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INFORMAL REPORT

LAMPF Users Handbook

(Preliminary Version)

January 1971

(Revised March 1973)

MASTER

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January 1971

(Revised March 1973)

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FOREWORD

The LAMPF accelerator produced the first 800-MeV beam in June of 1972, and it is planned to mount experimental programs beginning in the summer of 1973. As of this writing, prospective users are invited to submit research proposals. Specific allocation of beam time will be made shortly before the start of the experimental program. This handbook is a short effort to provide the experimenter with the basic information to make a realistic proposal at LAMPF.

The reader will realize that there will be changes -- possibly of a substantial nature -- as our plans for experimental facilities develop over the next two years. We will endeavor to inform all members of the Users Group of the progress of the project and any major changes that might affect experimenters.

This preliminary publication will be revised into a more complete version before the machine is operational. The revised, or "standard" version, of the handbook will have a special format designed for easy access to useful information. It will also have index tabs and be assembled in a binder so that it may be readily amended or expanded. It is realized that the format and contents of this preliminary handbook fall far short of the ideal level. However, it is expected that users will understand that a complete handbook is impossible at this time and that there is considerable value to experimenters in even a preliminary attempt to provide technical specifications. We hope that the obvious shortcomings will be overlooked. Users are always welcome to make direct contact with the LAMPF staff for fuller details.

SITE PLAN

LOS ALAMOS MESON PHYSICS FACILITY

Layout of Site Plan

LAMPF USERS HANDBOOK
(Preliminary Version)

I. THE LAMPF ACCELERATOR

A. Performance Characteristics

The LAMPF (Clinton P. Anderson Meson Physics Facility) accelerator has the following parameters:

Beam energy: 800 MeV, continuously variable
Beam intensities: average current, H^+ = 1 mA
average current, H^- = 100 μ A
(both H^+ and H^- accelerated simultaneously)
macropulse length = 500 or 1000 μ sec*
repetition rate = 120 cps
polarized H^- beam intensity = < .1 μ A (available in 1974)
Beam quality: energy spread = $\pm$ 0.4%
Transverse phase space: $\sim \pi/3$ mrad-cm

Macro duty factor: 6% or 12%*

rf microstructure: 0.25 ns pulses separated by 5 ns.

B. Operations and Schedules

Firm information about the LAMPF operating procedures and running schedule cannot be included in this preliminary version of the Handbook. It is planned that an Operations Office will be established in due course. At that time it will be possible to name the operations staff, the experiment coordinators, and the experimental support personnel.

It is tentatively planned to operate both the H^- and H^+ beams on a 24-hour-a-day 5-day-a-week basis. The various secondary beams in Experimental Area A should be able to accommodate simultaneous independent experiments. Similarly, experiments may be carried out in Areas B and C independently of Area A or each other.

II. RESEARCH PROPOSALS

A. Instructions for Submitting Proposals

Users are requested to follow the format given in the Sample Proposal, which follows on pages 4-9.

Proposals should be mailed to:

Dr. Louis Rosen, Director of LAMPF
Los Alamos Scientific Laboratory
Los Alamos, New Mexico 87544

B. Users Guidelines for LAMPF

This section is a complete verbatim copy of a draft entitled, "Users Guidelines for LAMPF" dated December 1, 1970.

1. Preamble

The Clinton P. Anderson Meson Physics Facility is a National Facility designed and constructed for the United States Atomic Energy Commission by the Los Alamos Scientific Laboratory (LASL) of the University of California. The heart of the Facility is a linear accelerator designed to provide a beam of protons of variable energy up to 800 MeV and average intensity of 1 mA. In accordance with its establishment as a National Facility the LAMPF will be generally available for use by qualified members of the scientific community (see Section 2.a).

The LAMPF provides a new and powerful means for carrying out an extensive program of research over a broad spectrum of scientific interest. Although mainly a tool for the atomic, nuclear, and elementary particle physicist and radiochemist, the machine holds considerable interest for the biologist and solid-state physicist. It has important applications in medicine, in isotope production, in defense science, and in the study of the structure of materials. Comprehensive use of this facility will expand our knowledge of the elementary constituents of matter and will provide new ways to

(Cont'd on p. 10)

*Available in Phase II operation.

RESEARCH PROPOSAL

LOS ALAMOS MESON PHYSICS FACILITY

TITLE OF EXPERIMENT

_____, SPOKESMAN

PARTICIPANTS AND INSTITUTIONS

Date: _____

SUMMARY OF EXPERIMENT

(Please limit to one page)

PROPOSAL INFORMATION

Beam Area:

Secondary Channel (if known):

Beam Requirements:

Type of Particle:

Momentum Range:

Momentum Bite:

Solid Angle:

Spot Size:

Emittance:

Intensity:

Beam Purity:

Target(s):

Primary Beam Requirements (State any requirements on the main accelerator beam, such as energy, intensity, or unusual pulse characteristics):

Running Time Required:

Installation Time Required (no beam):

Tune-up Beam (give intensity and hours needed):

Data Runs (give realistic estimate of hours needed):

Scheduling:

Realistic date when User will have the non-LAMPF apparatus ready:

Give all information on other commitments of research group that may affect scheduling:

Major LAMPF Apparatus Required:

Spectrometer, Magnets, Electronics, Computer

Shielding and Enclosures Required:

Special Services Required (power, water, engineering, shop work, etc.):

Space Required (attach drawing giving layout):

DETAILED STATEMENT OF THE EXPERIMENT

Include: Motivation, objective, relevance to other experiments and to theory, pertinent references, description of experiment and techniques to be used, measurements to be made, data rates and background expected, results and precision looked for, evidence of ability of research team to carry out the experiment, extent of participation of each participant. All proposals should be accompanied by biographies and lists of relevant publications for each participant.

SPECIAL APPARATUS TO BE FABRICATED BY LAMPF (give full description
including sketches and cost estimate):

IDENTIFICATION OF HAZARDS ASSOCIATED WITH THE EXPERIMENTAL APPARATUS
AND PRECAUTIONS TO BE TAKEN:

study a wide range of problems in other areas as well.

It has been intended from its conception that LAMPF should become a facility of national scope and service. It will serve the scientific community best if it is accessible to the widest possible selection of those with the competence to use it well, and will also serve the national interest by helping to keep the Los Alamos Scientific Laboratory viable and responsible to national problems when they arise. Every possible encouragement will be given to those with well-trained minds and good ideas, who can deepen the insight into natural phenomena, to participate in and develop the use of LAMPF.

The following set of proposed guidelines, written as the facility is emerging into reality, is intended to provide a basis for the policies of LAMPF for research in the basic sciences. As experience is gained, it may well be that better procedures will evolve, and changes should then be made.

2. General Information

a. Availability of Facilities. The LAMPF is a National Facility. Use of the facilities will be granted to experimenters on the basis of an evaluation of the scientific merit of the proposed research and of their qualifications. The LAMPF administration will encourage collaboration between its research staff and outside research groups, as well as with those desiring to gain pertinent experience or to improve their competence through cooperation.

In consideration of the fact that the AEC is providing the research facility, each non-LASL user will sign an appropriate AEC Guest Patent Agreement. This agreement recognizes the possible existence of prior agreements he may have with his home institution.

The Director of LASL will endeavor to minimize restrictions on the participation of foreign scientists in the LAMPF research program. Proposals for experiments submitted by foreign scientists which are found acceptable will, in conformity with present regulations, be referred to the AEC for approval prior to scheduling.

In order to realize maximum long-range effectiveness of the facility and to take advantage of

advances in technology, the LAMPF organization will maintain a staff effort to explore and implement improvements of the accelerator and experimental facilities. It is LASL policy that all members of the LAMPF research staff devote roughly 50 percent of their time to the improvement of the facility and to the technical support of the users. Also, at present, it is expected that approximately 50 percent of the LAMPF beam time will be allocated to non-LASL users.

b. Basis for Judging Proposals. The primary basis for accepting or rejecting research requests and assigning beam time shall be the scientific merit as judged by the Director of LAMPF after careful evaluation of the research described in a formal proposal. The main source of advice to the Director of LAMPF will be a qualified committee (Program Advisory Committee, see pp. 11 and 15). In the case of two or more acceptable proposals for essentially similar experiments, an effort will be made by the LAMPF Director to effect a collaborative approach by the groups involved.

c. Charges to Users. Users will normally be expected to provide their own detector systems, special apparatus and associated circuitry, travel and shipping expenses, and salaries and expenses of the participants. Furthermore, users are expected to reimburse the LASL for major computing time and for the design, fabrication, testing, delivery, operation, and maintenance of specialized equipment. Charge rates, including direct expense and distributed overhead costs, will be those currently in effect in the Laboratory and will apply equally to internal LASL groups for the same services.

Approved and scheduled experiments require advance planning and estimates. It is necessary that users work with an Experiment Coordinator (see Section 4.e) to estimate probable expenses, including a reasonable contingency, and arrange a purchase order to cover the estimated expense in advance of their needs.

d. LAMPF Support. Charges for beam time will not be levied. Moreover, users will have access to a considerable pool of equipment and technical services as described in Section 5., "Facilities and Services for Users."

A modest amount of direct support at LASL will be available for experiments assigned beam time.

This support will take the form of an allowance to cover, within budgetary limitations, shop work, the cost of minor stores items and consumables, and machine time at the LASL Central Computing Facility (CCF). The amount of the allowance will be prorated according to the amount of beam time scheduled.

It will be the policy actively to seek and encourage the best ideas and to exploit them to the maximum extent that available funds and effort allow. In the event that existing funds are inadequate to cover the necessary support for experiments deemed meritorious, the LASL administration will support efforts to secure funds from other sources.

3. Organization

a. LAMPF. The LASL-appointed Director of LAMPF has the responsibility for administering the program and carrying out the general policies set forth by the Atomic Energy Commission, the Regents of the University of California, and the Director of LASL. He has the responsibility for decisions on all matters pertaining to operations and scheduling of the facility.

b. The LAMPF Users Group. Although, as specifically stated above (Preamble and 2.a.) the LAMPF experimental facilities are to be generally available to members of the scientific community, an organization of active scientists and engineers with a special interest in LAMPF and, in particular, its research program, was formally established in 1969. This organization, operating under the short title "Users Group" set forth its objectives in its Charter:

"...The purpose of this group is two-fold:

a) To provide a formal channel for the exchange of information between the LAMPF administration and scientists of other laboratories who will utilize this facility for their research.

b) To provide a means for involving scientists and engineers from user groups in specific projects at LAMPF and for offering advice and counsel to the LAMPF management on LAMPF operating policy and facilities.

"Through a wide representation of scientists the group will make known to the LAMPF administration the needs and desires of those scientists actively engaged in research projects. As an example of the relationship between the users community and the LAMPF administration, it is understood that some members of the Program and

Scheduling Committee will be selected from candidates proposed by the Users Group."

Users are involved in the technical aspects of the LAMPF program through the Technical Advisory Panel (TAP). This panel, appointed by the Users Group Executive Committee, was formed "to collaborate with the staff of the LAMPF in devising new experimental facilities and evaluating future developments." A number of Users Working Groups have been established to participate in the task of planning experimental facilities.

Individuals or groups not already members of the "Users Group" and wishing to join or to receive further information about the Group should write to: The Liaison Officer, LAMPF Users Group, Los Alamos Scientific Laboratory, Los Alamos, N.M. 87544.

c. Program Advisory Committee. The LAMPF Program Advisory Committee shall consist of the Director of LAMPF, the Deputy Director of LAMPF, and additional members (not less than nine) appointed by the Director of LAMPF. The function of the Program Advisory Committee shall be to examine research proposals and to recommend acceptance or rejection to the Director of LAMPF. Scientific merit and feasibility will be the primary basis for evaluation of proposals. The Program Advisory Committee will recommend priorities for those found acceptable. If a proposal is rejected, the reasons should be stated in a notice of rejection. Modifications of a proposal may be suggested by the Program Advisory Committee and a revised proposal submitted. Approximately 50 percent of the Program Advisory Committee shall be selected from nominations made by the Users Group Executive Committee. Normally, term of office of the members shall be arranged so that one third (1/3) of the members will be succeeded each year. A member should not serve more than three (3) consecutive years. Factors that will be considered in constituting the Program Advisory Committee include a suitable balance in the representation of the various scientific disciplines to be pursued at LAMPF and a reasonable balance in geographical and institutional representation (i.e., national laboratories, universities, etc.).

