... Temple Univ.
James R. Barbour .... Florida A&M Univ.
Robert L. Barnard .... UNM Cancer Center
Philip R. Bevington Case Western Reserve Univ.
Christopher W. Bjork .... Univ. of Wyoming
Gary S. Blanpied .... Univ. of Texas
Felix Boehm .... California Inst. of Tech.
Joseph E. Bolger .... Univ. of Texas
Charles A. Bordner .... Colorado Coll.
Wilfred J. Braithwaite .... Univ. of Texas
Hubert Brandle .... UC, Los Angeles
James A. Buchanan .... Rice Univ.
Joseph J. Burgerjon .... TRIUMF
George Burleson .... New Mexico State Univ.
Roger D. Carlini .... Univ. of New Mexico
Donald E. Casperson .... Yale Univ.
Constantine Cassapakis ... Univ. of New Mexico
David T. Chiang .... Univ. of Washington
John M. Clement .... Rice Univ.
Robert K. Cole .... UC, Los Angeles
Josefino C. Comiso .... Univ. of Virginia
Dominic C. Constantino .... Yale Univ.
Joseph N. Craig .... Carnegie-Mellon Univ.
Thomas W. Crane .... Yale Univ.
Arthur B. Denison .... Univ. of Wyoming
Satish Dhawan .... Yale Univ.
Byron Dieterle .... Univ. of New Mexico
Joey B. Donahue .... Univ. of New Mexico
Mohan Doss .... Carnegie-Mellon Univ.
William H. Dragoset .... Rice Univ.
Steven A. Dytman ...... Carnegie-Mellon Univ.
Patrick O. Egan .... Yale Univ.
Robert M. Eisberg .... UC, Santa Barbara
Robert A. Eisenstein .... Carnegie-Mellon Univ.
Michael L. Evans .... Texas A&M Univ.
Yuriy K. Fatkulin ... Inst. for Nucl. Res., USSR
Richard D. Felder .... Rice Univ.
John C. Fong .... UC, Los Angeles
Robert Fong-Tom .... Yale Univ.
Rudolf Frei .... L. Hartmann, Switzerland
Gerhard Fricke .... Univ. of Mainz
Jozica Gabitzsch .... Rice Univ.
Robert J. Gehrke .... Aerojet Nucl. Corp.
David R. Giebink .... Univ. of Texas
Shalev Gilad .... Tel-Aviv Univ.
George Glass .... Texas A&M Univ.
Gary A. Glatzmaier ...... Univ. of New Mexico
Paul F. Glodis .... UC, Los Angeles
Robert L. Gluckstern .... Univ. of Maryland
Nancy E. Greene .... Univ. of New Mexico
Steven J. Greene .... Univ. of Colorado
Mark B. Greenfield .... Florida A&M Univ.
Chilton B. Gregory .... Univ. of New Mexico
Robert Lee Hall .... Univ. of Houston
Isaac Halpern .... Univ. of Washington
Richard G. Helmer .... Aeroject Nucl. Corp.
Walter Hensley .... Univ. of Rochester
Virgil L. Highland .... Temple Univ.
John C. Hill .... Iowa State Univ.
Norton O. Hintz .... Univ. of Minnesota
Martha V. Hoehn .... Florida State Univ.
Gerald Hoffman .... Univ. of Texas
Kenneth R. Hogstrom .... Rice Univ.
Vernon W. Hughes .... Yale Univ.
Ed V. Hungerford .... Univ. of Houston
Harvey Israel .... Private consultant
Steve Iversen .... Northwestern Univ.
Mahavir Jain .... Texas A&M Univ.
Mark J. Jakobson .... Univ. of Montana
David A. Jenkins .... Virginia Poly. Inst.
Randolph H. Jeppesen .... Univ. of Montana
Kenneth F. Johnson .... Temple Univ.
Charles A. Kelsey .... UNM Cancer Center
Robert Kenefick .... Texas A&M Univ.
Nicholas S. P. King .... UC, Davis
Thomas R. King .... Univ. of Wyoming
Harrold B. Knowles ... Washington State Univ.
Lynn D. Knutson .... Univ. of Washington
Kenneth Koester .... Univ. of Houston
Thomas Kozlowski .. Brookhaven National Lab.
Kenneth S. Krane .... Oregon State Univ.
Raymond Kunselman .... Univ. of Wyoming
Gary Kyle .... Univ. of Minnesota
Richard G. Lane .... UNM Cancer Center
Phillip M. Lang .... Northwestern Univ.
Chris P. Leavitt .... Univ. of New Mexico
Rodger P. Liljestrand .... Univ. of Texas
M. Stanley Livingston ...... Private consultant
Joseph W. Lo .... Univ. of Houston

Chris E. Long .... Florida A&M Univ.
Daniel Lu .... Yale Univ.
Steven C. Luckstead .. Washington State Univ.
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Isaac I. Rosen .... Univ. of New Mexico
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Mark A. Schardt .... Arizona State Univ.
Carol A. Selheimer .... UNM Cancer Center
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Suzanna E. Willis .... Yale Univ.
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Yoshishige Yamazaki ...... Florida State Univ.
Mary Ann Yates .... Carnegie-Mellon Univ.
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Alex Zehnder .... California Inst. of Tech.
Klaus O. H. Ziock .... Univ. of Virginia
Gisbert zu Putlitz .... Universitat Heidelberg

APPENDIX B

ELECTROMAGNETIC SEPARATION OF SAMPLES OF STABLE ISOTOPES — ERDA'S NUCLEAR SCIENCES SUBPROGRAM

The following information concerning separated isotopes is published at the request of Dr. John L. Burnett, Nuclear Science, Division of Physical Research, USERDA:

> The Nuclear Sciences subprogram of ERDA's Division of Physical Research is responsible for electromagnetic separation (calutrons at ORNL) of samples of stable isotopes. These are available on a loan basis for nondestructive research use from the Research Materials collection. For destructive-type research, samples can be purchased from a sales inventory. For details concerning either mode, contact Mr. Joseph Ratledge, ORNL, (615) 483-6661 (FTS: 850-6661).

As part of planning for future separations, the Nuclear Sciences subprogram is inviting research community input. If you have an unsatisfied requirement for an isotopically separated sample, please write to John L. Burnett, Nuclear Sciences, Division of Physical Research, U. S. Energy Research and Development Administration, Washington, DC, 20545. The request should identify: 1) the isotope desired for sale or loan, 2) the quantity needed, 3) the minimum enrichment required, 4) the time schedule on which this sample is needed, and 5) the scientific motivation behind the request. Since financial and physical resources are limited, long lead times are necessary for separation of isotopic samples.

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