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PHYSICS, COMPUTER SCIENCE and MATHEMATICS DIVISION

ANNUAL REPORT

1 January - 31 December 1978

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University of California
Berkeley, California**

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**PHYSICS,
COMPUTER SCIENCE
and
MATHEMATICS
DIVISION**

Robert W. Birge
Division Head

ANNUAL REPORT

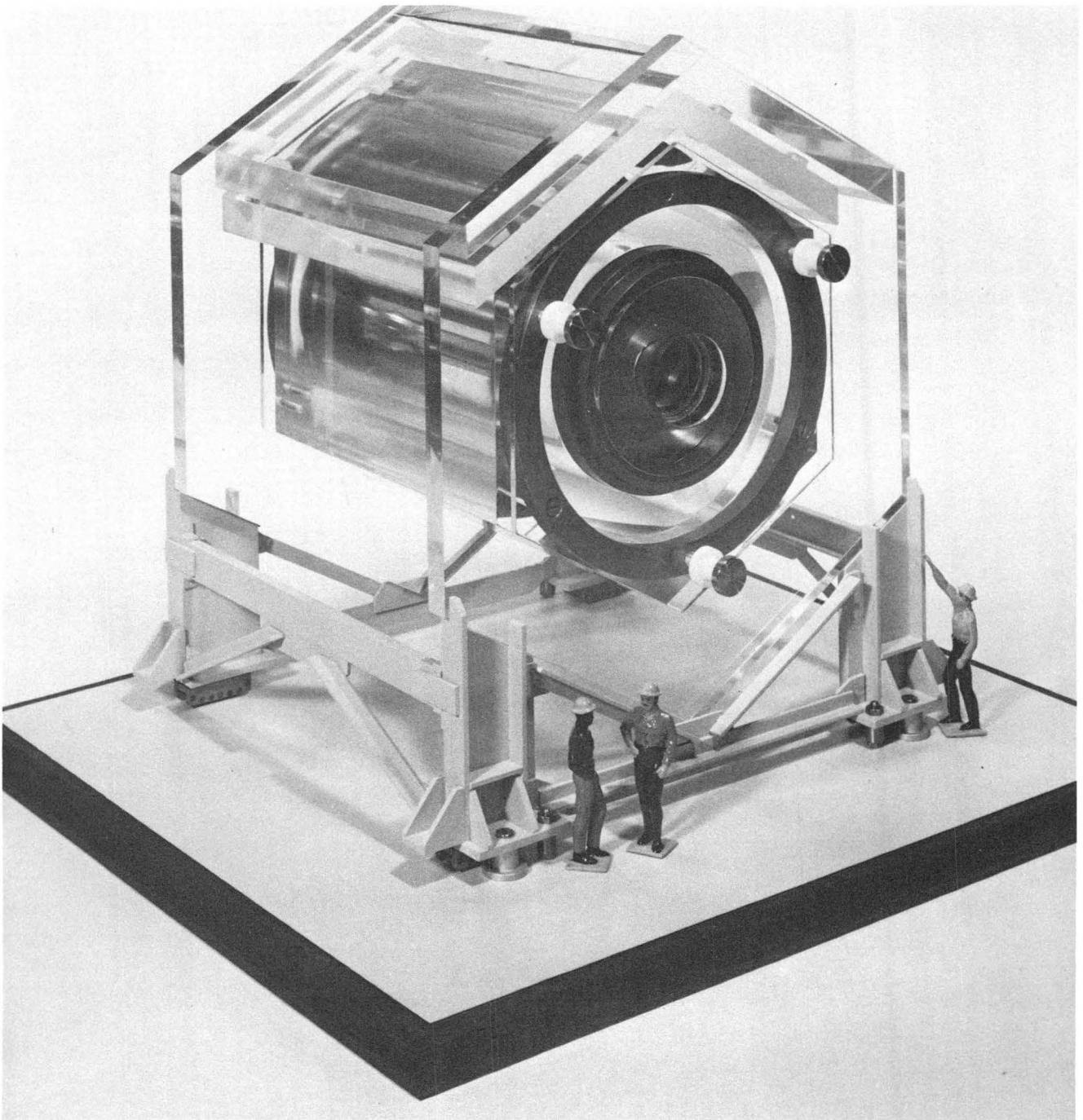
1 January - 31 December 1978

Joseph V. Lepore
Editor

**Lawrence Berkeley Laboratory
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The Time Projection Chamber (TPC) is the “heart” of the PEP-4 facility. Represented in this scale model, the TPC consists of a powerful superconducting magnet surrounding a cylindrical detection chamber, radially divided at the center into two drift regions. The TPC can identify particles more completely than any existing device. Design, testing and component construction were well advanced during 1978 (see also page 4). CBB 770-11488

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 1978. 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 Computer Center has recently been transferred to the Engineering and Technical Services Division so this is the last time its work will be described in our annual report.

Our major research activity is in high energy particle physics. Experimental research is carried out using the particle accelerators at Stanford Linear Accelerator Center (SLAC), Fermi National Accelerator Laboratory (FNAL), Brookhaven National Laboratory (BNL), and other laboratories. The broad purpose of this research is to determine by measurement those data which will crucially contribute to the development of a fundamental theory of matter. The extensive planning, design and analysis of these experiments is carried out at Lawrence Berkeley Laboratory (LBL).

The most important high energy physics activities at LBL are directed toward the full utilization of PEP, the LBL-SLAC Positron-Electron Colliding Beam Project (PEP). It is significant that LBL has been chosen to play a major role in three important experiments which will be carried out at PEP when it becomes operational. LBL also maintains a program for research and development of superconducting magnetic coils. This program has found application in one of the PEP experiments, the Time Projection Chamber, but will also be used for other physics and industrial applications. In addition, there is a continuing effort

on the development of various other types of detecting apparatus and their associated electronics. This latter work finds application not only in high energy physics but in nuclear medicine, crystallography and general x-ray detection.

The Division maintains a relatively small program of experimental research in medium energy physics. Its major purpose is to study basic nuclear interactions and nuclear structure by using mesons, nucleons and light nuclei to probe the nature of these interactions by scattering and radiative capture experiments on target nuclei.

The Computer Science and Applied Mathematics (CSAM) department, which is semi-autonomous, engages in research in mathematical and computational areas, in computer networking, data base management, graphics, and simultaneously provides service to other divisions of the Laboratory. The association with the Physics Division proves fruitful for both areas.

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.

PHYSICS, COMPUTER SCIENCE and MATHEMATICS DIVISION

STAFF

EXPERIMENTAL PHYSICS

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EXPERIMENTAL PHYSICS

(Continued)

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THEORETICAL PHYSICS

(Continued)

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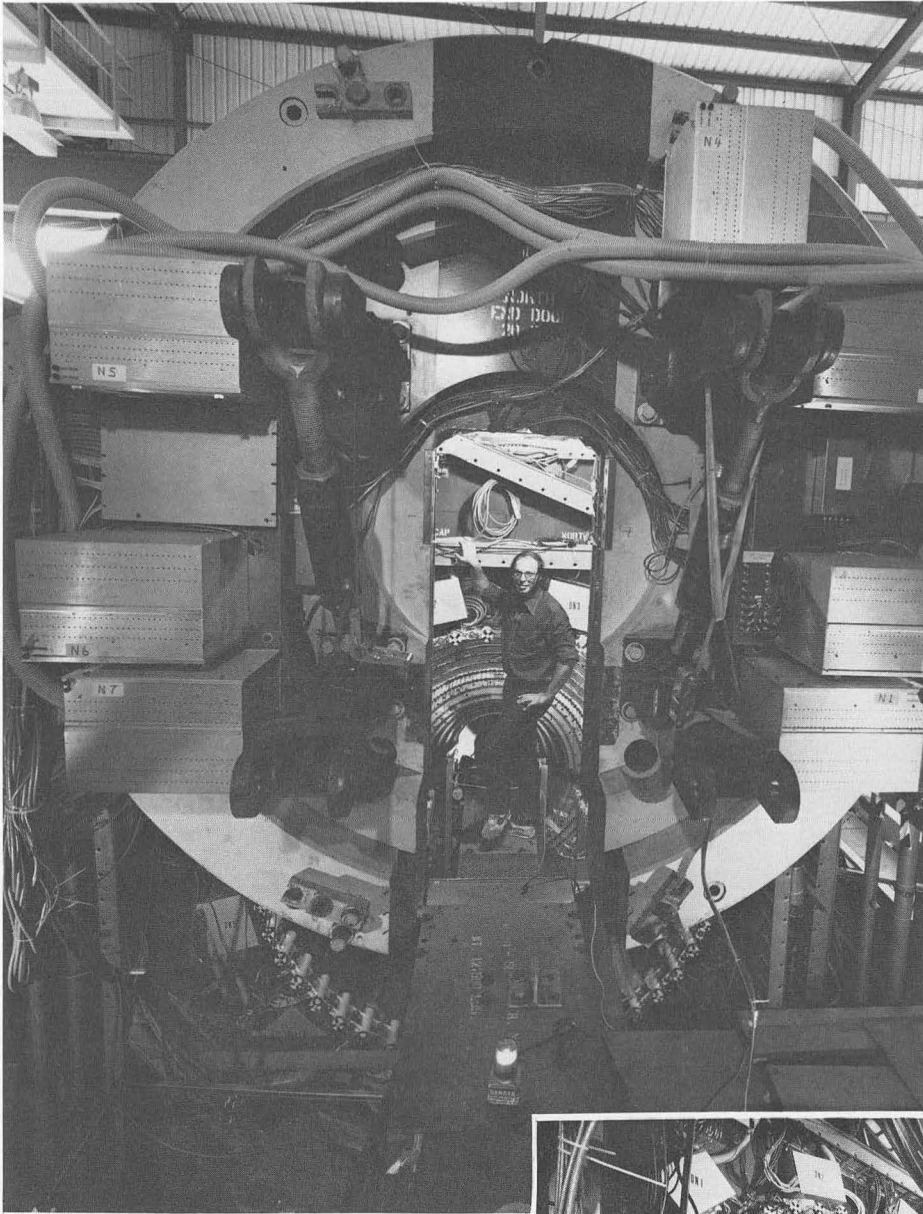
COMPUTER CENTER

