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PHYSICS, COMPUTER SCIENCE AND MATHEMATICS DIVISION. ANNUAL REPORT

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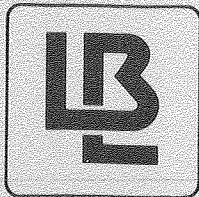
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# PHYSICS, COMPUTER SCIENCE and MATHEMATICS DIVISION

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## ANNUAL REPORT

1 January - 31 December 1977

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**PHYSICS,  
COMPUTER SCIENCE  
and  
MATHEMATICS  
DIVISION**

Robert W. Birge  
Division Head

**ANNUAL REPORT**

1 January -31 December 1977

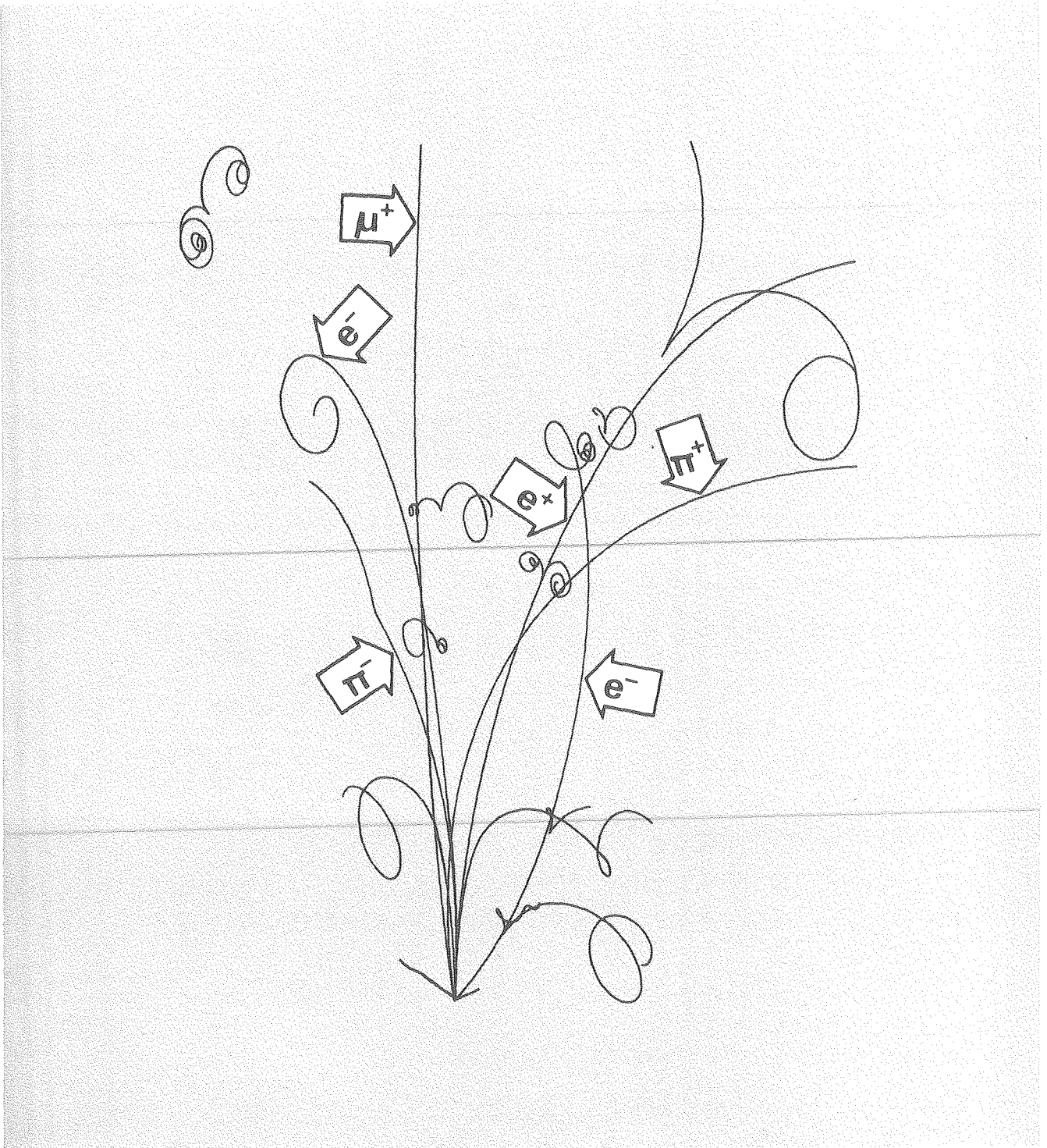
Joseph V. Lepore  
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Berkeley, California**



# CONTENTS

INTRODUCTION	v
PROFESSIONAL STAFF	vii
I. EXPERIMENTAL PHYSICS	
HIGH ENERGY PHYSICS	
Research on $e^+e^-$ Annihilation at SPEAR	1
Facility Development for Experiments at PEP	5
Research at FNAL	13
Strong Interaction Experiments at FNAL, BNL and LBL	16
Instrumentation for High Energy Physics	20
Particle Data Center	24
Astrophysics and Astronomy	25
PEP Experimental Facilities Coordination	28
MEDIUM ENERGY PHYSICS	
Mesonic Atoms	31
Scattering of Nucleons, Pions and Muons by Nuclei	31
Fission Studies with Mu Mesons	33
Radiative Pion Capture, Pion Scattering and Muon Decay	33
A Neutrino Experiment to Test Muon Conservation	35
Instrumentation	36
II. THEORETICAL PHYSICS	
Particle Theory	38
Accelerator Theory and Design	42
III. COMPUTER SCIENCE AND APPLIED MATHEMATICS	
RESEARCH	
Applied Mathematics	45
Advanced Systems	49
Software Engineering	50
Data Management	51
Computer Graphics	51
PROJECTS	
SEEDIS	53
Administrative Information Systems	56
Applications Development and Project Support	58
CSAM Educational and Training Program	60
IV. COMPUTER CENTER	65



A neutrino traveling vertically collides with a neon nucleus in a rare reaction which produces two electrons, a positron, a muon, a  $K_S^0$  meson, and several neutral pions. The  $K_S^0$  meson produced during the impact almost immediately decays in to a  $\pi^+\pi^-$  pair, and the neutral pions decay into pairs of gammas, which subsequently produce electron-positron pairs. This event was filmed during the LBL/FNAL/Hawaii/UC Berkeley/Wisconsin experiment 546, and above figure was traced from the photograph. XBL 785-914.

# INTRODUCTION

This annual report of the Physics, Computer Science and Mathematics Division describes the scientific research and other work carried out within the Division during 1977. The Division is concerned with work in experimental and theoretical physics, with computer science and applied mathematics, and with the operation of a computer center.

The major physics research activity is in high energy physics although there is a relatively small program of medium energy research.

*The High Energy Physics* research program in the Physics Division is closely related to those carried out at other National Laboratories and Facilities such as FNAL, BNL, and ANL and to the research programs of laboratories supported by other nations, such as the Rutherford Laboratory of England, Frascati of Italy, ORSAY of France, Serpukov of USSR, DESY of Germany and the giant European collaboration, CERN.

All of these laboratories, as well as many universities throughout the world, are concerned with fundamental research which will enable man to comprehend the nature of the physical world. LBL has an especially close relationship with SLAC in the collaboration on construction of PEP, the 20 GeV positron-electron colliding beam facility to be completed in the autumn of 1979.

The unexpected and revolutionary discoveries made by SLAC and LBL scientists during the last few years of the  $\psi$ -particle, the related  $\psi$ 's, (the heavy lepton and mesons which exhibit a basic new property called charm) imply that we are now at a new frontier of high energy physics. The LBL-SLAC collaboration on PEP offers a unique and exciting possibility for exploring this region and beyond.

While there is a continuing research effort of the Division at FNAL and BNL, which maintains a balanced program, our major effort is directed toward experiments with positron-electron col-

liding beam at PEP. These activities employ advanced techniques and developments initiated and perfected at the Laboratory. We expect that a new spectroscopy of strongly interacting particles will emerge from experiments at PEP and that new and unexpected phenomena will be found, as they have been in the past when increased energy has become available.

There are five regions at the PEP facility in which electron-positron collisions can occur and which now can be committed. We are proud that collaborative experiments in which LBL will play a major role have been chosen by the PEP Experimental Program Committee (PEPC), a national group of distinguished scientists. These are to be carried out in three of the five interaction regions. It suffices to say that proposals for experiments at PEP were presented by groups throughout the nation and that all were severely scrutinized.

The three proposals which have been selected by the PEPC are 1) The Time Projection Chamber, (PEP-4), 2) The Mark II Magnetic Detector, (PEP-5), and 3) A search for quarks (PEP-14). All of the three experiments are collaborative efforts. Collaborating with us on the Time Projection Chamber are UCLA, Johns Hopkins, UC Riverside and Yale. The Mark II is a joint LBL-SLAC effort to develop a more powerful version of the Mark I Magnetic Detector used in the discovery of the  $\psi$  particles. Finally the quark search is a collaboration with Stanford University, the University of Hawaii and Northwestern University.

One of the proposals accepted by the PEPC is uniquely important. This is the time projection chamber (TPC) experiment. The TPC is a radically new concept for particle identification and measurement. Its construction requires the deployment of physicists, engineers and highly-skilled technicians; it also requires an extensive computer facility. LBL will play a major role in its construction and operation as well as in the analysis of data from this facility.

The Mark II Magnetic Detector will be used first at SPEAR and afterwards will be moved to PEP when the latter becomes operational.

For the quark search experiment, LBL will be the center for construction of the necessary experimental equipment.

Our continuing program at FNAL covers work on Rare Muon Induced Reactions utilizing a new type magnetic spectrometer, neutrino and anti-neutrino interactions in the 15 ft. bubble chamber with the External Muon Identifier (EMI), and other strong interaction physics. LBL plays a major role in these experiments.

*The Medium Energy Physics* program is concerned with research using mesons and nucleons to probe the properties of matter. Our program is closely related to the programs being carried out at other National Laboratories and Facilities, such as ORNL and LAMPF, and to the research programs of laboratories supported by other nations, such as Harwell of England, TRIUMF of Canada and SIN of Switzerland, as well as the research effort of many universities throughout the world. This research is concerned with the study of nuclear structure, nuclear reactions and the interactions between nuclei and electromagnetic radiation and mesons. Experiments are being carried out by LBL scientists at the Bevatron, the ZGS, at TRIUMF and at LAMPF.

*The Computer Science and Applied Mathematics Department* engages in research in a variety of computer science and mathematics disciplines. The Department staff includes computer scientists, mathematicians, engineers, physicists, computer technicians, and administrative personnel. A balanced mix of project-oriented work and discipline-oriented research is supported by the Department of Energy and other federal and state agencies.

Work in computer science and applied mathematics includes construction of data bases, computer graphics, computational physics and data analysis, mathematical modeling, and mathematical analysis of differential and integral equations resulting from physical problems.

*The Computer Center* provides large-scale computational support to LBL's scientific programs. The Center operates an extremely powerful computer system. In addition to its primary scientific computation works, the Center serves the Laboratory by constantly upgrading computer facilities and services.

The staff of the laboratory is enhanced by the close association with the faculty and graduate students of the University of California at Berkeley and by collaborations with universities and laboratories elsewhere. In preparation for work at PEP and to continue our tradition of leadership in research work, we have augmented our permanent staff by a few outstanding young scientists. About one-third of the staff consists of temporary post-doctoral appointees while the remainder is split between permanent staff and faculty. Graduate student activities continue to be an important aspect of the program. The graduate students contribute substantially to the Laboratory's research program while fulfilling the requirements for their advanced degrees.

Recent graduates and some members of the permanent staff have moved into fields closely related to the energy program at the laboratory and now play important leadership roles in solar, conservation, and fusion programs. High energy physics developments in superconductivity, electronics and other instrumentation continue to find use in industrial and medical applications.

# PROFESSIONAL STAFF

1977

## Experimental Physics

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## Computer Science and Applied Mathematics

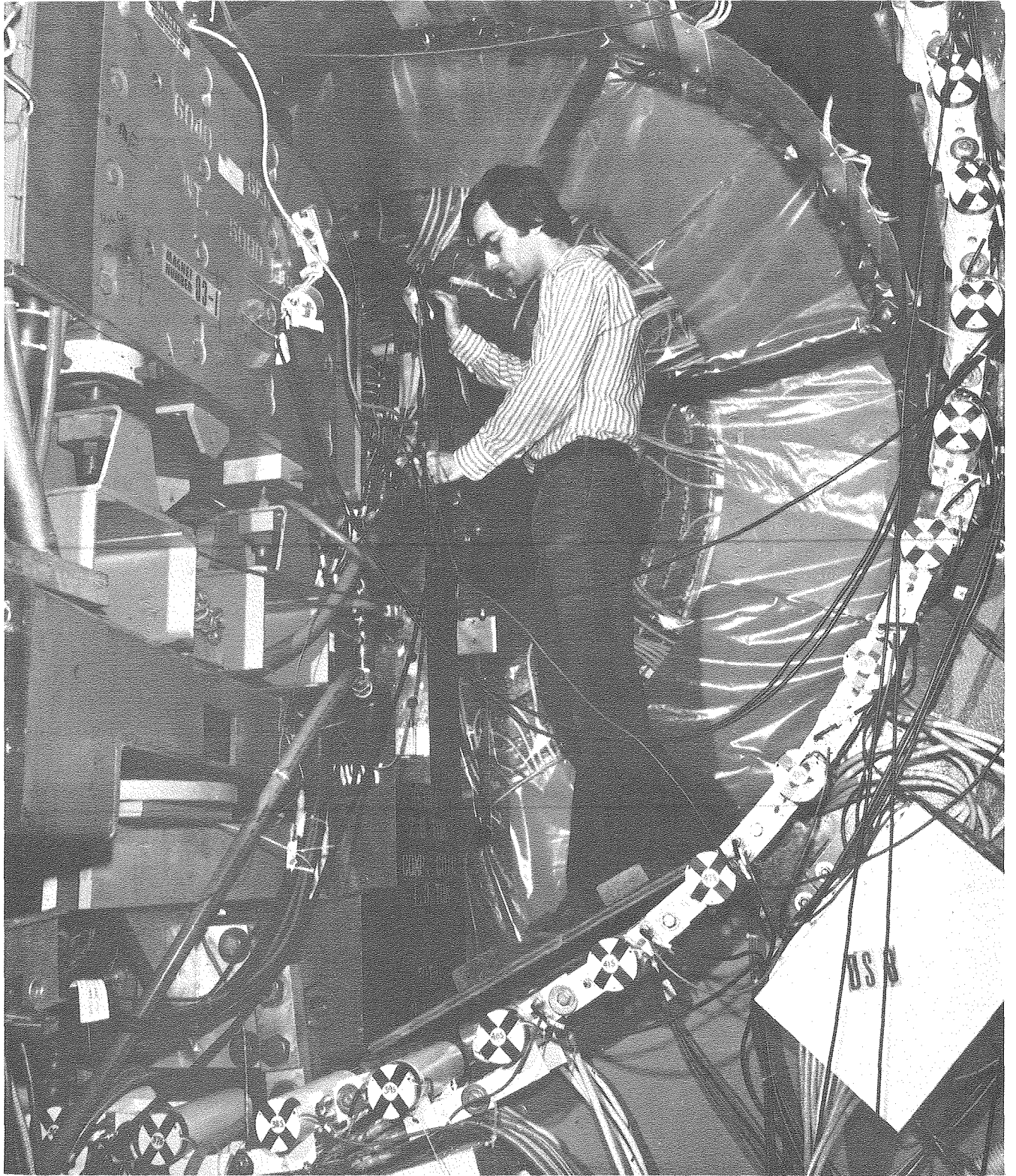
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# I. EXPERIMENTAL PHYSICS



The Mark II magnetic detector replaced the Mark I in the SPEAR facility at SLAC. Instrumentation of Mark II includes liquid-argon/lead-plate ionization chambers and the ring of trigger (time-of-flight) counters in which Craig Blocker, LBL physicist, stands. Mark II will be moved to PEP when the latter is completed. CBB 781-351

# HIGH ENERGY PHYSICS

## Research on $e^+e^-$ Annihilation at SPEAR

### Mark I and Mark II Magnetic Detectors

Although no experimental data was taken with the Mark I detector during 1977, analysis of data tapes obtained from earlier operation continued. The major thrusts of these analyses were as follows:

(1) A continuing study of the properties of the charmed mesons discovered in 1976 with the Mark I. These studies helped establish:

- The existence of the  $D^{*+} \rightarrow D^0 \pi^+$  decay mode of the excited state  $D^*$ , and an accurate  $D^{**} - D^0$  mass difference.
- The production processes of the D mesons in the energy region of 4.03 and 4.41 GeV where the annihilation cross section has substantial maxima. In particular the  $D\bar{D}^*$

and  $D^*\bar{D}^*$  cross sections appear remarkably large relative to  $D\bar{D}$  even near the  $D^*\bar{D}^*$  threshold.

- The relative branching ratios of several of the  $D^+$  and  $D^0$  decay modes.
- The energy dependence of the cross section for baryon production in the  $e^+e^-$  annihilation, with suggestive indication of production of charmed baryons.

(2) A continuing study of the properties of the  $\tau$  heavy lepton. These studies added to the information subsequently obtained by others running with Mark I. They make up a convincing case for the existence of the  $\tau^+$  as a heavier member of the  $e, \mu$  charged lepton family.

(3) The total analysis of radiative decay modes of  $\psi'$  was completed.

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## MARK I AND MARK II MAGNETIC DETECTORS

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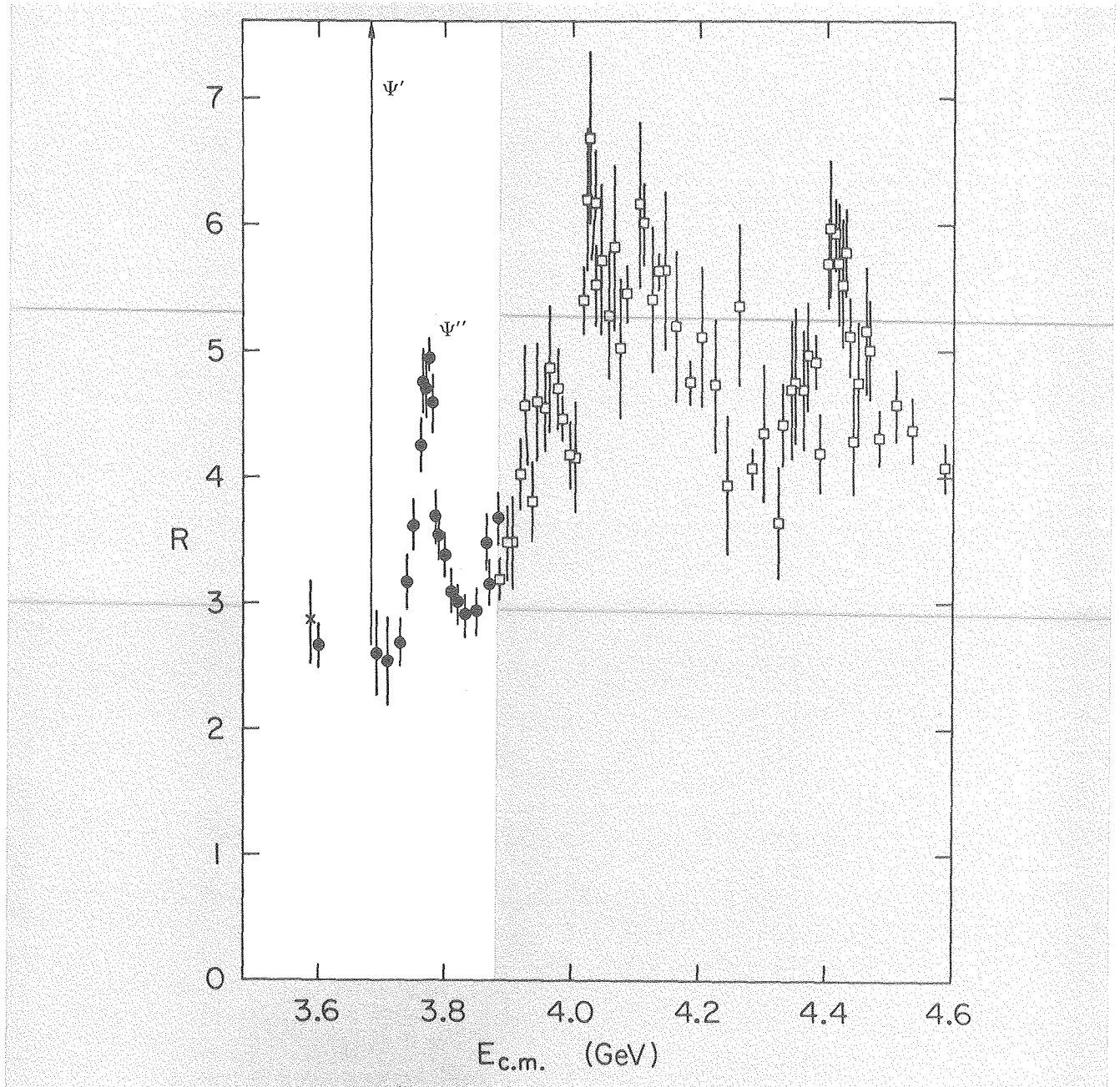
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M. Coles	M. E. Nelson
S. Cooper	J. Patrick
W. E. Dieterle	E. N. Vella
J. B. Dillon	J. S. Whitaker

## The Lead-Glass Wall

In this experiment, a wall of lead-glass counters is used to detect and identify electrons and photons with high precision, in order to study anomalous electron production and production of photons and  $\pi^0$ 's in  $e^+e^-$  annihilations at SPEAR. The wall was installed in one octant of the Mark I magnetic detector so that information on charged particles is

simultaneously recorded. The primary aim of the experiment was to search for events which arise from the production and decay of charmed particles and heavy leptons. The experiment ran at SPEAR.

A new resonance has been discovered in  $e^+e^- \rightarrow$  hadrons at a center-of-mass energy at 3772 MeV, just above the threshold for the production of charmed particles. This state, called the  $\psi(3772)$ , is a copious and clean source of charmed D mesons.



A new resonance of the  $\psi$  family,  $\psi''(3772)$ , was discovered during the Lead Glass Wall experiment.  $\psi(3095)$  and  $\psi'(3684)$  are made of hidden charm, whereas  $\psi''$  is made of naked (visible) charm. The  $\psi''$  is the resonance plotted with black points. XBL 7711-10394.



This allowed measurement of the D meson masses with high precision (better than 1 MeV), the semi-leptonic branching ratios of the D mesons, and made possible the observation of some new decay channels of the D meson. The existence of the heavy lepton,  $\tau$ , has been confirmed. In addition the leptonic branching ratio of the  $\tau$  into an electron and the branching ratio of the  $\tau$  into a single charged hadron plus neutral have been measured. The inclusive production of lambdas and anti-protons has been found. In this year the analysis of photons and  $\pi^0$ 's has been made in order to measure the inclusive photon spectrum and the properties of exclusive states containing photons or  $\pi^0$ 's. The analysis of anomalous electron production in multihadronic states as a function of center-of-mass energy has been completed.

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- Measurement of Semi-leptonic Decays of D Mesons to Electrons at the  $\psi(3772)$ , J. M. Feller, A. M. Litke, R. J. Madaras, M. T. Ronan, A. Barbaro-Galtieri, J. M. Dorfan, R. Ely, G. J. Feldman, A. Fong, B. Gobbi, G. Hanson, J. A. Jaros, B. P. Kwan, P. Lecomte, D. Lüke, J. F. Martin, T. S. Mast, D. H. Miller, S. I. Parker, M. L. Perl, I. Peruzzi, M. Piccolo, T. P. Pun, P. A. Rapidis, R. R. Ross, B. Sadoulet, T. G. Trippe, V. Vuillemin, D. E. Yount, *Physical Review Letters* 40, (1978). LBL-6772
- A Search for Neutral Heavy Leptons, D. I. Meyer, H. K. Nguyen, G. S. Abrams, M. S. Alam, A. Barbaro-Galtieri, A. M. Boyarski, M. Briedenbach, R. G. DeVoe, J. Dorfan, R. Ely, G. J. Feldman, J. Feller, A. Fong, B. Gobbi, G. Goldhaber, G. Hanson, A. D. Johnson, J. A. Jaros, J. A. Kadyk, B. P. Kwan, P. Lecomte, A. Litke, D. Lüke, R. J. Madaras, J. Martin, T. S. Mast, D. H. Miller, S. Parker, J. M. Paterson, M. L. Perl, I. Peruzzi, M. Piccolo, T. P. Pun, P. Rapidis, M. T. Ronan, R. Ross, W. Tanenbaum, G. H. Trilling, T. Trippe, V. Vuillemin, J. E. Wiss, D. Yount, submitted to *Physics Letters* (1977). LBL-6727.

The Lead-Glass Wall Addition to the SPEAR Mark I Magnetic Detector, J. M. Feller, A. Barbaro-Galtieri, J. M. Dorfan, R. Ely, G. J. Feldman, A. Fong, B. Gobbi, G. Hanson, F. B. Heile, J. A. Jaros, B. P. Kwan, P. Lecomte, A. M. Litke, D. Lüke, R. J. Madaras, J. F. Martin, T. S. Mast, D. H. Miller, B. Pardoe, S. I. Parker, M. L. Perl, I. Peruzzi, M. Piccolo, T. P. Pun, P. A. Rapidis, M. T. Ronan, R. R. Ross, B. Sadoulet, D. L. Scharre, T. G. Trippe, V. Vuillemin, D. E. Yount, *Proceedings of the IEEE 1977 Nuclear Science Symposium, San Francisco, CA, Oct. 19-21, 1977*. LBL-6466

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Electron-Muon and Electron-Hadron Production in  $e^+e^-$  Collisions, A. Barbaro-Galtieri, B. P. Kwan, A. M. Litke, J. M. Dorfan, R. Ely, G. J. Feldman, J. M. Feller, A. Fong, B. Gobbi, G. Hanson, J. A. Jaros, P. Lecomte, D. Lüke, R. J. Madaras, J. F. Martin, T. S. Mast, D. H. Miller, S. I. Parker, M. L. Perl, I. Peruzzi, M. Piccolo, T. P. Pun, P. A. Rapidis, M. T. Ronan, R. R. Ross, B. Sadoulet, T. G. Trippe, V. Vuillemin, and D. E. Yount, *Physical Review Letters* 39, 1058 (1977). LBL-6458

Study of D Mesons Produced in the Decay of  $\psi(3772)$ , I. Peruzzi, M. Piccolo, G. J. Feldman, P. Lecomte, V. Vuillemin, A. Barbaro-Galtieri, J. M. Dorfan, R. Ely, J. M. Feller, A. Fong, B. Gobbi, G. Hanson, J. A. Jaros, B. P. Kwan, A. M. Litke, D. Lüke, R. J. Madaras, J. F. Martin, D. H. Miller, S. I. Parker, M. L. Perl, T. P. Pun, P. A. Rapidis, M. T. Ronan, R. R. Ross, D. L. Scharre, T. G. Trippe, and D. E. Yount, *Physical Review Letters* 39, 1301 (1977). LBL-6755

Inclusive Baryon Production in  $e^+e^-$  Annihilation, M. Piccolo, I. Peruzzi, B. Richter, G. S. Abrams, M. S. Alam, A. Barbaro-Galtieri, A. M. Boyarski, M. Briedenbach, W. Chinowsky, J. M. Dorfan, R. Ely, G. J. Feldman, J. M. Feller, A. Fong, D. Fryberger, B. Gobbi, G. Goldhaber, G. Hanson, J. A. Jaros, A. D. Johnson, J. A. Kadyk, B. P. Kwan, R. R. Larsen, P. Lecomte, A. M. Litke, D. Lüke, V. Lüth, H. Lynch, R. J. Madaras, J. F. Martin, D. H. Miller, H. K. Nguyen, S. I. Parker, J. M. Paterson, M. L. Perl, T. P. Pun, P. A. Rapidis, M. T. Ronan, R. R. Ross, D. L. Scharre, R. F. Schwitters, W. Tanenbaum, T. G. Trippe, G. H. Trilling, V. Vuillemin, and D. E. Yount, *Physical Review Letters* 39, 1503 (1977). LBL-6775.