The Director of the LAMPF shall serve as Chairman of the Program Advisory Committee. The Chairman will call two or more meetings a year

after LAMPF is operational and at least once each year before then, and will arrange the agenda.

A listing of proposals giving the date received, the title, authors, and a summary of each proposal will be distributed to members of the Users Group. Copies of each proposal will be available in the LAMPF Library for study and copies will be furnished on request. A preliminary processing of each proposal will be carried out by the LAMPF Director's office as described in Section 4.b. All proposals which compete significantly for beam time or LAMPF resources will be submitted to the Program Advisory Committee.

Minutes of all meetings of the Program Advisory Committee will be kept and shall include all recommendations for approval or rejection of the proposal and reasons for such recommendations. The Director of LAMPF will issue to all parties of the proposal a summary of actions which he takes based upon the Program Advisory Committee recommendations.

It is a major objective of the LAMPF administration to provide a sufficient number of independent beam ports so that long waits for beam time will be avoided. In particular it is intended to augment the highly sophisticated secondary beam lines with a number of inexpensive pion and muon beams so that for many experiments there will not be severe competition for beam time. These can then be mounted without traversing the Program Advisory Committee route, if they do not make substantial demands on LAMPF resources.

4. Implementation of Research Proposals

a. The Proposal. The proposal for research at LAMPF should be submitted in writing to the Director of LAMPF. It should indicate the scientific purposes and objectives, a detailed description of the experiment and techniques to be used, an analysis of the expected data rates and backgrounds, an indication of the results and precision expected, an estimate of when the experiment will be ready, an estimate of the running time and beam requirements, and a statement about the necessary auxiliary equipment and support required from LAMPF. A list of experimenters should be provided, together with an indication of the extent of participation of each.

b. Procedures. A schematic Flow Chart for research proposals is given in Fig. 1. Upon

Fig. 11.9.1. LAMPF Research Proposal Flow Chart.

receipt of a proposal the LAMPF organization will carry out a preliminary processing of the proposal to judge its overall practicality. At this point suggestions for revisions may be made on the basis of technicalities, or the proposal may be forwarded to the Program Advisory Committee for its recommendation.

After reaching his decision on the experimental proposal, whether it be acceptance, postponement of action, or rejection, the Director of LAMPF will so inform the experimental group involved by letter. A letter of acceptance will indicate the amount of machine time assigned, the facility support allocated, and the order of priority to regulate the scheduling. A letter of rejection will indicate the reasons for such action and possible modifications that would merit reconsideration of the proposal. Experiments which do not compete significantly for beam time or LAMPF resources may be scheduled by the Director of LAMPF without involving

the Program Advisory Committee.

c. Hot Line. The Director of LAMPF can take it upon himself to bypass the Program Advisory Committee and request immediate scheduling of an experiment he judges to be of overriding importance and timeliness.

d. Experimental Operations. The day-to-day scheduling of experiments will be arranged by the LAMPF Chief of Experimental Operations, appointed by the Director of LAMPF. He will keep the Director informed about scheduling problems, feasibility of the planned layout, state of preparation of the equipment, and other problems that may arise in the course of operating the facility. The Chief of Experimental Operations will be supported by a staff, including the Experiment Coordinators (see 4.e.) and the senior staff of the machine and experimental area operations. The Chief of Experimental Operations will review, at regular intervals, the status of all experiments on line or in preparation. The experimenter should be prepared to support the review by providing complete information on the status of his experiment at that time. A request for extension or reduction of the time allotted should be brought to the attention of the Director of LAMPF at the earliest possible time.

The normal channel of communication for an experimenter will be through the Experiment Coordinator.

e. Experiment Coordinator. For each approved experiment the Chief of Experimental Operations will appoint an Experiment Coordinator. In order to minimize difficulties in the mounting of an experiment it will be necessary that the Coordinator have full knowledge of and participate in the planning of the experiment and estimating the experimental requirements. He will follow the progress of the experiment, arrange for appropriate assistance, and see that the work is both planned and done in compliance with LASL operational and safety requirements.

f. Schedule of Experiments. The Chief of Experimental Operations will prepare a schedule for moving each approved experiment on the floor and carrying out the run, based on the priorities assigned by the Director of LAMPF in the light of the recommendations of the Program Advisory Committee and the Coordinator's estimate of the

set-up time for the experiment. The Chief of Experimental Operations shall maintain a continual review of the state of preparation of the experiment with a view to permitting only ready apparatus to be mounted in place.

g. Safety. The Coordinator, the Radiation Safety Monitors, and the LAMPF Safety Officer shall continuously monitor the experiment with regard to personnel and equipment safety. The Safety Officer is authorized to close down any activity which in his opinion endangers personnel or equipment or is otherwise contrary to accepted safety standards. Appeals from decisions of the Safety Officer may be made to the Director of LAMPF or to the Group Leader of H-3 as the occasion may require.

5. Facilities and Services for Users

a. General. In general, the experimenter will provide and operate the detector system. The services and facilities required over and above those listed below which LAMPF provides should be requested on the experimental proposal and be approved by the Director of LAMPF.

b. Beam Transport. The LAMPF will provide, as its resources permit, the beam and targeting as required by the experiment, as well as the standard items of the beam transport system, including magnets, vacuum pipes, collimators, beam separators, and other nonspecialized components. Operational control of major permanent beam lines will reside with the Central Control Room.

c. Installation of Experiment. The LAMPF will provide the rigging of the experimental equipment and necessary surveying where required. It will also provide basic structures for mounting the equipment. This might include gas tents for safety purposes, troughs for supporting wiring, miscellaneous carpentry, plumbing, and electrical work. It will also provide the wiring and the power for the experiment and auxiliary equipment.

d. Hydrogen Targets and Liquid Hydrogen. The LAMPF will provide hydrogen targets of a generally useful design. If specialized hydrogen targets are required, the experimenter may be requested to pay for their construction. The LAMPF will also furnish liquid hydrogen if the requirements do not exceed a reasonable level of supply. Special gases used on the detecting equipment should be paid for

by the experimental group.

e. Magnets and Power Supplies. The LAMPF will attempt to build up a pool of magnets and power supplies that have general utility. These will include standardized bending and quadrupole magnets designed to be useful in a variety of experiments. Special magnets can be considered on request of the user or user group and built as money and manpower become available. The selection of magnets and other pool equipment for construction will be guided by the LAMPF Users Technical Advisory Panel.

f. Technical Assistance. The LAMPF will provide engineering and technician aid as required for purposes of general support. Specialized pieces of equipment may be designed by LASL engineers and constructed in LASL shops when this is anticipated in the proposal and approval obtained. In general, the experimenter should pay for the construction. On those occasions where a piece of experimental equipment fails or needs replacing, an effort will be made to carry out repairs as promptly as possible in LASL shops.

g. Enclosures for Electronics and Control. The LAMPF will erect or install appropriate enclosures for the electronics and for the control of the experiment, if these are required. It is expected that trailers or other office-type enclosures might be set adjacent to the experiment. The experimenter will be encouraged to provide his own trailer with electronics installed; however, it is anticipated that some trailers will be available at the LAMPF site for general use. The LAMPF will set such trailers in place and provide the necessary power, telephone, and control signal wiring.

h. Electronic Equipment Pool. The LAMPF will stock a supply of standard electronic equipment such as oscilloscopes, power supplies, logic circuits, scalars, scanners, printers, digital voltmeters, delay units, coincidence circuits, and related items. These pieces of equipment may be withdrawn from stock by the experimenter and a service section will be available to replace or repair malfunctioning units. The service organization may also repair the equipment belonging to the experimenter, on a limited availability basis. The LAMPF will be guided in the

operation and stocking by the Users Group Technical Advisory Panel.

i. On-Line Computers. On-line computing facilities will be available in limited supply for those experiments which are designed and approved to use them. Computers or computer systems which may serve such a function will be part of a regular acquisition and development program which will aim at expanding and updating such capabilities. A program library will be maintained. For interfacing to the experiments, standard logic modules will be available in limited supply on loan from stock. A service organization will be available for repair and maintenance. The choice and selection of these facilities will follow the guidance of the Users Group Technical Advisory Panel.

j. Computing Facilities. The nature of the experimental work at LAMPF will require extensive use of a large-scale computation facility. In general, experiments with a high rate of data collection can be anticipated, so that the task of data reduction and analysis will be substantial. Moreover, because of the better statistics and higher precision expected, the task of interpreting the data will be more demanding. It is reasonable to expect that the complexity of the theoretical models will grow, and that the amount of computation required to fit the data and test the theory will be more extensive.

Many users will prefer to utilize magnetic tape so that processing the bulk of their data can be done at their home institutions. However, an attempt will be made to make available a major amount of computing capability at LAMPF. This will be provided either by the central computing facility at LASL, or by a separate installation at the LAMPF site, or a combination of both. Computing service will be assigned as part of the approval of the experiment, with charges levied as stated in Sections 2.c. and 2.d.

k. Housing and Transportation. Every effort is being made to assure that housing will be available and reserved for those who are conducting experiments at the accelerator; transportation to and from the site will be facilitated as much as possible.

l. Office, Laboratory, and Set-Up Space. It is the intention of the LASL administration to

provide adequate office, laboratory, and set-up space for users' needs.

C. Program Advisory Committee, 1972

Kenneth M. Crowe, University of California,
LBL Berkeley

Judah Eisenberg, University of Virginia

Hans Fraunfelder, University of Illinois

Gerhardt Friedlander, Brookhaven National
Laboratory

Isaac Halpern, University of Washington

Arthur Kerman, Massachusetts Institute of
Technology

Francis Low, Massachusetts Institute of
Technology

D. A. Lind, University of Colorado

David F. Measday, University of British Columbia

Darragh Nagle, Alternate Chairman, Los Alamos
Scientific Laboratory

Roger Perkins, Los Alamos Scientific Laboratory

A. M. Poskanzer, University of California, LBL
Berkeley

R. R. Rau, Brookhaven National Laboratory

Joseph E. Rothberg, University of Washington

Louis Rosen, Chairman, Los Alamos Scientific
Laboratory

Fig. III.A.1. LAMPF Experimental Area.

III. EXPERIMENTAL FACILITIES AND BEAMS

A. General Information on Beams

A 50-mA ion source and a 750-keV Cockcroft-Walton accelerator inject positive ions into the 100-MeV Alvarez drift-tube linac through a klystron bunching system. The output of the Alvarez section injects into a Los Alamos designed waveguide linac which carries the energy from 100 MeV up to a maximum of 800 MeV. A separate H^- ion source and Cockcroft-Walton generator will be able to inject simultaneous H^- beams into the linac. Thus, the facility will have the capability of simultaneously accelerating an H^+ beam with an average current of 1 mA and an H^- beam with an average current of 100 μ A. The time profile will be characterized by a macrostructure of 170 pulses per second, each one being 500 μ sec long. Each macropulse will have a microstructure consisting of a 0.25-nsec burst every 5 nsec. The energy spread will be about ± 0.4 percent. (See Figs. III.A.1. - .2.)

The main LAMPF proton beam will go to Area A, the meson physics area, and will be shot successively through several targets to generate secondary pion beams. These secondary beams will provide the means for both high precision experiments and a wide variety of research. Four channels have been designed: (1) the Low Energy Pion Channel, (2) EPICS, (3) the Stopped Muon Channel, and (4) the P^3 Channel. See Sections III.B. through III.E. of this Handbook for details of these channels.

Near the entrance to the beam switchyard, the H^- beam is deflected to the north, where shortly a fraction of it is stripped to positive beam and deflected left into Area C, the High Resolution Spectrometer facility.