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Romanetta Adams	Lisa Braver
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James Baker	David Cleveland
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Michael Blunt	Dennis Dufalla
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Jerry Borges	Terry Edinton
Edward Boyum	Robert Fink

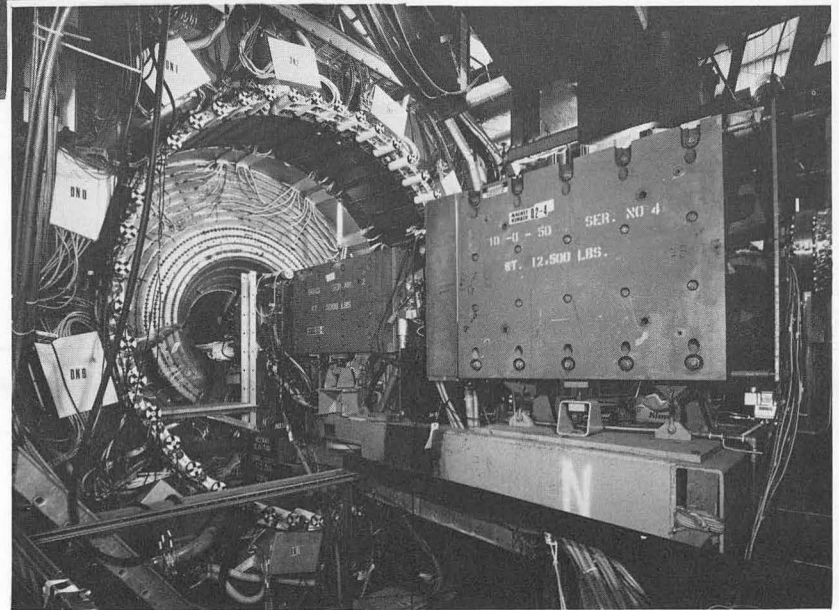
COMPUTER CENTER
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I. EXPERIMENTAL PHYSICS



Mark II's massive 25-ton north door of iron (12 to 18 inches thick) is shown in the withdrawn and raised position, framing Physicist Gerald Abrams who, with Bill Carithers, directed the LBL fabrication of the liquid argon chambers for Mark II.
CBB 788-9739



Beam line, surrounded by magnets, enters north port of Mark II. Detector components visible in photo are the drift chambers for detecting the charged particles; time-of-flight counters, identified by the photo-multiplier tubes marked with a cross on their ends; the magnet coil, by which momentum of the charged particles is measured; and liquid argon modules, in which the neutral particles are detected by the electromagnetic showers they create in the liquid argon.
CBB 788-9745

HIGH ENERGY PHYSICS

Research on e^+e^- Annihilation at SPEAR

The Mark II Magnetic Detector

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.

A new magnetic detector, Mark II, built in collaboration with SLAC, was installed in the west pit of SPEAR. The principal LBL responsibility in the construction work was the manufacture of eight large lead/liquid-argon shower counters and the associated front-end electronics. In addition to this hardware development and construction, LBL groups have been heavily involved in the development of software for the analysis of the data coming from all parts of the detector, including drift chambers, shower counters, time-of-flight counters, and others.

The development of an extensive Monte Carlo program to simulate the detector has also been a major LBL responsibility. The general performance for all parts of the Mark II is now satisfactory. After installation at SPEAR, some important improvements were made in the following systems: (1) the drift chamber system (replacement of noisy and discharging wires), (2) the liquid argon shower counter system (improvement of signal-to-noise characteristics and general electronic improvements), (3) the muon detection system (provision of more layers of steel and detecting tubes to improve muon separation).

Data have been taken at several different energies including 3.772 GeV (to study decays of charmed D mesons), 4.16 and 4.42 GeV (to search for the production of F mesons), 3.684 GeV (to study $\psi' \rightarrow \chi\gamma$ transitions), 3.095 GeV (to use ψ decays as calibrations of photon efficiency in the shower counters), and 7.4 GeV (to understand the system performance at high energy and high luminosity). An energy scan between 4.5 and 6.0 GeV, was also carried out. These observations show a clear step in baryon production near 5 GeV. The observations are made on the ratio to μ pairs, R, for antiproton production as well as Λ and $\bar{\Lambda}$ production. This strengthens earlier results with the Mark I detector. The implication of these data is that the step may correspond to a threshold for charmed baryon production.

The decay modes

$$\psi^1(3684) \rightarrow \gamma\chi$$

$$\begin{array}{l} | \\ \rightarrow \gamma\chi(3095) \\ | \rightarrow l^+ l^- \end{array}$$

have been re-examined by use of the improved γ detection available with the liquid argon shower counters. The by-now well-known states $\chi(3550)$ and $\chi(3510)$ show up clearly in this reaction. But no evidence is seen for the doubtful state $\chi(3455)$ which has been conjectured to be associated with the η'_c . The state $\chi(3410)$ is also clearly observed in the reactions

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$$\psi' \rightarrow \gamma 4\pi^\pm$$

and

$$\psi' \rightarrow \gamma 6\pi^\pm$$

Another result is that the τ decay mode, $\tau^\pm \rightarrow \pi^\pm \nu$, is now observed at the theoretically expected level.

The Mark II detector will continue its data taking at SPEAR until early June 1979. Data taking plans include further runs at 3.772 GeV (ψ''), 3.685 GeV (ψ'), large statistics at one fixed energy to look for new charmed objects such as the charmed baryon Λ_c , 6.5 GeV to study jets and τ leptons, and some further energy scanning to pin down accurately the total cross section between 3.8 and 5 GeV. A search for F meson production is also in progress.

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Radiative Decays of the $\psi(3684)$ Into High Mass States, W. Tanenbaum, M. S. Alam, A. M. Boyarski, M. Breidenbach, G. J. Feldman, G. Hanson, J. A. Jaros, R. R. Larsen, D. Luke, V. Lüth, H. L. Lynch, J. M. Patterson, M. L. Perl, I. Peruzzi, M. Piccolo, T. P. Pun, P. A. Rapidis, B. Richter, R. H. Schindler, R. F. Schwitters, J. Siegrist, F. Vannucci, G. H. Trilling, J. S. Whitaker, G. S. Abrams, W. Chinowsky, R. G. DeVoe, C. E. Friedberg, G. Goldhaber, A. D. Johnson, J. A. Kadyk, R. J. Madaras, H. K. Nguyen, F. M. Piere, B. Sadoulet, J. E. Wiss, Phys. Rev. D17, 1731 (1978).

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The Lead Glass Wall Experiment

In this experiment, a wall of lead-glass counters has been used to detect and identify electrons and photons with high precision, in order to study anomalous electron production and production of photons and π^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 was simultaneously recorded. The primary aim of the experiment was to search for events which may arise from the production and decay of charmed particles and heavy leptons. The experiment is a collaboration with SLAC Group E, Stanford University, Northwestern University and the University of Hawaii.