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## Facility Development for Experiments at PEP

### The Time Projection Chamber PEP-4

In the Positron Electron Project, the PEP-4 TPC facility will have the capabilities to detect and study, in detail, much of the phenomena expected at PEP and will provide exceptionally broad sensitivity in the search for new phenomena anticipated within the PEP energy range. The PEP-4 TPC detector system includes exceptional capabilities for charge particle pattern recognition, momentum analysis and mass identification within high multiplicity jet-like events, neutral reconstruction ( $\Lambda^0$ ,  $K_S$ ,  $\pi^0$ ,  $\eta^0$  . . .), electromagnetic calorimetry and muon identification.

This broad range of characteristics, which seems difficult to achieve simultaneously over most of  $4\pi$  solid angle by techniques other than those used by PEP-4 TPC, results in the detector having an anticipated productive life well beyond the first round of PEP running.

The major new ingredient of the PEP-4 TPC facility is the Time Projection Chamber itself which will provide particle identification over the entire momentum range for electrons, pions, kaons and protons.

The PEP-4 TPC detector consists of four major functional systems, the time projection chamber, a superconducting solenoid magnet (SSM), an electromagnetic calorimeter and a muon detector.

The initial goal after the construction and debugging of the PEP-4 facility is to search for evidence of new processes or the production of new particles at PEP. The ratio of hadron to muon pair production will be measured to high precision; the details of hadronic events will be observed in order to measure multiplicities, sphericity and inclusive particle spectra; scaling will be tested;

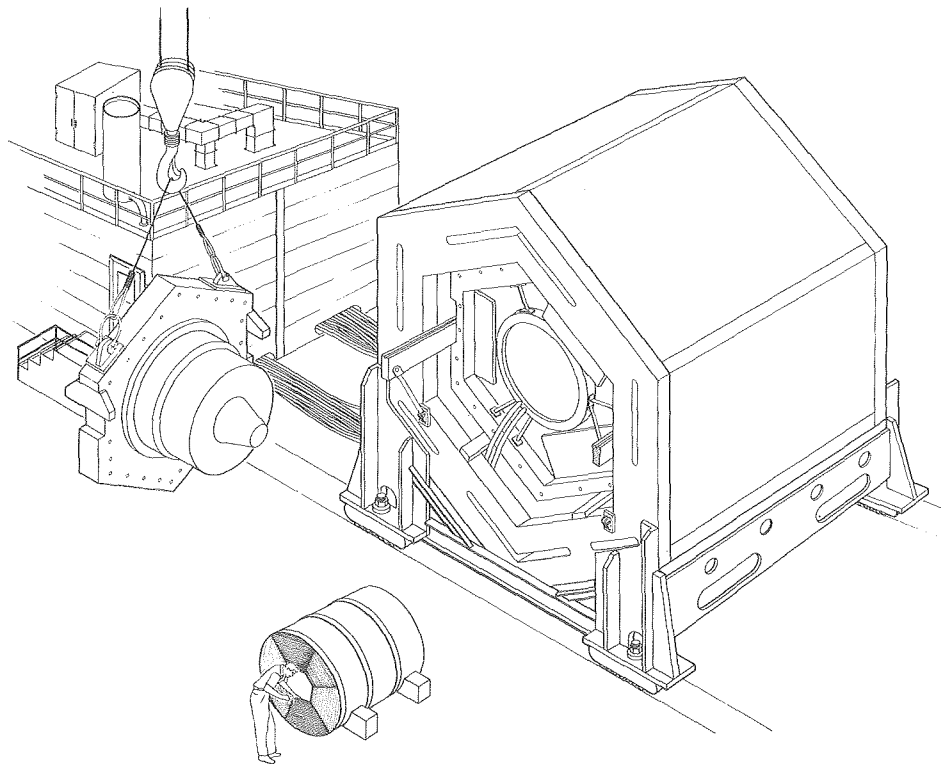
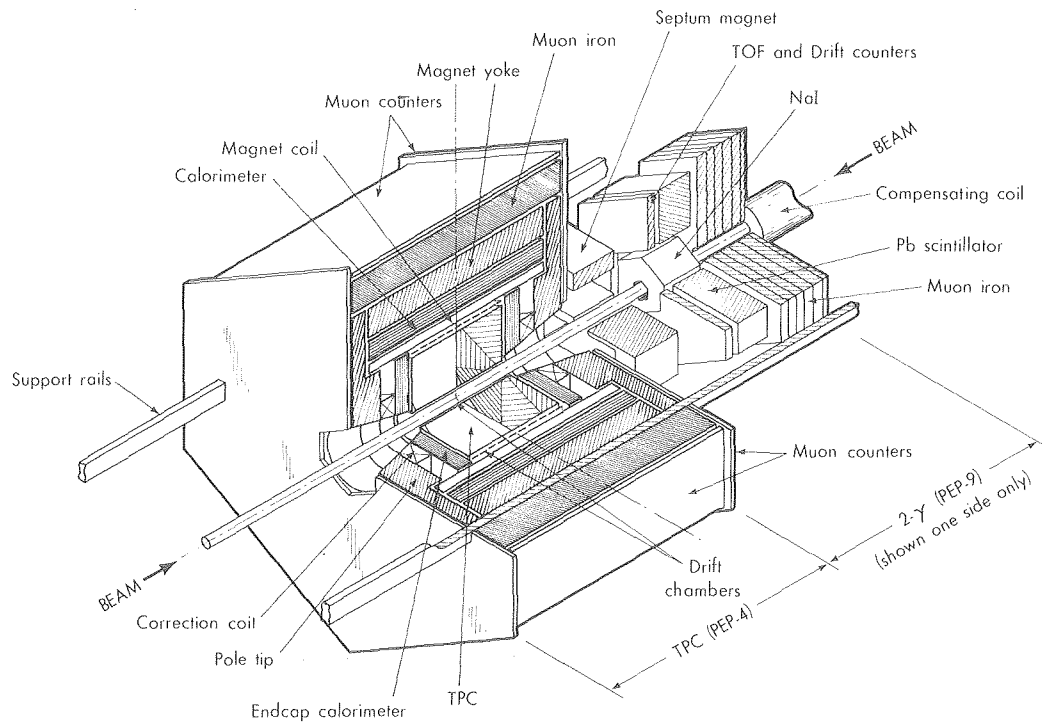
and a search for bumps in invariant mass spectra reconstructed from these final state hadrons will be made. It should be emphasized that if a new hadronic threshold is reached at PEP, the PEP-4 TPC facility is exceptionally well instrumented to spot new mass bumps, even far above threshold, because of the high quality particle identification available. An attempt to detect weak interaction effects will be made during this phase.

To summarize, the PEP-4 TPC facility for PEP will provide an extremely broad range of detection capabilities. This approach will maximize the useful information content per event at acceptable cost and so greatly enhance the understanding of  $e^+e^-$  annihilations in the PEP energy range.

*1. Time Projection Chamber (TPC)* — In this period, a large number of prototype/testing projects have been initiated or completed. Major areas of activity focus on the following:

- The gas circulation and purification process.
- Generation and insulation of the TPC high voltage.
- Testing and selection of materials for TPC construction.
- Simulation and optimization of TPC electrostatics.
- Optimization of parameters and operation conditions.
- Design, construction and testing of a TPC prototype sector.
- Determination of pad response function.
- Experimental studies with a complete TPC prototype at the Bevatron/Bevalac.
- Implementation of a charge-coupled device (CCD) readout system.
- Optimization of trade-offs between physics considerations and engineering constraints.
- Final design of PEP-4 TPC has begun and some construction has started.

TIME PROJECTION CHAMBER WITH  $2\gamma$  DETECTORS



The center of the Time Projection Chamber (TPC) is at the point of collision of the positron/electron beams. It is capable of detecting all known particles produced in an  $e^+e^-$  collision. It also provides full and immediate non-projective three dimensional reconstruction of the event, together with momentum measurement and particle identification. XBL 776-1137 and CBB 783-3085.

2. *Superconducting Solenoid Magnet* — The study of quenches has been pursued using new techniques of inducing quenches. This study has led to the development of rules that should be respected in superconducting magnet engineering and that permit the building of better, safer and cheaper magnets. This study will be continued.

The construction of the thin coil solenoid for the PEP-4 experiment is underway. Tests will continue on the 2m diameter test coil which has already reached the short sample current density. Superconductor and bore tube materials for the TPC magnet have been ordered. Studies of correction coil systems will be completed.

Some feasibility studies will be made for detectors to be used in colliding beam experiments at Fermilab. For future projects in general, aluminum based superconductors will be tested for their adequacy and reliability.

3. *Electronics* — During this year the project has investigated the various alternatives associated with the conceptual design. Then prototypes will be built and tested (see the PEP-4 management plan for details). In some cases, the production phase will be started. All of the conceptualization for the various systems has been completed. Overall agreement has been reached on the standardization of printed circuit card size, connectors, cables, card configuration, power supply distribution, cooling, multiplexing, etc. Finally the design of the various pre-amplifiers, amplifiers, multiplexers, digitizers and buffer stores required for the four detector components named above will be completed and preproduction will begin.

4. *Trigger System* — Measurements made during this year are concerned with the time, spatial, and angular resolution and efficiency of four layers totaling  $\geq 16$  inner drift chamber cells with final prototype associated trigger electronics and with measurement of the time resolution and efficiency of at least two adjacent prototype outer drift chamber cells with final prototype associated trigger electronics.

Full conceptual definition of all trigger mechanisms has been completed.

Circuit design has been completed for all major trigger electronics systems, except for all-neutral trigger.

Acceptable prototype circuits have been fabricated and tested for all trigger electronics systems associated with inner and outer drift chambers.

5. *Drift Chambers* — This system is the responsibility of collaborators at the University of California, Riverside.

6. *Electromagnetic Calorimeters* — Pole Tip Calorimeters: This system is the responsibility of collaborators at the University of California at Los Angeles.

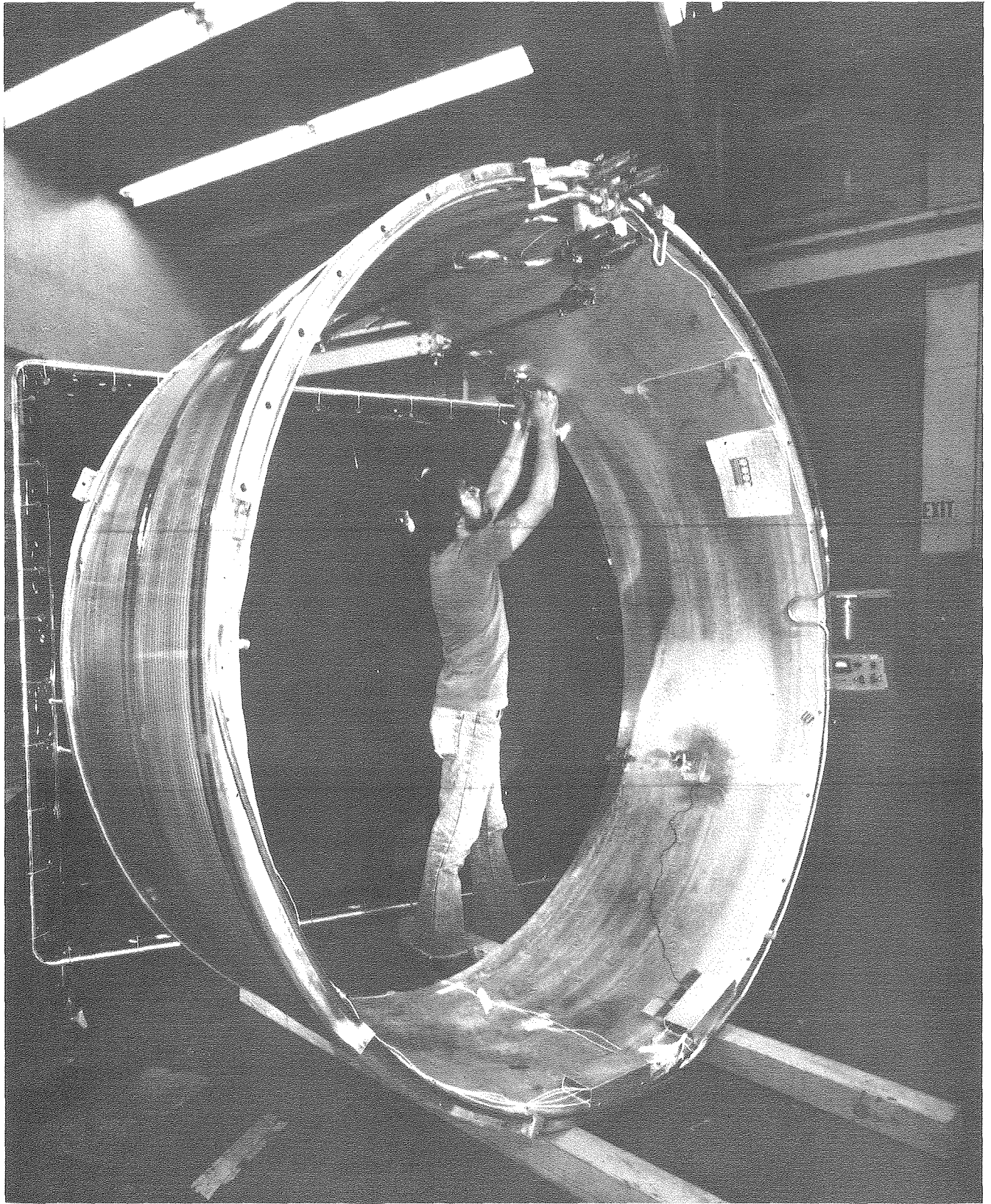
Cylindrical Calorimeter: This system is the joint responsibility of LBL and UCLA. Due to a decreased funding flow rate the PEP-4 collaboration has decided to defer the cylindrical calorimeter for one year with respect to the commission date of the PEP-4 TPC facility. Various R&D efforts directed toward design of the pole tip calorimeter will be considered for relevance to the cylindrical calorimeter. Preliminary conceptual designs are being considered, to arrive at a final design philosophy and construction schedule.

7. *Muon Detectors* — This system is the responsibility of collaborators at Johns Hopkins University.

8. *General Construction and Mechanical Engineering* — A final design review has been completed. Cost estimates and construction schedules have been updated. Purchase of support structures and various hardware for component systems of the detector have been made. Modeling of detector assembly and disassembly procedures is underway.

9. *On-Line Computing* — During this year efforts have focused on the specification and purchase of two powerful computers for use in the PEP-4 experiment. Because of the urgency to provide diagnostic capacity during hardware development a DEC PDP 11/70 has been purchased.

Software has been developed to test the data acquisition for the TPC. This includes I/O drivers for data input as well as routines to send test pulses to the detector and monitor response.



Exceptionally compact magnets producing huge magnetic fields may be constructed if superconducting coils are employed. This prototype for the TPC would be prohibitively large without the new technology.

CBB 776-6029



In addition to the 11/70 for monitoring and control, the experiment requires a powerful computer for on-line physics analysis. The PEP management has recommended the purchase of a VAX 11/780 system from DEC. for each of the PEP experiments.

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*10. Off-Line Software* — A vigorous effort has been devoted to the development of a comprehensive, sophisticated and fast off-line data analysis system for the TPC facility at PEP, designed to exploit the unique features of the data from this detector.

A rudimentary computer simulation of Monte Carlo generated events from  $e^+e^-$  interactions has been developed in the TPC detector. A reasonably complete computer simulation of events in the TPC, including such refinements as multiple scattering and energy loss effects has been achieved. The pattern recognition programs and some aspects of the geometric reconstruction programs have been completed.

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## Superconducting Solenoid Magnets and Low Temperature Research and Development

### TITLES AND DATES OF PUBLICATIONS:

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TPC Update, in *Research/Accelerators*, January/February 1977, Vol. 2, No. 1, LBL-6153, p. 11-13. Photo numbers: CBB 772-1299; XBB 772-1180; XBB 772-1181; XBL 773-546; XBL 773-547.

Agreement on the Fabrication of the PEP-4 Detector, December 8, 1977.

Over 200 internal publications and technical notes about PEP-4 TPC are now in our files. The project is still in the research and development stages, and technical data taking is still being done.

The aim of this program is to produce thinner and cheaper magnets for use in detectors for high energy physics. The technique is to develop different schemes of quench protection for superconducting coils and to test the quench protection schemes on specially built instrumented test coils capable of triggered quenching.

Techniques resulting from the program are being used in building the superconducting magnet for the PEP-4 detector and are being considered for magnets to be used in detectors at FNAL and CERN. The study of quenches has been pursued using these techniques for inducing quenches. It has led to the development of rules that should be respected in superconducting magnet engineering and that permit the building of better, safer and cheaper magnets. This study will be continued.

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The construction of the thin coil solenoid for the PEP-4 experiment is underway. Some feasibility studies will be made for detectors to be used in colliding beam experiments at Fermilab. For future projects in general, aluminum based superconductors will be tested for their adequacy and reliability.

#### TITLES AND DATES OF PUBLICATIONS:

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#### SUPERCONDUCTING MAGNETS

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## The Mark II Magnetic Detector PEP-5

In the last few years, many of the major new developments in high energy physics have come from the coupling of electron-positron storage rings with powerful and flexible detectors. The numerous discoveries made over a period of four years with the SLAC-LBL Mark I detector at the SLAC storage ring SPEAR demonstrate convincingly the power of these techniques.

The SLAC-LBL Mark II detector is an instrument of substantially greater sophistication than the Mark I. Its functions are both to deepen the annihilation studies in the 3 - 8 GeV energy range already initiated by the Mark I and to carry out exploratory work at the much higher energies to be available soon at the new facility, PEP. Some of the major improvements of the Mark II over the Mark I include the following:

- A very sophisticated detector of photons and electrons consisting of liquid argon-lead plate ionization chambers surrounding the detector.

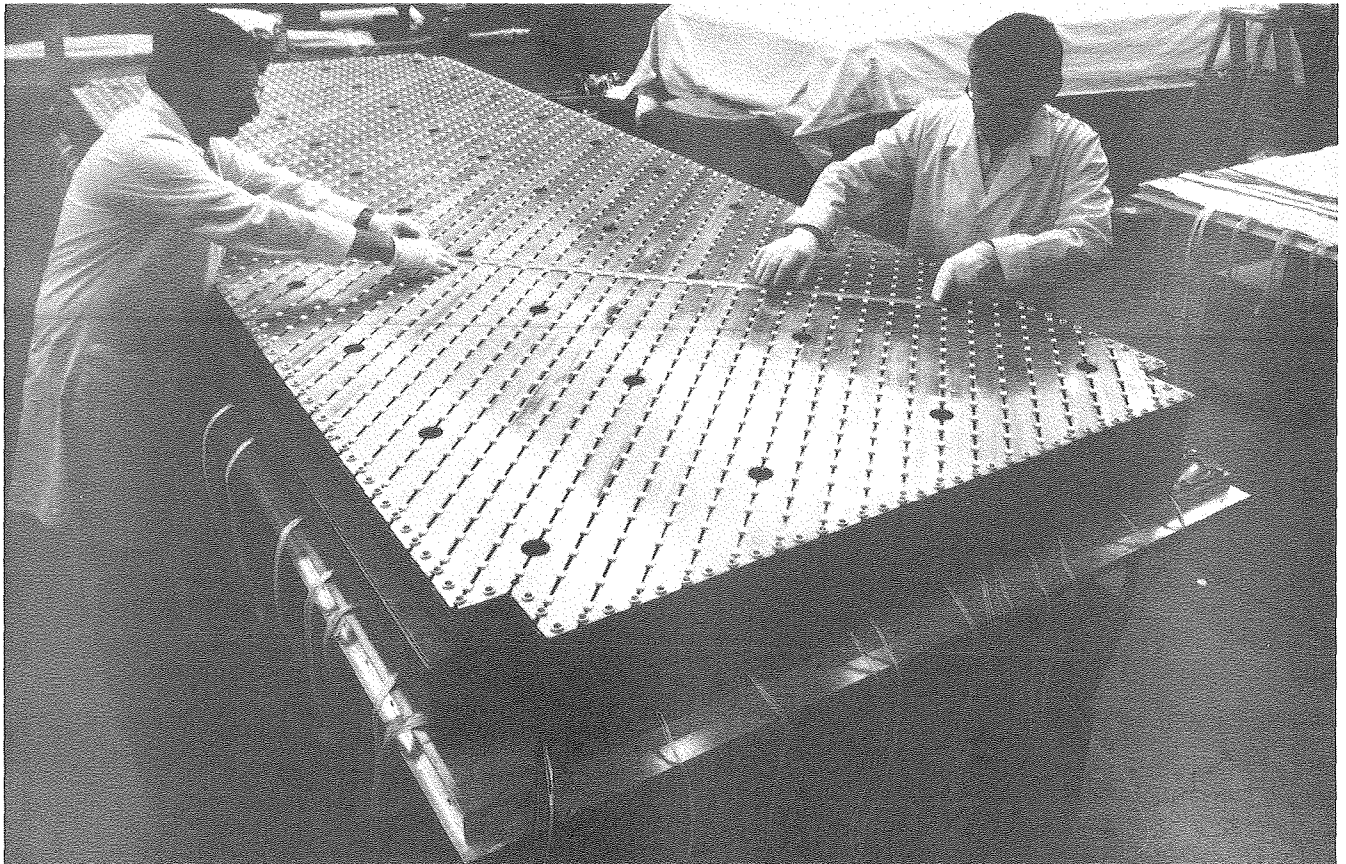
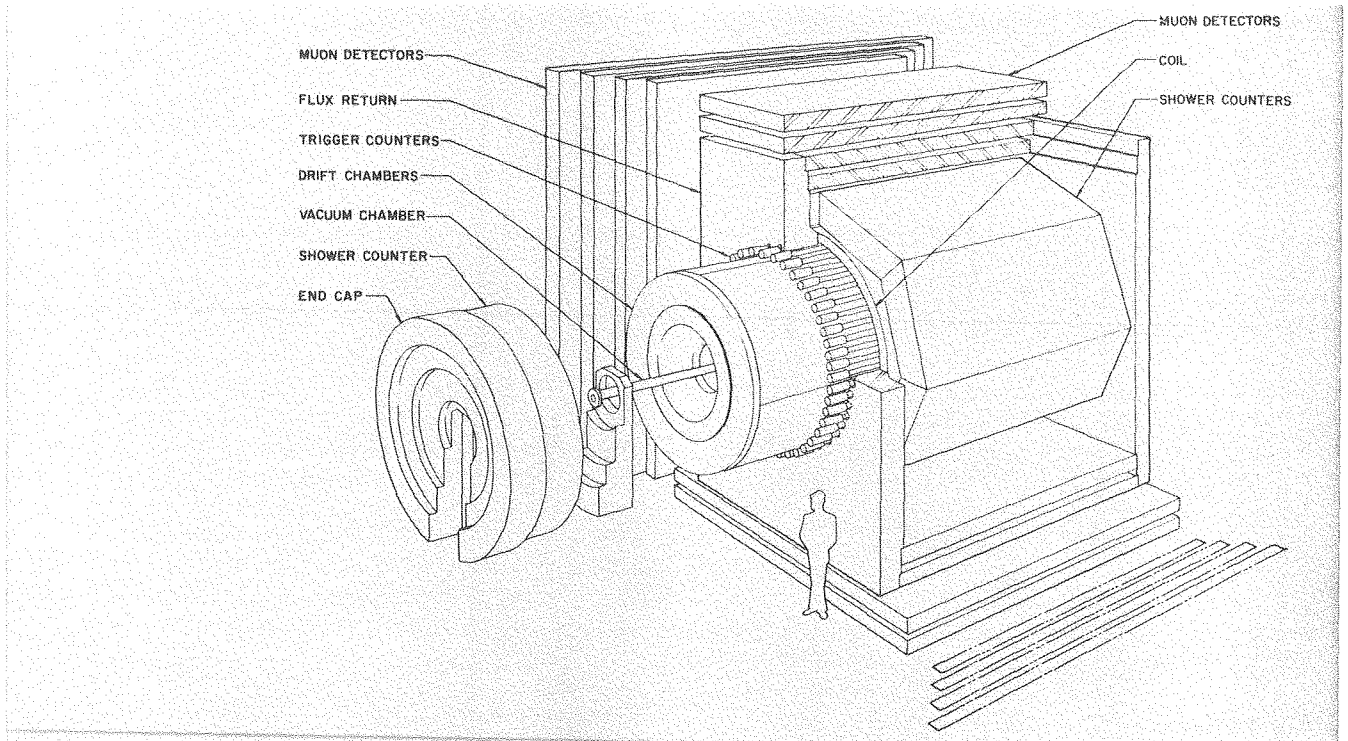
- The use of drift chambers for track detection; these can be used in the trigger logic and hence permit a much less biased trigger requirement.
- Improved solid angle coverage by both the tracking and the trigger system.
- The implementation over a substantial solid angle of a good muon identification system.
- The scintillation counter time-of-flight system was installed and seems to be working satisfactorily.
- The computer programs are working satisfactorily, and are being continuously improved on the basis of the operating experience.

With these improved capabilities, it is expected that the Mark II detector will be a major tool for the study of  $e^+e^-$  processes both at the SPEAR and at the PEP energies. The Mark II development and construction has been carried out in collaboration with groups at SLAC. The major LBL responsibilities have been as noted below:

- The design and construction of a group of eight liquid argon shower counter modules which surround the detector, each module covering an azimuthal region of  $45^\circ$ .
- The design and construction of part of the electronics which enables one to read out the information collected by the liquid argon shower counters.
- The design and construction of a vacuum vessel inside of which these modules are mounted, the purpose of the vacuum being to provide adequate thermal insulation.
- The development of computer programs for the analysis of data from both the liquid argon system and the drift chamber tracking detectors.
- The design and construction (in close collaboration with the SLAC groups) of the scintillation counter time-of-flight system.

The progress this year in those areas of the Mark II construction in which LBL has substantial responsibility includes the following:

- The eight liquid argon modules have been completed, tested and installed in the vacuum enclosure surrounding the solenoid coil of the Mark II detector.



Stacked lead strips are arranged at opposing angles and held apart by spacers in the liquid argon counters for the Mark II Magnetic Detector. Eight of these modules surround the superconducting solenoid, as indicated in the schematic. In the photo John Yeager, Jr. (left) and Al Barone check components of a module in the Mechanical Assembly Shop.  
 XBL 788-9929 and CBB 773-2771

- The electronics have been installed and debugged.
- The liquid argon system has been pumped down, cooled and filled with argon. Operation for physics research has begun.