The residual H^- beam then goes on to the Nucleon Physics Laboratory (Area B). Before reaching Area B, another stripper may be actuated, so that two spatially separated beams, one H^+ and one H^- , may be available in Area B.

Plans have been laid to provide a third ion source and Cockcroft-Walton generator to be used to inject polarized beams into the linac. The polarized beam can be generated by using either an H^+ beam or an H^- beam of greatly reduced intensity.

Experimental use of the polarized beam would be desirable in both Areas B and C, with earliest use anticipated within about a year after full-scale operation begins.

B. Low-Energy Pion Beam*

Responsible Staff Member: Robert L. Burman

1. Objectives

The proposed low-energy pion channel is designed to provide $\pi^\pm$ beams for the energy region from low energies (approximately 20 MeV) through the resonance region (approximately 300 MeV). It is intended to service a wide variety of research: nuclear structure, nuclear chemistry, elementary particle, and biomedical.

Design features of the channel include good momentum resolution for the nuclear structure experiments, a small (achromatic) spot for stopped pion experiments and for total-absorption counter experiments, and high intensity beams at moderate resolution. To facilitate the range of experimental requirements, the final spot size and divergence are variable over a factor of 20. (Fig. III.B.1.)

2. Parameters

General:	achromatic beam with provisions for switching to two experiments
Energy range:	0-300 MeV
Flux:	π^+ at 100 MeV 1.9×10^7 ($\Delta p/p = \pm .05\%$) 1.5×10^9 ($\Delta p/p = \pm 2\%$)
Resolution:	$\Delta p/p = \pm .05\%$ (max.)
Momentum bite:	up to $\pm 2\%$
Solid angle:	10-20 mrad
Beam emittance:	(± 13 cm x ± 40 mr) x (± 1.5 cm x ± 125 mr)
Spot size and angular resolution:	as above, but variable by 20
Beam purity:	p, eliminated by degrader $n, \sim 10^{-4} n/\pi^+$ $\mu, \sim .02 \mu/\pi^+$ in target region $\sim .08 \mu/\pi^+$ in halo $e, \sim .9 e^-/\pi^-$ at 50 MeV

3. Pion Flux

The proposed low-energy pion channel utilizes four rectangular bending magnets and two entrance and exit quadrupoles; a layout view is shown in Fig. III.B.1. The bend plane is vertical to reduce

*For complete information, refer to MP Division Internal Report, MP-7-10, "Properties of a Proposed

Low-Energy General Purpose Pion Channel," by J. Amato, R. Burman, H. Cowan, and M. Jakobson.

Fig. III.A.2. Experimental Area A.

Fig. III.B.1. Low energy general purpose pion channel. Beam envelope, $\Delta P/P = \pm 5\%$, $\Delta\Omega = 17$ msr. Bending magnets, 6" high x 20" wide x 34" long. Maximum field, 16 kG. Curvatures, $R1 = 2.17$ m, $R2 = 1.34$ m, $R3 = 5.71$, $R4 = \infty$. Quadrupole magnets, 10" diam bore, 16" long iron core, maximum field, 5 kG.

the effect of target length on resolution. The second and third bends are opposite in sign from the first and fourth. The channel is symmetrical about a plane midway between the second and third bends with the channel exit aligned with the channel entrance. Each bend magnet is oriented for symmetrical beam entrance and exit angles. The four rectangular magnets and spacings act as a drift in the bend plane and unit matrix in the transverse plane.

The bends are 60° with a one-meter radius of curvature. The acceptance solid angle for 10-in.-diam quads and 6-in. gap bending magnets is 17 msr. The momentum interval transmitted can be varied over a wide range from ± 0.05 to $\pm 2\%$ $\Delta p/p$. The channel is achromatic and essentially isochronous. The length, including a 0.75 m drift space after the last quad, is 14.0 meters. Removal of protons from the positive pions can be accomplished by differential absorption. The beam size at the exit can be varied by changing the position and fields of the exit quadrupoles. The maximum energy of the channel has not been selected but for the magnet lengths in Fig. III.B.1., 300 MeV pions would require 14 kG in the bending magnets and 4.5 kG for the quadrupoles.

The emergent pion flux has been calculated as a function of pion energy for a 3.0-cm carbon

production target and is given in Table III.B.1. Pion energies vary from 25 to 300 MeV. Two representative momentum bites have been used: $\pm .05\%$ and $\pm 1\%$. For each of these, the calculated flux of positive pions is given; negative pion fluxes will be about one-fourth the positive pion fluxes. Spot sizes, with given divergences, are also listed. Variations in size vs. divergence are considered in the next section.

4. Emittance

A comparison of the beam sizes and divergences requested for a number of proposed pion experiments revealed they are all different. The requirements could be grouped into general categories of (a) small beam-small divergence, (b) small beam-large (any) divergence, (c) large beam-small divergence, and (d) large beam-moderate divergence.

Some representative beam-waist spot sizes and angular divergences have been calculated for the channel using TRANSPORT, and are given in Tables III.B.2. and III.B.3. The calculations include second order effects. The waists in Table III.B.2. are those located 0.75 m from the last quadrupole. If the target position is held fixed and the position of the last quadrupole varied with proper adjustment of the field strengths, a range of approximately 2:1 in spot size from the Table III. B.2. values can be obtained.

TABLE III.B.1.
3 cm CARBON TARGET

T_{π} (MeV)	$\sigma(45^{\circ})$ ($\mu\text{b}/\text{MeV ster}$)	Decay Factor	$\Delta p/p = \pm 0.05\%$			$\Delta p/p = \pm 1.0\%$		
			$\Delta\Omega$	ΔE	N^{+}/sec	$\Delta\Omega$	ΔE	N^{+}/sec
25	13	.057	.01	.05	$.55 \times 10^6$	.02	.93	2.2×10^7
50	20	.142	.01	.09	4.0×10^6	.02	1.74	1.6×10^8
100	26	.276	.01	.16	1.9×10^7	.02	3.16	7.3×10^8
150	24	.373	.01	.22	3.3×10^7	.02	4.44	1.3×10^9
200	18	.445	.01	.28	3.3×10^7	.02	5.64	1.3×10^9
300	5.3	.548	.01	.40	1.9×10^7	.02	7.92	7.4×10^8
Horizontal Spot ^a Size			$\pm 1.5 \text{ cm}$			$\pm 1.6 \text{ cm}$		
			$\pm 125 \text{ mr}$			$\pm 130 \text{ mr}$		
Vertical Spot ^a Size			$\pm .13 \text{ cm}$			$\pm 1.0 \text{ cm}$		
			$\pm 40 \text{ mr}$			$\pm 40 \text{ mr}$		

^aSpot Size contains 95% or more of beam. Values given are for symmetrical entrance and exit quads. See Tables III.B.2. and III.B.3. for size-divergence trade-offs.

TABLE III.B.2.
OUTPUT BEAM SPOT SIZE AND ANGULAR DIVERGENCE^a

Channel $\Delta p/p$ (%)	Mode $\Delta\Omega$ (msr)	x		x	
		Spot Size (cm)	Divergence (mrad)	Spot Size (cm)	Divergence (mrad)
$\pm .1$	10	$\pm .13$	± 30	± 1.45	± 83
$\pm .2$	20	$\pm .16$	± 40	± 1.50	± 127
± 1	10	$\pm .7$	± 30	± 1.50	± 85
± 1	20	$\pm .9$	± 40	± 1.55	± 130
± 5	10	± 3.4	± 45	± 2.2	± 113

^aAll quantities assume a target located .75 m from the exit quad, a total pion source size of $\pm 1.1 \times \pm 1.5 \text{ cm}$ and the beam focused to a double waist at the target position. Calculations are to second order. Spot size includes 95% or more of beam. A range of approximately 2:1 in spot size can be obtained by varying the last quad location.

If a greater range in magnification is desired (at least 4:1 in Y), the target position can be changed, or both the target position and exit quadrupole position. Table III.B.3. gives a sample of typical output phase space configurations which are readily obtainable in the $\Delta p/p = \pm 1\%$, $\Delta\Omega = 10 \text{ msr}$ mode of operation. Of course, many other possibilities for tuning exist by using

the available degrees of freedom, particularly if one is willing to accept small deviations from waist focusing conditions.

5. Beam Contamination

a. Protons. Data from the LASL pion-production experiment indicate that a positive pion beam will be accompanied by about 50 protons/ π^{+} at 200 MeV, and by about 5 protons/ π^{+} at 50 MeV, at the end of the channel. These momentum-analyzed protons have much lower energy than the pions and correspondingly higher stopping power. It is then possible to eliminate the contaminant proton beam by an absorber without deteriorating the pion energy resolution.

Table III.B.4. shows, as a function of pion energy, the thickness of absorber needed to achieve proton separation and the effect it would have on the pion beam. The absorber was chosen to produce 10% change in proton momentum. This results in about a 22-cm shift in the proton beam centroid and is enough of a shift to completely separate the pion and proton beam envelopes (half-width 8 cm at $\Delta p/p = \pm 1\%$).

The effect on the pion-beam energy spread, as calculated from Landau straggling, is small below 150 MeV (less than $\pm 0.05\%$). It could be reduced at higher energies, for some experiments, by using a thinner absorber and accepting an increased level of proton contamination.

TABLE III.B.3.
SOME OF THE POSSIBLE VARIATIONS OF OUTPUT PHASE SPACE^a

Total Channel Length (m)	Optical Constraint	x (cm)	x' (mrad)	y (cm)	y' (mrad)
14.0	Vary Q4 position and focus to double waist	±0.7	±30	±1.5	± 85
14.0		±0.75	±28	±0.95	±133
14.0		±1.85	±10	±0.7	±178
13.75	Vary target position and focus to double waist	±0.65	±33	±1.1	±113
14.50		±0.80	±26	±2.3	± 55
15.50		±0.05	±21	±4.5	± 27
15.0	Double waist: small bend plane divergence	±6.0	± 2.7	±3.5	± 35
15.0	Double waist: large bend plane divergence	±0.84	±23	±3.2	± 39
14.0	Parallel focusing: low divergence in both dimensions	±9.7	± 1.4	±8.0	± 21
15.25	10 x 10 spot with low divergence	±5.0	± 6.5	±5.1	± 25

^aTotal input phase space: $x_o = \pm 1.1$ cm, $x_o' = \pm 30$ mrad, $y_o = \pm 1.5$ cm, $y_o' = \pm 80$ mrad.
Channel mode of operation = $\Delta p/p = \pm 1\%$.

TABLE III.B.4.
EFFECTS OF A PROTON ABSORBER

T_π (MeV)	T_p (MeV)	$.2T_p^a$ (MeV)	$\frac{dT_p^b}{dx}$ ($\frac{\text{MeV}}{\text{gm/cm}^2}$)	Δx (gm/cm^2)	$\frac{dT_\pi^b}{dx}$ ($\frac{\text{MeV}}{\text{gm/cm}^2}$)	ΔT_π (MeV)	$\pm .1 \frac{\Delta T_\pi^c}{T_\pi}$ (%)	$\langle \theta^2 \rangle^{1/2}$ (mrad)
20	2.6	.52	145.	.0036	5.4	.019	±0.01	3.6
50	8.8	1.8	55.2	.032	3.2	.10	±0.02	4.7
100	20.	4.0	28.2	.14	2.0	.28	±0.03	5.3
150	34.	6.8	18.3	.37	2.0	.74	±0.05	6.2
200	49.	9.8	13.6	.72	2.0	1.4	±0.07	6.8
250	67.	13.4	10.6	1.26	2.0	2.5	±0.10	7.5
300	88.	17.6	8.5	2.1	2.0	4.2	±0.14	8.3

^a. $2T_p$ represents $\Delta p/p \approx 10\%$ for protons.

^b $\frac{dT}{dx}$, $\langle \theta^2 \rangle^{1/2}$ for CH_2 .

^cStraggling from Landau distribution: FWHM $\approx 20\%$ of ΔT .