Studies of the charmed mesons produced in e^+e^- annihilation have been carried out. The branching ratio for D decays into electrons have been found. Also D decays into K mesons of different

charge have been observed and the energy distribution of different secondary particles (π , K, γ , leptons) has been measured. The γ and π^0 production spectrum in e^+e^- annihilation in the 4 to 7 GeV region has been measured for the first time. Finally, the branching ratio for the τ heavy lepton decay into a three pion final state has been determined.

Lead Glass Wall Staff

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Inclusive Electron Production in Multiprong Events Produced by e^+e^- Annihilation, 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. Luke, J. F. Martin, D. H. Miller, S. I. Parker, M. L. Perl, I. Peruzzi, M. Piccolo, T. P. Pun, P. A. Rapidis, R. R. Ross, D. L. Scharre, T. G. Trippe, V. Vuillemin, and D. E. Yount, *Phys. Rev. Letters* **40**, 1677 (1978).

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Facilities Research and Development for Experiments at PEP

Time Projection Chamber (TPC) PEP-4

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 PEP-4 TPC facility will have the capabilities to detect and study, in detail, many 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 unique capabilities for charged particle pattern recognition, momentum analysis and mass identification within high multiplicity jet-like events, neutral reconstruction (Λ^0 , K_s , π^0 , η^0 , . . .), electromagnetic calorimetry and muon identification.

This broad range of characteristics, which seems difficult to achieve simultaneously over most of 4π 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.

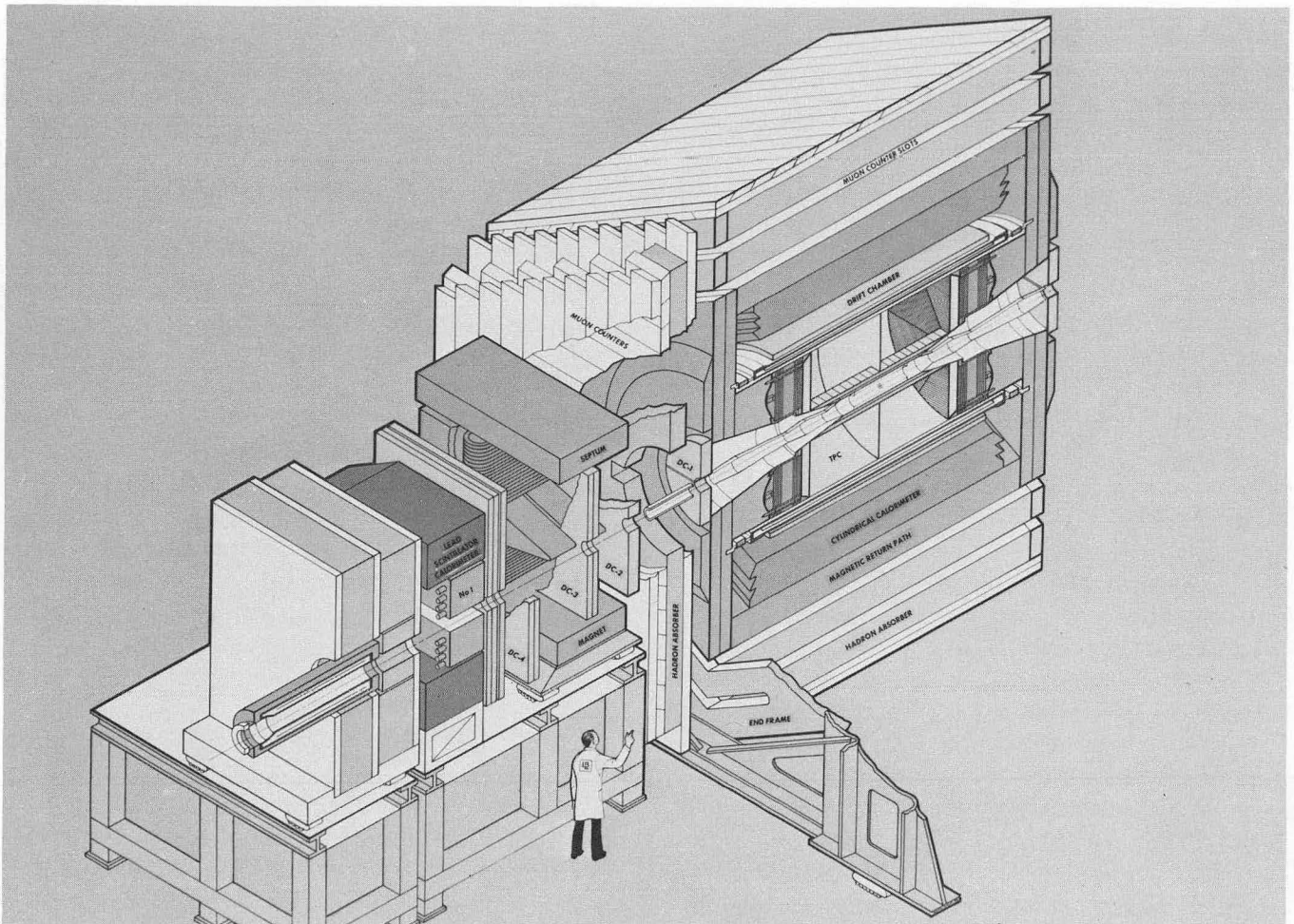
The PEP-4 TPC detector consists of four major functional systems, the time projection chamber, a superconducting solenoid magnet (SSM), an

electromagnetic calorimeter and 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 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.

The major effort this year has been concerned with hardware development, data acquisition and processing systems and superconducting solenoid magnet research development and construction.

Hardware Development

- *Materials.* An extensive program of testing for contaminative outgassing has been completed. The results of these studies has allowed the selection of acceptable materials



Drawing of PEP-4 facility, showing the Time Projection Chamber (TPC) and one of the two PEP-9 Pole-Tip Calorimeters which will be added in order to detect reaction products emerging in directions close to that of the colliding-beam axis. These processes are the so-called 2γ reactions.

CBB 794-4268

for construction of the TPC sensitive volume and has led to simplification of the gas system.

- **Gas System.** The conceptual design is now complete and final engineering design is underway. Because of the successful material testing program, the anticipated level of gas consumption is low and will not necessitate a recirculating purifier. An on-site argon-methane mixing system will be used to provide both flexibility and reproducibility.
- **High Voltage System.** The specifications for the high voltage system including the power supply, cables, insulation and field cages are complete. Contracts have been let for the supply and the high voltage insulation. The graded insulation technique developed at

LBL for this purpose represents an advance in high voltage practice, and is expected to provide exceptional reliability with relatively small thickness.

- **Readout Proportional Planes.** The study of electrostatic characteristics is complete and the final wire and pad geometry has been chosen. The mechanical design of the sectors (six on each end of the TPC) is complete and prototypes have been tested successfully for rigidity, flatness and construction techniques. Prototypes are currently undergoing tests for operating electrical characteristics. All backplane artwork and electronic configuration design is complete. A number of related studies such as cooling, pad response, electrostatic stability, gas mixtures, opera-



Prototype of the Time Projection Chamber used in feasibility tests at the Bevatron. CBB 787-9080

ting conditions and calibration techniques have been completed.

- *Operating Prototype at the Bevatron/ Bevalac.* A series of tests in a charged particle beam at the Bevatron/ Bevalac has demonstrated that the necessary performance can be achieved. A sixteen channel CCD system has been incorporated, completing the signal

processing chain. A transverse spatial resolution of 100 microns rms has been achieved with the cathode pads and a longitudinal resolution of 300 microns rms has been achieved with the CCD information. A resolution of better than 3% has been achieved for ionization density allowing particle identification over the entire PEP range of momentum. The data-taking phase is

finished and the analysis is nearly complete.

- *Overall System Interface.* All dimensions have been fixed as well as external connectors, plumbing wiring and installation requirements.
- *Test Vessel.* A large multi-purpose vessel, used for testing the TPC, the cryostat of the superconducting solenoid, and the fabrication of the high pressure signal feed-through rings is nearly completed.

Data Acquisition and Processing Systems

During this year installation of most computer hardware for the TPC was completed. The computers have been set up in Bldg. 80 to allow testing of the data acquisition system and the development of analysis and testing software.

Many of the physics analysis programs have been written on the VAX 11/780 as well as on the CDC 7600. Using Monte Carlo simulation of raw data as input, routines have been developed and tested to decode raw data, do pattern recognition and fit particle trajectories. In the case of pattern recognition for example, two different approaches have been developed. Each has an efficiency of track finding of greater than 99% even when synchrotron radiation background at 50 times the level that can be tolerated by the TPC hardware is included. While continued refinement and tuning definitely are necessary, a set of programs now exists which can analyze in real-time on the VAX some of the data taken in the experiments at PEP.