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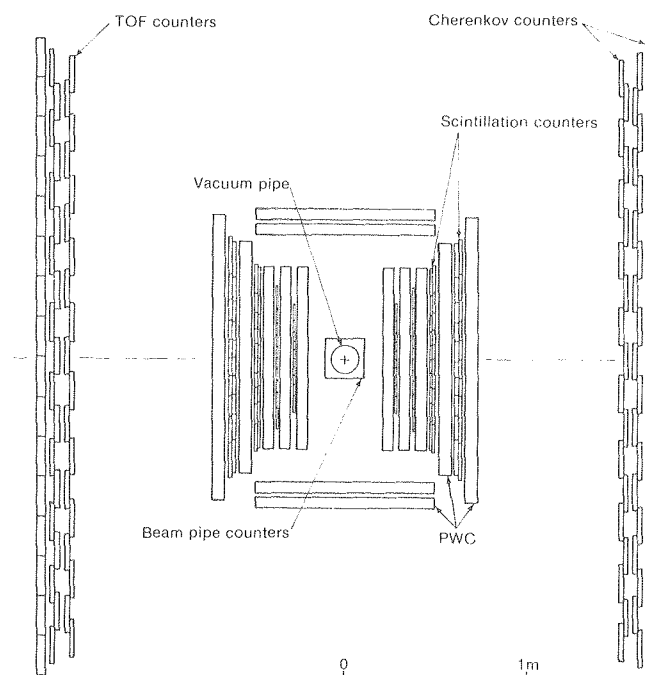


Diagram of counter designed for seeking free quarks at PEP. Their presence is to be detected by the charges of produced particles and by measurement of their time of flight, and their energy loss per cm. Eight layers of scintillation counters will be used. XBL 788-1535

allow for efficient detection of quarks even if produced within a jet of hadrons.

All pieces of equipment will be carefully monitored to ensure stable gains and high detection efficiency for particles with fractional electric charge.

The major activity this year involved the final design of the overall detector and development work on various components. Major responsibility for LBL was the proportional chamber design and construction, the development of associated proportional chamber electronics, the modification of the LSD system developed at LBL for the scintillation pulse height measurement, and the lay-out of on-line and off-line analysis for the experiment. In particular, a prototype proportional chamber has been built and tested and schemes for the monitoring of the gain have been developed.

The Search for Quarks PEP-14

A large part of experimental results of present day high energy physics can be explained with quarks being the fundamental building blocks of elementary particles; as yet no quarks have been observed. PEP opens up a completely new domain for the search for charged particles. This experiment offers a simple detector that would be able to detect quarks of mass up to the maximum PEP energy of 15 GeV and with enough sensitivity such that a negative result will raise serious doubt about the existence of these hypothetical objects.

Charged particles produced by  $e^+e^-$  collision will be detected by a set of eight layers of scintillation counters. Combining measurements of  $dE/dx$  and time-of-flight for these particles enables one to determine the charge of individual particles. A set of proportional chambers will be used for tracking and a lucite Cerenkov counter will indicate high velocity particles. This quark detector will cover a solid angle of  $4\pi/3$  sr. and will be segmented to

PEP-14 STAFF

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## Research at FNAL

### Rare Muon Induced Reactions

Experiments on rare muon induced reactions are now being conducted at FNAL. Electronic techniques are being used for particle identification and momentum measurements.

The 470-ton segmented target/spectrometer used for these experiments (FNAL 203/391) was completed and magnetic field measurements carried out. The total design has proven quite successful, the magnetic characteristics are very close to the designed requirements.

The gaps of the segmented magnet have been fully instrumented with 19 proportional/drift chamber combinations. In addition, trigger and hadron calorimetry systems were installed and tested. The entire target/spectrometer system is now operative and multi-muon final states are being observed and studied.

#### MUON EXPERIMENT STAFF

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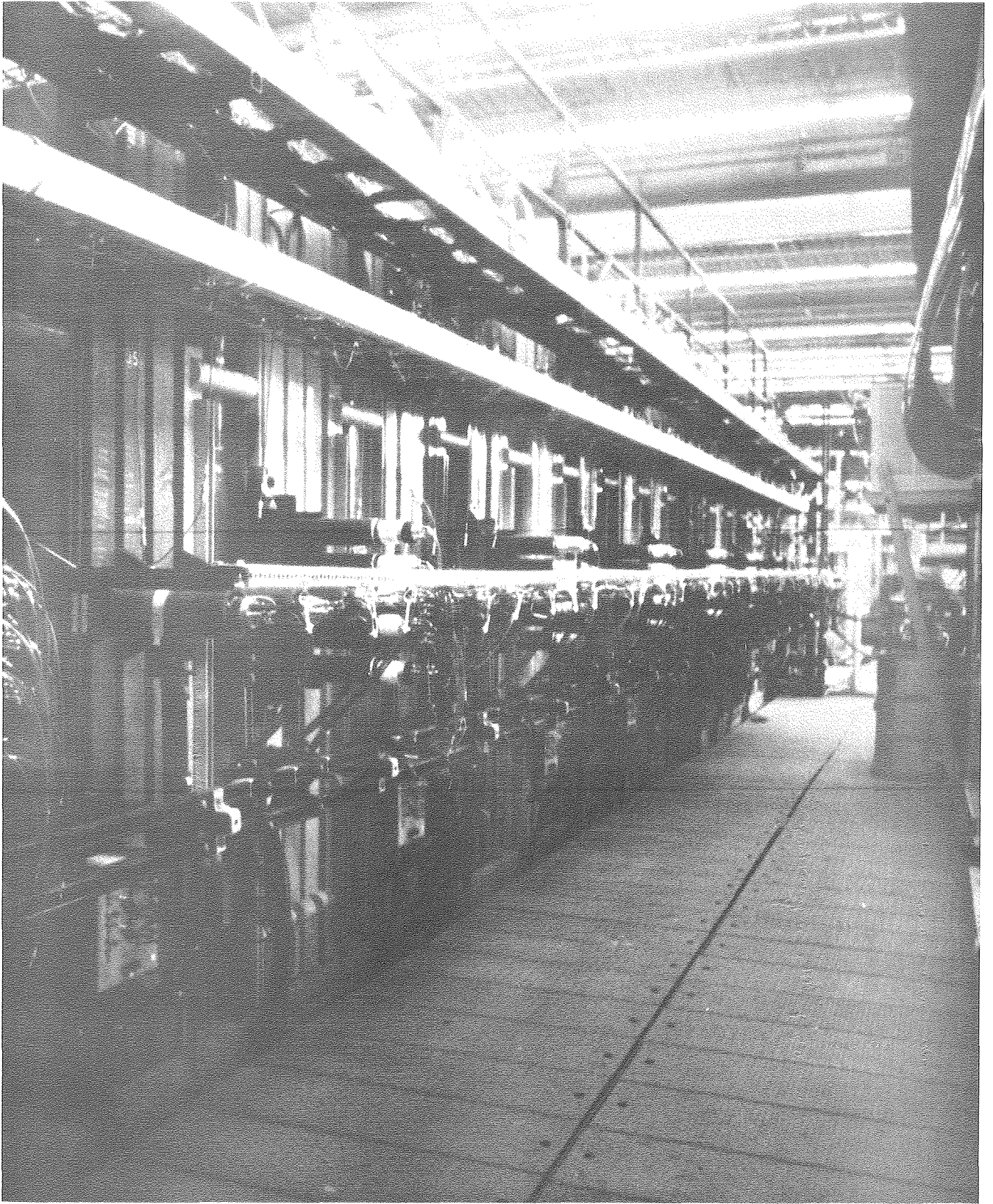
### Neutrino and Anti-Neutrino Interactions

Research is aimed at understanding the interactions of neutrinos and anti-neutrinos by analyzing the events observed on the film taken at the FNAL 15' bubble chamber.

The LBL group participated in the following four collaborations:

- Experiment 28 (with groups from CERN, Hawaii and Wisconsin) is a neutrino experiment in 'light' neon. It was this experiment that first saw direct positron production in neutrino events. Among other topics this experiment is studying the hadronic system in neutral current events.
- Experiment 45 (with groups from FNAL, Hawaii and Michigan) is a neutrino experiment in hydrogen. Many topics including vector meson production, neutral Vee production and the reaction  $\nu\rho \rightarrow \mu^-\Delta^{++}$  are being analyzed. A measurement of the neutral current rate was completed.
- Experiment 172 (with groups from Hawaii, Seattle, and UC Berkeley) is an anti-neutrino experiment in 'heavy' neon. This experiment has recently yielded results from the observation of dileptons in anti-neutrino interactions.
- Experiment 546 (with groups from FNAL, Hawaii, UC Berkeley and Wisconsin) studies neutrino interactions in a 'medium' neon mix. This experiment has recently yielded results from the observation of dileptons produced in anti-neutrino interactions. During this experiment, 546 has yielded 330,000 pictures of high energy neutrino interactions in a 'medium' neon mix. For this experiment the external muon identifier (EMI) has been reconfigured into two planes using the 14 additional EMI chambers and the 45 new digitizers that have been built in Berkeley in the past year. The analysis of this experiment dominated the effort this year. The highest priority has been given to the study of dimuon events, events that could not be studied with the previous configurations of the EMI.





Observation and study of multi-muon final state is made possible by this 470-ton segmented target spectrometer just completed at FNAL. Collaborating physicists for the initial experiments are from LBL, Princeton, and Fermilab. CBB 785-5315

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Hadronic Structure of the Weak Neutral Current, John Marriner, (Ph.D. Thesis) Sept. 1977. LBL-6438

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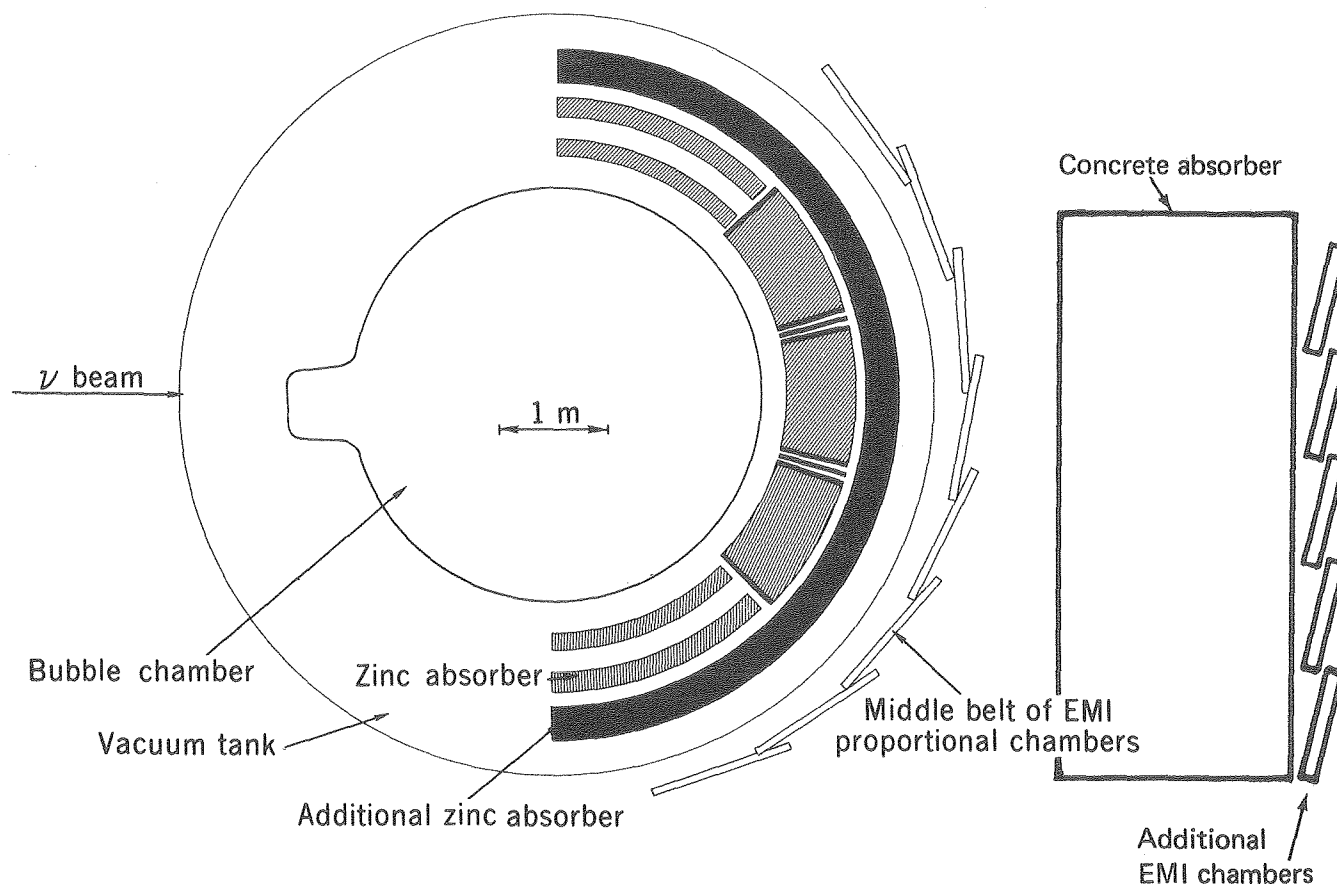
Observation of  $\mu e$  Events in  $\bar{\nu}$  and  $\nu$  Interactions in Neon, H. C. Ballagh, H. H. Bingham, P. Bosetti, W. B. Fretter, D. Gee, J.-F. Grivaz, G. R. Lynch, J. P. Marriner, J. Orthel, F. C. Porter, M. D. Sokoloff, M. L. Stevenson, G. P. Yost, R. J. Cence, F. A. Harris, M. D. Jones, T. Katsura, S. I. Parker, V. Z. Peterson, M. W. Peters, V. J. Stenger, T. H. Burnett, S. Csorna, H. J. Lubatti, K. Moriyasu, H. Rudnicka, G. M. Swider, B. S. Yuldashev, *Physical Review Letters* 39, 1650 (1977).

**NEUTRINO AND ANTI-NEUTRINO  
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High priority was given to the study of dimuon events when LBL reconfigured its external muon identifier at the FNAL 15' bubble chamber. In the new array, additional EMI chambers and a concrete absorber are employed, as indicated in this top-view schematic. These events could not be studied with the previous configuration. XBL 774-809.

## Strong Interaction Experiments at FNAL, BNL, and LBL

### Experiments at FNAL Using Polarized Particle Beams and Polarized Targets

Fermilab Experiment E-61: Elastic Scattering from a polarized target has been studied using  $\pi^+$ ,  $\pi^-$ , and protons on a polarized proton target. This experiment is a collaborative effort involving physicists from Harvard, Yale, Argonne National Laboratory, Fermi National Accelerator Laboratory and BNL (FNAL E-61).

Further experiments using polarized proton and anti-proton beams have been planned. This is possible since polarized proton and polarized anti-proton beams with reasonable intensity can be constructed for the use of counter physics. A proposal has been made to construct such a facility and to study the substructure of hadrons through the spin effects at high energy. We expect to measure total cross section difference and high- $x_F$  low  $p_\perp$  inclusive pion production using a polarized beam and a polarized target. This will be a collaborative effort involving physicists from Argonne National Laboratory; LAPP, Annecy, France; Rice University; INFN, Sezione di Trieste, Italy; and LBL.

Fermilab Experiment E-61 concluded data taking in the autumn of 1977 and has been dismantled. Data has been taken to measure the polarization parameter,  $P$ , in pion-proton and proton-proton elastic scattering at beam momenta of 100 and 200 GeV/c, and in the momentum transfer region  $.15 \leq -t \leq 1.5$  (GeV/c)<sup>2</sup>. At the beam momentum of 300 GeV/c the polarization has been measured in proton-proton elastic scattering over the range  $.15 \leq -t \leq 2.0$  (GeV/c)<sup>2</sup>. Also double-scattering data has been taken which should allow determination of the depolarization parameter,  $D$ , in proton-proton scattering at 200 and 300 GeV/c in the low- $|t|$  region.

The results of the  $\pi^+p$  and  $\pi^-p$  scattering at 100 GeV/c have been published and preliminary data from the proton-proton scattering have been reported. Analysis of all our data has been completed.

The polarizations measured are generally quite small (less than .05 in magnitude) and consistent at low- $|t|$  with the  $s^{-5}$  falloff expected from a simple Regge model of elastic scattering.

In the region of the dip in the differential cross-section at  $t = -1.4$  (GeV/c)<sup>2</sup> and beam momentum above 200 GeV/c, there may be indications of large and rapidly-changing polarization arising from the interference between a near-vanishing leading trajectory and the residual scattering amplitudes.

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- Polarization in pp Elastic Scattering at 100 and 300 GeV/c, J. Snyder, M. E. Zeller, I. P. Auer, D. Hill, B. Sandler, D. Underwood, A. Yokosawa, A. M. Jonckheere, P. F.-M. Koehler, R. V. Kline, M. E. Law, F. Pipkin, W. Bruckner, O. Chamberlain, G. Shapiro, H. Steiner, and W. Johnson, *Bull. Am. Phys. Soc.* 22, 622 (April, 1977).
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## Inclusive Cross Sections for Neutral Meson Production at FNAL and $K^\pm p$ work at BNL

Activities at Fermilab began four years ago with the study of the pion charge exchange reactions  $\pi^-p \rightarrow \pi^0n, \eta^0n$  in the energy range 20-250 GeV/c. The work is a collaboration with Caltech. A continuing program included studies of high  $P_\perp \pi^0$  inclusive production in  $K^+p, \pi^+p$  and PP collisions and also a study of  $\pi^-p$  inclusive charge exchange in the triple-Regge region. Running has been completed for the entire program.

Experiment 268 provides the first detailed comparison of high  $P_\perp \pi^0$  production phenomenon in the reactions  $K^-p \rightarrow \pi^0X, \pi p \rightarrow \pi^0X$  and  $pp \rightarrow \pi^0X$  at high energies and has yielded significant information about the possible quark structure of these initial particles.

Data were collected at beam momenta of 100 and 200 GeV/c and for center-of-mass production angles ( $\theta_{cm}$ ) from about 10 to 110 degrees. In the transverse momentum ( $P_\perp$ ) region studied, 1-4 GeV/c, the measured invariant cross sections for inclusive  $\pi^0$  production vary by about a factor of a million.

The ratio of inclusive  $\pi^0$  production sections,

$$R(p/\pi) = \sigma(pp \rightarrow \pi^0 + X) / \sigma(\pi p \rightarrow \pi^0 X)$$

decreases with increasing  $P_\perp$ , and is independent of beam energy when expressed as function of  $x = P_\perp / P_{max}$ . A comparison of this data with prediction of various theoretical models indicates significant disagreement in every case. In particular, models which assume quark-antiquark "fusion" interactions as dominant production mechanisms can be ruled out.

In addition a search for  $\psi$ 's and other heavy heavy neutral mesons in  $pp$  and  $\pi^-p$  interactions was also made. Since no massive neutrals were found in the test run, this program was dropped.

As by-product very high statistics data on a variety of two and three body final states such as  $\pi^-p \rightarrow n\omega, n\eta', n\eta^0, n\pi^0\pi^0$  have been collected. Because of the wealth of data accumulated, the data analysis will continue until late 1978. Some of the topics covered are: (1) comparisons of  $\pi$  and  $p$  collisions with protons to study the quark structure of particles, (2) the high  $P_\perp$  transition regions into the triple-Regge region and (3) model comparisons with the data.

The final experiment, E-350 of this collaborative group was to investigate the reaction  $\pi^-p \rightarrow \pi^0 + \text{anything}$  in the forward direction. The triple-Regge formalism has been successful in fitting the  $pp$  inclusive cross sections in the kinematic region  $0.8 < x < 1.0$  but since the formalism has so many free parameters in  $pp$  interaction, this is not a very conclusive test. The triple-Regge prediction for the reaction  $\pi^-p \rightarrow \pi^0 + \text{anything}$  is very simple by comparison, and the measurement of this inclusive cross section is providing a definitive test of the triple-Regge theory and is extending our knowledge of the  $\rho$  trajectory to much larger values of the momentum transfer than were previously accessible. Preliminary results have clearly indicated that the  $\rho$  trajectory is non-linear and that it is asymptotic to -1 at  $|t| > 3$ . Some differences exist between  $\rho$  trajectory results based upon our triple-Regge experiment and those based upon an earlier elastic  $\pi^-p \rightarrow \pi^0n$  experiment, in the range of  $|t| \leq 2$  where the two experiments overlap. This discrepancy is giving rise to second thoughts about the triple-Regge formalism in its simplest ( $\rho$  exchange only) form. An extension to more complicated exchanges is probably called for at this stage of the work.

A series of experiments, E-634, has been carried out at BNL to measure the total and differential cross-sections for  $K^-p \rightarrow \bar{K}^0n$  in the region from 500 MeV/c to 1100 MeV/c. These experiments are a search for baryon resonances in the  $\bar{K}$ -nucleon system. The  $\bar{K}$ -nucleon system requires a much more complicated partial wave analysis than does the pion-nucleon system. This is primarily due to the existence of several channels ( $\bar{K}^0N, \Lambda\pi, \Sigma\pi$ ) which must be analyzed simultaneously. Previous to this experiment a unique phase shift solution could not be obtained due to lack of precise data. Existing analyses are ambiguous, especially in the region from 600 MeV/c to 800 MeV/c. An extensive phase shift analysis has now been completed.

A new Brookhaven National Laboratory experiment (E-691) is nearly prepared for installation. It will be a study of  $K^\pm p$  elastic scattering at  $180^\circ$ . This backward region has been investigated only in a cursory manner by experiments of low statistical precision. Improved data from our experiment will hopefully reveal structural effects to a statistical level of a few %.

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Precision Measurement of the  $K^-p \rightarrow K^0n$  Cross Section below 1.1 GeV/c, M. Alston-Garnjost, R. W. Kenney, D. L. Pollard, R. R. Ross, and R. D. Tripp, Lawrence Berkeley Laboratory, H. Nicholson, Mt. Holyoke College, South Hadley, Massachusetts, M. Ferro-Luzzi, CERN, Geneva, Switzerland, Physical Review Letters 38, 1003 (1977).

Further Evidence on New Resonances in the KN System, M. Alston-Garnjost, R. W. Kenney, D. L. Pollard, R. R. Ross, and R. D. Tripp, Lawrence Berkeley Laboratory, H. Nicholson, Mt. Holyoke College, South Hadley, Massachusetts, M. Ferro-Luzzi, CERN, Geneva, Switzerland, Physical Review Letters 38, 1007 (1977).

Total Cross Section of the Reaction  $K^-p \rightarrow \bar{K}^0n$  from 515 to 1065 MeV/c, M. Alston-Garnjost, R. W. Kenney, D. L. Pollard, R. R. Ross, R. D. Tripp, H. Nicholson, and M. Ferro-Luzzi, LBL-6491, Phys. Rev. D, in press.

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Partial Wave Analysis of the  $\bar{K}N$  System from 360 to 1320 MeV/c, M. Alston-Garnjost, R. W. Kenney, D. L. Pollard, R. R. Ross, R. D. Tripp, H. Nicholson, M. Ferro-Luzzi, Submitted to Physical Review D.

## High Energy Hadron Production at FNAL

An exploratory program in the 15-foot bubble chamber at NAL (NAL C-341) to study hadron production at high energies has been undertaken. An initial exposure of 25,000 pictures of 400 GeV/c protons in hydrogen has been taken and the events with 2 or more neutral Vees are being used to test scanning and measuring techniques specially designed for this chamber.

All of the 4-prong events and all of the events with 2 or more neutral Vees in the 20,000 frames from the 400 GeV/c p-p exposure have been measured. An analysis of charged and neutral multiplicity distributions is underway and preliminary results have been reported. The equipment developed had the capability to accurately measure events of high multiplicity. However the expense of doing the high statistics experiments necessary

to study high energy strong interactions in the fifteen foot chamber can't be justified at the present. Except for some low level analysis projects this experiment has been completed.

## Pion-Proton Interactions at the Bevatron

A study has been made of pion and kaon exchange in  $\pi^+p$  reactions between 2.0 and 2.7 GeV/c. This experiment was performed in the 25" HBC at LBL. The goal has been to identify and parametrize the natural and unnatural parity exchanges. Baryon exchange reactions were also investigated (Bevatron E-155). This experiment was designed to study baryon exchange mechanisms in backward  $\pi^-p$  inelastic scattering around 4 GeV/c. A large aperture Cerenkov counter and hadroscope was used to trigger the LBL streamer chamber on interactions producing a fast forward proton or  $K^+$ .

The 300,000 pictures have been used to measure meson and  $N^*$  production via nucleon and delta exchange. These experiments may be used to test Reggeon exchange models. In the case of  $\pi^+p$  inelastic scattering from 2.0 to 2.7 GeV/c the analysis of  $S = 0$  final states has been completed. This led to information about  $\pi\pi$  scattering and the interference with natural parity exchange amplitudes. All of the remeasures of the  $S = 1$  final states have been completed, and analysis of these reactions is in progress.

Following the completion of all of the measurements from the streamer chamber film (Bevatron E-155) appropriate data summary tapes were made. Analyses of meson production by  $\Delta$  exchange interference between meson production and  $N^*$  production in Baryon exchange processes were carried out.

All of the high statistics  $\pi^-p$  charge exchange data between 0.6 and 2.5 GeV/c have been put on magnetic tape for analysis on the LBL computer. The techniques developed by Barrelet which were used to analyze the  $\pi^+p$  data have been applied to the  $\pi^-p$  data. The solutions are being compared with the many sets of phase shifts found at other laboratories.

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- Barrelet Zeros and Data Selection, D. M. Chew, Submitted to the Conference on Partial Wave Analysis at Karlsruhe, LBL-6102, June 1974.
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**STRONG INTERACTION**

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## Instrumentation for High Energy Physics

This work is concerned with the development engineering of instruments and instrumentation systems which have broad and general application in experimental physics. It similarly involves instruments for the Counting Pool, and for Nuclear Science experiments.

Much instrumentation research has concentrated on the development of various combinations of Drift and Multiwire Proportional Chambers, using delay line readout or other techniques, and their associated electronics.

Position-sensitive detectors have been investigated using the light emitted from charged particles drifting in high electric fields (streamers). The position-determining element employed was either a photo sensitive CCD (Charged Coupled Device), or a CID (Charge Injection Device), arranged in arrays of 128 x 128 elements.

Micro channel plate detectors (with and without photocathodes) for use in the presence of high magnetic fields, such as would be encountered in proposed PEP detectors, have been investigated.

The program to measure the resolving time and behavior of Micro channel Plate Photomultipliers in magnetic fields has continued. The good time response ( $> 200$  p sec) is of potential use for making time-of-flight measurements on particles, and position locations of particle tracks in scintillators. The insensitivity of Micro channel Plate Photomultipliers to magnetic fields is of importance for large magnetic detectors such as those currently used in SPEAR or those that are being designed for use in PEP. We are testing curved channel plates made by L. E. P. and photo multipliers with 3 channel plates made by I. T. T.