The last column gives the multiple scattering contribution of a CH_2 absorber. Since it adds in quadrature to the beam envelope, it is a small effect at solid angles of around 10 msr, where the beam divergence at the absorber is about 30 mrad is fixed by the production target length, and so the absorber will have little effect on the final beam horizontal divergence. In the bend plane, the divergence is proportional to the input acceptance angle, and so an absorber could represent a lower limit to the final horizontal divergence.

b. Neutrons. For the four-bend channel the neutron contamination in the pion beam will be due primarily to neutrons produced by pions and protons in the channel. The cascade and evaporation neutrons from the target and the secondary neutrons produced in the target cell will be attenuated sufficiently so that they do not dominate the flux at the channel exit. The flux in the surrounding shielding provides a lower limit to the flux in a channel.

The neutron contamination values given in Table III.B.5. are for a 45° pion production angle and a 3-cm carbon target.

TABLE III.B.5.
NEUTRON CONTAMINATION VALUES

T_π (MeV)	T_P (MeV)	contaminant (MeV)	Neutrons/ π^+ ^a	Neutrons/ π^- ^a
50		8.7	10^{-4}	5×10^{-4}
100		20	10^{-4}	5×10^{-4}
200		50	3×10^{-4}	5×10^{-4}

^a Assumes shielding is placed around the exit quads.

c. Muons. For a central pion momentum of 200 MeV/c (100 MeV) and a momentum bite $\Delta p/p = \pm 1.0\%$, the calculated muon contamination at the end of the channel was 8.5%. Since the muons are distributed over a large area, at least 10×10 cm, while the pions are typically focused to 2×3 cm, the number of muons within the area of the pion beam should be smaller by an additional factor of 10. When the contribution due to decay of pions near the production target (1.5%) is added, a muon contamination within the final image of about 2.5% results.

d. Electrons. The relative yield of electrons and pions was measured in the LASL pion production experiment. The results are given in Table III.B.6.

TABLE III.B.6.
ELECTRON CONTAMINATION

T_π	Carbon Target	
	e^-/π^-	e^+/π^+
25	8.5	2.1
50	.89	.21
100	.11	.03
150	.04	.01
200	.01	.006

6. Floor Layout

The actual shielding surrounding a given set up will be determined by the particular experimental requirements. A possible arrangement is shown in Fig. III.B.2.

Fig. III.B.2.

C. EPICS, Energetic Pion Channel and Spectrometer

Responsible Staff Member: H. A. Thiessen

1. Objectives

EPICS is designed to serve two primary demands:

(1) good energy resolution (~ 100 keV) and good angular resolution (~ 10 mrad); and (2) a pion energy range and beam intensity sufficient to measure cross sections from low energies to above the (3,3) pion-nucleon resonance with adequate counting rate.

The complete system consists of a high intensity, high resolution pion beam channel, a particle separator for reducing backgrounds, and two spectrometers.

A complete description of EPICS can be found in the report, LA-4534-MS, entitled, "A Proposal for EPICS: A High-Resolution Pion Beam and Spectrometer Facility for Nuclear Structure Research at LAMPF." All prospective users should familiarize themselves with this document. The following is a brief summary of salient information.

2. Description

Two spectrometers will measure the energy of pions (both positive and negative) and protons with the necessary resolution over the entire energy range of EPICS. Total energy absorbing detectors, including solid state counters and sodium iodide counters, etc., can be used to detect positive pions and protons at energies on the order of 100 MeV or less, and such detectors will be used with EPICS as required. However, magnetic spectrometers are required for negative pions and for high-energy positive pions and protons. For this reason the system is optimized for spectrometer experiments.

Low energy experiments with solid state detectors can be carried out more conveniently with the proposed low energy channel.

a. Dispersed Beam. The essence of the dispersed beam technique is a beam in which the momentum of each particle is correlated with its position in the beam. By determining the intercept of the scattered particle trajectory with the scattering target, the momentum of the interacting pion can be determined with much better accuracy than the momentum spread of the beam. The momentum spread of the beam can be as large as 2% (fwhm), whereas the momentum measuring accuracy is 3×10^{-4} (fwhm). By using the dispersed beam

technique, we have a beam intensity 200X larger than can be obtained in a monochromatic channel of the same resolution, solid angle, and length, viewing the same production target.

Full advantage of this intensity is obtained by using a scattering target size of 20 x 8 cm (for $\Delta p/p = 2\%$). This is not unreasonably large for a spectrometer, and many separated isotopes can be obtained in the required quantity (16 grams). For those isotopes that cannot be obtained in a large enough size, we will use reduced intensity. Even in such a situation, it is not possible to obtain a higher intensity per unit target area with a monochromatic beam of the same resolution and angular divergence.

b. VHV Configuration. Because the scattering plane is horizontal, a nearly parallel beam is required, and is necessarily large by conservation of phase space. This requirement is basically inconsistent with the small (monochromatic) spot size required for good momentum resolution. A small spot and large divergence are acceptable, however, if the dispersion is done in the plane normal to the scattering plane. Dispersion in this vertical plane is also consistent with the preparation of a pion source with a small size in the vertical plane. Except for small scattering angles ($\leq 15^\circ$), we can have good momentum resolution, high intensity, and good angular resolution simultaneously by choosing this combination of vertical beam analysis and horizontal scatter. The spectrometer then will have dispersion in the vertical plane. This VHV configuration (Vertical analysis/Horizontal scattering/Vertical analysis) offers the best possible combination of performance and flexibility for a broad range of spectrometer experiments.

c. 35° Production Angle. The choice of production angle for the pion beam (35°) was based on a compromise between the highest possible intensity (obtained with zero degree production) and the necessity of choosing a large angle in order to provide enough space at the scattering target for both spectrometers.

d. Pion Production Target. The target, a block of graphite 2 mm x 2 cm x 3 cm, will be oriented so that the longest dimension is parallel to the proton beam and the smallest dimension verti-

cal. The low density and thermal characteristics of carbon make for a tolerable cooling problem, and the low Z and low density combine to keep multiple scattering of the proton beam to a reasonable limit.

Ceramic materials such as Al_2O_3 are also being considered because of their better pion production rates.

The small (2 mm) vertical size allows good resolution of the EPICS channel. The proton beam spot will not be uniform, however, and the center of the target will be more brightly illuminated than the edges. The projected fwhm of the beam is approximately 1 mm.

TABLE III.C.1.
PROJECTED SPOT SIZE

Beam Maximum (mm)	Projected fwhm (mm)	EPICS Resolution (fwhm)
± 1.0	1.2	1.2×10^{-4}
± 0.8	0.9	0.95×10^{-4}
± 0.5	0.6	0.7×10^{-4}

For any experiment in which resolution is critical, it will be necessary to monitor the proton beam size at the target with a profile monitor.

e. Energy Range of Channel. The energy range of the EPICS channel was chosen to be as large as possible so that experiments can be performed under optimal conditions. Unfortunately, funding limitations prevented the most general possible system. This resulted in a compromise on maximum energy, which restricted the peak energy to 300 MeV. However, the short channel design for 300 MeV allows good performance over the region from 100 to 300 MeV, which is precisely the interval where the most exciting discoveries in medium energy physics in the next decade are expected to occur.

f. Energy Range of Spectrometers. The higher momentum spectrometer will cover the range 0-1000 MeV/c, which will allow (π, π') , (π, p) , $(\pi, \pi'p)$, and (π, pp) reactions without compromise; (π, d) reactions can be studied at beam energies up to 150 MeV, and (π, t) reactions at 75 MeV or less. The lower momentum spectrometer will be the first to be constructed and will have a range of 0-700 MeV/c.

TABLE III.C.2.
MAXIMUM MOMENTUM OF EPICS REACTION PRODUCTS

Reaction/Beam Energy	100 MeV	200 MeV	300 MeV
(π, π')	200 MeV/c	310 MeV/c	420 MeV/c
(π, p)	700	860	1000
(π, d)	950	1160	1340
(π, t)	1150	1390	1600
$(\pi, \pi'p)$	pion	310	420
	proton	644	808
(π, pp)	P_{max}	860	1000
	P_{equal}	580	670

g. Layout. The channel and 700 MeV/c spectrometer are shown in Figs. III.C.1. and III.C.2.

Fig. III.C.1.

Fig. III.C.2.

3. Performance of System

a. Beam intensity and counting rate for a (π, π') experiment are given in Table III.C.3.

TABLE III.C.3

PION INTENSITY

	T_π (MeV)	Incident Pions ^a				Scattered Pions ^b	
		Survive	ΔE	$d^2\sigma/d\Omega dE$	π/src	Survive	$\pi/\text{hr}/\mu\text{b}/\text{sr}$
π^+	50	.120	1.74	13.0	1.1×10^7	.168	.33
	100	.247	3.16	22.0	7.4×10^7	.309	4.0
	150	.342	4.45	24.5	1.7×10^8	.406	12.0
	200	.405	5.64	23.5	2.6×10^8	.478	22.0
	250	.473	6.79	21.5	3.2×10^8	.533	30.0
	300	.520	7.91	15.0	2.8×10^8	.578	28.0
π^-	50	.120	1.74	4.5	3.5×10^6	.168	.10
	100	.247	3.16	5.1	1.8×10^7	.309	.96
	150	.342	4.45	4.4	3.0×10^7	.406	2.2
	200	.415	5.64	3.6	4.1×10^7	.478	3.4
	250	.473	6.79	2.4	4.0×10^7	.533	3.7
	300	.520	7.91	1.5	3.0×10^7	.578	3.0

^a3.4 msr; 2% $\Delta p/p$; 3 cm carbon target; 35° production angle; 15.24 m channel.

^b9.7 msr; 100 mgm/cm³ carbon; 12.77 m spectrometer. $\delta = \pm 5\%$

Fig. III.C.3. EPICS #90 output beam.

b. Channel Performance. Properties of the EPICS channel, as investigated with a Monte Carlo program, with a 0.8 mm high proton beam, are:

Solid Angle: 3.4 msr
 $\Delta p/p$: 2.0%
 Beam Size (horizontal): 9 cm
 (vertical): 20 cm
 Beam Divergence (horizontal): 5 mrad
 (vertical): 100 mrad
 Momentum Resolution (fwhm): 2×10^{-4}

Fig. III.C.4. EPICS system layout.

In Fig. III.C.3. distributions at the end of the channel for 3000 events are plotted.

c. System Resolution. Detailed Monte Carlo calculations of the performance of the com-

plete system are available on request. A summary of the expected resolution for the system, i.e., channel and first spectrometer, is given in Table III.C.4.

TABLE III.C.4

EPICS RESOLUTION SUMMARIZED

Channel	$\Delta p/p = 3 \times 10^{-4}$		$\Delta \epsilon = 5 \text{ mrad}$				
Spectrometer	$\Delta p/p = 3 \times 10^{-4} \text{ @ } 100 \text{ MeV}$ $= 2 \times 10^{-4} \text{ @ } 300 \text{ MeV}$		$\Delta \epsilon = 5 \text{ mrad}$				
$(\pi, \pi') \text{ } 100 \text{ mg/cm}^2 \text{ } ^{26}\text{Mg target}$							
T_π (MeV)	Optics (keV)	Straggling (keV)	$\Delta \epsilon_{ms}$ (mrad)	Multiple Scattering (keV)	Scattering Angle (deg)	Non-zero Target Angle (keV)	Total Resolution (keV)
100	67.9	40.3	12.8	4.74	0	0.0	79
					45	9.6 ^a	80
					90	29.0 ^b	84
300	131	33.8	5.0	3.15	0	0.0	135
					45	20.0 ^c	137
					90	55.0 ^d	146

Target angle from channel focal plane: a - 20°
b - 44°
c - 16°
d - 40°

D. P^3 Channel

Responsible Staff Member: Robert Macek

1. Objectives

The P^3 channel will be a very flexible, general purpose pion line capable of transmitting the highest energy pions which LAMPF can produce. Additional characteristics are moderate resolution, high intensity, and the flexibility for matching to a wide range of experimental requirements.

Channel design criteria were drawn primarily from the diverse requirements of the following classes of experiments:

- All experiments requiring pions above 300 MeV
- Elementary particle physics with pions
- Nuclear physics and nuclear chemistry studies that can be made with a momentum resolution of 0.25% or larger.