Software for the PDP 11/70 is designed to do extensive diagnostic testing and calibration of TPC hardware. A multiuser system has been developed which will permit simultaneous and independent testing of many devices.

A high speed micro-programmed bus controller has been designed and constructed to interface the computers with the TPC. Two of these, one for the VAX 11 and one for the PDP 11/70 have been built and extensively tested. A third unit has been completed for communication with the PEP-9 computer system.

Final definition of the trigger for the TPC

experiment and a complete Monte Carlo simulation of the single particle ripple trigger and the two particle collinear trigger are complete. In addition, design, construction and testing of prototype electronics for the inner drift chamber trigger have been finished. This equipment has been used to measure the time, spatial and angular resolutions and efficiencies obtained with four layers of a rectangular drift chamber.

Superconducting Solenoid Magnets

This is a program to study the design of superconducting magnets required for particle detectors in high energy physics. This study includes the physics of quench phenomenon and the effect of different techniques of quench protection. Techniques resulting from this study can be used in other laboratories such as CESR. Private companies have also expressed interest in these techniques.

Our study of quenches in magnets with conducting bore tube and with an external protection circuit has been completed and a computer program to analyze the data has been developed. Calculations and displays show that a pessimistic theory which was developed works in all its aspects and can be used safely in the design of magnets of this type. Quench velocities have been studied. A theoretical expression for them has been established which fits the data within 30%.

A study of forced cooling of the type used in the TPC magnet has also been made. It shows that there are low frequency oscillations in the helium flow which will have to be taken into account. In addition, the design and possible problems of the future cryogenics building, which is under construction now, were carefully considered.

Studies of quench properties were carried out using a 2m diameter \times 0.7m length test coil. Based on these results, quench protection will be provided for the PEP-4 thin coil by two passive and two active systems. The two passive systems are the aluminum bore tube and a winding of ultra-pure zone-refined aluminum wire. The two active systems include SCR controlled high current pulse into the superconducting coil center tap, which will drive the entire coil normal, and a SCR controlled power supply disconnect allowing magnetic energy to be dissipated in a varistor bank. This set of techniques

provides a large safety margin to protect the coil from burnout.

The work has led to a final design of the TPC magnet and construction is underway. Tests have been performed under operating conditions on various components and materials that will be used in building the TPC. These include superconducting wire, aluminum plates and wire, and epoxies. New types of helium pumps and flexible transfer lines were designed and were partially tested by year's end.

The following components have been developed:

- *Cryogenic System:* The design is complete and major components have been ordered or fabricated. The helium pump has been tested successfully, giving higher volumetric efficiency than other similar devices. The final transfer lines, built at LBL, are nearly complete. Integration of the LBL and SLAC parts of the entire cryogenic system is proceeding.
- *Coil Construction:* Fabrication of the bore tube and subsequent reshaping and annealing to meet circularity and conductivity specifications are complete. The ultra-pure aluminum wire has been wound and encapsulated in epoxy. The superconductor is being wound at present.
- *Cryostat.* The design is complete and construction underway at an outside vendor, with delivery expected in mid-March.

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- *Pole Tip Contour.* An extensive program of computer simulations has provided an optimum contour, and has eliminated the need for any correction coils. The magnetic field within the TPC sensitive volume is now expected to be uniform to better than 1 part per 1000.

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CBB 788-10514

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The Mark II Magnetic Detector

In addition to those efforts connected with the on-going Mark II effort at SPEAR, LBL physicists were involved in some of the work carried on in preparation for the move of Mark II to PEP. The design of the shielded vacuum pipe, a collaboration between LBL physicists and PEP vacuum group engineers, was essentially completed. Development work on new software for PEP, particularly on-line software to accommodate the new VAX 11/780 computer, was carried on collaboratively between LBL and SLAC members of the Mark II group. In general the preparations for the PEP move are coming along well.

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LBL physicists and technicians participating in the search for free quarks at PEP gather around a completed proportional chamber as it is being tested. From left are Les Nakae, Vincent Vuillemin, Joe Weiner, and Dave Favot. The quark search will be carried out by a collaboration of about 20 scientists from LBL, Northwestern University, Stanford, and the University of Hawaii. This project is also known as PEP-14. The chambers and supporting electronics systems are being built at LBL; the counters used for dE/dx and time-of-flight measurements are being built at Northwestern and Stanford Universities. CBB 788-9915

The Search For Free Quarks

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^- collisions

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

The Free Quark Search (PEP-14) depends upon the distribution of ionization of 16 layers of

scintillator to distinguish particles of charge $1/3e$ and $2/3e$ from singly charged particles. To accommodate the assumption that the detected particle originates in the interaction region, 10 layers of multiwire proportional chambers (MWPC) are used for tracking. The scintillation counters are being constructed at Northwestern University and Stanford University, and the MWPC are being built at LBL. In the past year the mechanical parts of the MWPC have been fabricated and 6 of the 10 chambers have been tested. In addition, the first big chamber was under fabrication. Trigger design was completed and a prototype was under construction.

The chambers have especially sensitive readout to detect charges of $1/3e$. The electronics have been designed, tested and are in various states of fabrication. All of the mechanical and electrical systems will be complete and assembled by May

1979. LBL also has responsibility for the fast electronics to analyze the pulse height of the scintillation counters and to read the data into the computer. These systems are under order. The software to program the VAX 11/780 which will control the experiment is the joint responsibility of all laboratories and is well underway. We expect to meet the October 1, 1979 deadline with an assembled and working experiment.

This is a collaborative effort with Stanford University, Northwestern University, University of Hawaii and Frascati.

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PEP Experimental Facilities Coordination

The PEP experimental coordination during this year has involved the following activities:

1. The development of the PEP experimental areas, including special modifications needed for the experiments after their assignment to specific areas.

2. The interface of users with the PEP machine's environment.

3. Coordination of the development of the support system for PEP experiments, such as on-line computer, real time links to the central computers, refrigeration plants for superconducting magnets and design of systems for access and movement of detectors.

4. The evaluation of the impact of PEP proposals on equipment funds and operating resources.

5. The coordination of the use of LBL resources necessary for the PEP experimental program.

6. The negotiation of agreements with the proponents on the detailed responsibility of the participating institutions and the distribution of funds for the approved experiments.

7. The monitoring of the physical development and of cost and commitments of the detector projects under development.

8. The long range planning for the utilization of PEP.

9. The publication of the bi-monthly PEP bulletin for all PEP users and the publication of the quarterly PEP News with a circulation of 1300.

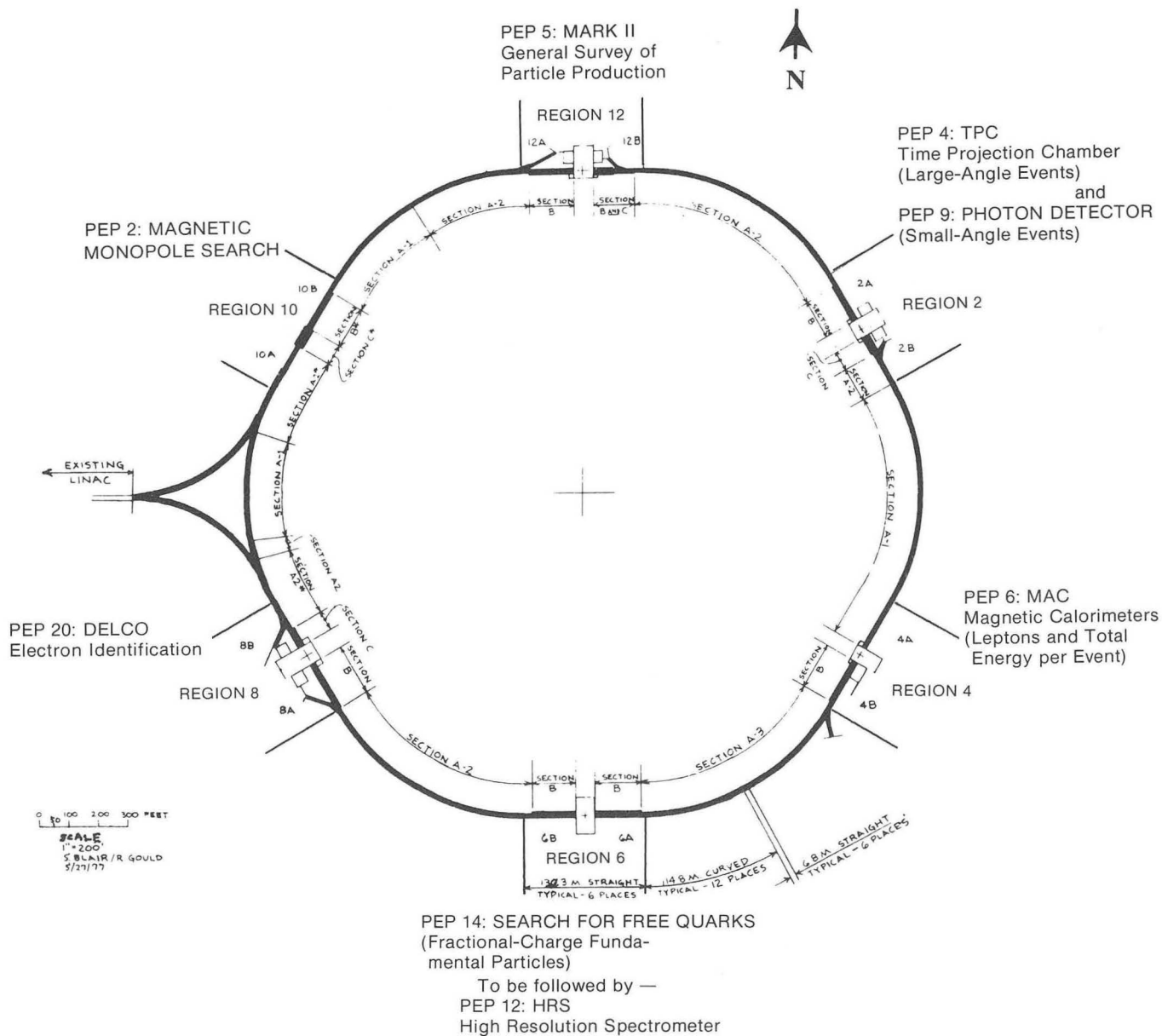
Development of the area is now about 75% complete. A total of 20 proposals have been analyzed and eight of these proposals have been approved for operation at PEP. These detectors have been assigned to experimental areas as follows:

Area 12: MK II Detector

Area 2 : TPC & Two-Photon Detectors

Area 4 : Magnetic Calorimeter

Experimental Physics
High Energy



PEP map shows locations of interaction halls housing initial experiments. PEP-5: Mark II is at Region 12; PEP-14: Search for Free Quarks is at Region 6; and PEP-4: Time Projection Chamber is at Region 2.

Area 6 : High Resolution Spectrometer &
Free Quark Search

Area 8 : DELCO Detector

Area 10: Monopole Search

The coordination group monitors the development of all the detectors, including milestones in the fabrication and associated R&D cost and commitments and budgetary projections. Detailed reports are provided to the agency on the development of the entire experimental program on a quarterly

basis. Starting in 1980 this work will be carried in the Facilities Operations budget.

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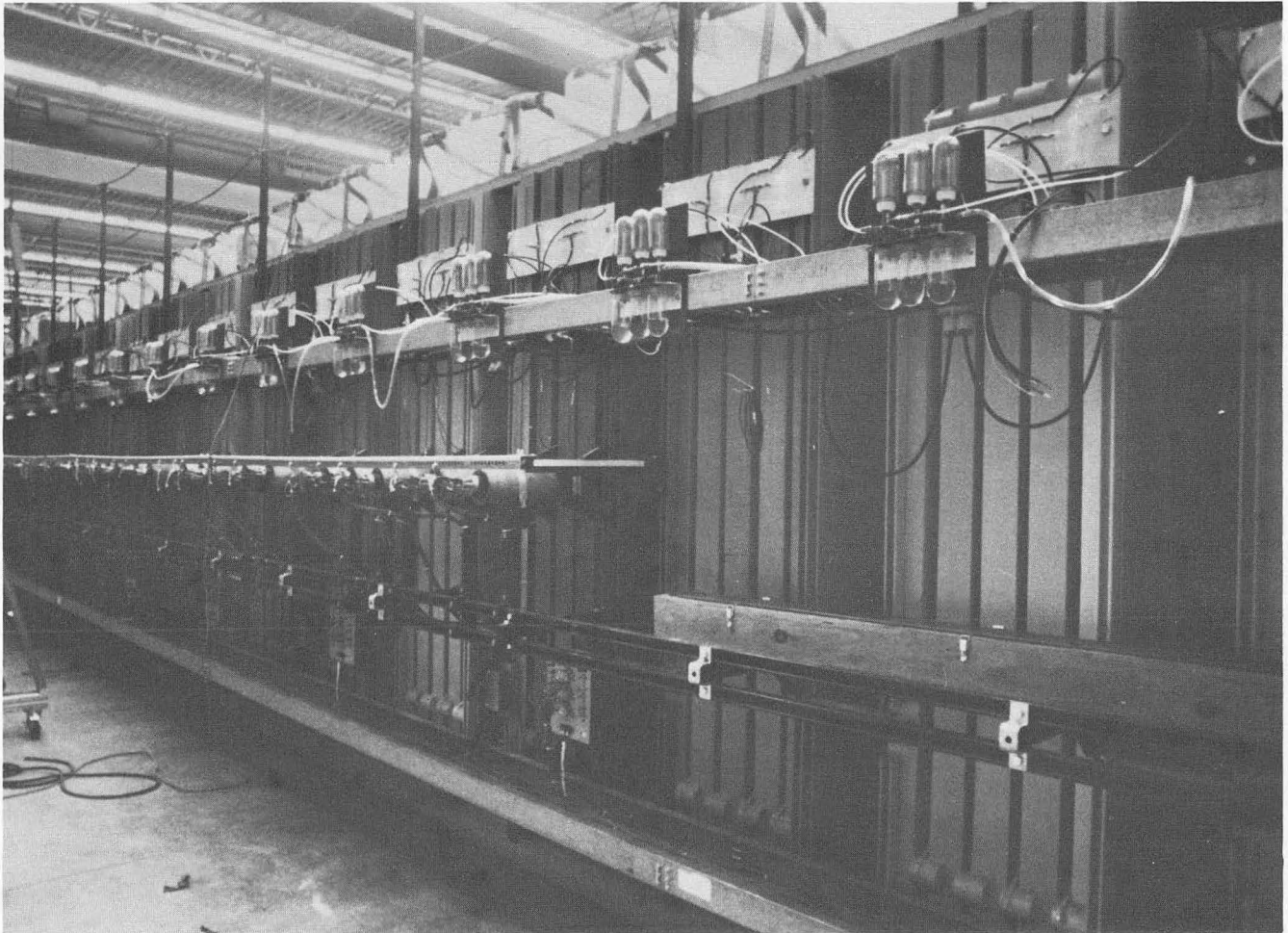
INTERNAL REPORTS

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Research at FNAL on Muon and Neutrino Reactions



The 470-ton spectrometer magnet used in muon reaction experiments at FNAL.
CBB 785-5321

Muon Reactions

Experiments on rare muon induced reactions are now underway at FNAL. Electronic techniques are used for particle identification and measurement. The 470 ton spectrometer magnet used for these experiments has been completed and magnetic measurements carried out.

Analysis of about 10% of the data from this experiment has been completed. The analysis has shown that a full data sample includes of order 10^6

deep inelastic muon scatterings

$$[Q^2 \geq 20 \text{ (GeV/c)}^2], 10^5 \psi \rightarrow \mu^+ \mu^-$$

decays, and 2×10^6 examples of muon-induced extra muon production. At these high statistical levels, quite detailed analyses are meaningful (we anticipate further results with increased scope and precision). At present, the following general conclusions are evident:

Experimental Physics Medium Energy

- The inelastic structure function $F_2(x, Q^2)$ has been measured in the range

$$20 < Q^2 < 150 \text{ (GeV/c)}^2$$

with errors dominated by systematic uncertainties, which continue to diminish as the analysis is refined. "Bumps" in the invariant hadron mass W at $W \approx 10 \text{ GeV/c}^2$ seen in a previous, less precise experiment remain unconfirmed by these data. Unmistakable scale noninvariance of the variety originally observed has been verified. Detailed QCD parameterization of the scalebreaking is in progress.

- ψ production through virtual photon diffraction off nuclear, nucleon, and "quark" targets has been identified and the respective cross-sections measured. In addition, diffractive production of $\psi' \rightarrow \psi \pi \pi \rightarrow \mu^+ \mu^- \pi \pi$, and deep inelastic ψ production have been identified with use of hadron calorimetry. The ψ is produced with polarization nearly fully transverse for the nuclear and nucleon-diffraction process, and less so for the others. The level and Q^2 -dependence of diffractive ψ -production is in qualitative agreement with Vector Dominance expectations.
- A missing energy signature has been observed both in muon-produced 2μ and carefully cut 3μ final states. The extra muons

and missing energy are interpreted as arising from the daughter muons and neutrinos in one or both of the decays

$$c \rightarrow s \mu^- \bar{\nu}$$

$$\bar{c} \rightarrow \bar{s} \mu^+ \nu_\mu,$$

where the $c\bar{c}$ are found, for example, in diffractive virtual photoproduction of $D\bar{D}$.