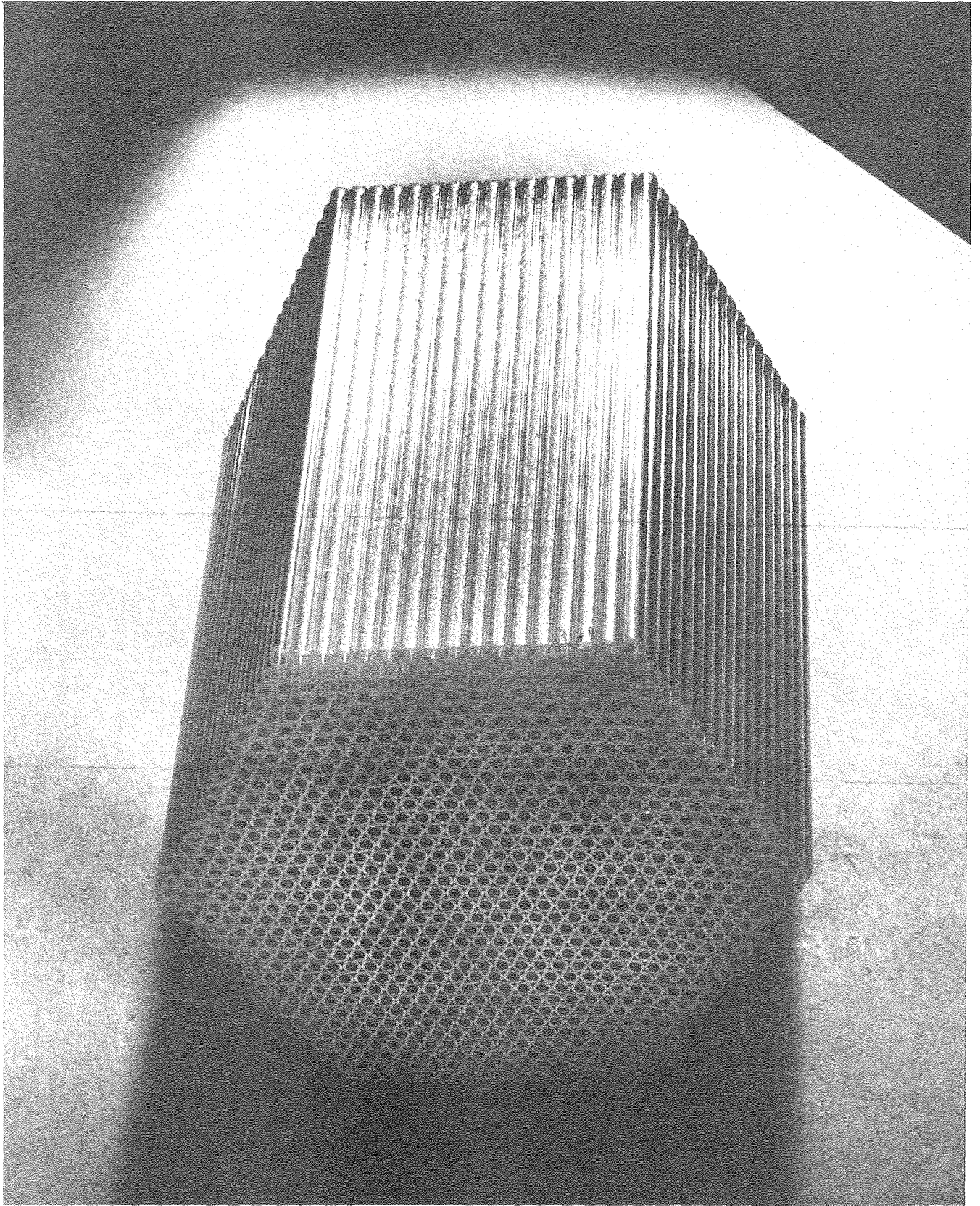
Work on the development of gamma and neutron imaging detectors for Nuclear Medicine and Neutron Radiography has continued. In connection with these, computer programs for the 3 dimensional determination of the distribution of gamma emitters within an object have been developed.

The Large-Scale Digitizer (LSD) System, an economical modular system for digitization of analog data from hundreds of signal channels simultaneously, is a continuing activity from FY 1976, when the first 320-channel charge-digitizing system was successfully used in the Pb-glass wall experiment at SLAC. A total of 1280 Channels of charge or time digitizers have been installed to date and another 80 channels of time digitizers are completed and ready for installation. The buncher (wire multiplexing) has been checked out and is working. The buncher will increase the effectiveness of the system in many applications. Some of the design concepts of LSD are being transferred to the PEP-4 project.

The characterization of charge coupled devices (CCD's) was completed in 1977 and reports have been published. A 16 channel prototype has been constructed to evaluate the CCD's under beam conditions. An improved version of the CCD 321 was developed and is used in the prototype. This new version will be subjected to further evaluation and characterization. Numerous applications for the CCD's are considered, but the most exacting demands on the CCD at present are in the PEP-4 Time Projection Chamber (TPC) application. The improved CCD 321A's show good promise.

Forty-four time digitizers for use with delay line read out of multiwire proportional chambers (MWPC) used as External Muon Identifiers (EMI) have been delivered to Fermilab. These EMI digitizers use high speed emitter-coupled logic memories to digitize directly at the 28 MHz rate called for by the resolution requirements of the experiment. They have been installed and successfully checked at Fermilab.

LBL supplied the low noise preamplifiers for the Mark II Liquid Argon Detector which was constructed by LBL. Much of the design and fabrication of the preamplifiers was done in FY 1977 and the installation and checkout of the preamplifiers was completed this year. The knowledge and experience gained on Mark II will be applied to PEP-4.



Lead glass construction from which sections are cut for use in conjunction with multiwire proportional chambers. This instrumentation is designed to detect drifting electrons in particle showers.  
CBB 765-4207

Two new developments have been for Multi-wire Proportional Chambers (MWPC's). First, a new system for readout of MWPC's was developed. It utilizes a shift register for delay of the wire information in place of the conventional one shot delay, thus greatly reducing dead time of the system without the high cost of using delay cables for this function. The initial application of this system is for an experiment at BNL. Second, expansion of an existing 2000 wire MWPC Readout system by 1500 channels is in progress. This utilizes standard readout electronics developed by LBL.

An approach to multiplexing existing beam monitor devices at the Bevalac has been developed. A proposal has been submitted.

Two LSI-11 Microcomputer systems have been developed and installed. The first system replaces an existing IBM 1130 unit which has served our needs for the last 8 years. The new LSI-11 system gives us better flexibility, speed, memory size and programming capability to meet the ever-increasing sophistication of present day systems.

The second system is a portable system which can be taken to experimental areas for troubleshooting. By using simple diagnostic programs and procedures, a problem can be more readily pinpointed with the LSI-11 microcomputer.

Photomultiplier tube evaluation, including microchannel photo versions for ultra-precision timing, is a continuing activity carried on within this program. Commercial manufacturers are encouraged to produce these photo tubes with improved lifetimes and immunity to magnetic fields.

General services are provided in connection with all electronic instruments used in Physics Division Programs. The services include maintenance of electronics shared with the division, maintaining inventory records, procurement of new equipment, providing operating manuals and consulting on all aspects of instruments and detectors used in research programs.

Special effort has been made to strengthen the equipment pool and to secure a reasonable degree of integration of the equipment pool with those serving other LBL Divisions. A single pool is now operating with advantages to all divisions and with better utilization of equipment.

Circuits, systems, and systematic methods for data acquisition techniques also have been developed, such as (1) for data-channel calibration, (2) for fast and moderate-speed on-line decision making, (3) for fast and efficient data transfer, and (4) for partial on-line analysis. Competence in these areas will be critically important when making design decisions for instrumentation of the large facilities and detectors to be used in experiments at PEP.

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## INSTRUMENTATION

### STAFF

<i>J. B. Carroll</i>	<i>C. C. Lo</i>
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## Particle Data Center

During 1977, the Particle Data Center was involved in five major activities. The principal areas served and corresponding projects are outlined in the following paragraphs:

In the continuing program of compilation of particle properties, updating of data for the "Review of Particle Properties" was maintained and a supplement to the Review was published.

Compilation of descriptive and bibliographic information on published articles, preprints, and current experiments in progress was also maintained. Indexed guides to current literature and experiments were prepared for inclusion with later material in a planned FY 78 publication.

Compilations assembled by outside collaborators (at Cal Tech, Durham University, Glasgow University, McGill University, and Rutherford Laboratory) were incorporated into our database for experimental reaction data (this is an ongoing project). A flexible language for encoding all such data was completed and is now being used by our collaborators. Work with special processors to standardize the data and make it easily accessible also continued.

The second generation of the Berkeley Database Management System became operative in 1977 and was applied to maintain our various databases and to allow complex queries to be carried out on the databases. We have also made it possible for outside users to interrogate our document database for their own special needs.

Most members of the Particle Data Group are active in research projects, both with LBL and with outside collaborators. References regarding this work are contained in this report. These projects include the following:

- The Lead Glass Wall experiment at SPEAR to study neutral particle production and anomalous electron production in  $e^+e^-$  annihilation.

- The Carnegie-Mellon University-LBL partial wave analysis collaboration which has developed approaches for combining statistical techniques and analyticity theory in the amalgamation and partial wave analysis of pion nucleon scattering data. First results were announced in 1976 and included confirmation of an anomalous D35 resonance at 1925 MeV. Analysis continued in 1977, and final results are projected for 1978-79.
- Pion and anti-neutrino beam bubble chamber experiments at SLAC and FNAL.
- $K^-p$  interactions at 4.2 GeV/c in a high statistics bubble chamber experiment. This experiment has yielded a large variety of interesting topics for physics analysis. Among these, and of particular relevance to "Review of Particle Properties," are several studies of strange baryon and non-strange meson systems produced by hypercharge exchange.

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### PARTICLE DATA GROUP

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## Astrophysics and Astronomy

### Measurements of the Anisotropy of the Cosmic 3°K Blackbody Radiation

A part of the astrophysics program at LBL is to detect and map the large-angular-scale anisotropies in the 3°K primordial blackbody radiation. The data collected during 1977 has been sufficient to detect a first order anisotropy in cosmic blackbody radiation of about 3 m°K. This anisotropy has been interpreted to be the result of the motion of the solar system relative to the cosmic microwave background and thus the average of the distant and ancient matter in the universe. If this anisotropy actually is the result of the motion of the earth ("new Aether Drift") relative to the blackbody radiation then the galaxy as a whole is moving at 600 km/sec. The limit on higher order anisotropies has been pushed down to the millidegree level or about one part in 3000.

In this program of measuring the anisotropies in the cosmic microwave background, LBL is in the design phase of a NASA sponsored satellite-borne version of this experiment. This experiment on the Cosmic Background Explorer (COBE) satellite should yield data in 1982. In parallel with this effort a small ground-based experiment to measure the polarization of the blackbody radiation is being developed.

### Rubber Mirror Telescope

Because of atmospheric distortion, a large telescope at a good location on a mountain top typically gets only 1 arc sec angular resolution. This is the theoretical diffraction-limited resolution of a 4" telescope. A 100" telescope would achieve 1/25 arc sec resolution if there were no atmospheric distortions. The Rubber Telescope project intends to greatly reduce atmospheric distortion in ground-based astronomical telescopes. It uses an optical element called a "rubber mirror" to correct the perturbed phase front of the incoming light. The rubber mirror is driven in a feedback loop by the measured "sharpness" of the image of the star or other astronomical object. Existing equipment can measure properties of the perturbing atmo-

sphere, resolve close binary pairs, and perhaps improve some planetary measurements. Future larger apparatus could greatly extend these measurements. We believe we can significantly improve the resolution of a large telescope for objects as dim as 9th magnitude.

A 12" telescope equipped with a 6-element rubber mirror and with its own equatorial mount was operated successfully at Mt. Wilson Observatory. The first use of real-time correction of atmospheric seeing to resolve a double star was accomplished, under seeing conditions where the double star was unresolvable without the rubber mirror turned on (5 arc second seeing, 2 arc second separation of two stars), but clearly resolved with the mirror turned on. The member of the double star chosen to be corrected was corrected to the diffraction limit of the 12" telescope (0.4 arc sec).

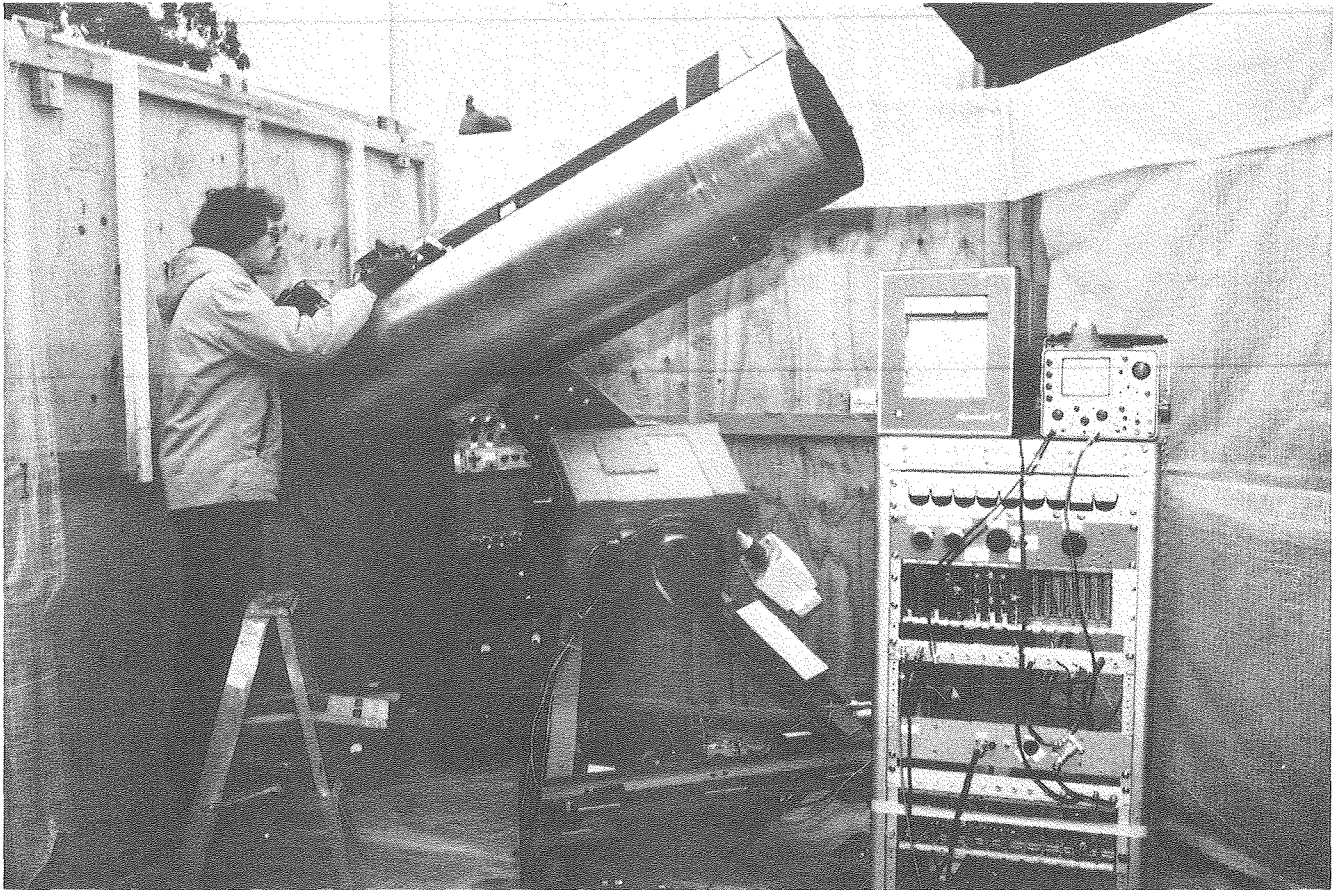
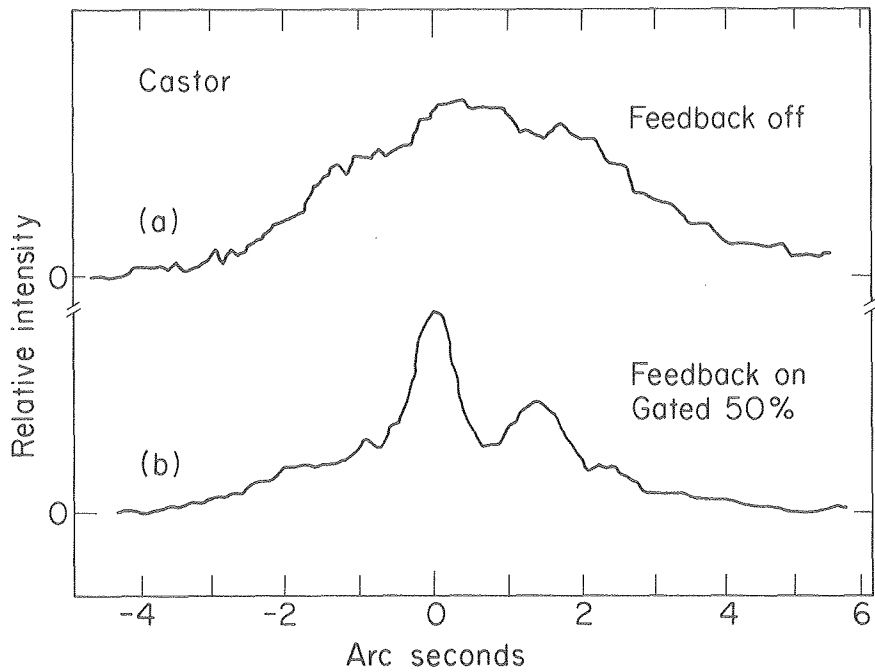
Some sixty double star measurements were then made with available double stars separated by from 2 to 10 arc seconds, in order to begin to determine the size of the field of view that is simultaneously correctable. We found on several occasions a 10 arc sec correctable field, encouraging us to believe we will be able to achieve significant image sharpening of extended objects (typical planet size is 50 arc sec).

In addition, a portable "speckle-time measurer" was developed and tested and found to agree with the 12" rubber telescope as to the time dependence of the atmospheric seeing distortions. This enabled us to measure this time dependence at various sites in order to pick promising locations for the rubber-mirror telescope.

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Compensation for atmospheric distortion of images is provided in the Rubber Mirror telescope by a phototube-monitored, piezoelectric-powered segmented mirror. Steve Pollaine, LBL graduate student, is making the adjustments in this view. A chart of the signals from images of Castor, a double star, recorded at Mount Wilson on 3 October 1977, is reproduced here. XBL 7711-11052 and CBB 771-236

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## Search for Black Holes, Neutron Stars, White Dwarfs

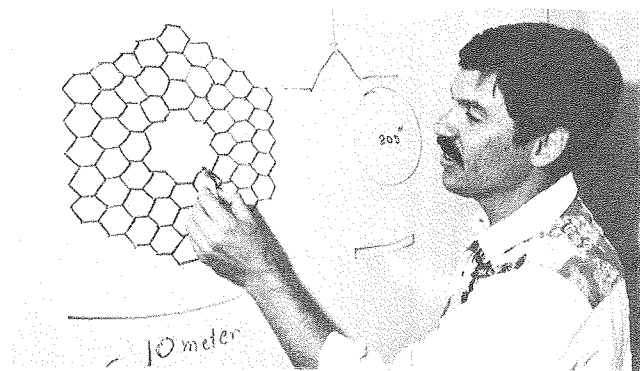
The major emphasis of this astrophysical research is the study of compact objects (Black holes, neutron stars and white dwarfs) and the phenomena associated with them. These objects are found in certain classes of observed systems, in particular X-ray sources, pulsars, cataclysmic variables, and close binaries. These objects have been studied by examining their short time scale behavior, both photometrically and spectrophotometrically.

Fast photometry is well suited to the study of optical pulsations or flickering that many of these stars exhibit. The details of their time dependent behavior can shed light on many critical parameters of the systems, including their masses and mass accretion rates.

In this year, time resolved spectrophotometry has been used to examine in greater detail the nature of these systems. The spectrum (wavelength dependence) of their pulsations and flickering is sometimes accessible and this can reveal details of temperature distributions, and light reprocessing mechanisms in accretion disks that would be otherwise unobtainable.

The implementation of these techniques involves large amounts of data and sophisticated analysis programs for their reduction. A variety of computer programs is under development and modification to suit the particular objects under study.

Time resolved spectrophotometric observations of three oscillating stars were made and reduced. HZ Her/Her X-1 with 1.24 second pulsations was analyzed. DQ Herculis with 71 second pulsations was studied. WZ Sagittae with



Proposed design for UC Berkeley 10 m telescope is described by Jerry Nelson, chairman of the telescope design committee. Relative positions of mirror segments are continuously monitored by edge sensors. XBB 789-12355

28 second pulsations has also been analyzed. Although these systems have many fundamental differences (HZ Her-X-ray source; DQ Her-Nova; WZ Sge-recurrent nova) it now appears that all these systems have optical pulsations coming from their accretion disks, and the disks are illuminated by a central compact star.

A set of coordinated X-ray and optical observations HZ Her/Her X-1 has been completed and results on the comparison between X-ray and optical pulsations have been found.

A program to study the color variations in the oscillations of some cataclysmic variables and white dwarfs was begun. This is currently being done at the Kitt Peak National Observatory.

Some spectral observations of the AM Her variables have been made. These stars (3 are known) have extremely complex spectral and magnetic characteristics and little is known of their short time scale behavior. These and planned additional observations should elucidate some of the questions about the inner mechanisms for their behavior.

A group of astronomers of the University of California have begun the design of a 10 meter optical telescope. LBL is directly involved in this effort. A number of design concepts have been investigated and more detailed study of the favored alternatives is now in progress.

### ASTROPHYSICS

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#### GRADUATE STUDENT

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## PEP Experimental Facilities Coordination

The Positron Electron Project (PEP) Experimental Facilities Coordination is involved in the following activities:

- Designing the experimental areas.
- Solving technical problems associated with the interaction of the machine and the proposed experiments.
- Interfacing users with the PEP machine and environment.
- Coordinating the development of support systems for PEP experiments such as on-line computers, real-time links to the central computers, refrigeration plants for superconducting magnets and the design of systems for access and movement of detectors.
- Evaluating the impact of proposals on PEP resources and equipment funding prior to PEP Experimental Program Committee (PEPC) decisions.
- Coordinating the use of the LBL resources necessary for the PEP Experimental Program.
- Negotiating agreements with the proponents of experiments on the detailed responsibilities of the participating institution and the distribution of funding for the approved detectors.
- Long-range planning for the utilization of PEP.

Working with the PEP Convention Facilities Group and the PEP Architectural, Engineering, Construction, and Management (AECM) group, the detailed design of experimental areas 12, 2, 4, 8 and 10 have been completed. The construction of these areas for the approved detectors has been made in such a way as to optimize efficiency of use and future flexibility.

Analysis of all submitted proposals (PEP-1 through PEP-19) were completed prior to consideration by the Director and PEPC in order to obtain uniform costs for all proposals including items usually assumed to be provided by the laboratories.

The PEPC after extensive deliberations, including open presentations of all submitted proposals, recommended approval of seven detectors for the initial PEP Program:

- A Proposal to Search for Highly Ionizing Particles at PEP (PEP-2) UCB, SLAC.
- A Proposal for PEP Facility Based on the Time Projection Chamber (PEP-4) (TPC) LBL, UCLA, Yale, UCR, Johns Hopkins.
- General Survey of Particle Production at PEP (PEP-5) (Mark II) SLAC, LBL.
- A Proposal for Lepton-Total Energy Detector at PEP (PEP-6) Colorado, Northeastern, SLAC, Stanford, Wisconsin, Utah.
- A Proposal for PEP Forward Detector Facility (PEP-9) UCSD, UCSB, UCD, Amsterdam.
- A Proposal for a High Resolution Spectrometer at PEP (PEP-12) (HRS) ANL, Indiana, Michigan, Purdue.
- A Search for Free Quarks at PEP (PEP-14) LBL, Northwestern, Stanford, Hawaii.

Following approval of the proposals by the laboratory Directors, the coordinating group carried out detailed negotiations with the successful proponents. The agreements reached cover the fabrication of the hardware; they itemize the responsibilities of the groups involved, the personnel commitments, the milestones to be met in the fabrication and associated R&D programs, and outline the distribution of funds for the participating institutions.

Computer programs developed by the group were used for the detailed design of vacuum chambers, including the difficult masking problems due to synchrotron radiation and degraded beam electrons.

The acquisition of the PEP on-line computer was started after extensive work on the specifications for the system using inputs from the approved collaborations. The recommendations have been forwarded to DOE and delivery of the first system is expected in May or June of 1978.

New problems in the magnetic compensation of detectors were discovered and solved. In particular, the TPC and  $2\gamma$  detectors will be compensated by using eight rotated quadrupoles instead of the usual solenoidal compensation.

The group coordinated the activity necessary to start the central helium facility and refrigeration plants for PEP. In connection with superconducting magnets a special workshop including outside consultants took place to analyze the proposed systems.

The group coordinated support provided to

proponents on areas of special LBL expertise, such as the new designs for the superconducting magnets.

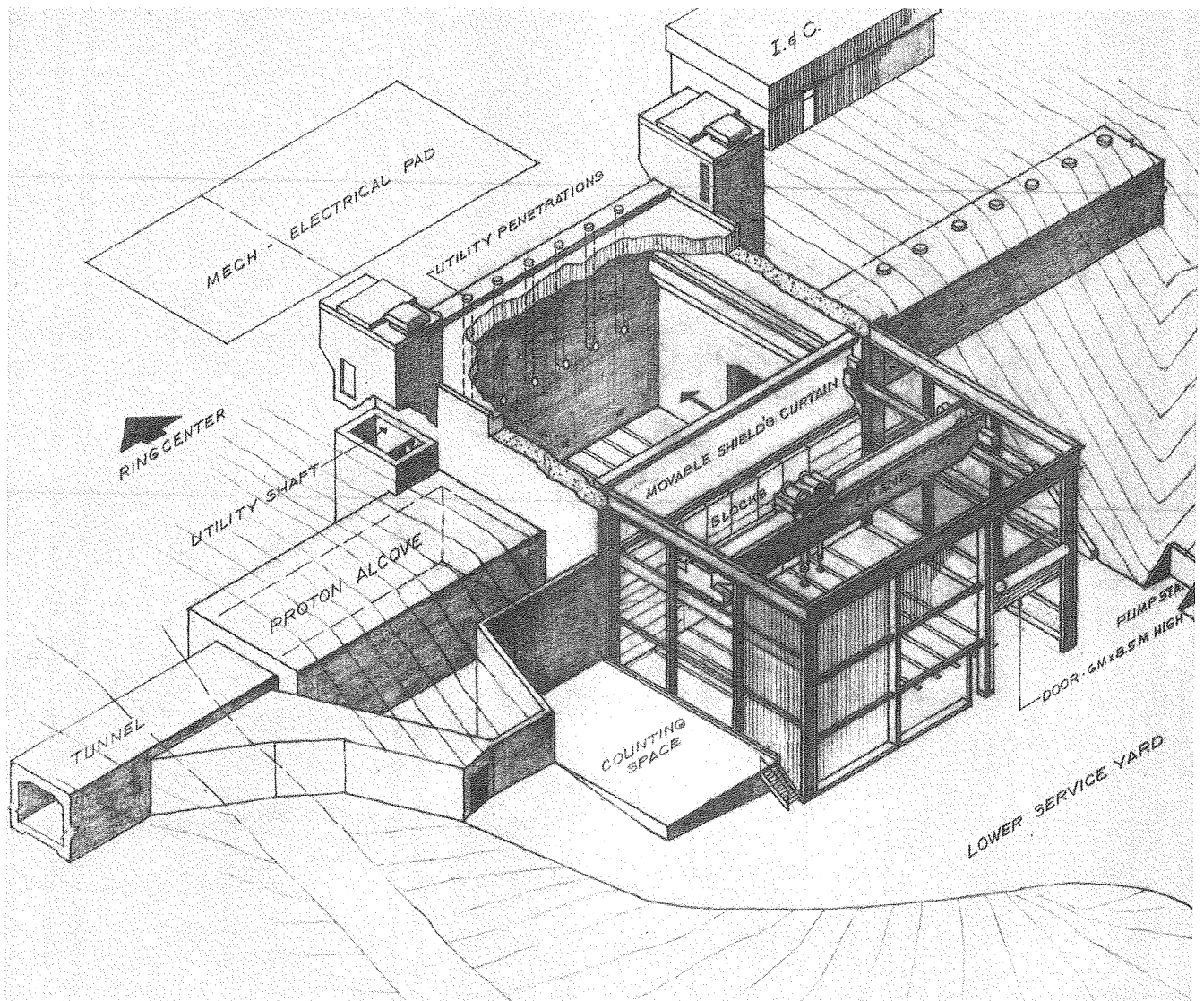
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PEP Experimental Areas, PEP Design Handbook, July 1977.

The PEP Experimental Program, Invited Talk, Novosibirsk Meeting, September 1977.