Fig. III.D.1. High energy pion channel.

2. Design

This channel is basically a two-bend channel augmented with a third bend which will switch the beam among at least two spatially separated experimental areas. The beams, after the third bend, can each be achromatic.

A schematic layout of this channel is shown in Fig. III.D.1. An intermediate focus with a

momentum acceptance slit is located between Q_4 and Q_5 . A degrader for removing protons from π^+ beams will also be located here. The third bend, B_3 , steers the beam to the appropriate experimental port. The last portion of the channel consists of two doublets for each leg. These can be tuned to match the beam phase space to the phase space requirements of the experiment at their exit.

Additional variable slits or apertures for changing channel solid angle acceptance and for beam clean-up will be incorporated in the channel at appropriate places. The four output quadrupoles of each leg will be outside the main shielding. They can, therefore, be readily repositioned and tuned to change output magnification, for example. In general, they can be adjusted to provide a wide range of phase space adjustment and trade off.

Further description of this channel can be found in the report, "A Proposal for P^3 , A Versatile High Energy Pion Beam Facility," LA-4535-MS, September 1970. More detailed channel design considerations, which are closely related to this design, are to be found in "Preliminary Report on Some General Purpose Two-Bend Pion Channels," MP6/RJM-1, April 1970 and Addendum I to this report, "A Multiplexed P^3 Channel" by R. Macek, September 1970.

3. Characteristics

In Table III.D.1. are listed $\pi^\pm$ flux estimates as a function of pion kinetic energy for maximum $\Delta p/p$ and $\Delta\Omega$. Other important characteristics are listed below:

Two or more achromatic output ports

max $\Delta\Omega = 8$ msr

max $\Delta p/p = 10\%$

production angle = $15-20^\circ$

resolution for 6 cm long production target = 1.6% ($\pm 0.8\%$)

best resolution = 0.25% (for 0.8 cm long target)

horizontal phase space = 25π mm-cm

vertical phase space = 50π mm-cm

total length = 20 meters

rms spot size

unity magnification, ± 1.2 cm in x

maximum $\Delta\Omega$ and $\Delta p/p$ = ± 1.0 cm in y

Fluxes for reduced momentum bite, smaller production targets, stopped-down apertures, etc., can be estimated by scaling Table III.D.1. appropriately.

TABLE III.D.1.
MAXIMUM P³ CHANNEL FLUX ESTIMATES^a

T _π	π ⁺ (x 10 ³ /sec)	π ⁻ (x 10 ³ /sec)
550	0.5	0.01
480	2.4	0.1
400	8.4	0.5
350	16.0	1.2
300	18.0	1.8
250	14.1	1.8
200	9.6	1.4
150	5.7	1.0
100	2.7	0.6
70	1.1	0.3
45	0.4	0.2

^a Preliminary π-production cross sections by 740 MeV proton from the recent LASL measurements were provided by H. A. Thiessen, private communication.

The calculations shown in the above table used:

6-cm long carbon target
ΔΩ = 8 msr
Δp/p = 10%
Channel length = 20 meters
(Decay losses are included).

E. Stopped Muon Channel

Responsible Staff Member: Patrick Thompson

I. Objectives

- Positive and negative muons
- Muon intensity: as high as possible

a number of stopped muons per g/cm²

- Muon momentum: in range from 0 to

200 MeV/c

- Polarization: |P| > 0.5

- Beam purity: as low as possible

background fluxes of π[±], e[±], p, n, γ

- Muon target: typically a thin target

(often gas of 1 to 100 mg/cm²; thicker targets up

to 5 g/cm² may also be used; x-y area: typically,

10 x 10 cm (gas) or 10 x 0.5 cm (for crystal diffraction spectrometer).

g. Two simultaneous beams (Fig. III.E.

1., p. 29).

2. Performance

The fluxes in Table III.E.1. are based on an 800-MeV proton beam of 1 mA intensity striking a carbon target of 5.5 cm thickness.

TABLE III.E.2.
BACKGROUND PARTICLES IN MUON BEAM

Beam	Particle	Background flux/Muon flux (upper limit)	
		Estimate from Beam Optics	Estimate with Scattering
μ ⁺	π ⁺	0	0.05
	p	0	0.01
	e ⁺	10 ⁻⁴	0.004
	n		10 ⁻⁵
	γ		10 ⁻⁶
μ ⁻	π ⁻	0	0.05
	e ⁻	10 ⁻⁴	0.01
	n		10 ⁻⁶
	γ		10 ⁻⁷

a. Stopped Muon Beam.

Example 1: Thin H₂ gas target at a pressure of 1 atm, with a length of 30 cm, and a cross sectional area of 10 cm x 10 cm. The density ρ = 0.090 x 10⁻³ g/cm³ and the thickness is 2.7 mg/cm².

The beam can be focused onto the target with an angular divergence of 0.05 rad. If a carbon moderator having an energy loss of 45 MeV for a muon momentum of 110 MeV/c is used before the H₂ gas target, then the number of muons stopped in the target is about 1.1 x 10⁵ sec⁻¹ for μ⁺ and 2 x 10⁴ sec⁻¹ for μ⁻.

TABLE III.E.1.
BEAM CHARACTERISTICS

Pion Central Momentum (MeV/c)	Muon Decay Direction	Muon Central Momentum (MeV/c)	Maximum Flux		Emittance cm-rad	Polarization
			μ ⁺ (sec-MeV/c) ⁻¹	μ ⁻ (sec-MeV/c) ⁻¹		
180	Backward	102	9.5 x 10 ⁶	1.6 x 10 ⁷	1-2	< P _μ ≈ 0.8
90	Backward	50	0.4 x 10 ⁶	0.14 x 10 ⁶	1-2	P _μ > 0.9

Fig. III.E.1. Stopped Muon Channel.

Example 2: A relatively thick solid carbon target with a thickness of 1 g/cm^2 and a cross sectional area of $4 \text{ cm} \times 4 \text{ cm}$.

The beam of about 1 cm-rad emittance can be focused onto the target with an angular divergence of 0.5 rad . If a carbon moderator having an energy loss of 35 MeV for a muon momentum of 102 MeV/c is used before the stopping target, then the number of muons stopped in the target is $4 \times 10^7 \text{ sec}^{-1}$ for μ^+ and $7 \times 10^6 \text{ sec}^{-1}$ for μ^- .

Example 3: Preliminary studies have been made of a very low energy beam. This has the following properties:

$$p_\mu = 50 \text{ MeV/c}$$

Polarization $\geq 90\%$

Stopping rate in a 100 mg/cm^2 target $4 \times 10^5 \text{ muons/sec}$

Total beam flux $13 \times 10^5 \text{ muons/sec}$.

b. Time Structure. RMS value of rf micro-structure $< 50\%$.

F. Area B, Nucleon Physics Laboratory

Responsible Staff Member: Chester F. Hwang

1. Objectives

High quality nucleon beams at $300\text{--}800 \text{ MeV}$ will be provided at the Nucleon Physics Laboratory (NPL). At least two neutron beams and a low-intensity, flexible, external proton beam are planned. The neutrons will be generated by $1 - 100 \text{ }\mu\text{A}$ proton beams in a liquid deuterium target. The neutron beam will be formed by collimation in the forward direction. The external proton beam is planned as a low intensity beam of $10 - 100 \text{ nA}$ current; much higher currents are possible but will require the addition of a substantial amount of shielding. It is expected that the LAMPF polarized proton beam (about 100 nA at $P \sim 0.9$) will be available in 1975.

A plan view of the Nucleon Physics Laboratory is shown in Fig. III.F.1. on page 29. Water and power for large items, such as auxiliary magnets, will be provided in the building. Clean power will also be provided. The building has a 15-ton bridge crane.

A detailed description of the NPL along with a rather complete statement of the experimental objectives in nucleon-nucleon and related research can be found in the report, "Proposal for a Nucleon Physics Laboratory at LAMPF," dated December 9, 1969.

2. Performance

The NPL is located at the end of the LAMPF H^- beam line. The H^- beam, which will be shared on a simultaneous use basis with the HRS facility in Area C, will be capable of a maximum current of $100 \text{ }\mu\text{A}$. After part of the H^- beam is stripped and diverted to Area C, the remainder is sent toward the NPL. Once again, part of it can be stripped to form two separate simultaneous beams, one of positive ions and the other negative, both of which enter the NPL. It is planned to develop operating techniques that will permit simultaneous operation of both beams so that two experiments can proceed at the same time in the NPL.

a. Neutron beam at 0° . (Based on initial operation of $1\text{--}10 \text{ }\mu\text{A}$ proton beam with a 50 watt liquid deuterium target; beam levels a factor of 10 higher are planned for 1974 and later.)

Energy Range: Neutrons in the high-energy spike have about 5 MeV less than incident protons. Proton beams in range 300-800 MeV are possible.

Flux: Neutrons in a 795-MeV spike: 2×10^6 n/cm²-sec at 6 m from target with a 10- μ A 800-MeV proton beam on 15 cm liquid deuterium target.

Resolution: About ± 5 MeV in spike

Spot size: Variable; typically 10 cm² at 6 m

Background: Neutron spectrum has low energy tail

b. Neutron beam at $\theta_n = 28^\circ$ (Based on initial operation of 10 μ A proton beam with a 50 watt liquid deuterium target; beam levels a factor of 10 higher are planned for 1974 and later.)

Flux: Neutrons in a 560 MeV peak; about 10^6 n/cm²-sec at 6 m from target with a 10- μ A 800-MeV proton beam on 15-cm liquid deuterium target

Resolution: About ± 30 MeV in peak

Polarization: $P = 0.35$ at $\theta_n = 28^\circ$

Spot size: Variable; typically 10 cm² at 6 m

Background: Neutron spectrum has low energy tail

c. External Proton Beam

Energy range: 300 - 800 MeV

Current: 10 - 100 nA

Resolution: Full beam contained in ± 3.5 MeV at 800 MeV

Beam emittance: ≤ 1 cm-mr

3. Miscellaneous Information

A service corridor containing cable trays will be provided at the northwest corner of the NPL building. This service corridor leads to a trailer parking area where experimenters may set up their counting room equipment. Outside users will be encouraged to bring their own trailers, but it is anticipated that a modest amount of floor space will be available in permanent trailers.

Tentative plans have been made to acquire several major items of experimental equipment, including a polarized target system, a spin precession magnet, a dedicated data computer, and general purpose steering and focusing magnets. As these plans are not yet firm, details will have to be deferred until late 1973 or early 1974.

The shielding design for the NPL dictates that personnel will not be permitted access to the building when beam is on. Experimenters are advised to

plan the apparatus for remote data taking.

G. Area C, High Resolution Proton Spectrometer

Responsible Staff Member: Nobuyuki Tanaka

1. Objectives

The High Resolution Spectrometer (HRS) facility (Figs. III.G.1. and 2.) will be designed to obtain an overall resolution in momentum of 0.01% (corresponding to about 100 keV energy resolution at a bombarding energy of 800 MeV; 50 keV, at 400 MeV) and ± 0.8 mrad resolution in scattering angle.

Nuclear reaction products resulting from the population of low-lying states of many nuclei can be individually resolved, and, at the same time, measured with sufficient angular resolution to delineate clearly the rapid angular oscillations of the cross section that characterize nuclear reactions near 1 GeV. The large solid acceptance angle of the spectrograph, 3.6 msr, will make it possible to measure cross sections 10^{-2} smaller than have been previously measured near 1 GeV, maintaining .01% momentum resolution and utilizing an unpolarized proton beam intensity, optimized for data collection of 30 μ A. The counting rates expected will typically be .04 counts per second per nanobarn/sr with a beam of 30 μ A and 20 keV target.

Research possibilities with unpolarized proton beams using the HRS lie in the fields of nuclear spectroscopy and nuclear correlations in nuclei. Details of this facility may be found in the 135-page report, "A Proposal to the Atomic Energy Commission for a High Resolution Spectrometer Facility (HRSF) for Studying Proton Induced Reactions near 800 MeV," dated April 23, 1968.