- Unmistakable evidence of muon-produced final states containing more than 3 muons is in hand. Conventional and exotic explanations are under intensive study.

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Neutrino and Anti-Neutrino Reactions

This research (FNAL experiment E-546) is aimed at determining the interactions of neutrinos and anti-neutrinos by analyzing events observed on film taken at the FNAL 15' bubble chamber.

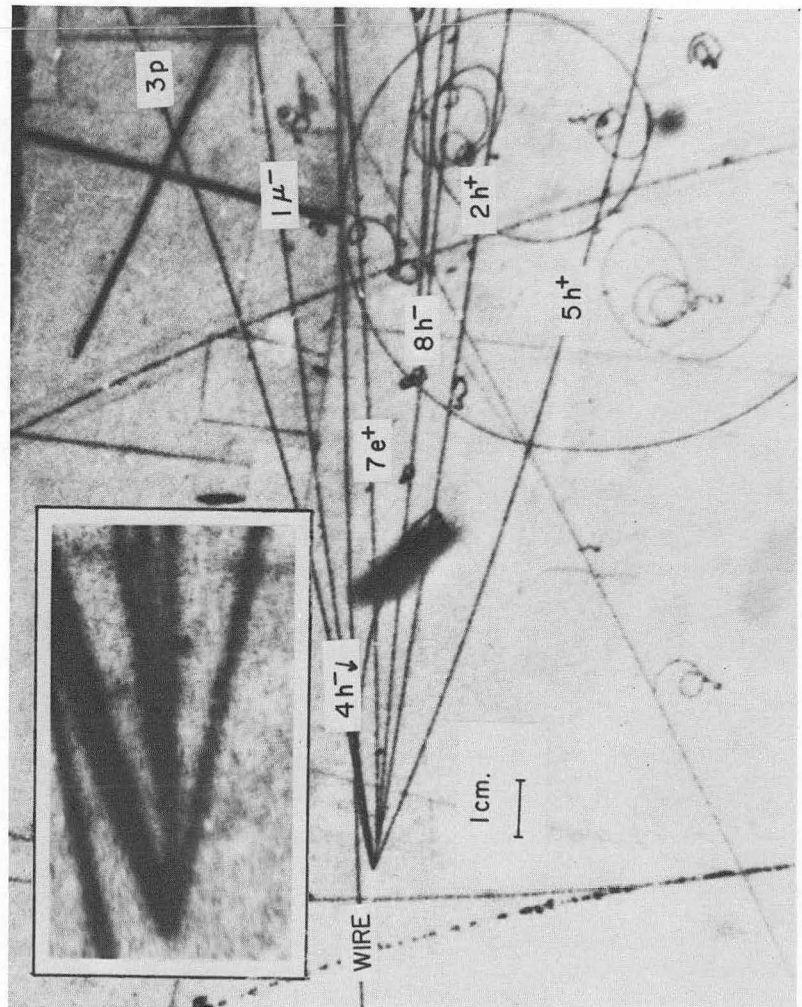
The hadronic behavior of di-muon and μe events has been the subject of extensive analysis which is continuing. The K^0 content of these events is consistent with the production of charmed mesons and their semileptonic decay. Preliminary results were reported at the "Topical Conference on Neutrino Physics at Accelerators," Oxford 4-7 July 1978. Also reported at this conference was the

"Characteristic of the FNAL 15 ~ foot bubble chamber with a 1/3-Scale Internal Picket Fence and a Two-Plane External Muon Identifier", a joint Hawaii-LBL-(FNAL) Development.

A new program of physics research involving neutrino interactions of high momentum has been started in the film of E-546. The purpose of this study is to look for effects of the hypothetical gluons of quantum chromodynamics. It should be completed in this fiscal year.

Preparations are under way to start the first half of a new neutrino experiment E-388 in April

Neutral decay of a charmed particle observed in a Fermilab bubble chamber experiment by a Berkeley/Fermilab/Hawaii/Seattle/Wisconsin collaboration. The decay is consistent with a D^0 meson decaying into a positron and a negative kaon, where tracks 7 and 8 are a positron and a negative kaon respectively. The decay distance is 6.7 mm. The positron does not project back to the primary vertex. Track 2 is not associated with the decay. The neutrino enters the picture from below. *Fermilab Photo*



1979. This experiment will be carried out in a heavy neon mixture. This will involve a dichromatic neutrino beam of two fairly narrow energy bands rather than a broad spectrum and should permit a more accurate determination of the structure functions. These experiments are a collaboration involving FNAL, Hawaii, UC Berkeley and the University of Washington.

PHYSICISTS

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Strong Interaction Experiments at FNAL and BNL

Experiments at FNAL Using Polarized Particle Beams and Polarized Targets

During this year the data from experiment E-61, a study of the elastic scattering of charged pions and protons by a polarized proton target have been analyzed. The polarization parameter P was determined for incident π^+ , π^- and protons of momenta 100 and 200 GeV/c in the momentum transfer

region $.15 \leq -t \leq 1.5 (\text{GeV}/c)^2$. In addition π has been found for protons of momentum 300 GeV/c and in the range $.15 \leq -t \leq 2.0 (\text{GeV}/c)^2$.

The polarizations measured are generally quite small (less than .05 in magnitude) and consistent at low $|t|$ with s^{-5} falloff expected from a simple Regge model of elastic scattering. In the region of the dip in the differential cross section at $t = -1.4 (\text{GeV}/c)^2$ and beam momentum above 200 GeV/c, there may be indications of large and rapidly changing polari-

zation arising from the interference between a near-vanishing leading trajectory and the residual scattering amplitudes.

Further analysis will make it possible to obtain the depolarization parameter D for incident protons of momenta 200 and 300 GeV/c in the range $.15 \leq -t \leq 1.5 (\text{GeV}/c)^2$ a polarized proton target. This experiment is a collaborative effort involving physicists from Harvard, Yale, Argonne National Laboratory, Fermi National Accelerator Laboratory, and LBL.

Lambda and anti-lambda production at Fermilab energies is so abundant that enriched anti-proton, polarized proton, and polarized antiproton beams with reasonable intensity can be constructed for the use of counter physics. Planning of such a facility and for its use in studies of the substructure of hadrons through the spin effects at high energy has been underway. It will be possible to measure total cross-section difference and high x_F low p 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.

PHYSICISTS

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PUBLICATIONS

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Polarization Measurements in Elastic Scattering in the 100-300 GeV Range, M. E. Zeller, J. Snyder, L. P. Auer, D. Hill, B. Sandler, D. Underwood, A. Yokosawa, W. Bruckner, O. Chamberlain, H. Steiner, G. Shapiro, A. Jonckheere, P. F. M. Koehler, R. V. Kline, M. E. Law, F. M. Pipkin, W. Johnson, XIX Conf. on High Energy Physics, Tokyo, Japan, August 23-31, 1978.

Inclusive Cross Sections for Neutral Meson Production at FNAL

High transverse momentum inclusive π^0 production in k^+p , π^+p and pp collisions has been studied in experiment E-268 at FNAL in the range 20-200 GeV/c. Data analysis is nearing completion on all these reactions. The π^-p reaction was studied in the region where the triple Regge mechanism is valid. This work is in collaboration with Caltech and BNL.

FNAL experiment E-350 (Inclusive scattering in the triple Regge region) is now about midway in its analysis phase. The 100 GeV analysis is substantially complete and only one summary paper remains to be written. The remaining 200 GeV data are partly analyzed and only conference reports have been given on these results. Data from E-350 have shown at 100 GeV that the ρ trajectory asymptotes to -1 at large $|t|$. The data extend to $\sim |t| \leq 6$. Some discrepancies at small $|t|$ between the ρ trajectory derived from E-350 data and the clearly deduced ρ trajectory from E-111 (elastic $\pi^-p \rightarrow \pi^0 n$) have prompted more careful examination of the simple triple Regge formalism. Some consideration of more complicated exchanges than simple ρ exchange are being investigated.