Physicists in the Experimental Physics Coordination Group will design six interaction halls at PEP according to the needs of the long-range plans for experimental programs. XBB 776-6079

Review of the Expectations for Polarization at PEP and the Current Work to Understand Beam Polarization at SPEAR; TPC-LBL-77-27, Invited Talk, Novosibirsk Meeting, September 1977.

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Agreement on the Fabrication of the PEP-6 Detector, December 1977.

Agreement on the Fabrication of the PEP-9 Detector, December 1977.

Impact Report Second Round PEP Proposals, P. Oddone, et. al., December 1977.

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# MEDIUM ENERGY PHYSICS

## Mesonic Atoms

The study of mesonic atoms has provided the most accurate measurement of the mass of pions and kaons. Valuable information on the  $\pi^-$  nucleus and  $K^-$  nucleus interaction has also been obtained but the physics of the meso-atomic system is still not well understood. There is a striking dependence of the x-ray intensities on the atomic number that was unexpected and remains unexplained. A clear implication is that solid state and atomic physics play an important role in the formation of mesonic atoms — a situation that was not anticipated.

The absorption coefficient of kaonic potassium x-rays has been measured in erbium for the transition  $n = 6 \rightarrow 5$ . These x rays fall on the erbium K-edge which allows us to accurately determine their energy. The negative kaon mass can be calculated from the x-ray energy. Data have been analyzed and preparation of a report is in progress.

In cooperation with the University of Victoria group at TRIUMF, the pionic x-ray intensities of 60 chemical elements have been measured. Data analysis is in progress.

## Scattering of Nucleons, Pions, and Muons by Nuclei

### Nuclear Structure and Few Nucleon Systems

Much of recent effort has been devoted to probing the wave functions of light nuclei. A series of experiments has been devoted to the measurement of elastic scattering cross sections and polarization in a number of systems involving nucleons and light nuclei in the energy range from a few hundred MeV up to several GeV. In addition to nuclear structure information, the results of these experiments are strongly influenced by the basic nucleon-nucleon interaction, and should prove useful in understanding its behavior in this energy range.

A pion double-charge-exchange experiment at LAMPF is studying many body forces in the 3- and 4-nucleon system. The nuclear structure program will continue with experiments to measure

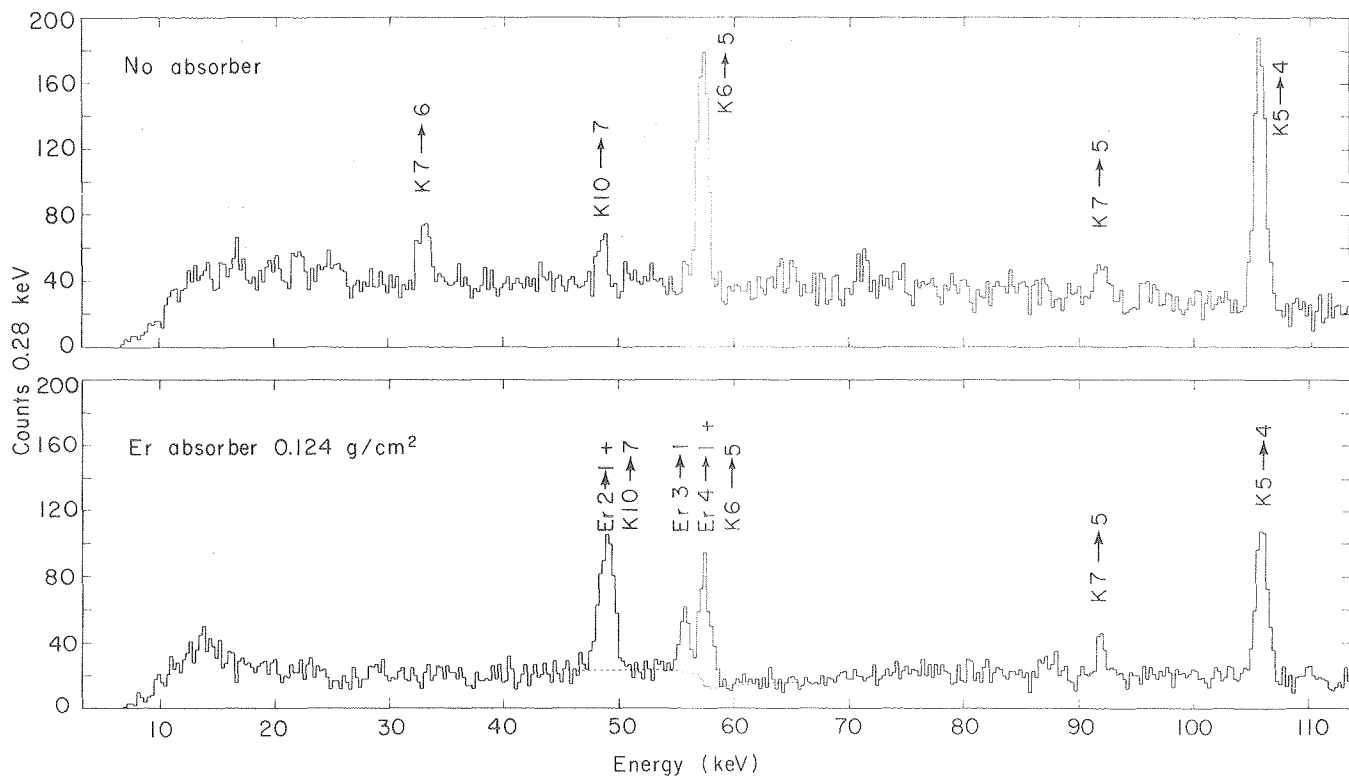
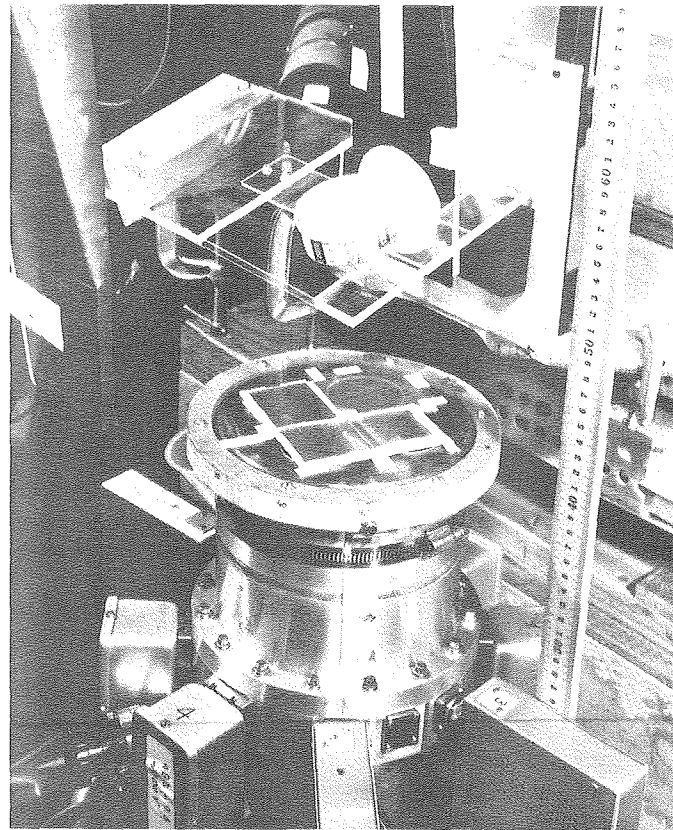
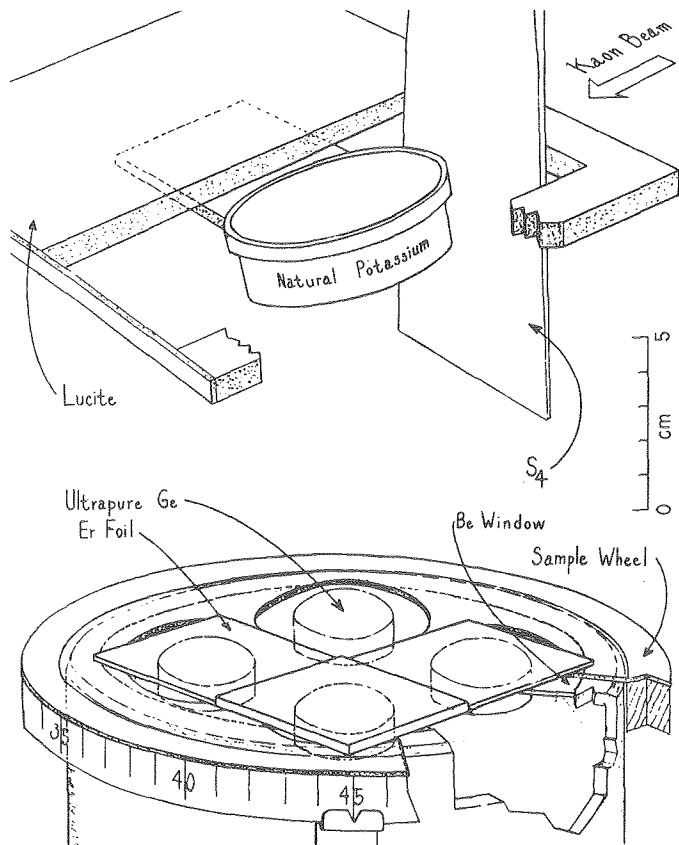
N-N correlations in light nuclei, and to measure off-shell effects in the N-N interaction.

Work has continued on data analysis and publication of results from our earlier measurements of forward elastic scattering in the  $p$ - $^4\text{He}$  system at (equivalent) proton energies of 0.4, 1.05, 2.68, and 4.89 GeV. It is expected that the error in absolute normalization will be considerably reduced.

The study of forward elastic scattering has been extended to include measurements of  $p$ - $^3\text{He}$  at 2.68 GeV. ( $0.1 < t < 0.76$ ), and  $d$ - $d$  at 4.18 GeV ( $0.08 < t < 2.09 \text{ GeV}/c^2$ ). On-line analysis during data acquisition indicated good separation of signal from background, and we expect the quality of this data to be comparable with that from earlier measurements. Analysis of the data has yielded preliminary results.

In a collaborative experiment at ANL, measurements were made of: 1) polarization in





Spectrometer for studying x rays from pionic and kaonic atoms. Sketch shows the method used for measurement of x rays from the  $n=6 \rightarrow n=5$  transition. Measurements are made with and without the Er absorber. The ratio of the observed intensities yields the absorption coefficient. XBL 781-6683

elastic p-p and p-n scattering at 1.03 GeV. The p-n measurements are the first to be done in this energy range and the data have been analyzed. 2) polarization in backward elastic p-d scattering at 0.68, 1.03, and 1.53 GeV. The data have been analyzed and the preliminary results are being studied.

An extension of this program will permit measurement of forward and backward elastic p-d scattering using ANL's polarized deuteron beam. These measurements enable use to study the d-state and N\* components of the deuteron wave function.

An experiment to measure the angular distribution and energy dependence of pion double-charge-exchange in  $^3\text{He}$  and  $^4\text{He}$  is running in the EPICS channel at LAMPF. This experiment is a

continuation of earlier work on 3 and 4 neutron systems, and will study an expanded region of phase space. The work is being done in collaboration with Dr. A. Stetz of Oregon State University.

The success of the MIT "bag" model in explaining the mass spectrum and other static properties of light hadrons has led some of its proponents to hypothesize the existence of resonance-like baryonic states containing  $3n$  quarks, where  $n$  is greater than one. A first generation experiment is underway to detect (or set an upper limit for) such a state in the  $d + ^4\text{He}$  system ( $n = 6$ ). The experiment involves an excitation curve for the total cross section and for the inclusive proton channel.

## Fission Studies with Mu Mesons

The investigation of the interaction of muons with fissile nuclei has moved to TRIUMF and is using the high intensity, high-duty-factor muon beam.

A multiplate Fission chamber was designed and built at LBL for use in the  $\mu$  beam at TRIUMF.

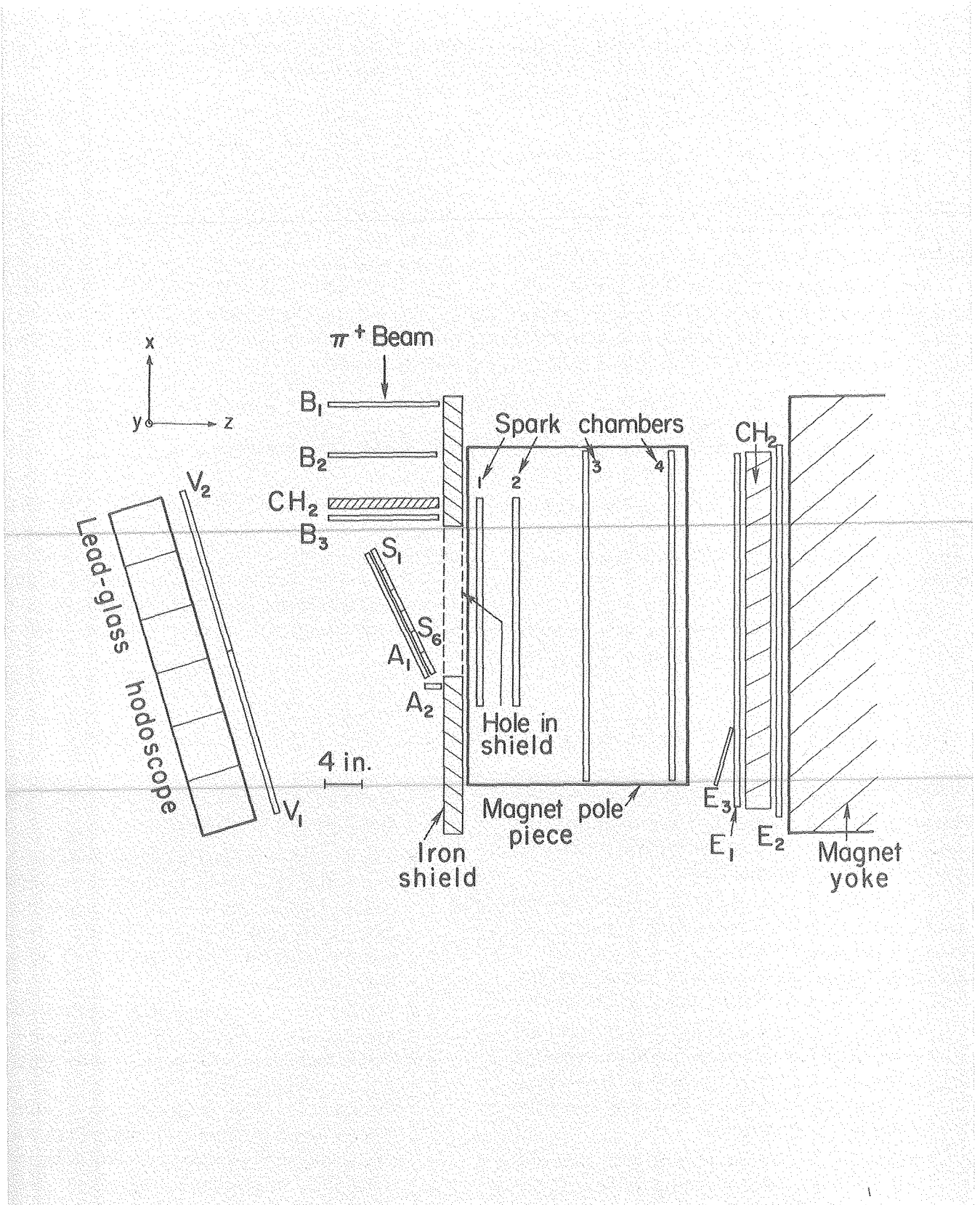
At present it contains 1.05 grams of U-238. It is being used to study the interaction of negative muons at rest with Fissile nuclides by analyzing the time and energy spectrum of the emitted  $\gamma$  and x-rays. The aim of this work is the mapping out and understanding of the double humped Fission barrier.

## Radiative Pion Capture, Pion Scattering and Muon Decay

Experiments are performed employing low energy pions and muons in order to study their intrinsic properties and to use them as probes for nuclei and condensed materials.

The study of radiative pion capture, i.e., the measurement of the high energy gamma ray spectrum produced when pions are captured in nuclei, has been conducted from the several different points of view briefly described below.

- First, the understanding of basic quantitative structure of the photo-pion transition operator has been accurately fixed by a comparison of theory with measurements on a series of light nuclei.
- Second, these results may be compared with those from electron scattering and photo-pion production near threshold and muon capture processes on the same nuclei. Only recently have these comparisons led to a consistent set of constants.
- Third, a new set of reactions has been chosen to use this as a probe to study the excited states of nuclei. The new phenomena which have been seen are giant dipole states, possible quadrupole excitations and other more complex states.
- Fourth, since radiative pion capture has been shown to induce the same Gamow-Teller transitions to bound states (e.g.,  $\pi^- ^6\text{Li} \rightarrow ^6\text{He}\gamma$ ,  $\pi^- ^7\text{Li} \rightarrow ^7\text{Li}\gamma$ ,  $\pi^- ^{12}\text{C} \rightarrow ^{12}\text{B}\gamma$ ) the rates for these processes can be combined with information from other weak and electromagnetic processes dealing with the same state to test predictions from CVC, PCAC, etc., as for example, the Goldberger-Treiman relation for the nuclear case.



Experimental arrangement for radiative pion capture. The coordinate system is indicated at upper left. XBL 768-3247

The systematic study of gamma ray spectra from the capture of negative pions in nuclei has been an on-going program for our group. The current studies are of the light nuclei  $^3\text{H}$  and  $^{20}\text{Ne}$ . The aim is to elucidate the points mentioned in the previous paragraph.

With an improved, high resolution, pair-spectrometer the tritium  $\gamma$ -spectrum resulting from pion capture has been determined with considerably greater accuracy than here-to-fore. The experiment has run for 450 hours. Work has continued in updating and developing software for use with the PDP-11 computer at LAMPF. This will allow a more rapid data transmission from the MWPC systems consistent with the higher beam intensities.

The significant data on the tritium spectrum has been partially analyzed. The results, with a factor of 10 more good events than earlier work, are in basic agreement with the earlier effort. However, there was no evidence for a possible bound state of 3 neutrons. In any case, complete analysis of the data will allow much more accurate nucleon structure constants to be extracted for comparison with theory of the three-body system.

A measurement has been made at LAMPF of the high energy gamma spectrum (50-150 MeV) from radiative capture of pions from atomic orbits in tritium. Overall resolution is 1.5 MeV from a pair of spectrometer utilizing a 3-plane MWPC. No 3-neutron resonances or bound states are seen.

Studies of the sensitivity to 3-neutron resonances or bound states are in progress, and an

upper limit on their existence will be presented. Fits were also obtained to the quasi-elastic spectrum based on the calculations of Phillips and Roig<sup>1</sup>, which treat the interaction of the outgoing neutrons in the Amado model.

An experiment using  $^{20}\text{Ne}$  was also carried out. Preliminary analysis indicates a gamma ray peak at the expected energy for an M1 transition. The energy is very close (within  $\sim 1$  MeV) of that resulting from  $\pi^-$  capture in hydrogen so the results must initially be regarded cautiously. However, the result is sufficiently encouraging so that we would like to do the  $^{20}\text{Ne}$  again for a longer time.

Low energy pion beam designs have been extensively studied. The objective was to produce an inexpensive, very high luminosity doubly achromatic channel for  $\pi$  with kinetic energies of 15-50 MeV. Momentum resolution of  $\sim 1\%$  and small beam divergence in at least one plane were also required, since the channel was intended for  $\pi$  scattering at the TRIUMF meson facility in Vancouver.

The final design used three quadrupoles between the bending magnets. These quadrupoles achromatized the beam and acted as field lenses to greatly reduce the size of the beam envelop in the channel. Second order effects and beam loss problems were eliminated.

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<sup>1</sup>A.C. Phillips and F. Roig, contribution to the Sixth Int. Conf. on High Energy Physics and Nucl. Structure (Santa Fe, 1975); A.C. Phillips, in: *Nuclear and Particle Physics at Intermediate Energies* (J.B. Warren, Ed.), Plenum Press, London (1976), p. 359.

## A Neutrino Experiment to Test Muon Conservation

An experimental study of the nature of neutrinos from muon decay is underway at the Los Alamos Meson Physics Facility (LAMPF). The experiment is designed to distinguish between an additive and a multiplicative muon conservation law. The objectives and plans are detailed in a

proposal to Los Alamos (LAMPF No. 31).

In the initial phase of this experiment data has been taken using anti-neutrinos. The 6 ton Cerenkov counter has been filled with water during these runs. We plan to switch to a heavy water ( $\text{D}_2\text{O}$ ) fill when taking neutrino data next year.

## Instrumentation

Considerable instrumentation work is carried out, including efforts on Multi-wire Proportional Chambers and associated readout techniques, tests of micro channel plate photo-multipliers for fast timing application and development of multiplicity counters for fragment detection. General services are provided in connection with all electronic instruments used in Physics Division programs. The services include maintenance of electronics shared within the division, maintaining inventory

records, procurement of new equipment, providing operating manuals and consulting on all aspects of instruments and detectors used in research programs. Special effort has been made to strengthen the equipment pool and to secure a reasonable degree of integration of the equipment pool with those serving other LBL divisions. A single pool is now operating with advantages to all divisions and with better utilization of equipment.

### LBL STAFF

*J. Bistirlich*  
*K. Crowe*  
*S. Kaplan*  
*J. Miller*

*P. Nemethy*  
*V. Perez-Mendez*  
*S. Rosenblum*  
*C. Wiegand*

### MAJOR COLLABORATORS

#### FEW NUCLEON SYSTEMS

*G. Igo, UCLA*

#### POLARIZATION EXPERIMENTS AT ANL

*M. Marshak, University of Minnesota*

*R. Klem, ANL*

*G. Igo, UCLA*

#### Mesic X rays

*R. Pearce, University of Victoria*

#### Mesic Atoms

*R. Pearce, University of Victoria*

*C. Sabev, CERN*

*W. Sperry, Central Washington University*

#### RADIATIVE PION CAPTURE

*Masahiro Koike, Institute of Nuclear Study  
University of Tokyo*

*Aaldert Wapstra, IKO Institute for Nuclear Physics  
Amsterdam*

*Helmut Baer, LASL*

*Peter Truol, University of Zurich*

*Gerd Strassner, SIN*

### GRADUATE STUDENT RESEARCH ASSISTANTS

*Carl Clawson*

*Charles Martoff*

*Bill Zajc*

### TITLES AND DATES OF PUBLICATIONS

$P + {}^4\text{He}$  Elastic Scattering at 2.68 GeV, M. A. Nasser, M. Gazzaly, J. Geaga, B. Hoistad, G. Igo, J. McClelland, A. Sagle, H. Spinka, J. Carroll, V. Perez-Mendez, E. T. B. Whipple, LBL-6125, Submitted to Nucl. Phys.

$p\text{-}{}^4\text{He}$  Elastic Scattering at 5.75 GeV/c, M. A. Nasser, M. M. Gazzaly, J. V. Geaga, B. Hoistad, G. Igo, J. B. McClelland, A. L. Sagle, H. Spinka, J. B. Carroll, V. Perez-Mendez, and E. T. B. Whipple, LBL-7287, Accepted for publication in Phys. Rev. Letters.

Polarization in Elastic p-p and p-n Scattering at 1.03 GeV, M. Marshak, E. A. Peterson, K. Ruddick, T. Mulera, J. Roberts, R. Klem, J. Carroll, R. Talaga, and A. Wriekat, A.N.L. Report, Submitted to Phys. Rev.

d-d Elastic Scattering at 4.18 GeV, J. B. Carroll, G. J. Igo, J. B. McClelland, H. M. Spinka, R. L. Talaga, A. L. Sagle, V. Perez-Mendez, and E. T. B. Whipple, LBL-7288, Abstract submitted for Spring Meeting of the A.P.S., April 1978.

$p\text{-}{}^3\text{He}$  Elastic Scattering at 2.68 GeV, E. T. B. Whipple, J. B. Carroll, A. L. Sagle, V. Perez-Mendez, G. J. Igo, J. B. McClelland, H. M. Spinka, and R. L. Talaga, LBL-7489, Abstract submitted for the Spring Meeting of the A.P.S., April 1978.

Analyzing Power Measurements in Backward Elastic pd Scattering at GeV Energies, E. A. Peterson, M. L. Marshak, K. Ruddick, E. Biegert, W. Dragoset, J. Lesikar, T. Mulera, J. B. Roberts, R. Klem, J. B. McClelland, R. Talaga, A. Wriekat, and J. B. Carroll, A.N.L. Report, Bull. Amer. Phys. Soc. 23 Vol 1 (January 1978) p 80.

Determination of the Axial-Vector Form Factor in the Radiative Decay of the Pion, A. Stetz, J. Carroll, D. Ortendahl, V. Perez-Mendez, G. Igo, and M. Nasser, LBL-5393, Accepted for publication in Nucl. Phys.

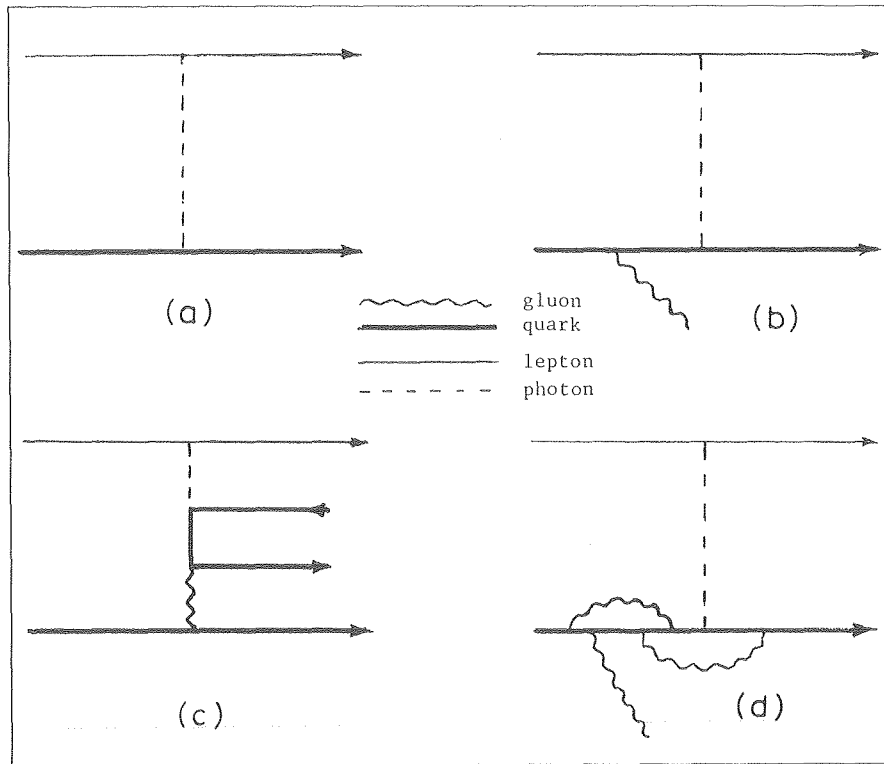
One Dimensional Curved Wire Chamber for Powder X-ray Crystallography, D. Ortendahl, V. Perz-Mendez, J. Stoker and W. Beyerman, LBL-7206, To be published Nuc. Inst. & Methods.

Experiments on Hadronic-Atom X-Ray Intensities of Hydrides and Deuterides, C. E. Wiegand, G. K. Lum, and G. L. Godfrey, Phys. Rev. A15, 1780 (April 1977).