2. Specifications

- Mean radius of curvature = 3.5 meters
- With this radius of curvature, 800 MeV protons at 14 kG and 635 MeV tritons at 19 kG and 800 MeV deuterons at 18.2 kG can be analyzed
- Solid angle acceptance = 3.6 msr
- δp acceptance of 2.5%
- Momentum resolution, $\delta p/p = 2.44 \times 10^{-5}$ around the center ($\delta T/T = 30$ keV/800 MeV) and $\delta p/p \leq 10^{-4}$ over 20 MeV

Fig. III.G.1. Scale model of the HRS showing beam line entering from lower right center. The tracks have been replaced by an air pad system. Entrance on right side.

SECTION HRS FACILITY

0 5 10
GRAPHIC SCALE
IN FEET

Fig. III.G.2. Plan and section of Area C with HRS.

f. Incident energy range of proton 300-800 MeV.

g. Range of scattering angles: $2.5 - 10.0^\circ$ with reduced beam intensity and use of an internal beam stop, i.e., beam stop inside the scattering chamber; $10 - 170^\circ$ with beam current up to $30 \mu\text{A}$.

h. Angular resolution = 0.8 mrad . The scattering chamber is designed so that gas, cryogenic or solid targets can be used. Figures III.G.4-6 show the HRS and scattering chamber in detail.

Many electrical feed-throughs will be provided so that certain kinds of detectors, such as solid-state detectors, can be placed in the scattering chamber and their signal can be brought out from the scattering chamber.

Two detector systems are being developed: one at LAMPF and one at BNL by Harry Palevsky's group. These two independent systems will be available to users, but if a special system is required, this may be set up in the space available around the existing detectors.

Fig. III.G.3. Spectrometer configuration 3.5 m system.

H. Nuclear Chemistry

Prepared by: Bruce J. Dropesky, CNC-11

1. Experimental Facilities

The following is a list of the facilities, either completed or under development, for nuclear chemistry studies:

a. Nuclear Chemistry Laboratory

Part of D Wing added to the LAMPF Laboratory-Office Building includes 4 chemistry labs, 5 spectrometry or counting rooms, and 8 offices. (Fig. III.H.1.)

Full basement for large research instruments, radioactive storage, shielded counting room, staff shop, 2 stockrooms, etc.

Chemistry labs equipped with centrifuges, balances, refrigerators, ovens, etc. Stockrooms well equipped with chemicals, glassware, supplies, etc. Counting rooms equipped with: 2 low-background β proportional counters; 1 $3'' \times 3''$ NaI(Tl) shielded scintillator; 1 $2'' \times 2''$ NaI(Tl) well-type shielded scintillator; 1 pair of $3'' \times 3''$ NaI(Tl) scintillators in coincidence array; 2 400-channel pulse height analyzers; 2 Ge(Li) detectors; and 2 4096-channel pulse height analyzers with magnetic tape outputs.

b. Nuclear Chemistry Hot Cell and Intermediate Level Chemistry Bench

Four station (10 K Curie) hot cell in Merrimac Service Area (Fig. III.H.2.)

Two stations equipped with lead glass windows and manipulators.

Hot cell contains central switchgear for "rabbit" system.

Adjacent chemistry bench with two hoods for intermediate activity level separations.

c. Pneumatic Target Transport System

Initially: "Rabbit" system (Fig. III.H.3.) will transport targets from the Low Intensity Proton Station, Area B, and the Energetic Neutron Station, Beam Stop, through the Hot Cell to the Nuclear Chemistry Laboratory.

Future: System may transport targets from meson stations, on-line mass separator, Bio-Med facility, Area C, and WNR facility.

d. Thin Target Area

Special enlargement on beam tunnel is built and target chamber and drift tube are being designed (Fig. III.A.1.) For counter telescope and catcher foil studies of nuclear recoils.

e. Low-Intensity Proton Station

Located in Nucleon Physics Lab, Area B, just beyond beam bend (Fig. III.A.1). Beam currents to $10 \mu\text{A}$ later. Targeting Vault, with personnel access, will contain a remote targeting chamber on "rabbit" system, a manual target insertion station, and a general purpose scattering chamber (Fig. III.H.4.)

f. Energetic Neutron Station

Located along side main beam stop, remote targeting with "rabbit" system (Fig. III.H.3). Energetic neutron flux of the order of $10'' \text{ n/cm}^2/\text{sec}$ expected. Spectrum of secondary neutrons will vary depending on target location.

(Cont. on page 41)

Fig. III.G.4. General view of the High Resolution Spectrometer.

Fig. III.G.6. Plan view cross section of the Scattering Chamber for the HRS.

LAMPF NUCLEAR CHEMISTRY LABORATORY

Fig. III.H.1. Nuclear Chemistry Laboratory

Fig. III.H.2. Four-station hot cell in Merrimac Service Area.

Fig. III.H.3. Nuclear Chemistry pneumatic transport system.

Fig. III.H.4. Low-intensity proton station, Area B.

g. Meson Stations

Noninterfering, semipermanent targeting stations are being planned for the stopped muon channel, the low energy or stopped pion (LEP) channel, and the high energy pion (P³) channel.

The following future facilities have had some provisions made for them:

(1) High Intensity Proton Station

To be located in the first meson production target cell and to facilitate targeting in the 1 mA beam.

Provisions have been made for pneumatic transport of target from hot cell to station and back.

(2) On-Line Mass Separator Facility

Proposed for study of the properties of nuclei far from β stability, having half-lives down to 1 sec or less.

Stub-out from proton beam tunnel provided by LAMPF (Fig. III.A.1.) Isotope separator on hand. Funding for this national facility being sought.

2. Experimental Studies

The uniquely high intensities of pion and muon beams from LAMPF offer the nuclear chemist opportunities, for the first time, to do detailed studies of the interaction of these particles with complex nuclei. Although physicists for many years have been able to perform very significant experiments with available meson beams, using counter and emulsion techniques, the nuclear chemist has been severely handicapped by very low beam intensities and, therefore, has been limited to studying a few meson reactions yielding short-lived products. Heavy emphasis will be placed, at LAMPF, on utilizing radiochemical techniques to investigate, first in exploratory fashion and then in detail, the interactions between π and μ mesons and complex nuclei. The development of activation foil techniques for measuring integrated meson beam currents and determining the amounts of beam contamination will be first priority. Comparisons of meson-induced spallation, fission, and fragmentation with the corresponding proton-induced reactions will undoubtedly provide much meaningful information for the theorists. Also, a very interesting class of studies is being planned involving the complex extranuclear phenomena (chemical effects) associated with the stopping of negative pions and muons in matter.

The high proton beam intensity of LAMPF also offers us some unique opportunities for studying poorly understood aspects of high energy proton

reaction mechanisms and for exploring nuclei far from β stability (the thin target area, the high intensity proton station, and the proposed on-line mass separator facility). The expertise at LASL for the detailed investigation and interpretation of the decay characteristics of nuclei, especially in the deformed rare earth and actinide region, will be applied to studies of the many neutron-deficient species to become available.

I. Isotope Production Facility

Prepared by: Bruce J. Dropesky, CNC-11

1. Objectives

A program has been initiated in the LASL Radiochemistry Group (CNC-11) directed toward utilizing the residual proton beam at the LAMPF Beam Stop to produce a) substantial quantities of several spallation reaction radionuclides of recognized value for nuclear medical applications and b) modest research quantities of a variety of "new" radionuclides for potential applications in nuclear medicine, metallurgy, agriculture, etc. The Isotope Production Facility, nearing completion, plus existing hot cells at other LASL sites will provide the needed facilities for carrying out this program.

2. Facility Construction and Operation

The Isotope Production Facility, which represents an addition of about 400 ft² to the LAMPF main beam stop structure, was designed as a minimal targeting facility (Fig.) Functionally the Facility is designed to enable an operator to: 1) remotely attach a target-containing chamber to the end of a stringer (26 ft long x 8 in. high x 2 in. wide); 2) drive the stringer through a slot in the stringer housing in the beam stop shielding so that the target is in position to intercept the proton beam; 3) carry out the irradiation, with adequate water-cooling of the target; and, after an appropriate irradiation period, 4) retract the stringer, remove the target chamber and transfer it to a shielded cask for transport to hot cell facilities located at other LASL sites.

The basic facility will have an initial set of four independently-operable stringers, but will also have provisions for increasing this number to twelve in the future. Each stringer, in addition to having cooling-water lines, instrumentation cables, and granular shielding material in the voids, will also

contain tubes that may be used for removal of gaseous products from a special target chamber during the irradiation. The standard target chamber will be all metal, probably Inconel or stainless steel, with thin front and back windows the diameter of the proton beam (6 in.), and will accommodate target disks of total thickness up to about 1.5 in. The cooling water will flow as a thin layer over the front and back face of each target disk. Fig.III.I.2. shows the approximate configuration of one of the target chambers coupled to the end of a stringer and positioned ahead of the beam stop.

Just outside the main shield wall is a steel-shielded trench or target handling pit where simple remote operations can be performed on the ends of the stringers, operations such as connecting water lines, coupling or uncoupling the target chambers,

etc. Simple tools operating through the steel working deck will be used to safely perform these operations, while periscopes will enable the operator to observe the manipulations. A remotely controlled cart will serve to transport an irradiated target through a pressure-sealed isolation door to an access port in the loading area for removal into a bottom-loading shipping cask.

Fig.III.I.2. A typical target chamber coupled to its stringer; positioned in proton beam ahead of beam stop.

Fig.III.I.1. Sectioned plan and elevation views of the Isotope Production Facility being constructed onto the main LAMPF beam stop structure.

J. Biomedical Facility

The proposed biomedical facility will consist of a beam transport system, shielded target vault, a treatment room (to be expanded into two rooms in the future), beam control facilities, patient staging area, simulator facilities, animal staging area, laboratories, offices, and other support facilities. (See Fig. III.J.1., p. 44). Complete details may be found in "A Proposal for a Biomedical Addition to the Los Alamos Scientific Laboratory's High-Flux Meson Physics Facility," report LA-4490-P dated September 1970.

Tentative plans for the pion channel include the following characteristics:

1. Capability of irradiating volumes up to 10-cm-thick at mean depths up to 25 cm. Maximum momentum acceptance of channel, $186 \text{ MeV}/c \pm 8\%$.
2. Capability of irradiating up to a $15 \times 15 \text{ cm}$ field.
3. Dose rates $\approx 20 \text{ rad/min}$, uniform to $\pm 3\%$ over the largest irradiated volume.

Figure III.J.2. shows the pion channel design. Up-to-date information on channel design can be

Fig. III.J.2. A broad-band biomedical pion channel.

obtained by contacting R. L. Hutson, MP-Division, Los Alamos Scientific Laboratory.

Extensive dosimetric calculations and preclinical trials with animals and cell cultures will be done before human therapy is contemplated. Also investigations will be made into the utilization of pi-mesic x-rays for delineating the treatment volume, diagnostic uses of muons, and use of the unusual radioisotopes produced by the isotope production facility.

Interested users should contact one of the following for latest information:

Dr. Paul Todd, Chairman
618 Life Sciences Laboratory
Pennsylvania State University
University Park, Pennsylvania 16802

Dr. Edward Knapp
The Clinton P. Anderson Meson Physics Facility
Los Alamos Scientific Laboratory
P. O. Box 1663
Los Alamos, New Mexico 87544

Mr. Paul R. Franke, Jr., Group MP-6
The Clinton P. Anderson Meson Physics Facility
Los Alamos Scientific Laboratory
P. O. Box 1663
Los Alamos, New Mexico 87544

Dr. Richard L. Hutson, Group MP-3
The Clinton P. Anderson Meson Physics Facility
Los Alamos Scientific Laboratory
P. O. Box 1663
Los Alamos, New Mexico 87544

Mr. Arvid Lundy, Group MP-3
The Clinton P. Anderson Meson Physics Facility
Los Alamos Scientific Laboratory
P. O. Box 1663
Los Alamos, New Mexico 87544

IV. EXPERIMENTAL EQUIPMENT, ACCESSORIES, AND SERVICES

A. Equipment Pools

1. Magnets, Separators, and Electronics Apparatus

IAMPF plans to build up a pool of magnets, power supplies, and particle separators of general experimental utility. There will also be in stock a supply of standard electronic equipment for loan to users. Detailed plans for these pools have not been made as of this writing. Further information will be given in the (2nd) revised version of the Users Handbook.