PHYSICISTS

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PUBLICATIONS

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Experimental Physics High Energy

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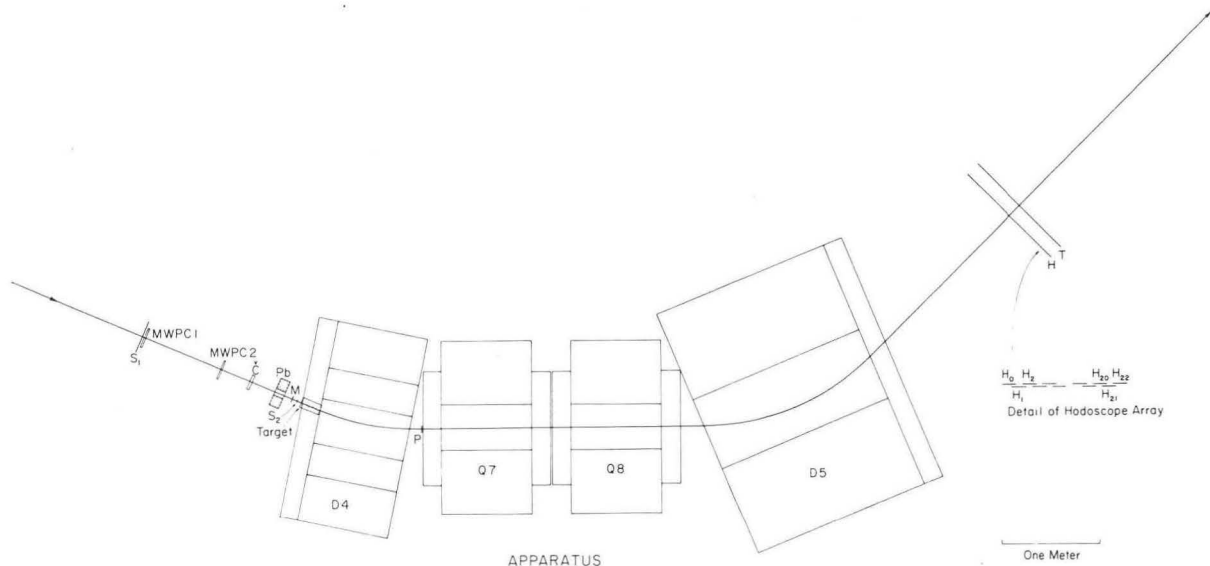
Inclusive π^0 and η Production in the All Neutral Mode from 100 GeV/c $\pi^{\pm}p$ Collisions. A. V. Barnes, G. C. Fox, R. G. Kennett, R. L. Walker, California Institute of Technology; O. I. Dahl, R. W. Kenney, A. Ogawa, M. Pripstein, Lawrence Berkeley Laboratory, Nuclear Phys. B145, 67-84 (1978).

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Experiments on \bar{k}, p Cross Sections at BNL

These experiments have yielded measurements of the total and a series of differential cross-sections for $K^-p \rightarrow \bar{K}^0 n$ in the region from 500 MeV/c to 1100 MeV/c. They are a search for baryon resonances in the \bar{K} -nucleon system. The 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 ($\bar{K}N$, $\Lambda\pi$, $\Sigma\pi$) which must be analyzed simultaneously. Previous to this experiment a unique phase shift solution could not be obtained due to the lack of precise data.

A new BNL effort has been in progress for the measurement of the differential cross section for the elastic scattering $K^{\pm}p \rightarrow K^{\pm}p$ and $\Sigma^- \pi^+$ at 180° . This backward region has been investigated only in a cursory manner by experiments of low statistical precision. The importance of the backward direction (180°) in this reaction can be seen from a partial wave expansion. The backward spin flip amplitude is zero and the predominant absorptive nature of the interaction yields amplitudes that are dominated by their imaginary parts. It follows that waves of opposite parity cancel, leaving a small background above which a resonant amplitude can be seen more easily than at other angles.



The apparatus for the backward elastic scattering experiments performed at BNL.

XBL 793-8844

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PUBLICATIONS

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, M. Ferro-Luzzi, Phys. Rev. 17, 2216 (1978).

The Differential Cross Section of the Reaction $K^-p \rightarrow \bar{K}^0n$ from 515 to 956 MeV/c, M. Alston-Garnjost, R. W. Kenney, D. L. Pollard, R. R. Ross, R. D. Tripp, H. Nicholson, Phys. Rev. 17, 2226 (1978).

Partial Wave Analysis of the KN 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, Phys. Rev. D18, 182 (1978).

Experiment on \bar{p} Elastic
Scattering at 180°

An investigation of the anti-nucleon-nucleon system below 1 GeV/c was carried out at BNL by measuring the backward elastic scattering of $\bar{p}p$. The running was completed in December of the FY and the data are currently being analyzed.

PHYSICISTS

R. Tripp
R. Kenney

M. Garnjost
D. Pollard

Graduate Student
Research Assistant

R. Hamilton

Cross Sections for $\bar{p}p$ Reactions

Two separate experiments are being run concurrently at BNL, namely the total cross section for $\bar{p}p$, and the $\bar{p}p$ charge exchange total cross section.

PHYSICISTS

R. Tripp

T. Pun

Graduate Student
Research Assistant

R. Hamilton

Small Angle Scattering
of π^\pm , K^\pm , p and \bar{p} on Protons

The scattering cross section is measured in the coulomb-nuclear interference region to obtain the real part of the nuclear scattering and amplitude. Data taking is concluded and analysis is in progress.

PHYSICIST

P. Nemethy

Final Results of Earlier
Research on πp and pp Interactions

Research on πp interactions is concerned with the diffractive production and decay of nucleon isobars, a study of interference between pion exchange amplitudes and the diffraction amplitude, and a search for baryon resonances.

Proton-proton interactions at 400 GeV/c have been studied by measuring all events with one or more neutral strange particle decays on gamma-ray conversions to e^+e^- pairs and four-pronged or 6pronged events.

In addition πp elastic and charge exchange scattering has been carried out using Barrelet moment analysis.

PHYSICISTS

D. M. Chew
R. P. Ely

G. Gidal
W. Michael

PUBLICATIONS

ϕ -Meson Production in 3.75 GeV/c π^+p Interactions, G. Gidal, W. Michael, G. Trilling, G. Abrams, K. Barnham, B. Daugeras, D. Lissauer, G. Alexander, A. Levy, Y. Oren, Phys. Rev. *D17*, 1256 (1 March 1978).

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Charged and Neutral Particle Correlations from 400 GeV/c pp Collisions in the Fifteen Foot Bubble Chamber, R. D. Kass, W. Ko, R. L. Lander, W. Michael, D. E. Pellett, P. M. Yager, R. Ely, G. Gidal, submitted to Washington, D. C. Spring 1978 meeting of the American Physical Society (24-27 April 1978).

A Study of the Reaction $\pi^+p \rightarrow \Delta^{++}\pi^0\pi^0$ at 4 GeV/c, G. Boreanì, F. Marchetto, D. Maurizio, E. Menichetti, G.

Rinaudo, C. M. Fisher, J. G. Guy, M. Suk, S. Tuli, J. W. G. Wignall, R. Ely, G. Gidal, D. Grether, H. Leutz, J. Tuckmantel, H. Wenninger, submitted to Nucl. Phys. B. (June 1978).

Observation of Interference Between $I_0 = 1/2$ and $I_0 = 3/2$ Baryon Exchange Amplitudes in 4 GeV/c Backward Inelastic Scattering, G. Gidal, J. W. Chapman, R. P. Ely, W. Michael, P. Oddone, D. Scharre, Phys. Lett. *76B*, 657 (3 July 1978).

The Discrete Ambiguity Resolution and Baryon-Resonance Parameter Determination, D. M. Chew, M. Urban, submitted to the 19th International Conference on High Energy Physics, Tokyo, Japan (23-30 August 1978), LBL-6103 Rev. (April 1978).

A Method for Selective Amalgamation Applied to Elastic π^+p Parameter Determination, D. M. Chew, M. Urban, submitted to the 19th International Conference on High Energy Physics, Tokyo, Japan (23-30 August 1978), LBL-7264 (April 1978).

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Charged and Neutral Particle Production from 400 GeV/c pp Collisions, R. D. Kass, W. Ko, R. L. Lander, W. Michael, D. E. Pellett, P. M. Yager, R. Ely, G. Gidal, P. Hanson, UCD PPL 7871A, submitted to Phys. Rev. D (1978).

Particle Data Center

The Particle Data Center is involved in five major activities:

1. Compilation of particle properties, and the issuance of the "Review of Particle Properties," with the associated data booklet and pocket diary.
2. Compilation of descriptive and bibliographic information on published articles, preprints, and current experiments in progress. Issuance of indexed guides to current literature and experiments.
3. Maintenance of a database of compiled high energy physics reaction data. Periodic issuance of reports and tapes covering these data.
4. Maintenance and continued development of a computerized database management system to store, maintain, update, retrieve, and display the compiled information referred to above. The system described in (2), (3), and (4) comprises the "Particle Physics Data System."
5. Individual participation in research projects.