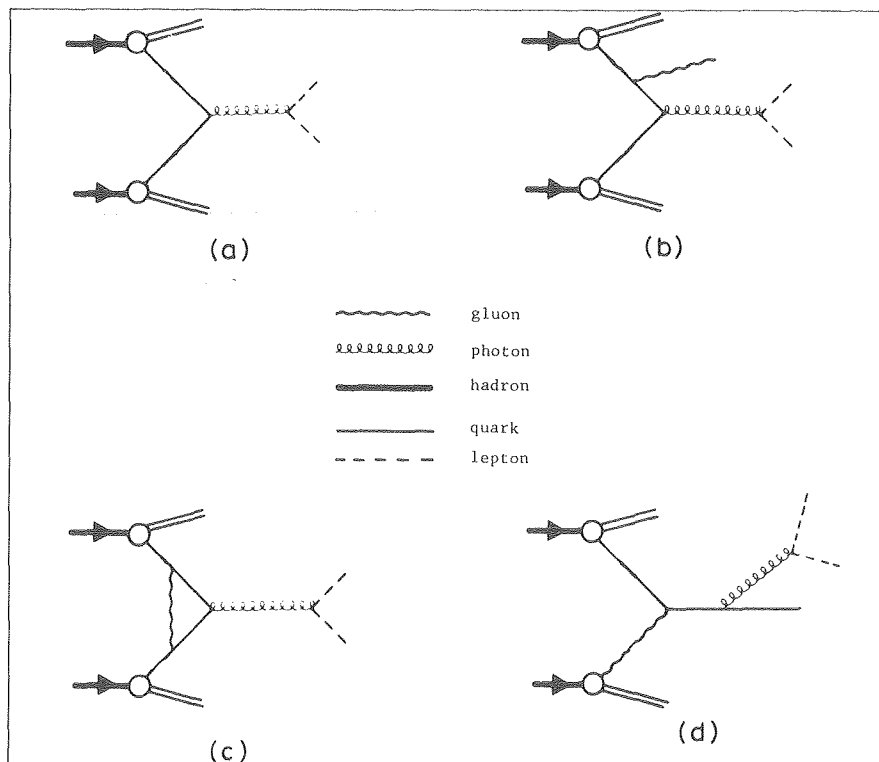
Kaon Mass by Critical Absorption of Kaonic-Atom X Rays, G. K. Lum and C. E. Wiegand, Bull. Am. Phys. Soc. 23, 64 (January 1978).

## **II. THEORETICAL PHYSICS**





Some of the possible mechanisms contributing to lepton-nucleon scattering.



Some of the possible mechanisms for lepton pair production in hadron-hadron collisions, in which a quark from one hadron annihilates with an antiquark from the other.

## II. THEORETICAL PHYSICS

The theory of the interactions of fundamental particles is the principal area of research of the Theoretical Physics Group. Other areas of importance are the physics of particle beams and their interactions, especially in the context of advanced and specialized accelerator systems, nuclear science, atomic physics, and mathematical physics. More generally, group members are concerned with research in those areas of physics which are part of the overall laboratory program.

An important adjunct of the theoretical physics research program is the training of graduate students working for the doctorate in theoretical physics. These students make important contributions to our research in the course of fulfilling the requirements for the degree.

The Theoretical Group is now composed of 7 faculty, 4 senior staff, 5 term appointees and self-supporting visitors from other institutions. At the present time there are 8 graduate students working under the direction of members of the Theoretical Group.

The regular term appointees are usually chosen from recent Ph.D.'s who have demonstrated unusual capacity for making important contributions to particle theory. As such they contribute crucially to the vitality of our program. These term appointments are more or less in the nature of postdoctoral fellowships.

For the past twenty-seven years the Theoretical Group has maintained a stimulating summer program. The Berkeley research program and the unusual features of the Bay Area have made it relatively easy for us to attract outstanding scientists at modest expense. Both the theoretical and experimental programs at the laboratory benefit from these visitors who often interact as much with the experimenters as with the theorists.

Our summer program is usually also enriched by a bonus of self-supporting visitors who are

active in our research areas. We offer them our hospitality and are rewarded by seminars on their current research and often by direct contributions to our work.

During the academic year we also have visitors, eager to participate in our research, who frequently make significant contributions to our work. They are supported by their own institutions or by special research grants or fellowships. We cooperate with these theorists by supplying office space, limited computing facilities and secretarial help.

### Participating Guests and Temporary Employees

Balazs, Louis	Purdue University
Bishari, Mordechai	CEN-Saclay/Weizman Institute
Capra, Fritjof	
Chan, Hong-Mo	SUNY-Stony Brook/ Rutherford Laboratory (England)
Clark, Thomas	University of California- Berkeley
Coster, Joseph	Western Illinois University, Macomb
Harper, Charlie	California State University- Hayward
Joglekar, Satish	University of California- Berkeley
Jones, Stanley T.	University of Alabama
Konishi, K. I.	Rutherford Laboratory (England)
Kwiecinski, Jan	Inst. of Nucl. Phys., Krakow, Poland
Mannheim, Philip	University of Oregon
Morrison, Harry L.	University of California- Berkeley
Niculescu, Basarab	University of Paris/NATO
Rarita, William R.	Retired; Brooklyn College, N.Y.
Rosenzweig, Carl	Syracuse University, N.Y.
Schmid, Christoph	ETH-Zurich, Switzerland
Senjanovic, Pavao	University of California- Berkeley
Veneziano, G.	CERN/Weizmann Institute

## Particle Theory

Research in particle theory encompasses the strong, electromagnetic and weak interactions of fundamental particles. Its approaches range from rigorous field theoretic considerations to practical analysis and interpretation of experimental data.

The LBL physics group has in the past been specially noted for its scattering matrix (S-matrix) approach to the theory of strong interactions. These efforts continue to bear fruit. The dual-topological-unitarization (DTU) scheme was actively studied this year, with special focus on the so-called baryonium states. The DTU approach, while S matrix in character, yields quark-like attributes of hadronic structure and also aspects of strong interaction dynamics more popularly attributed to asymptotic freedom and emission of gluons in quantum chromodynamics (QCD). There is even a hint of the equivalent of the "color" degree of freedom.

The S-matrix research effort received great stimulus from an informal workshop held at LBL in July, 1977 with approximately 40 participants from all over the world.

Another dominant activity this year concerned non-Abelian gauge theories for the intensive study of the mechanism of quark confinement. In addition the mathematical structure of these gauge theories has been explored. Instantons, topological invariants, Gribov ambiguities, and boundary conditions are among the aspects considered.

On a more practical level, radiative corrections are being studied in QCD in order to make predictions for a number of physical processes that cannot be treated adequately by other methods.

Considerable attention continues to be paid to SPEAR/PEP physics and the new particles. Research includes work on the spectroscopy of the psi states as well as the newly discovered epsilon states at 10 GeV, and also the study of weak decays of the new particles and high-energy neutrino interactions.

The question of the existence of ultra-heavy leptons and quarks is being studied in the context of gauge theories of weak and electromagnetic interactions at very high energies. The aim is to see

whether or not such particles bear on weak interactions at present energies.

The efforts in accelerator theory and design have focused on ESCAR, PEP and heavy-ion fusion, with lesser efforts on synchrotron light storage rings.

More detailed descriptions of research done in the Theoretical Physics Group this year are given in the following paragraphs.

### Topological Expansion of the S Matrix

During the past four years there has been developing an approach to hadron theory in which particle order, as expressed topologically through graphs, plays a key role. The new approach has been called dual topological unitarization (DTU). It has been found that many of the quarklike attributes of hadron structure are inevitable as manifestations of order. Quarks need not be introduced as separate entities. At the same time, the pomeron and OZI-rule violations have become understood as unitarity-required deviations from perfect order; to understand such phenomena there is no need to introduce gluons. A hint has appeared that ordered relationships compatible with unitarity require precisely 3 "colors" among hadronic degrees of freedom. Investigation of the connection between "order" and "color" will continue.

Hopefully a deep and detailed understanding of the hadron spectrum will emerge, including the newly discovered states that are sometimes called "baryonium." An already established feature of the ordered approach to hadron dynamics is the prediction of an infinite sequence of hadron families, of which the lowest-lying are ordinary mesons and baryons and the next is baryonium.

It remains to be seen whether the detailed properties of ordered baryons and baryoniums correspond as closely to observed hadrons as have the properties of ordered mesons. (G. F. Chew, H. P. Stapp, J. P. Surssock, G. Weissman)

In related research, a study has been made of the definition and properties of quark diagrams for baryons. The distinction between charge-

conjugation and signature properties of quark diagrams for mesons has also been investigated. (Y. Eylon)

An informal DTU workshop was held in the LBL Theoretical Group during the week of July 25-29, 1977. There were approximately 40 participants, coming from Europe and Asia as well as from all parts of the U.S. Included were two theorists, Professor Gabriele Veneziano of the Weizmann Institute and CERN and Dr. Chan Hong Mo of the Rutherford Laboratory, who were co-institigators in 1974 of the DTU approach to hadron theory. Emphasis during the workshop discussions was on the newly-discovered baryonium states. Workshop participants agreed that the week-long intensive discussions and debates were enormously profitable. From the LBL Theoretical Group there emerged at least three lengthy papers that were strongly influenced by the workshop.

#### Guests at Workshop on Dual Unitarization and the Topological Expansion, Summer 1977

Alcock, John W.	Bristol University, England
Aurenche, P.	Ecole Polytechnique, France
Balazs, Louis	Purdue University
Berger, Edmond	Argonne National Laboratory
Bishari, Mordechai	CEN-Saclay/Weizmann Inst.
Bopp, F. W.	University of Siegen, West Germany
Brower, Richard	UC-Santa Cruz
Desai, Bipin	UC-Riverside
Chan, Hong-Mo	SUNY-Stony Brook/Rutherford Laboratory
Duke, Dennia	Fermi National Accelerator Laboratory
Finkelstein, Jerome	Columbia University
Freeman, J. R.	U. of Nebraska
Girardi, G.	CEN-Saclay, France
Harmes, Ben	U. of Alabama
Harper, Charlie	California State University at Hayward
Hossain, Monowar	U. of Texas at Austin
Hoffman, Hanna L.	Rutherford Laboratory, England
Jones, C. Edward	U. of Nebraska
Konishi, K. I.	Rutherford Laboratory, England
Koplik, Joel	Inst. for Advanced Study, Princeton

Kwiecinski, Jan	Inst. of Nucl. Phys., Krakow, Poland
Mannheim, Philip	U. of Oregon
Nicolescu, Basarab	University of Paris, France
Roberts, R. G.	Rutherford Laboratory, England
Rossi, G. C.	CERN, Geneva, Switzerland
Rosenzweig, Carl	Syracuse University
Sakai, N.	Tohoku University, Sendai, Japan
Schmid, Christoph	ETH-Zurich, Switzerland
Snider, Dale	U. of Wisconsin-Milwaukee
Sorensen, Cristian	Argonne National Laboratory
Tan, Chung-I	Brown University
Thorn, Charles	MIT
Tsou, S. T. (Florence)	SUNY-Stony Brook/U. of Oxford, England
Tow, Don M.	U. of Texas at Austin
Uschersohn, J.	NORDITA, Copenhagen, Denmark
Veneziano, G.	CERN/Weizmann Inst.
Warnock, R. L.	Ill. Inst. of Tech., Chicago
Weis, Joe H.	U. of Washington

## Reggeon Field Theory, Regge Phenomenology

In collaboration with R. Brower and M. Mosche (UC-Santa Cruz), M. Furman has recently completed an extensive, accurate numerical calculation of the critical exponents of the reggeon field theory, computed from an analogue quantum-spin model which had been previously introduced<sup>(1)</sup>. The results give strong support to the conjectured fact that this spin model is in the same universality class as the original field theory. The critical exponents allow one to predict the asymptotic behavior of the total cross-section and diffractive slope of hadron scattering.

There are several related calculations to be carried out in the near future, the most important one being the computation of the scaling function. This will allow one to predict the asymptotic behavior of the elastic differential cross section,

(1) D. Amati, M. LeBellac, G. Marchesini, and M. Ciafaloni, Nucl. Phys. *B112*, 107 (1976); R. C. Brower, M. A. Furman, and D. Subbano, Phys. Rev. *D15*, 1756 (1977).

and to help decide whether or not nature has chosen the critical solution of the theory, if any. (M. Furman)

Research in Regge phenomenology is concerned with the nondiffractive renormalization of the pomeron singularity through flavoring, with special interest in the phenomenological consequences of flavoring.

An investigation of the inclusive cross sections in this context has been recently completed; now interest focuses on the reactions  $K^\pm \rightarrow K^* p^\pm$  and their interpretation assuming the identity of the pomeron and f trajectories. (S. T. Jones)

## Gauge Theories, Quark Confinement

During the past year Halpern, together with Senjanovic, and Jevicki of Princeton University, studied methods of introducing particle and string variables to replace field variables. With graduate student research assistant W. Siegel, he was able to identify the limit in which such "geometrical" variables are the natural description. A new semiclassical, strong coupling expansion was identified around this new limit, which holds much promise for connections between strings and fields. Halpern also studied the possibility of using field-strengths as fundamental variables in non-Abelian gauge theories. The resulting theory is well defined under most configurations (instanton) etc., but needs more work in the vicinity of "field-strength copies." This work also led to a gauge-invariant description of such theories, in the same regime of validity. With Koplik, the Gribov copy phenomenon was studied in a didactic manner, giving simple, demystifying examples. With graduate student research assistant (GSRA) D. Friedan, Halpern studied a broader class of finite action configurations (than were previously assumed to exist). (M. B. Halpern; D. Friedan, W. Siegel)

Bardakci has been working on various theories of confinement involving instantons with his student, S. Samuel. They were and are investigating various field theoretic models in two and three dimensions which satisfy Wilson's criterion and therefore are believed to confine. Recently they have developed methods for the calculation of the spectra and the Green's functions in these models and have confirmed the linear rise of the trajectories.

They have also discovered some unexpected and interesting properties of these models. (K. Bardakci, S. Samuel)

Mandelstam has been attempting to construct a trial vacuum state for non-Abelian gauge theories. The bare vacua in the usual physical gauges have infinite energy, even when the ultraviolet divergences are cut off. He has been attempting to remove this infinity by constructing a coherent plasma of Wu-Wang monopoles. Such a vacuum would automatically satisfy the Wilson condition for confinement. At present he has obtained a formal definition of a suitable trial vacuum state, and he has been studying the formal charge-monopole symmetry in non-Abelian gauge theories, and its relation to electric and magnetic Higgs vacua and confinement. (S. Mandelstam)

Mandelstam and his graduate student, Susan Moore, have been investigating the properties of the operator arising in a path integral formulation of QCD which, when sandwiched between quark-antiquark states, represents a gauge-invariant meson operator. It has the form of a path-ordered exponential of the integral, between  $q$  and  $\bar{q}$  positions, of the gluon field contracted with the appropriate color gauge matrix. They use the approximation of heavy quarks and a confining vacuum that appears bare on the scale of the meson. They wish to show that certain ultraviolet divergences due to the overlapping of multiple paths of integration can be avoided by gauge-equivalent distortion of the paths. This can be achieved, they believe, by rewriting the terms in the expansion of the exponential (a product of  $N$  gauge matrices in  $N$ th order) as a sum of pieces of definite symmetry with respect to the permutation of gauge indices. They are attempting to prove this decomposition can always be done and to find the coefficients of the  $N$ th order term in the limits of large  $N$  and long path length. (S. Mandelstam, S. Moore)

Ömer Kaymakçalan, another GSRA of Mandelstam, has been working on the quantum theory of the free electromagnetic field in the axial gauge. At the present time, he is trying to construct a finite energy vacuum state for the electromagnetic field in the axial gauge interacting with a doublet of Higgs bosons. (O. Kaymakçalan, S. Mandelstam)

The existence of topologically nontrivial "instanton" or pseudoparticle solutions of  $SU(2)$  Yang-Mills theory has led to a new nonperturbative

picture of the Yang-Mills vacuum. In collaboration with T. Eguchi at SLAC, A. J. Hanson has been investigating the possibility of similar solutions of Einstein's theory of gravitation. If such solutions can be found they would have profound implications for the structure of the gravitational vacuum and the gravitational path integral. They have defined criteria for identifying gravitational instantons and applied them to the Taub-NUT metric and to a new Euclidean metric which they have found.

The foregoing results are described in two reports, LBL-6177 and another in preparation. The given metrics meet some, but not all of their criteria. (H. J. Hanson, T. Eguchi)

Besides the instanton solutions of Euclidean SU(2) Yang-Mills theories, there are other "meron" solutions which have two singularities in space-time, each carrying one-half unit of topological charge. Callan, Dashen and Gross have speculated that solutions of this type can explain the confinement of quarks in quantum chromodynamics.

A more rigorous analysis of this conjecture requires the knowledge of multimeron solutions, with more than two topological charge singularities. With T. Eguchi (unpublished), Hanson has found approximate *collinear* multimeron solutions; essentially the same results were independently published by Glimm and Jaffe. His present research centers on eliminating the collinearity condition and seeking exact multimeron solutions to SU(2) Yang-Mills. (A. J. Hanson)

A study is in progress of quantization of gauge theories. The emphasis is on viewing the theory in the  $A_0 = 0$  gauge as quantum mechanics with infinite number of degrees of freedom. (Y. Eylon)

## Quantum Chromodynamics

First order radiative corrections are being studied in Quantum Chromodynamics (QCD) using the improved perturbation theory of the renormalization group. The goal is to attempt to sharpen predictions that have been made for a variety of processes that cannot be treated by operator product techniques. In a related work, GSRA, N. Fleishon is using the  $1/N$  expansion in two-

dimensional QCD to study a number of applications of the parton model that are also unjustified by operator product methods. (M. Chanowitz, N. Fleishon)

A study is in progress of testable predictions of QCD. Of particular interest are the so-called soft processes, where predictions are not backed by rigorous arguments. These provide a vital check on the calculational techniques of QCD perturbation theory. (I. Hinchliffe)

## New Particle Spectroscopy

Research continues in the analysis and interpretation of the spectroscopy of new particles, in particular on the radiative transitions between states below the flavor threshold and on the dynamics of the resonances above the flavor threshold. (J. D. Jackson, P. de Forcrand)

## SPEAR-PEP $e^+e^-$ Physics

During this year work was completed on the effects of the weak neutral current on a right-left asymmetry in hadron production with highly transversely polarized  $e^+$  and  $e^-$  beams in storage rings. Measurement of this asymmetry would provide unambiguous evidence for parity violation in  $e^+e^-$  annihilation and would confirm the existence of a weak neutral current for electrons. (R. Simard, M. Suzuki)

Research is continuing on new particle physics in  $e^+e^-$  annihilation and high energy neutrino reactions. Of particular interest is (1) the weak interaction property of the fifth quark constituting the upsilon particle since its weak interaction will surely reveal the entire structure of the weak interaction theory and (2) the gluonic aspect of strong interactions that will be more easily seen in the energy region of the upsilon particle or higher. In parallel, the effects of instantons in lepton-hadron processes will be considered to get some numerical estimate of their effects.

Calculations are currently being done for the instanton correction to the  $e^+e^-$  total cross section and magnetic moments of quarks. (M. Suzuki, C. Flory)



## Weak Interactions at the TeV Energy Scale

The consequences are explored for the  $SU(2) \times U(1)$  gauge theory of weak and electromagnetic interactions if there exist ultra-heavy quark and lepton flavors. For masses  $\geq 1$  TeV it is found that the perturbation expansion fails and that the ultra-

heavy flavors are strongly coupled to the W and Z gauge bosons and to ultra-heavy Higgs bosons. This also implies a breakdown in the perturbative expansion for radiative corrections to phenomena at presently accessible energies. It is now being investigated whether this breakdown allows one to use present experimental data to decide whether ultra-heavy quarks and leptons exist. (M. Chanowitz, M. Furman, I. Hinchliffe, and S. Jones)

## Accelerator Theory and Design

At the end of this year three of the accelerator theorists (A. A. Garren, L. J. Laslett, L. Smith) transferred from the Physics Division to the Accelerator and Fusion Research Division. This leaves research in accelerator theory and the physics of particle beams within the Theoretical Physics Group largely in the hands of D. L. Judd. During 1977, research in this area was mainly devoted to the LBL program on "heavy-ion fusion," aimed at exploring the design of high-energy accelerators for beams of heavy ions in low charge states as igniter systems for inertial-confinement fusion power plants. (D. L. Judd)

For the record, the research activities of A. A. Garren for the period under review are also summarized. Garren works in areas relevant to PEP, to synchrotron radiation storage rings, and to heavy ion fusion, with primary emphasis on PEP.

For PEP he has been investigating the effects of magnet misalignments on electron beam properties such as emittance and damping rates (in collaboration with B. Autin, visitor from CERN), designing a very high luminosity insertion, and pursuing new ideas for the proton ring which may be added in the future.

Concerning synchrotron light machines, he worked on lattices to enhance brightness, on effects of wiggler magnets, on the development of computer programs for the magnet error effects mentioned in connection with PEP. The transport of heavy ion beams leaving the accelerator and focusing them onto a target for pellet fusion is the third main area of research (in collaboration with D. Neuffer). Recently this activity has been directed toward the so-called intermediate experiment.

On a miscellaneous topic, Garren collaborated with a visitor, M. Szilagy, on the application of dynamic programming techniques to electron optics, because of its relation to his earlier application of linear programming to cyclotron magnet trimming and the draft of a report was written. Further work is needed to round out this interesting matter, but so far it has had to be postponed for more pressing problems.

### TITLES AND DATES OF PUBLICATIONS

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- Breaking of Scale Invariance in the Presence of Instantons, M. S. Chanowitz, Phys. Lett. 68B, 180 (1977), TH-2300 CERN preprint, LBL-6435, March 1977.
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- Ordered Hadron S Matrix, Geoffrey F. Chew, Jerome Finkelstein, Jean-Pierre Sursock and George Weissmann, Submitted to Nucl. Phys. B, LBL-7237, December 1977.
- Galilean Presymmetry and the Two Fluid Model of Superfluidity, R. Creswick and H. L. Morrison, submitted to J. Low Temp. Phys., LBL-6734, August 1977.

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- Quark Diagrams for Baryons, Y. Eylon and J. Finkelstein, *Nucl. Phys. B127*, 141 (1977), LBL-6428, April 1977.
- Quantization of Gauge Theories, Y. Eylon, submitted to *Phys. Lett. B*, LBL-6476, June 1977.
- Kinetic Energy Considerations and the Vacuum, Y. Eylon and E. Rabinovici, *Phys. Rev. D16*, 2660 (1977), LBL-6475, July 1977.
- Charge-Conjugation, Signature and Twists, Y. Eylon, To be published in *Nucl. Phys. B*, LBL-6736, August 1977.
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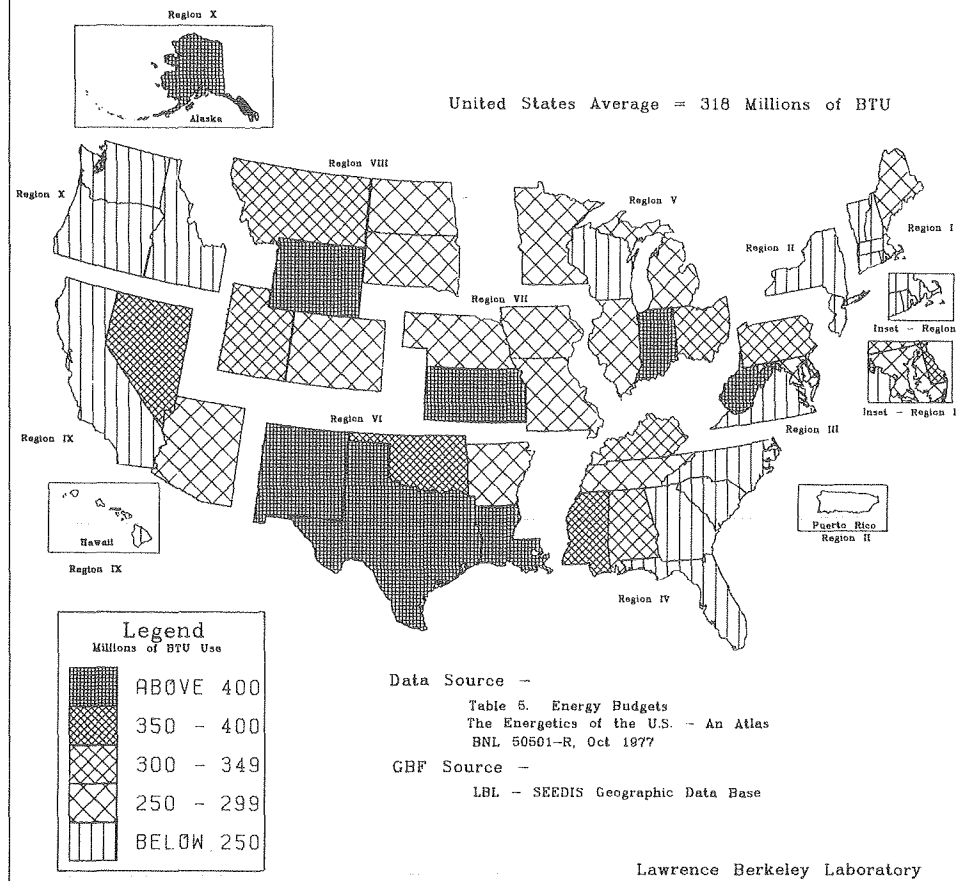
## Doctoral Theses

During this year five graduate students working in the Theoretical Physics Group were awarded the Ph.D degree. They and their theses are listed below.

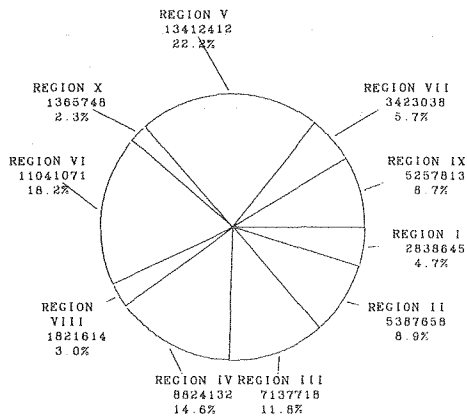
- Lucht, Philip, "Multiperipheral Ring Dynamics and a Definition of the Complete twisted Reggeon Loop," Ph.D. thesis (University of California-Berkeley).
- Millan, Jaime, "Self-Consistent Model Calculation of the Ordered S Matrix and the Cylinder Correction," Ph.D. thesis (University of California-Berkeley).
- Roth, R. S., "Topics in Dual Models and Extended Solutions," Ph.D. thesis (University of California-Berkeley).
- Siegel, W., "Topics in Theoretical Particle Physics," Ph.D. thesis (University of California-Berkeley).
- Simard, Richard, "Weak Interaction Effects with  $e^+e^-$  Annihilation with Polarized Beams," Ph.D. thesis (University of California-Berkeley).

### **III. COMPUTER SCIENCE and APPLIED MATHEMATICS**

# Total Fuel Consumption Per Capita United States by Federal Region



ANNUAL TOTAL FUEL CONSUMPTION  
BY FEDERAL REGION  
TABLE 5 - ENERGY BUDGETS  
THE ENERGETICS OF THE UNITED STATES OF AMERICA -  
AN ATLAS. BNL 50501-R, OCTOBER 1977



IN BILLIONS OF BTU FUEL USE

The flexibility of SEEDIS tools allows the user to create a display which highlights particular facets of selected data (pie chart), or one which shows a more detailed view (map).

# III. COMPUTER SCIENCE AND APPLIED MATHEMATICS

The Computer Science and Applied Mathematics (CSAM) Department provides computation and information management methods and tools applicable to a wide range of laboratory and Department of Energy (DOE) programs. Basic and applied research in a variety of computer science and mathematics disciplines are fundamental to development and demonstration projects. A balance between project-oriented work and discipline-oriented research is maintained by funding from DOE, and from other federal and state agencies.