Fig. III.J.1. Floor plan of Proposed Radiobiology and Therapy Research Facility.

B. Data Acquisition System*

Responsible Staff Member: H. Butler;
R. Thomas, Software; D. Machen, Hardware

The on-line data-acquisition facilities at LAMPF are organized around the concept of a small computer dedicated to each experiment. The computer will acquire, preprocess, record, and display data, monitor the condition of the experimental apparatus, execute necessary control functions, and perform preliminary analyses which forecast the results of the experiment.

LAMPF has standardized on the DEC PDP-11 series of computers. The configuration of each computer includes a central processor with 16 K of core memory, a clock, hardware multiply/divide, a DEC writer, a 256 K-word disk, one or more 7-track magnetic tape drives, a CAMAC branch driver, and a Tektronix-4010 storage display scope.

The manufacturer's Disk Operating System (DOS) was adapted as the standard software. One important option was added to DOS to allow the user to imbed an intercept driven data-acquisition program in the monitor. This underground (UDG) program can be written to acquire data, preprocess it, write it on tape or disk, and to communicate with the background of DOS. A standard procedure is available for imbedding an UDG program in the DOS monitor. Copies of the system can be supplied on magnetic tape to those users possessing a PDP-11.

Program development for the data-acquisition computers is done on the terminal computer, a PDP-11 having the standard configuration plus a card reader, a line printer, a high-speed paper tape unit, and dual DEC tapes. The software developed on the terminal can be transferred to the user's computer through the medium of magnetic tape. Key punch machines (IBM-026), a reproducer (IBM-519), and an interpreter (IBM-557) are available to support the user's work. This equipment is available to all users, subject only to scheduling constraints.

In order that LAMPF be able to accommodate the widest variety of users, CAMAC was adopted as the standard for interfacing experimental equipment to the dedicated computers. CAMAC crates are connected

to each PDP-11 by a Microprogrammed Branch which can drive up to eight concurrent processes at a combined rate in excess of 100,000 words/sec. The MBD is actually a special-purpose stored program computer whose memory is loaded through the PDP-11. Standard MBD programs for the more common tasks of data acquisition have been developed. Special-purpose programs are readily prepared using DEC's MACRO-assembler.

CAMAC will also be the medium for implementing the network of data links which will eventually connect each data-acquisition computer and the LAMPF control computer (SEL-840 MP) to the terminal computer. The Terminal will, in turn, be connected over a 300,000 bit/sec microwave data link to the LASL Control Computing Facility (CCF). Through such a network each experimenter will have access to the control capability of the SEL-840 MP and the computing capacity of the CCF. This network will come into existence slowly in phases beginning in the latter half of 1973 and may not be fully operational until 1975. A recognized need for this capability could accelerate the schedule.

LAMPF will rely on the LASL CCF for its bulk computing needs. The CCF maintains an inventory of the most modern, large-scale computers, presently including two CDC-7600's and three CDC-6600's. A third CDC-7600 is expected in 1973. These computers will be tied together in a network called HYDRA. LAMPF will have a 4800-bit/sec link into HYDRA by mid-1973. This link will give users the capability for submitting jobs into the CCF batch stream from the LAMPF Site. An estimate of bulk computing requirements should be included for each experiment proposed.

Accelerator timing and synchronizing signals will be available to each experimenter in a form compatible with NIM, CAMAC, and PDP-11 standards.

The LAMPF data-acquisition system was designed to satisfy the recognized needs of most experiments. Specialized requirements can be satisfied by the LAMPF staff if approved by the Director. Nothing in the system design precludes the experimenter from bringing his own computer and operating in a self-sufficient mode.

* Complete details of this system can be found in Los Alamos Scientific Laboratory report, LA-4504-MS, "LAMPF Data-Acquisition System" by H. Butler.

C. Experimental Area A Utility Services

1. Mechanical Services

A nonradioactive (cold) process water system is provided in the experimental area to serve the power supplies and similar components not on the beam lines. This is nonferrous demineralized system.

Where large experimental cooling requirements exist, the experimental equipment is to include a closed process water system. To serve such systems, cooling tower water supply and return are provided (8-in. lines with 6-in. valved taps, 70°F supply).

Compressed air is available, 100 psi, 2 in.-lines with 3/4-in. valved taps.

Radioactive liquid waste drains are installed along the proton line. No floor drains exist in the experimental area outside the main shield.

2. Electrical Services

The power in the Experimental Area is generally divided into three systems. All three systems are derived from a common 115 kV-utility company transmission network, but an attempt is being made to maintain isolation at the 13.8-kV level and below. It is hoped that this will minimize communication of harmonics induced by SCR equipment, arc-discharge lighting, etc., to computers and instrumentation. Also, voltage dips caused by motor starting should not be communicated to the above type circuits.

The available systems are as follows:

Building Power -	480 volt, 3-phase
	277 volt, 1-phase
	208 volt, 3-phase
	120 volt, 1-phase

Magnet Power -	480 volt, 3-phase
----------------	-------------------

Instrument Power -	208 volt, 3-phase
	120 volt, 1-phase

The Building Power and Instrumentation Power Systems are wye connected, grounded neutral systems. The Magnet Power System is an ungrounded, 3-wire system.

3. Utility Bridges

All services are available at the inside face at the outer walls of the experimental area. They can be extended to experimental installations inside or outside the main building. Movable utility bridges are provided to carry services across the experimental areas within the building. These

bridges will normally be installed 23 ft. above the experimental floor. All services to experimental setups will then be from above.

Cable trays are provided on the utility bridges and along the building walls allowing cable communication between experimental setups and outside trailers and the operations center.

Experiments using hydrogen (>200 cc) or having other exhaust requirements must be locally hooded with piped exhaust to the exterior building walls. The utility bridges will accommodate exhaust lines where needed.

4. Handling Equipment

Experimental Area A is served by two 30-ton capacity bridge cranes. One crane serves the north side of the main beam line while the other covers the south side of the Merrimac area. Hook coverage extends to within 11 ft. of inside column faces.

Forklift capacity up to 18 tons is available. Roll-up doors 20 ft. wide by 16 ft. high on both the north and south sides of the building allow access of the larger forklift. For greater access and also to allow for extension of experiments through the building walls, sections of the north and south walls are removable up to 20 ft. above the floor.

D. Experimental Area A Radiation Levels

An attempt has been made to establish some reasonable guide lines for the operation of the various LAMPF experimental areas with regard to permissible radiation levels. Undoubtedly, exceptional modes of operation will be desired and will be subject to further review.

On the floor of Beam Area A, the guide line background radiation level adopted is 2.5 mrem/hr from all sources. The background radiation is expected to be predominantly due to neutrons having a 1/E spectrum. The average flux will be about 20 neutrons/cm²-sec. In general, shielding will be required for all beam lines and beam stops.

Areas B and C will be exclusion areas in their designed modes of operation. The combined leakage dose to the occupied areas outside of Areas B and C proper will be limited to 1 mrem/hr.

E. Remote Handling

It is anticipated that induced activity levels in the vicinity of the main beam line will require unacceptable decay time to permit manual maintenance. Provisions are being incorporated to accommodate remote equipment replacement and rudimentary equipment maintenance. A shielded room which contains lead glass windows in its roof and carries a hoist and a manipulator inside is being fabricated. The room is transported to the work site by a rubber tired gantry which drives on top of the shielding 23' above the Area A experimental floor. The combination of box and gantry, dubbed the "Merrimac," provides fairly conventional hot cell capability at any desired location. The shielding over components requiring remote manipulation is stacked to form a horizontally opening door. Merrimac straddles the door which, when opened beneath the room, forms a vertical shaft to the component. The room is lowered into the shaft until its roof is flush with the roadway. Technicians sit on the roof to operate the manipulator inside. The room acts as a shield cask for the transport of large components.

Manipulation capability 100 lbs

Hoisting with manipulator 1000 lbs (cannot lift into room)

Hoisting with remote hoist 10,000 lbs (can hoist into room and transport an object 41 in. high)

Hoisting with building crane 60,000 lbs (requires special fixturing which must be designed into the component to be lifted; maximum height of component and fixture is 69 in.)

Inside width of room 124 in. (110 in. available)

Inside length of room 182 in. (120 in. available)

It is possible to transport an object 69 x 110 x 120 in. and weighing 30 tons to the hot cells. Two 10 x 15 ft. hot cells are available. The service cell has 5 operating stations (consisting of a window and a pair of master slave manipulators) available. The chemistry cell is reserved for radiochemistry work and is the terminus for the rabbit transfer system. It has 4 operating stations available. The master slave manipulators can handle 10 lb. objects. Merrimac may be positioned over either cell so that its hoist and manipulator may be used.

V. GENERAL INFORMATION

This section is intended to be of a summary nature only and will be expanded in the next edition of the users handbook.

A. Safety

An official LAMPF publication, "MP Division Radiological Safety Procedures" and the MP Division Safety Manual will be the standard references for all Users on safe conduct at the facility. All users will be expected to familiarize themselves with these texts. If users are planning use of hydrogen targets, or hazardous materials, should consult these manuals before making final plans.

B. Patents

LASL patent regulations require that any person working at the Laboratory sign a patent agreement. (see next page)

C. Housing

Users who expect assistance with housing must make arrangements in advance of their visit. Assistance will be provided by the Users Liaison Office, Mrs. Billie F. Miller, Los Alamos Scientific Laboratory, P. O. Box 1663, Los Alamos, N.M. 87544. (Telephone 505-667-5759) The Laboratory has reserved a limited number of kitchenette apartments and furnished one-bedroom and two-bedroom apartments for assignment to LAMPF users. The Users Office will also offer assistance in making private rental arrangements.

D. Transportation

The accompanying map may be useful in planning travel to Los Alamos. Several major airlines serve Albuquerque and connecting flights to Los Alamos are available on Ross Airlines, which maintains convenient schedules.

Transportation to and from the LAMPF site and the Los Alamos hotel area will be facilitated by various means; however, a personal car is strongly urged and will be found to be the most convenient.

Government permits to drive official vehicles may be available from LASL's H Division, if warranted. These vehicles, of course, may only be used for official business between LASL sites.

E. Support Services

Secretarial, drafting, machinist, and other services will be available to users on a limited basis, but every effort will be made to meet all needs.

F. Supplies

Users will be instructed on withdrawal of supplies from central storage areas. Small items will present no problems, however, unusual requests will require approval of a designated LAMPF official.

G. Shipping

Ordinary shipments of materials and/or equipment should be addressed:

Los Alamos Scientific Laboratory
Receiving Department, Building SM-30
Los Alamos, New Mexico 87544

Attention: MP Division Property Representative

For: User's full name and organization

Shipment of materials of a hazardous nature must be made in accordance with LASL safety procedures, available upon request. If shipments are

to be made from foreign countries, the shipper should contact LASL Shipping and Receiving Department (at the above address) well in advance for proper instructions regarding customs regulations, etc.

H. Accounting

Accounting procedures will be set up to provide equitable charges for materials and/or services to users. There will, of course, be no charges for beam time, use of space in experimental areas, and the like.

I. MP-Division Administrative Listing (LAMPF)

See pages 49-51.

J. Maps and Useful Phone Numbers and Addresses

For purposes of orientation, two simplified maps are given here, and a phone listing is appended (see pages 52-54).

PATENT AGREEMENT - VISITOR

Undersigned, as a condition to and in consideration of access to facilities and information at the Los Alamos Scientific Laboratory, agrees as follows:

(1) That he will promptly furnish to the University complete information concerning any and all inventions or discoveries made by him in the course of said access to facilities and information, and waives any right or claim to pecuniary award or compensation under the provisions of the Atomic Energy Acts of 1946 and 1954 with respect to such inventions or discoveries.

(2) That the Atomic Energy Commission shall have the sole power to determine whether or not and where a patent application shall be filed, and to determine the disposition of the title to and rights under any application or patent covering such inventions or discoveries.

(3) That he will execute all documents and do all things necessary and proper to carry out this agreement; and all drawings, reports, notebooks and other scientific or technical information of every description relating to or deriving from his work in connection with this association, shall be subject to inspection by the University and Government at all reasonable times and usable by the Government for any purpose whatever without claim on the part of the undersigned for compensation.

(4) That as to any material acquired through such access which he wishes to publish he will secure patent review before publication through the Director, Los Alamos Scientific Laboratory.

IN WITNESS WHEREOF, I have hereunto set my hand and seal this

_____ day of _____, 19____.

Witness

MP-DIVISION ADMINISTRATIVE LISTING

		Room	Telephone
DIVISION LEADER	Louis Rosen	A-214	667-5907
ALTERNATE DIVISION LEADER	Darragh E. Nagle	A-218	6375
ASSOCIATE DIVISION LEADER FOR PRACTICAL APPLICATIONS	Edward A. Knapp	A-228	5051
ASSOCIATE DIVISION LEADER FOR OPERATIONS	Donald C. Hagerman	A-114	5967
ASSISTANT DIVISION LEADER FOR FACILITY PLANNING AND BUDGET CONTROL	Paul D. Edwards	A-232-B	6176
ASSISTANT DIVISION LEADER FOR SAFETY	Thomas M. Putnam	A-232	6177
MP Division Office - Mrs. Eleanor Dunn, Administrative Aide		A-216	5907
Mrs. Mary Riggs, Division Secretary		A-216	5907
Mrs. Mary Marlett, D. Nagle's Secretary		A-222	6375
Mrs. Paulina Ungnade, Division Safety Office Secretary		A-232-A	6176
USER LIAISON			
Liaison Officers - Lewis E. Agnew or Hillard H. Howard		B-115	4295
Users Group Secretary - Mrs. Billie F. Miller		B-113	5759
CENTRAL CONTROL ROOM - Harold S. Butler		MPF-4-210	6178
INJECTOR CONTROL ROOM - Ralph R. Stevens		J-119	5053
GROUP MP-1 - ELECTRONIC INSTRUMENTATION & COMPUTER SYSTEMS			
Group Leader	Raymond A. Gore	C-140	5241
Alternate Group leader	Harold S. Butler	MPF-4-210	6178
Assistant Group Leader	Donald R. Machen	C-146	6939
Assistant Group Leader	Richard F. Thomas	C-142	6260
Group Secretary	Mrs. Patsy Trussell	C-138	5241

As the instrumentation and computer system group in the division, MP-1 supports a variety of activities. Along with the continuing hardware and software support of the accelerator control system, extending the computer interface and local control hardware into the experimental areas and developing the operating programs represent the bulk of the group's activity. In addition to the equipment required for control of the various experimental lines, the group provides the design of special equipment

for each line such as power supply regulators and NMR interfaces to mention only two. The other major activity is the development of the experimental data-acquisition system. This is a computer-based system for which the group provides the system programming and hardware interfacing. As part of this last activity, the group actively supports the developing LAMPF instrumentation pool and assists in detector electronic development.

GROUP MP-2 - ACCELERATOR OPERATIONS

Group Leader	Robert Warner	MPF-4-208	6929
Group Secretary	Mrs. Sheila Beauchamp	MPF-4-208	6929

Group MP-2 is responsible for the operation of the LAMPF accelerator. Primarily, this group will provide crews of trained operators to man the accelerator on a schedule determined by the needs of

LAMPF accelerator development and usage. To meet these needs, some shift work by the crews is required. In addition, light maintenance functions related to the accelerator will be performed by this group.

GROUP MP-3 - PRACTICAL APPLICATIONS

Group Leader	Edward A. Knapp	A-223	5051
Group Secretary	Mrs. Kaye Miller	A-226	5051

Group MP-3 is engaged in developing the practical applications of the LAMPF Facility. Applied uses of LAMPF include the application of π meson beams to the treatment of cancer, studies of radiation damage in materials induced by the intense fluxes of neutrons and other radiations available, studies in solid state physics, the measurement of the chemical composition of materials by the characteristic x-ray spectra produced when μ mesons stop in the material and the production of short-

lived radioisotopes for tracer applications. This group is designing and overseeing the construction of a beam line to produce the π beam for radiation therapy. Experiments are being planned to observe μ meson x-ray spectra from materials, including in vivo tissue analysis. Liaison between groups planning experiments in radiation chemistry, radiation damage, solid state physics, and the production of isotopes is the responsibility of this group.

GROUP MP-4 - NUCLEAR AND PARTICLE PHYSICS

Group Leader	Darragh E. Nagle	A-218	6375
Group Secretary	Mrs. Mary Marlett	A-222	6375

Group MP-4 is developing experimental equipment and software for use in the experiments at LAMPF. It is planned that most of this work and the facilities will be generally applicable to the physics program. Capabilities are being developed to fabricate and test various detectors and systems for

reading the data into computers. A pool of research equipment is being set up, and plans are being made to create a library of programs for data acquisition and analysis.

A substantial part of the physics research program will be done within MP-4.

GROUP MP-6 - EXPERIMENTAL AREAS

Group Leader	Donald R. F. Cochran	A-128	4291
Alternate Group Leader	Robert Macek	A-118	6976
Associate Group Leader	Mahlon T. Wilson	A-120	5515
Assistant Group Leader	Paul R. Franke	A-122	5775
Group Secretary	Mrs. Freda Grote	A-126	4291

Group MP-6 efforts are directed to the functions of operation, management and maintenance of the LAMPF switchyard and experimental areas. The functions include in part a significant effort devoted to the scheduling, planning and support of the experimental program. The group is responsible for the LAMPF remote systems technology which includes the design, test and operation of the required

primary beam targets and beam stops. The operation of the beam stop areas is closely coordinated with the isotope production and radiation damage programs. The group is represented in an advisory capacity in the divisional recommendations for electronics, instrumentation and cryogenics for experiments and general use, and actively supports the cryogenic program.

GROUP MP-7 - SECONDARY BEAM LINES

Group Leader	Lewis E. Agnew	A-142	5680
Alternate Group Leader	Henry A. Thiessen	A-146	6991
Group Secretary	Mrs. Pat Thorn	A-144	5680

Group MP-7 is responsible for the design and installation of the secondary beam channels and spectrometers for pion, muon, and nucleon physics research at LAMPF. This includes four separate beams in Experimental Area A for low-energy pions, high-energy pions, high-resolution pion spectroscopy and low-energy muons, as well as high energy

neutron beams and an external proton beam in Experimental Area B, and a high-resolution proton spectroscopy facility in Experimental Area C. The basic diagnostic devices, standard monitoring instrumentation, and integrated portions of the data acquisition systems are also being provided by the personnel in this group.

GROUP MP-8 - ENGINEERING SUPPORT

Group Leader	Thomas J. Boyd, Jr.	D-153	5968
Alternate Group Leader	Hairston G. Worstell	D-150	5521
Assistant Group Leader	Edgar D. Bush, Jr.	D-147	4913
Assistant Group Leader	Paul J. Tallerico	D-149	5507
Group Secretary	Mrs. Kitty A. Maraman	D-151	5968

The primary purpose of MP-8 is to make available to the LAMPF users and operators an experienced pool of mechanical and electrical engineers. These engineers are currently organized to provide the following services:

Accelerator maintenance: A major portion of the group effort is concerned with medium and heavy maintenance support of accelerator operations. Such support includes maintenance of all of the rf power systems together with the accelerator structures and virtually all of their ancillary equipment.

Klystron repair: The large number (44) of 805 MHz klystrons required to power the side-coupled linac portion of LAMPF makes it economically and operationally attractive to acquire an in-house klystron repair capability. Such a facility has been assembled and represents an amalgamation of the equipment and expertise resulting from the design and fabrication of the side-coupled linac and from the klystron research and development carried out in parallel with the klystron procurement and testing programs.

Division and user support: The group currently provides a large share of the effort directed toward the design, fabrication and installation of the

primary and secondary beam lines. When LAMPF becomes operational, it is anticipated that a large portion of this effort will become available for support of the experimental facilities and the various experimental programs. Such support would include general mechanical and electrical engineering, vacuum, coolant design, precision alignment, magnet design, procurement and testing, field plotting, optical tooling, laser tooling, mechanical inspection, optical/magnet coordinate superpositioning, power supply design, procurement, testing and maintenance, current regulator systems, current measuring devices, drafting, branch and staff machine shop services, brazing, welding, cleaning and structural support design. In support of these activities, the group will maintain several staff machine shops, a metrology laboratory, a magnet laboratory, a cleaning facility, a clean room facility, an H₂ furnace brazing facility, a vacuum laboratory, and a mechanical/electrical drafting facility. In general, the experimental support will be short term in nature and will include design, procurement, testing, installation and maintenance and will be organized to provide a flexible and speedy response capability.

GROUP MP-9 - ACCELERATOR SYSTEMS DEVELOPMENT

Group Leader	Robert A. Jameson	A-116	4433
Associate Group Leader	Donald A. Swenson	A-109	5563
Assistant Group Leader	Ralph R. Stevens, Jr.	J-119	5053
Group Secretary	Mrs. Lois Rayburn	A-112	5967

MP-9, the accelerator systems group, has two major areas of work: (1) development of the injector systems for the LAMPF accelerator, and (2) development of the entire accelerator to full-intensity operation. The injector program includes the high intensity H⁺ injector, a 100-200 μ A H⁻ injector (later to be capable of 2 mA peak current), and the development of a polarized ion injector. Simultaneous acceleration of H⁺ and H⁻ beams is to be developed. The group is responsible for determining the experiments and calculations necessary to develop accelerator parameter tuning procedures needed to bring the machine to the design beam intensity. System reviews and engineering required

to specify improvements, build prototypes, test and evaluate performance are being done in collaboration with the operations and maintenance groups. Development of advanced concepts for accelerator control and operation is a long-range goal. Much of this work will evolve around the central computer control system. A primary objective is to achieve high on-line availability of the entire accelerator complex. The talents resident in the group which are being used to meet these objectives include beam dynamics, accelerator physics, systems engineering, systems management, application of computers to complex real-time systems, and modern automatic control techniques.

LISTING OF USEFUL ADDRESSES AND PHONE NUMBERS

AREA CODE FOR NEW MEXICO: 505

LOS ALAMOS SCIENTIFIC LABORATORY - Post Office Box 1663, Los Alamos, New Mexico 87544

Director - Harold M. Agnew, 667-5101

Housing - 667-6632

Information Services

Science Exhibit Hall, tours, meetings - 667-4444

Library services - 667-4448

Medical Library - 667-4281

Mail services - 667-4515

Locator - 667-5061

Payroll - 667-4594

Personnel Services

Employment - 667-4391

Consultants, Visiting Staff Members - 667-6632

Public Relations - 667-6101

Taxi - 667-5061 (Official Use Only)

Travel Services

Reservations and Ross Aviation Schedules - 667-5174

LOS ALAMOS COUNTY SERVICES

Airports

Los Alamos - 662-4031

Albuquerque Sunport (listed by individual airline)*

Santa Fe - 982-5000*

Banks

Los Alamos National Bank - 662-5171

First National Bank of Santa Fe, Los Alamos Branch - 662-4155

Chamber of Commerce

Albuquerque - 243-2201*

Los Alamos - 662-5595

Santa Fe - 983-7317*

County Building - 662-4122

Schools - 662-4141

Hospital - 662-4201

Library

Mesa Public Library - 662-2997

Lodging

Los Alamos Inn - 662-7211

Los Alamos Motor Inn - 662-2997

Museum

Los Alamos Historical - 662-6272

Rental Cars

Los Alamos Avis Rent-a-Car - 662-5046

Santa Fe Avis Rent-a-Car - 982-436 *

U. S. Post Office - 662-2153

*Not located in Los Alamos County.

HK:427(420)