The staff is comprised of computer scientists, mathematicians, engineers, physicists, computer technicians and administrative personnel. Included

are UCB faculty, post doctoral appointees and graduate students.

Principal research and development areas of work during 1977 were as follows:

- Applied Mathematics
- Advanced Systems
- Software Engineering
- Data Management and Information Systems
- Computer Graphics

The first section of this CSAM report summarizes research and development work in the above areas, while the second section details the various project and support activities in a wide range of applications.

## RESEARCH

### Applied Mathematics

Research in applied mathematics centers on computational mathematics, applied analysis, numerical studies of turbulent combustion and fluid flow, and mathematical software development. The staff also provides consulting services to LBL staff members and supervises the Computer Center mathematical software library.

#### Computational Mathematics

Work in computational mathematics emphasizes the numerical solution of hyperbolic

and elliptic partial differential equations, development of numerical methods applicable to problems in fluid flow and combustion, numerical study of capillary phenomena, and development of algorithms for ill-posed and inverse problems.

One of the topics under active investigation is the development of numerical techniques for obtaining solutions that are discontinuous or nearly discontinuous for hyperbolic and parabolic partial differential equations. The discontinuous solutions under study contain shocks and other jump discontinuities satisfying constraints.



Nearly discontinuous solutions occur in the theory of flames and in boundary layer theory, when a hyperbolic system of equations is disturbed by a singular (parabolic) perturbation.

These studies are of substantial importance because:

- discontinuous and nearly discontinuous solutions occur very often in applications;
- the standard tools of numerical analysis often depend on smoothness assumptions that are not realized in these cases;
- the appropriate mathematical tools are only now beginning to become available.

Research developments are intended to be useful in a number of physical applications, including turbulence theory, multi-phase flow, and combustion theory.

Another topic actively under investigation is the numerical solution of elliptic partial differential equations. The development of fast-direct methods and the coupling of them, and of other methods, with the conjugate gradient method have made possible the solution of problems that would otherwise not have been feasible within normal limitations on computing resources. Furthermore, the reliability and ease of use of such methods make them generally attractive. Methods are being developed for the iterative solution of nonlinear elliptic equations and of problems on irregular domains in two and three dimensions. Simultaneously, the use of other iterative methods and of higher order finite element methods for such problems are being studied.

An area of practical importance to which these methods are applied is the determination of the shape of capillary surfaces. Similarly, methods for hyperbolic and parabolic equations are applied to problems in which capillarity plays a role, such as two-phase flow in porous media in petroleum and geothermal reservoirs.

Investigations are being pursued in the area of ill-posed and inverse problems. One of these investigations is the development and evaluation of algorithms for the reconstruction of the image of an object from projection data of its transverse sections.

*Fluid Flow and Combustion* — Glimm's method and related random choice methods were developed for the computation of discontinuous solutions of hyperbolic systems. A novel and very successful grid-free random walk procedure was developed for solving the Prandtl boundary layer equations numerically, and coupled to a random choice method in an analysis of a singular perturbation of a two-dimensional hyperbolic system.

An investigation was begun of the numerical solution of the Buckley-Leverett equation, which arises in applications to the flow of petroleum in underground reservoirs and to geothermal flows. The random-choice method was used to develop a numerical technique for the sharp tracking of the discontinuities, such as the interfaces between immiscible liquids, which occur in these flows.

*Numerical Methods for Elliptic Equations* — The study of the generalized conjugate gradient method in combination with fast-direct and other splitting methods continued. Extensions were made to nonlinear problems, such as the minimal surface equation, and the methods were found to compare favorably with other numerical techniques for such problems, thereby increasing further the areas of successful application.

Studies continued of the efficient use of fast direct methods for the numerical solution of separable elliptic equations on irregular domains. A method for obtaining highly accurate solutions for the Dirichlet problem was developed by combining the usual second-order finite difference scheme with the method of deferred corrections, a capacitance matrix technique being used for solving the resulting system of algebraic equations. Implicit variants of the capacitance matrix technique were used to develop a method, having only minimal computer storage requirements, that permits efficient solution of Helmholtz's equation on a general plane-bounded region containing a very large number of mesh points.

A dynamic alternating-direction-implicit method has been developed for solving general second-order elliptic equations. The method, which relies on a heuristic, automatic choice of acceleration parameters, has been found to be effective for solving linear equations in two and three dimensions and has been extended to strongly nonlinear equations for the two-dimensional case.

*Capillary Phenomena* — The stability of capillary surfaces in inverted containers was studied numerically for the case in which the surfaces do not include the axis of symmetry. Also, it was found that the analytical bounds developed earlier for the limits of existence for capillary surfaces on curved domains are in close accord with the critical values observed from numerical experiments on an ellipse.

Some of the numerical methods developed for solving nonlinear elliptic equations were adapted to solving the capillary free-surface problem and extended to include domains containing corners for cases in which the solution is unbounded. These lower-order methods were compared with a higher-order finite-element method that utilizes biquadratic elements.

### Applied Analysis

Work in applied analysis centers on the study of nonlinear elliptic partial differential equations — a study separate from but related to larger computational mathematics projects in this area. Of primary current interest are the equations arising in the theory of capillary surfaces. This work is concerned with the questions of the existence, stability and qualitative behavior of solutions of these equations, particularly as such questions relate to areas of physical, biological, and engineering sciences in which capillarity plays a significant role. This work has led in a rigorous mathematical manner to new results concerning the possible equilibrium configurations of liquids that are freely suspended or confined to a space bounded by a solid, which they partially fill. The goal is to develop these methods further and to obtain definitive results on more general questions, including those of stability. It is anticipated that this work will extend to more general classes of equations and that it will interact substantially with numerical computation and with physical experiments.

Work continued on the capillary free-surface problem. New analytic estimates for the shape of pendent liquid drops were obtained. These estimates were used to prove some preliminary results about the convergence to the singular pendent drop as the vertex height extends downward to infinity. These results are the first such ever obtained and it appears that the comparison techniques used to obtain them may be applicable to broader classes of problems.

The stability of capillary surfaces in inverted containers was studied for rotationally symmetric cases in which the surface does not include the axis of symmetry. New results were obtained for the limiting form of the boundary conditions for neutral stability for the case of perfectly wetting liquids. These results have been used in numerical computations, the results of which have been found to agree with physical experiments.

### Numerical Studies of Turbulent Combustion and Fluid Flow

In these studies, computational techniques are being developed for analyzing turbulent combustion phenomena, such as those that occur in an internal combustion engine. The goal is the construction of realistic models that are suitable for comparison with experiments and are capable of being used for design purposes. Specific features of the methods being developed are (1) the use of sampling and random-choice procedures and (2) the use of “dictionaries” of known phenomena as building blocks in the numerical schemes. These features allow resolution of the major difficulties that have stood in the way of the application of other numerical techniques to the study of physical combustion phenomena. These methods, unlike others, have little or no numerical diffusion (and thus no cell Reynolds number restrictions), i.e., they can deal realistically with high Reynolds number flow. Because these methods are based on sampling rather than averaging, they can take into account the effect of organized structures (coherent eddies) in a flow. This feature is very important because real chemical phenomena are greatly affected, even determined, by the existence of coherent eddies and will not be reasonably reproduced if these coherent eddies are not taken into account.

Work has continued on the development of random choice and random vortex methods for the analysis of turbulent and/or combusting flow. A coarse graining method has been developed, which represents a substantial advance over previously available methods. A new version of the vortex method more accurate and computationally more efficient than previous versions, has been developed and analyzed. These two methods have been combined in a computer program that can analyze



A prototyping network comprised of three minicomputers serves as a "test bed" for investigating alternatives for DOE intersite networking, and for distributed computing. Seated are (l to r) Don Austin, Carl Quong, and Bill Greiman; standing (l to r), Helena Gin, Lesta Nadel, and Rosemary Allen.

turbulent boundary layers and bursting sequences for flow in a model cylinder-piston assembly. This is the first such program ever written capable of performing these calculations. It was observed that the bursting sequences dominate the turbulence and are the probable origin of intermittency in the flow.

## Mathematical Software and Consulting Services

In addition to its research activities, the Applied Mathematics group supervises the maintenance and improvement of the Computer Center

mathematical software library, which covers essentially all the major areas of contemporary numerical methods. In connection with this activity, consulting service to Computer Center users is provided in numerical mathematics, applied analysis, and statistics.

Improvements and new additions were made to several areas of the mathematical software library, and consulting services were provided to LBL staff members and other Computer Center users. The project of preparing brief tutorial reports covering major areas of computational techniques continued, and a program to reorganize the mathematical software library was initiated.

## Advanced Systems

The research and development effort in the establishment and utilization of inter-site networks in DOE (ERDA) is described extensively in a four volume report entitled "General Purpose Computer Networks and Resource Sharing in ERDA," dated July 15, 1977 and co-authored by researchers from seven DOE sites. This study touched on mission-oriented research from nearly every major DOE program and demonstrated direct benefits to be obtained from continuing work in this field, including enhanced facilities for scientific and managerial collaboration; sharing of unique hardware, software, and databases; reduction of duplicate effort; and interaction with researchers from the universities, and private and federal agencies. Network facilities developed using the Advanced Research Projects Agency Network (ARPANET) were used for experiments involving most major DOE programs and were shown to be of potential benefit to every computational or information management function currently undertaken in DOE. Teleconferencing and network mail facilities were introduced to the DOE community and their use continues to expand.

The success of this project has encouraged continuation and expansion of the effort to bring about an environment for software and hardware development in DOE much richer than currently exists. The inter-site network activity will focus on the creation of a high-level Network Command Language (NCL). This would significantly reduce the effort required to use network facilities and

provide a uniform interface to computational and information management systems in the DOE community, particularly in the important areas of distributed data management and large-scale scientific computing.

Facilities for using existing software at other sites (both DOE and non-DOE) have become extremely important in a number of research programs supported by other DOE divisions. The teleconferencing and network mail facilities, explored as part of this effort, are rapidly becoming a major resource throughout DOE for scientific collaboration and program management.

This research effort has enjoyed a high degree of visibility and has effectively enhanced the manner in which research and development is conducted. Short-term payoffs in this area have been readily accepted, and long-term developments can be expected to revolutionize the computational environment of energy-related research and development.

The Distributed Computing Network (DCN) for data management, under development at LBL through a Memorandum and Understanding between DOE and the U. S. Department of Labor (DOL), will form the basis for a distributed network based on a commercial communications backbone, independent of the ARPANET. The DCN will form a testbed for ideas developed by this research and help point the way for future DOE alternatives for inter-site networking.

During 1977, a review of available computer systems was carried out to determine which systems met minimum levels of performance. The study concentrated on performance and limitations of hardware, operating systems, utilities and communications software. A detailed specification spelling out minimum levels of functional capability and performance for the central processing unit (CPU), peripherals, operating system, utilities and

network software was prepared and served as the basis for a formal request for proposals issued to vendors. Evaluation of responses included the performance of benchmarks to determine network software performance, CPU performance and graphics output capability. An order for three systems was placed for implementation of a prototype network.

## Software Engineering

Software engineering is concerned with the creation of software tools designed to aid in the construction of reliable, transportable, and easily maintainable software. The motivation for this effort is based on the observation that, while the cost of hardware has continued to decrease dramatically over the past decade, software costs have continued to rise. This is because software production has remained labor-intensive and insufficient effort has been devoted to developing standards for programming, command languages, and basic utilities.

### FORTRAN Standard

CSAM continued its participation in official capacity on the American National Standards Institute (ANSI) X3J3 FORTRAN standards committee which was completing the new FORTRAN77 standard. The FORTRAN standardization effort directly impacts most of the scientific computing done in DOE. DOE's large investment in FORTRAN makes it imperative that DOE's requirements be represented in the specification of a new standard. Transportable programs could potentially save a large amount of duplicated effort and provide valuable resources to groups lacking sufficient facilities to develop large analysis programs of their own.

The incorporation of the IF-THEN-ELSE control structure into FORTRAN77 was a direct result of LBL's participation and should have a major effect on program reliability and maintainability in the future. The FOR-WORD FORTRAN Development Newsletter, sponsored by the Ad Hoc

Committee on FORTRAN Development of the Special Interest Group on Programming Languages (SIGPLAN) is edited, printed and distributed as part of LBL's continuing efforts to keep the scientific community informed of new language developments.

### Software Tools

The development of a comprehensive set of software tools which is transportable to many operating systems, also has the potential for saving a vast amount of software development effort by providing scientific programmers with a much higher level of basic building blocks than currently exists at most sites. The development of a common command language is critically dependent on these tools for implementation.

Work began in late FY 1977 with the acquisition of a set of standard software tools developed at Bell Laboratories for the creation of a Programmers' Workbench. A tape was obtained from Addison-Wesley Publishers containing a basic set of utilities, such as a text editor, a text formatter, and various low-level routines for character handling and file manipulation. These routines are written in a FORTRAN-compatible high-level language called RATFOR, a compiler for which was included in the set of basic tools. A small amount of effort was required to implement a critical set of these tools on the LBL Computer Center systems to demonstrate the feasibility of this approach. Development began on BKY of a UNIX-like "shell," a command interpreter with such software engineering facilities as pipelines and forks. The



shell concept provides one approach to transparent use of heterogeneous machines and operating systems in a network environment by extending the command syntax and making the shell software available on all participating "host" machines.

Another method under investigation involves frontending a host system with a "network access machine" (NAM) which allows network access commands to be written in terms of each host's syntax.

## Data Management

The data management research program at LBL is oriented toward the development of generalized data management tools for the support of applications relevant to the DOE mission. The research carried out by the staff of the Computer Science and Applied Mathematics Department is primarily concentrated in the areas of human engineered interfaces and distributed database techniques.

Data management tools are necessary to support many applications that otherwise support their own data management in an overlapping and wasteful manner. Preliminary research for long-term development of human-oriented interfaces to data management involved the study and analysis of several logical data models and their semantics. The study revealed that the query languages depend heavily on the amount of semantics imbedded in the data model. A data model, called the Entity-Relationship model, was selected for the development of a query language which takes advantage of its semantics.

The work on physical database structures is still at the study phase. Various methods for

physical database organization covered in the literature are being categorized. The correlation between data characteristics, hardware limitations, and intended use of the database, and the choice of a physical organization is being sought. This work should lead to a formulation of these correlations with the hope of automating the process of a physical database organization, which will allow the user view to be independent of the physical organization of the database.

Data management tools developed at LBL include a hierarchical caching system designed specifically for use with interactive software, INTERAC, and Berkeley Database Management System (BDMS) a hierarchical database management system specifically designed to efficiently handle numerical as well as character and bit string data. BDMS has a database definition language that is easy to learn, a powerful free-format data input language, and a sophisticated database editor. Its query language includes Boolean and relational operators, range searching, and the ability to use intermediate search results in later queries.

## Computer Graphics

During 1977, support requirements for various projects and addition of new hardware mandated modifications and further development of several graphics programs. The CHART program for interactive design of tables, charts, and graphs, was transported to Digital Equipment Corporation PDP-11 minicomputer systems as a basic utility for the Distributed Computer Network.

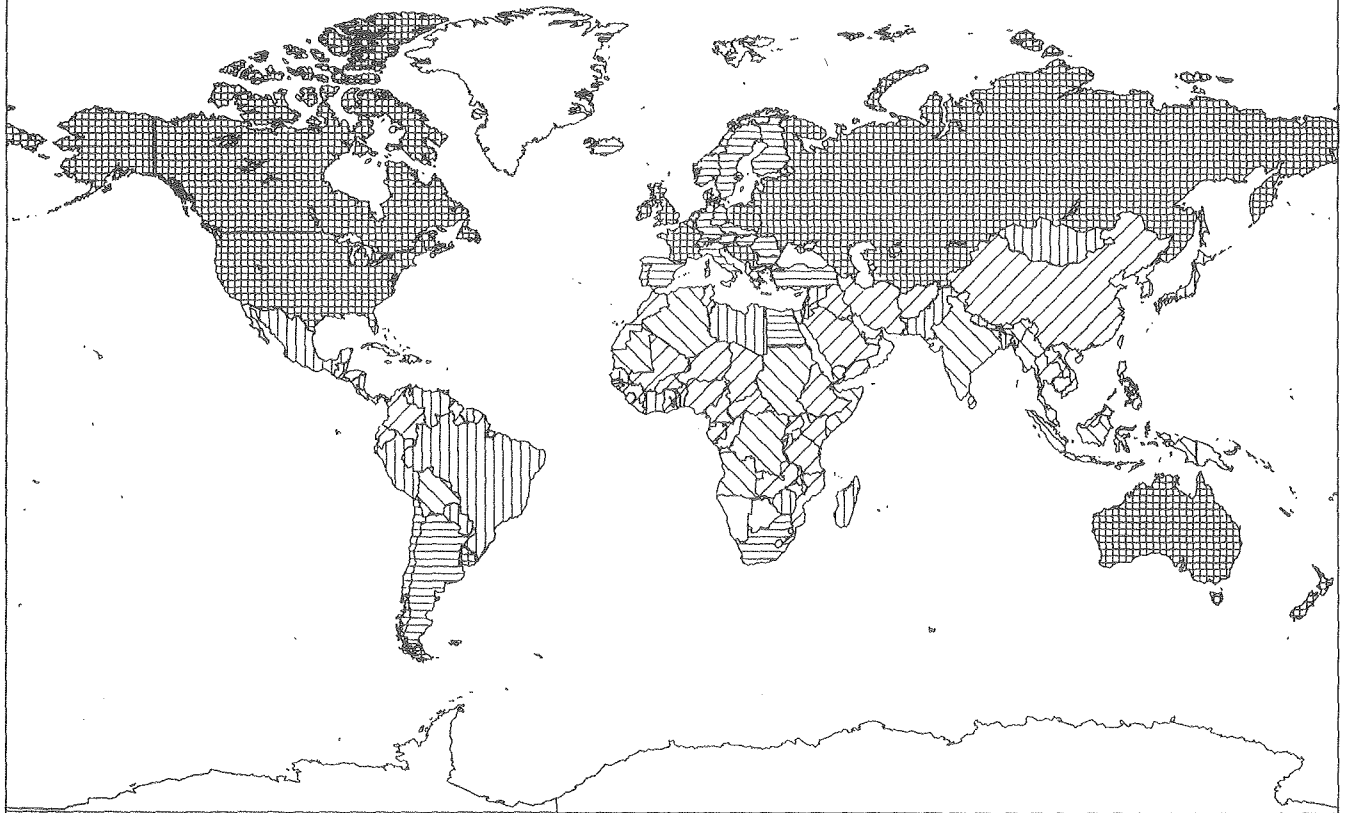
Color, shade and format specifications were incorporated for use of CHART on a color video terminal; these features were transported back to the CDC 6600-BKY version of CHART to use color with a ZETA plotter and color COM device.

A project in forestry explored the interface of linear programming models with computer mapping. The interactive version of CARTE, a thematic

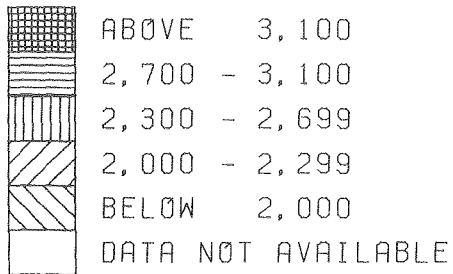


# AVERAGE DAILY CALORIC INTAKE

for most countries of the world in 1970



**CALORIES PER PERSON PER DAY**



DATA SOURCE -- WORLD DATA HANDBOOK  
 U.S. DEPARTMENT OF STATE  
 AUGUST, 1972

GEOGRAPHIC BASE FILE -- WORLD DATA BANK I  
 MILLER PROJECTION

MAP COMPILATION -- INTERACTIVE CARTE  
 COMPUTER SCIENCE AND APPLIED MATH DEPT  
 LAWRENCE BERKELEY LABORATORY

This map was produced using CARTE, a thematic mapping program which is part of the Socio-Economic Environmental Demographic Information System (SEEDIS). The map is designed interactively, allowing the user to refine the display until it most effectively presents the data of interest. It is then produced as "hard copy" on a Zeta plotter, in black or colors.

mapping program, was enhanced to display point and line data. Thematic maps were made of back-country trail and campsite use in Glacier National Park under various policy constraints, for example, minimizing dangerous bear contacts.

Capabilities for displaying and analyzing LANDSAT data were developed to support a joint project between LBL-CSAM and the Space Sciences Laboratory. The World Data Bank II geographic database and associated mapping

program POLYVRT were integrated into the computer mapping facilities at LBL during 1977.

The program PLOT was developed to support the Nuclear Theory Group simplifying use of the GRAFPAC package in support applications. A version of the plotting program VERF was implemented at LBL using IGS/NCAR plotting routines. VERF plots observed concentrations of various pollutants against time at various observation stations in the San Francisco Bay Area and in the St. Louis area.

## PROJECTS

### SEEDIS

The Socio-Economic-Environmental-Demographic Information System (SEEDIS) is comprised of a very large integrated database and sophisticated analytical and display capabilities. The objective of the SEEDIS project is to establish a coherent, comprehensive, computer-based information system for energy policy analysis, environmental impact studies, and other socio-economic analysis applications. Many LBL projects contribute significantly to SEEDIS by supporting research, and development of retrieval, analysis and display programs and/or by contributing new data resources. The system contains a variety of large databases, such as the 1970 Census, air quality data and geographic base files. SEEDIS contains nearly 50,000 different data elements for geographic area records, states, Standard Metropolitan Statistical Areas (SMSA's), counties, census tracts, etc.

A uniform dictionary for SEEDIS data is under development, as a database in itself. Each data element will be described and keyed by a collection of index terms to be utilized in subject-oriented search and retrieval. SEEDIS is accessible to computer users at LBL, over the ARPANET, on dial-up terminals, and from remote batch stations. A comprehensive set of user-oriented software modules provides data in tabular format, charts and maps, on interactive terminals and on high-quality hard-copy devices.

Computer science techniques involved include very large databases, distributed data management, computer networks, image processing, and computer graphics. Work has begun on interfacing the system to a distributed minicomputer network, as well as the ARPA network, and on implementation techniques for installing and distributing summary data from the 1980 Census. Current research activities include techniques for integrating information collected from several, frequently diverse, sources; synthesizing data for specific modeling studies; and updating base data from auxiliary sources.

### REAP

The REAP system for retrieval of county-level data was enhanced with the following developments.

- 1) The following files were installed:
  - a) 1974 U.S. Census of Agriculture and
  - b) 1962-1973 BEA Income and Employment Time Series.
- 2) A batch version of REAP was developed for access of REAP files from the CDC-7600.
- 3) A file-merging program was developed to merge files at the record and data-element level to create new databases for personalized analysis.

- 4) A report-formatting facility, Yet Another Report Generator (YARG) was developed and tested.

## Planning for the 1980 Census

Because of its extensive experience with the 1970 Census, LBL is providing staff support in coordinating DOE input to the Federal Agency Council on the 1980 Census, its working committees, and other pertinent census organizations. Composed of approximately 90 federal agencies, the council provides an organizational channel through which federal agencies making extensive use of decennial census materials can transmit advice to the Bureau of the Census. The council's efforts focus on broad aspects of the 1980 Census, including proposals for new questions, major changes in procedures or samples, and tabulation and publication plans.

As an official Census Summary Tape Processing Center, LBL continues to respond to a large number of requests for detailed information about the use of census data. Requests come from legislators, planning agencies, and others who discover that they simply are unable to easily obtain the required information from libraries or other public sources. In anticipation of future demand, LBL is also investigating techniques for processing and distributing to DOE laboratories and other government agencies the 1980 Census data required for specific programs and applications. In addition, subject-oriented retrieval mechanisms will be developed for the 1980 Census comparable to those available for the 1970 Census.

## System Integration

As SEEDIS grew and the user community expanded, demand developed for a user-friendly interface to these modules. The result is SEEDIS Monitor, an executive program which isolates the user from the vagaries, complexities, and rigid requirements of local computer operating systems. The monitor is hierarchically organized to guide the user, step by step, through specifying a geographic area (or areas) of interest, searching the available databases for specific data items, and then selecting, analyzing, and displaying the data in a format appropriate for the intended application.

A HELP program was developed for on-line access to documentation on SEEDIS modules. The program was designed to model the way people look things up in daily life — by page number, and hierarchical reference to topics from the table of contents. The Users' Guide for CHART, the Regional Management Information System (RMIS), and the SEEDIS Monitor were made available for on-line access by HELP.

## RMIS

The development of a Regional Management Information System (RMIS) was initially funded by the Department of Labor in 1974 to determine if existing DOL databases could be integrated with SEEDIS to satisfy DOL information demands in a more efficient manner. Although the Employment Security Automated Reporting System (ESARS) database was the only DOL source that met the criteria for submission to LBL, the decision was made to continue the project. An interactive retrieval tool was then developed based on a foundation of feedback from the eventual DOL user community.

Because this community is concerned with solving problems and not learning about computers, the emphasis of the research has been on interactive human-machine communication. In order to study the dynamics of such communication, it was determined that existing database management system software could not be successfully used on BKY because interactive response time would be too large. Further, even if an existing database management system were transported to BKY and streamlined for acceptable response time, none could be found with an interface which provided good human-machine dialog for inexperienced computer users. Therefore the ESARS interactive retrieval tool was developed from the ground up at BKY, aided by some existing indexed sequential file handling and dialog-handling software modules already designed for interactive use.

The initial user interface was purposefully limited to a skeleton of capabilities, one of which was easy on-line feedback to the designers about what additional capability was desired. This approach has proved very successful and has been extended throughout SEEDIS.

This project has helped support the development of other generalized tools, namely graphical analysis (CHART) and hierarchical file storage (INTERAC). In addition, the development of a report generation tool based on an interface of the ESARS retrieval tool, CHART and the SEEDIS Monitor has been supported. Finally, field development activity originally supported by RMIS has been extended throughout SEEDIS. This includes user consulting, users' guides, workbooks, seminars, demonstrations, films, video tapes and status reports.

During 1977, RMIS development included:

- 1) online access to the "guide to ESARS Retrieval" through the SEEDIS-wide help capability,
- 2) a new retrieval command to specify concurrent access to multiple geareas (for example, all 10 Federal regions or all 50 states),
- 3) a new retrieval command to allow checking for the existence of data without actually accessing it and
- 4) daily ESARS retrieval "news" announcement given when the tool is started.

## LMPM

The affiliated State Employment Security Agencies (SESAs) of the Department of Labor-Employment and Training Administration (DOL-ETA) supply local planners in Comprehensive Employment and Training Act (CETA) projects with estimates of persons in need of manpower services. To be of maximum use, these estimates should reflect "current" local needs. In collaboration with DOL-ETA, LBL/CSAM has developed an estimation procedure through its Labor Market Projections Model (LMPM). The goal of the LMPM project is to provide a comprehensive modeling system to be used by local SESA analysts.

Since LMPM started at LBL in the summer of 1975, two methods of estimating "current" local needs have been developed. The first method updates certain tabulations of the 1970 Fourth Count Census by using the 1970 Current Population Survey (CPS) tapes and the latest CPS tapes. Current updated Census tabulations are computed by multiplying the 1970 Census data by the ratio of

the latest CPS data to 1970 CPS data and normalizing the results.

The second method of estimating current local needs uses a refined cohort-component method to determine population projections. This involves the separate projection of mortality, fertility, and net migration for five year age cohorts to give population by age, sex, and by race for a particular area. Labor force and unemployment projections are based on the labor force and unemployment of the gearea in the base year, national changes in the labor force and unemployment from the base year to the target year, and the population projections for the target year as calculated above. This past year, the labor force and unemployment projections were calculated as just described, and then recalculated using state change in labor force participation rates and unemployment rates as determined by the Current Population Survey of 1976. In order to implement this model, data from several diverse sources had to be collected and integrated into a comprehensive database, GISFILE. The main sources are:

- 1) 1970 Fourth Count Census, tabulations 17, 54 and 55;
- 2) 1970 Sixth Count Census, tabulation 1150;
- 3) 1960-1970 County Migration by race, by sex, by age, from G. K. Bowles, U.S. Department of Agriculture, Economic Research Service; University of Georgia, Institute for Behavioral Research, and National Science Foundation;
- 4) Projections of Resident Population for July 1979 for states, counties, Minor Civil Divisions (MCDs) in New England, and cities with 50,000+ in 1973;
- 5) Labor force participation rates for July 1979, from the states;
- 6) Unemployment rates for July 1979, from the states;
- 7) National Fertility Rates by age, and by race from *Vital Statistics of the United States 1971*, Vol. 1;
- 8) National Survival Rates by age, and by sex, from *Current Population Reports, Population Estimates and Projections Series*, p. 25, No. 493, December 1972; and
- 9) *Current Population Survey*, March 1976.

At the end of each calendar year, both models are run for all states, SMSAs and prime sponsors. The results are mailed to the State Employment Securities Agencies in each of the 50 states.

## Urban Migration Study

The purpose of the Urban Migration Study was to develop and test a model for analyzing and forecasting in and out migration, employment change, and wage change for metropolitan areas at the two-digit level of industrial detail. The model was developed for those SMSAs with 250,000 people or more, as this is about the smallest geographic unit with the desired amount of socio-economic data.

Several different data sources were combined in building the model:

- 1) 10% sample from the Continuous Work History Sample (CWHS) that is maintained by the Office of Research Statistics of the Social Security Administration;
- 2) 1969, 1970 and 1971 County Business Patterns;
- 3) Change in the Consumer Price Index from the CPI Detailed Report for 1970, 1971 and 1972; and
- 4) 1970 and 1972 unemployment rates from 1974 *Manpower Report of the President*, Tables D-8, D-4.

The coefficients for the four simultaneous equations defining in-migration, out-migration, change in wages and change in employment were estimated using two-stage least-squares. Using these estimates, forecasts for in- and out-migration were made using data from the Office of Research Statistics of the Social Security Administration.

## SIRAP

In 1977, the major development of the U.S. Army Corps of Engineers' System of Information Retrieval and Analysis for Planners (SIRAP) was the installation of File C (Census Tracts, Minor Civil Divisions, and Enumeration District/Block Groups) of the 1970 Fifth Count Census. This three-billion character database contains 300,000 records covering the nation at a fine level of geographic detail. Report programs were prepared and debugged for reporting from this data, and plans were initiated to provide selective retrieval. Additionally, the 1972 Census of Manufacturers and 1972 Census of Mining and Mineral Industries were made available using the QWICK QWERY system.

## Populations at Risk to Air Pollution (PARAP)

Under an interagency agreement with the Environmental Protection Agency's (EPA) Health Effects Research Laboratory, and in cooperation with Brookhaven National Laboratory, EPA, and System Sciences, Inc., an information system containing comprehensive information on demographic characteristics, air quality, and mortality is being developed. The database will cover the entire U.S. at the county level and will be used by LBL's Energy and Environment Division and UCB's School of Public Health to estimate populations at risk to various levels of air pollution, and to investigate possible statistical correlations between air quality and human health.

# Administrative Information Systems

## Fiscal Management Systems

Work continued on three separate systems serving the three management orientations —

project management by research divisions, resource management by the support departments, and overall coordination by the Budget Office. In all three systems users may enter and store plan data about allocation and scheduling of resources to projects. The accounting data, obtained from Data

Processing Services at Livermore, are entered into the system for monitoring against the plan data. Discussions have begun about combining all of these systems into one integrated fiscal management system.

The Budget Management System has about 30 users at different levels of laboratory management; divisions, departments, and research groups. These users may plan and monitor spending on their own selection of accounts. The system has been reorganized to facilitate rapid access to such personalized selections of data. The users now maintain a profile of their requirements from their terminal. These profiles include the selection of accounts, their aggregation to several levels, and the ordering of reports. Users may request standard reports of their selected data, or access the accounting detail through the BROWSE information retrieval system for interactive analysis or impromptu reports.

The Engineering and Technical Services Division uses the Support Management System for resource management, namely planning and monitoring the effect of support personnel. Account groupings and the selection and ordering of reports are now at the user's discretion; and data aggregation and report generation can be instigated from a terminal in the division office.

The Budget Office uses the SKED92 system for overall coordination of the laboratory's fiscal requirements. This program has been extensively modified to treat effort in F.T.E. (full-time equivalents) rather than man-years. The interactive system for manipulating input decks was turned over to the user, and comprehensive documentation was begun.

Accounting data are also aggregated and formatted for transmission to the Critical Path Management with Graphics (CPWG) system. This interface has been modified to maintain data for more than one year.

## Bibliographic Information Systems

Bibliographic Information System projects are carried out in support of LBL's Information

Research Group (IRG), Library, and Technical Information Division. The IRG's selective dissemination-of-information system was maintained, improved, and generalized to conform with changing input, programmatic requirements, and operating systems. Support of the IRG effort also involved research in the area of database evaluation, comparison, and mapping.

The needs of the Library and Technical Information Division are being served by the Reports Issued Systems (RIS) project. When ready, RIS will replace the current system for handling LBL reports. RIS will use the IRATE system for input, a 12-bit version of BDMS for data management, and interactive terminals, standard Computer Output of Microform (COM), and OPTIK for output.

## System for the Director's Office

An interactive system was developed for creating and maintaining a database from which several different lists of mailing labels can be produced. Features of this system include template-type prompting for update and input, formatted data display, data ordering, and truncated searches. The system has also been used for producing CSAM's labels for the 1978 Workshop on Distributed Data Management and Computer Networks, and for managing IRG's library directory for the Energy Librarians of the Bay Area (ELBA).

## SAN-MIS Study

A study was conducted of management information requirements of the San Francisco Operations Office of DOE. The study modeled Management Information System (MIS) activity to derive quantitative estimates based on past activity of database size and transaction processing load. In addition, the study surveyed available database management systems and minicomputer hardware with an eye to satisfying processing requirements. The summary investigates alternative courses of development for the operations office.



## Applications Development and Project Support

Personnel from CSAM support a variety of projects and applications programs throughout the laboratory, including the following:

### Computational Physics

*Neutral Beam Shielding* — The Mirror Fusion Test Facility (MFTF) shielding study is a continuing investigation directed toward designing the necessary shielding to protect the neutral beam of the magnetic fusion project MFTF from external magnetic fields. The study is in two phases:

- 1) simulation of neutral beam enclosures and design of the shape, thickness, and materials necessary to decrease the magnetic field inside the enclosure to acceptable levels; and
- 2) design and construction of a 1/10 scale model of the apparatus in order to measure the magnetic field inside the enclosure and compare it with computational results.

*Heavy Ion Fusion Beam Stability* — One of the studies of the heavy ion fusion project of the stability of beam propagation of high energy heavy ions. The Accelerator Group has developed an analytic technique for investigating beam stability with respect to particular particle distributions. This technique leads to systems of equations which were solved by computer programs written under the direction of researchers in the Accelerator Theory Group. Another technique for the study of beam stability is the use of simulation programs to numerically calculate the trajectories of particle beams through a focussing system. Simulation programs are being written for this purpose.

*MFE Neutral Beam Development* — Work done in collaboration with the Neutral Beam Subgroup of the Magnetic Fusion Energy Group of the Accelerator and Fusion Research Division encompasses two facets of neutral beam development. Neutral beam, i.e., intense neutral deuterium gas, is used for heating and fueling of a magnetically confined plasma, such as that in the Tokamak Fusion Test Reactor at Princeton, the Doublet III of General Atomic at San Diego, and the Mirror Fusion Test Facility at Livermore. By means of

neutral beam heating, it is hoped that these machines will come close to the fusion energy breakeven point ratio of fusion energy released to heating energy supplied.

#### 1) Ion Beam Optics and Neutralizer Physics

After deuterium ions are created in the discharge chamber, they are extracted, accelerated and focussed to become an ion beam by means of multi-stage electrostatic grids. The computer program WOLF is used to aid the design of the shapes, configurations, and the potential loads of those grids, such that the outgoing ion beam has a root mean square angular dispersion of less than one degree, meantime avoiding the breakdown electric field between grids, suppressing the downstream secondary electrons from running backward, etc.

When this ion beam passes the neutralizer, it becomes a neutral beam by charge exchange reaction. The computer program CHUBBY is used to simulate the neutralizing molecular gas flow in the neutralizer. It was successful in determining the optimal side location of the injection point of the gas, such that the desired neutral target thickness can be most easily achieved.

#### 2) Plasma Ion Source Modeling

Development of a computer model to describe the low pressure thermionic discharge in the plasma ion source began in 1974 as part of the basic ion source research of the MFE group. It is hoped that this model will contribute to a better understanding of the physical phenomena of the discharge. Thus, the performance of the source can be improved, for example, increasing the ion current density, the gas efficiency, the proton yield and decreasing the transverse ion temperature. The basic elements of the model are a set of equations describing local ion generation due to electron-neutral collision, ion free-fall motion, and gas recycling at the walls.

Currently, enhancements to the model make it more realistic by including ionization and dissociation processes involving particle species of D, D2, D+, D2+, and D3+.

*TORMAC* — The Toroidal Magnetic Cusp (*TORMAC*) is a new exploratory magnetic containment device, which is intended to produce and sustain hot deuterium plasma. Work with the Magnetic Fusion Energy Branch of the Accelerator and Fusion Research Division focussed on two research areas.

First, the development of a physical model was undertaken to simulate *TORMAC* plasma heating, the shaker heating method. Plasma heating is achieved by launching into the plasma large-amplitude and low-frequency nonresonant magneto-acoustic waves, which propagate in the direction orthogonal to the internal toroidal field. Wave propagation in plasma is described by a two-dimensional, time-dependent, nonlinear equation of the second order with some initial conditions and Neumann Boundary conditions. A finite-difference scheme for such a problem was elaborated.

Second, a physical model is being developed to find plasma equilibrium configurations in *TORMAC*-type combination of magnetic fields. This includes:

- 1) calculation of vacuum magnetic fields from the external *TORMAC* confinement coils;
- 2) consideration of plasma that interacts with these vacuum magnetic fields; and
- 3) final calculation of plasma equilibrium configuration. (The problem possesses axial symmetry.)

A computer program for the calculation of vacuum magnetic fields was written. Results are used as input for a program which calculates plasma equilibrium. This program is also used (1) to calculate a set of data (current distributions in external coils, their sizes and spatial positions), which produces magnetic fields of required properties for *TORMAC* plasma confinement, and (2) as guidance parameters in designing new experiments.

*SYNCH* — The program *SYNCH* is a large multi-purpose system for design of synchrotrons and analysis of orbit properties, originally written in the 1960s. The program has been expanded from

time to time for different applications. Because of the PEP project, additions have been made relevant to electron storage rings. Facilities added recently include:

- 1) computation of closed orbits, emittances, and damping rates in a ring with misaligned magnets;
- 2) computation of effects of wiggler magnets and certain nonlinear elements on the beam;
- 3) improvements in the description of the magnet lattice in the input language; and
- 4) introduction of a general fitting facility.

Because the program is used at other laboratories, considerable effort has been made to provide them with up-to-date versions. In the case of the Stanford Linear Accelerator Complex (*SLAC*), with its IBM computer, this has involved making large changes because the input language of *SYNCH* is character oriented and because the previous IBM version is about nine years old.

*HEMP* — The program *HEMP* is capable of solving elastic-plastic flow equations in complex (many slide lines) geometry with broad set of boundary conditions and different options. Implementation of an early version of *HEMP* on the Berkeley CDC 7600 computer system was completed. The program was significantly revised and debugged. Graphical support producing *CALCOMP* plots became operational. Development of a new version of *HEMP* was continued, including further development of a new slide line algorithm, in which mapping of projected normal stresses and masses is done for both sides of a slide line. The set of geometrical options and boundary conditions was significantly broadened due to development of a new type of ordering procedure on the slide line.

A "tied sliding" algorithm was added to the new version, thus permitting full *REZONING* and *DEZONING* capabilities on the slide line. In the process of implementation of the new version, *HEMP* was substantially restructured. This restructuring permits easier documentation of programs. Some portions of documents describing these changes were prepared.

## Physics

Support of physics research groups included the development of software for experiments on the MARK II detector at the SPEAR accelerator located at SLAC and continued maintenance of existing support software.

*MARK II Detector* — The transfer of summary data from MARK II experiments required the development of programs interfacing IBM system formats produced at SLAC to LBL's CDC triplex.

A pattern-recognition scheme for finding charged tracks in the MARK II detector was formulated and implemented in the program TRAKR, which operates on the IBM-triplex and Sigma-5 computers at SLAC. Together with ARCS, a track orbit reconstruction program, and VTXA, a program for vertex fitting with beam position constraints, TRAKR comprises a complete set of data analysis codes for the detector, required for the reconstruction of real events and serving as a valuable diagnostic tool for calibration and tuning of the detector.

*Software Maintenance* — Existing applications software, utilized by the Trilling-Goldhaber Group, Group A and the Ely Group and maintained by CSAM personnel, include ERGON, a data summary and display system, KIOWA, a plotting program, and CICERO, a system for scanning and measuring film from large-volume bubble chambers.

## Biomedical, Environment and Safety

*Epidemiological Effects of Magnetic Fields* — CSAM personnel are working with researchers at the Laboratory for Chemical Biodynamics on a study of the effects of magnetic fields on humans. This effort includes the measurement of residual

magnetic fields around accelerators and collection of medical record and magnetic exposure data for personnel at LBL and other national laboratories. The program MDTST has been developed to compile, statistically analyze and display the collected data.

*Cell Populations* — Also in conjunction with investigators in Chemical Biodynamics, a program for retrieving maximum information about the life cycle distribution of cell populations from their DNA histograms was developed. Beginning with a model of the evolution of information during succeeding stages of Flow Cytometry (FCM) analysis, a method was developed whereby the DNA histogram of a synchronous G1 population is used as a reference to fit the histograms of arbitrarily distributed populations of the same cell type. A linear least-squares (with no-negative constraints) optimization package is used to determine the number of cells in succeeding cell cycle stages in the model and results correlate well with other, far slower, methods such as autoradiography.

*Trains* — Working with personnel in the Instrument Techniques Group, the program BRAKES was developed to analyze train braking data. The analysis is performed on digital data, which have been converted from analog signals, recorded in a multi-track analog tape recorder, carried on-board the train under test. Signals on this tape are from an accelerometer, metal detector, open-loop braking indicator and tachometer. BRAKES converts the voltages to the proper units by use of calibration signals recorded on the tape and determines the effectiveness deceleration and velocities at various times over the entire braking cycle. These results are printed along with specified times and distances, and plot and debug prints are produced for each braking sequence.

## CSAM Educational and Training Programs

In order to maintain a rich environment for the exchange of ideas and experience, the Computer Science and Applied Mathematics (CSAM) Department sponsors workshops, colloquia and seminars; provides supervision of graduate students in the master's and doctoral programs in applied

mathematics and computer science at UC Berkeley; and provides specialized training for users of the SEEDIS data and tools.

The Second Berkeley Workshop on Distributed Data Management and Computer Networks was

held at the Claremont Hotel in May, 1977. Jointly sponsored by LBL/CSAM and DOE, the workshop drew over 125 attendees from industry, government and the university community.

A UC Extension Course, "Computer Mapping for Environmental Planning," was jointly developed and presented by LBL/CSAM and the Association of Bay Area Governments late in 1977.

The SEEDIS educational program facilitates both the introduction of new users to the basic capabilities of SEEDIS and the introduction of new features to existing users. Training sessions, held at LBL and at DOE headquarters, give the user comprehensive training in those systems of particular interest as well as a cursory look at those which might be of future use. In addition, a consultant is available to help the user from the beginning, starting with equipment familiarization and log-on procedure and carrying through to data access and storage. Educational aids include a series of manuals and training workbooks which help familiarize users with SEEDIS features. Videotapes of actual interactive sessions have been prepared and digital cassette tapes showing interactive graphics capabilities are available for demonstration at remote sites.

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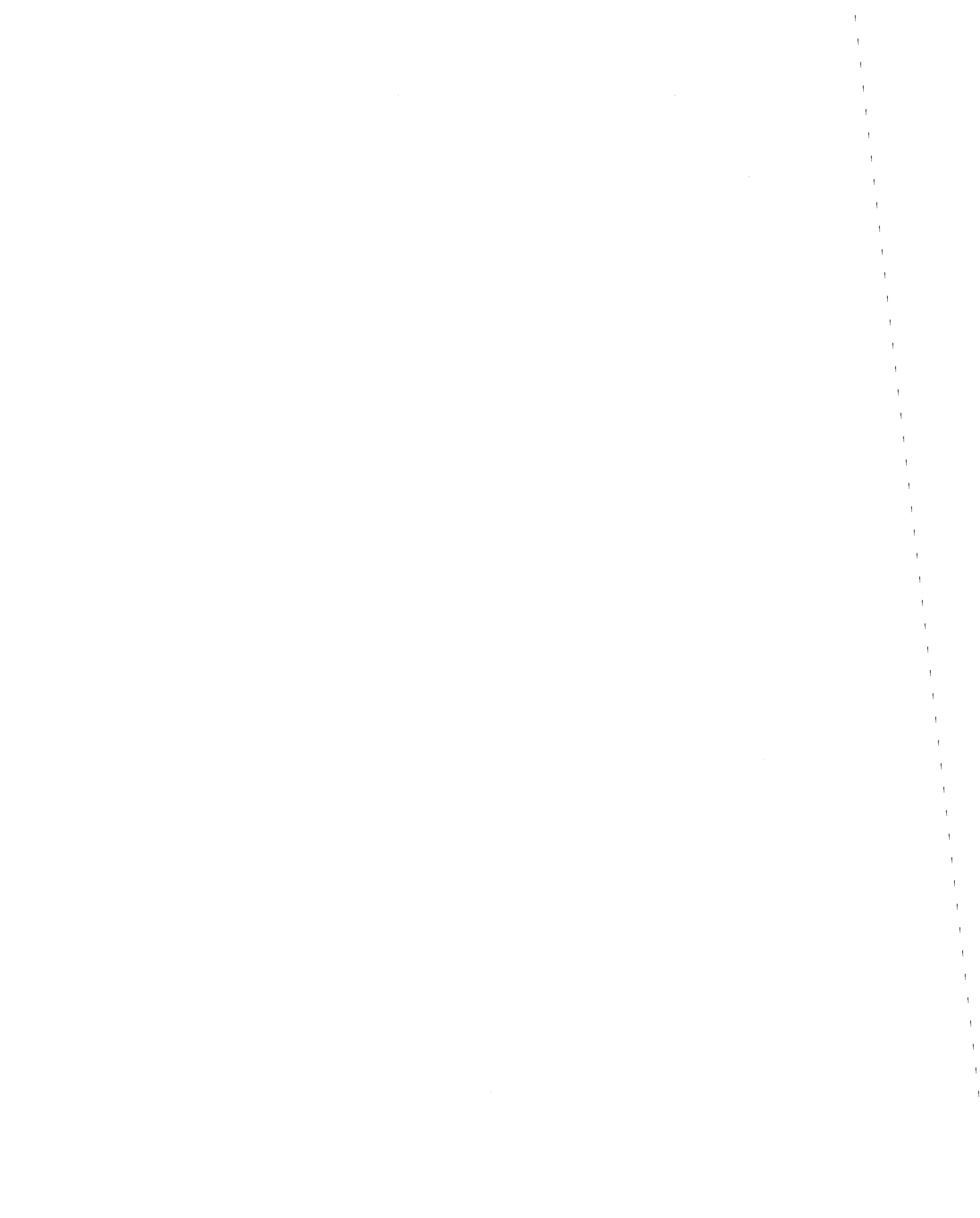
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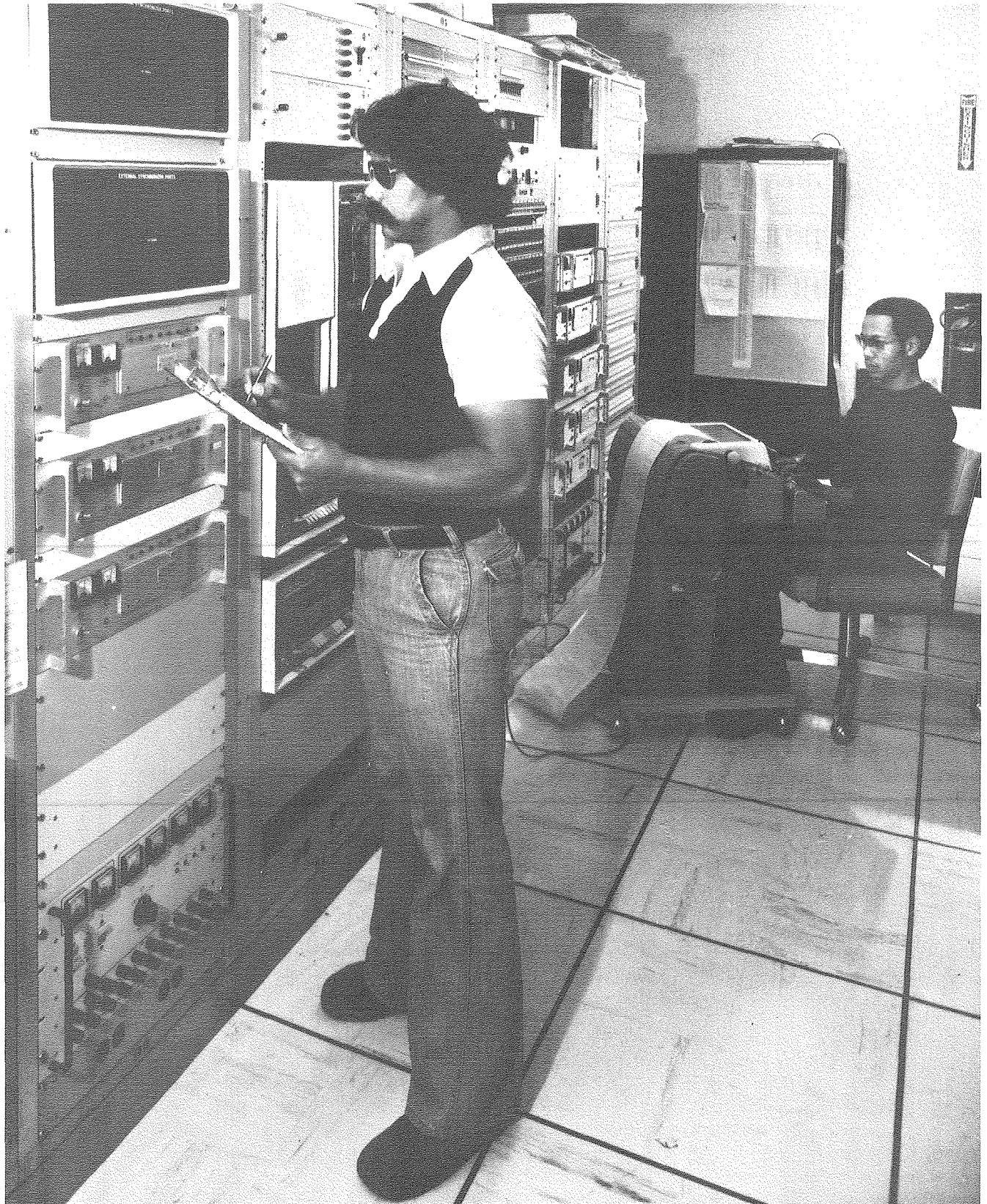
A graphics display terminal is checked out by Fred Gey, Deane Merrill, and Rosemary Allen.

XBB 7810-12991





## **IV. COMPUTER CENTER**



Don Dumpit (foreground) and Everett Anthony set up RECC II, whose operation doubles the asynchronous (interactive) port capacity of the LBL Computer Center Facility. The RECC I unit is in the panel directly behind Dumpit. XBB 781-14161

## IV. COMPUTER CENTER

The principal responsibility of the Computer Center is providing large-scale computational support to LBL's scientific program. This includes access to an extremely powerful computer (a CDC 7600), maintenance of a very large mass storage system (an IBM Photodigital Store, containing  $3 \times 10^{11}$  bits of on-line storage), and availability of an excellent selection of peripheral devices. Large numbers of jobs are processed (almost 1.2 million in 1977) with excellent turn-around (about 70% were completed within 20 min. each).

A comprehensive set of interactive facilities is offered, including text editing, document preparation, program preparation and submission, several interactive graphics subsystems, and the ability to interact with any job running on the "front-end" (CDC 6600 and 6400) computers.

LBL is a node on the ARPANET, which connects more than 100 computer centers (some of them overseas) together. The network carries both interactive and batch traffic between LBL and other centers. LBL is also a node on two commercial networks: TELENET and TYMNET.

Ancillary services provided include a professional consultants' service, on-line user documentation of the entire system, and a wide range of standard products and libraries.

In accordance with the Federal Economy Act, LBL makes its excess computing capacity available to other DOE laboratories and contractors. The most significant single outside user during 1977 was the National Magnetic Fusion Energy program, which received more than 1000 hours of block-time during 1977. A number of university physics groups also find remote use of LBL's Computer Center to be convenient and economical.

In addition to the normal support tasks, the Computer Center maintains a number of develop-

ment efforts in both hardware and software. Of these efforts, the most interesting are the four listed below.

- 1) PEPNET, which will utilize the existing microwave link between the two sites to provide expanded communication between SLAC and LBL. Design for the system was completed during 1977, and development is on schedule; the system is expected to become operational during 1979.
- 2) RECC II: This project is a doubling of the asynchronous (interactive) port capacity of the LBL facility (from 288 to 576). It was begun in the last quarter of 1977, and is expected to see completion in 1978.
- 3) Support for the IBM HASP multileaving (remote job entry) communications protocol (LBL currently supports COPE-mode and CDC's UT200 protocols). This project also was begun in 1977 and is expected to be operational before the end of 1978.
- 4) Acquisition, installation, and support of an interim replacement for the mass storage system based upon the IBM Photodigital Store. (This unique device is being phased out by the manufacturer. As a result, the WRITE element will be turned off in 1978, the READ element in 1979.) A survey of the industry conducted during 1977 revealed no suitable, permanent replacement for the Photodigital Store. As a result, it was decided to install an automatic tape-handling device, the California Computer Products Automatic Tape Library. This device is capable of storing approximately 2,300 reels of conventional computer tape, of fetching these tapes under computer control, and of mounting them on IBM-

compatible tape drives. In the LBL installation, five tape drives accessible from both the 6400 and 6600 computers are attached to the ATL.

The ATL system will be used in conjunction with a tape storage system (GSS) which permits users to store and access multiple files on a single tape reel. Only 6,250 byte per inch tape will be employed in this system.

When the ATL system becomes operational early in calendar year 1979, it will substantially decrease turnaround times by eliminating most manual tape mounts.

Another development of great interest to the LBL Computer Center was the selection, in July, of LBL to be the site of the National Resource for

Computation in Chemistry. While this endeavor is not a part of the Computer Center, it is expected that the two organizations will work closely together, and that each will be influenced by the other.

#### TITLES AND DATES OF PUBLICATIONS

Misleading Computer Performance Measures: A Measurement Guide for Upper Management, D. F. Stevens, March 1, 1977, LBL-6115.

Preliminary Report on GRUMP, A Symbolic Fortran Dump, E. Fourt, March 1977, LBL-6762.

PMIS Seminar 2: Performance Information Requirements, D. F. Stevens, May 1977, UCID-3927.

Obfuscatory Measurement, D. F. Stevens, July 25, 1977, LBL-6115 Rev. 2, presented at the joint SIGMETRICS/CMG VIII Conference in Washington, D.C., November 1977.



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