During 1978 the complete "Review of Particle Properties" and its associated Data Booklet and Pocket Diary were issued. The listings of particle properties continue to grow at a rate of 10% per annum.

The assembly and updating of our document database, containing detailed descriptions of about 12,000 high energy physics documents produced during the last decade, continued. Information in this database was published as LBL-90, "An Indexed Compilation of Experimental High Energy Physics Literature." Also issued was the second edition of "Compilation of Current High Energy Physics Experiments" (LBL-91 Revised), first issued in 1976. Updated versions of both of these documents are published periodically.

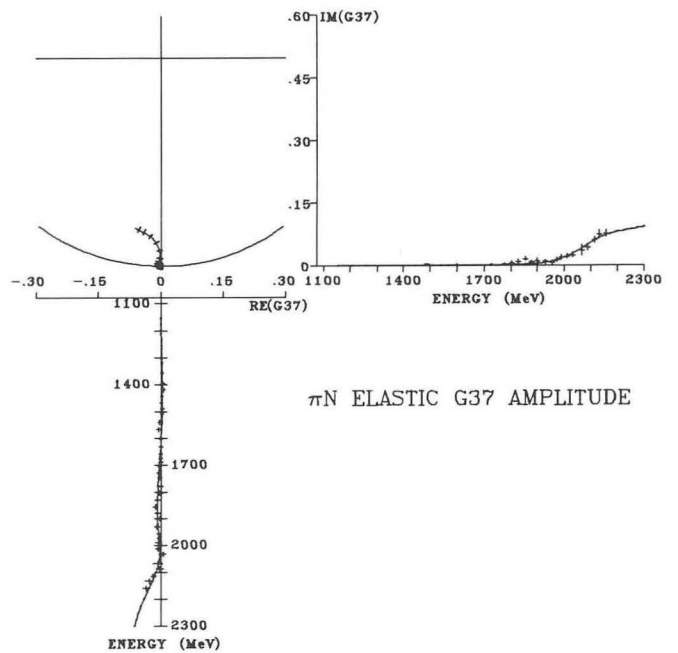
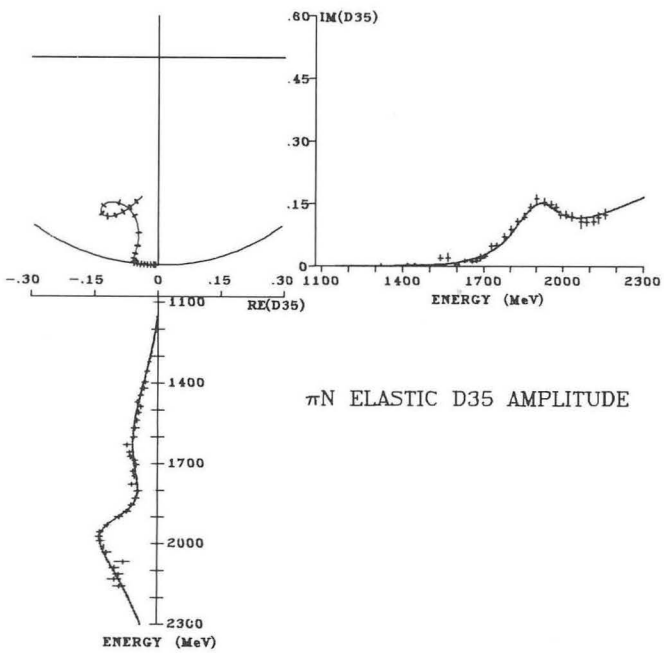
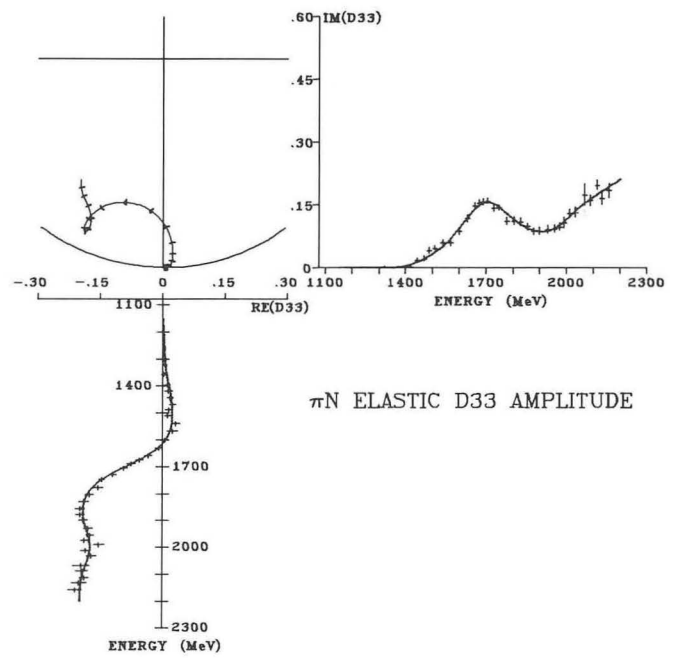
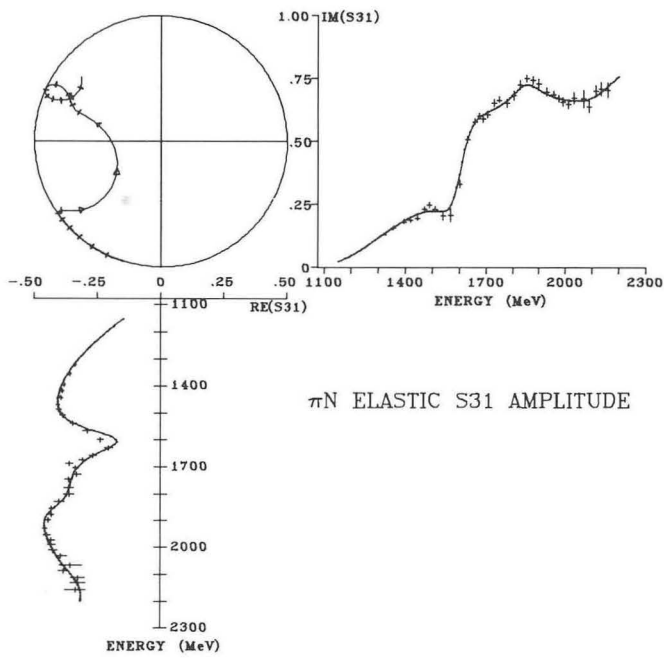
Compilations assembled by outside collaborators (at Cal Tech, Durham University, Glasgow University, McGill University, and Rutherford Laboratory) were incorporated into the database for experimental reaction data. A flexible language for encoding all such data has been completed and is being used by our collaborators. A major effort is planned to issue documents and tapes on selected portions of this database.

The second generation of Berkeley Database Management System has continued to be used to maintain various databases, produced LBL-90 and LBL-91, and allows for complex queries to be carried out on the databases. Outside users have interrogated our document database for their own special needs.

Members of the group are active in research projects. Kelly is active in the (Carnegie-Mellon University) CMU-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. Final results below 2 GeV/c were obtained in 1978, and will be published in 1979. Plans are to extend the analysis up to 3 GeV/c. This analysis represents a major advance in our quantitative knowledge of non-strange baryon resonances.

Losty was previously a member of the Amsterdam-CERN-Oxford Collaboration studying K-p interactions at 4.2 GeV/c in a high statistics bubble chamber experiment. The 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.

Losty and Horne are now involved in the PEP-14 quark search experiment. Trippe is participating in the Lead-Glass Wall experiment at SPEAR to study neutral particle production and anomalous electron production in e^+e^- annihilation. Twelve



Δ resonances with interesting properties are visible in these πN partial wave amplitudes from the CMU-LBL partial wave analysis collaboration. The mass difference between the prominent S31 and D33 resonances is an indication of 3-body spin-orbit interactions between quarks. The D35 resonance is a high lying state which may contain excited gluons as well as quarks.

XBL 795-9579

publications have resulted from the analysis of this experiment so far and several others are in preparation. Trippe is currently involved in the analysis of inclusive gamma production in psi (3100) decay. Yost is participating in pion and anti-neutrino beam bubble chamber experiments at SLAC and FNAL.

PHYSICISTS

C. P. Horne	T. G. Trippe
R. Kelly	C. G. Wohl
G. Losty	G. Yost
A. Rittenberg	

PUBLICATIONS

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- ω -Production in $K^- p$ Reactions at 4.2 GeV/c*, R. J. Hemingway, R. Armenteros, C. Dionisi, Ph. Gavillet, A. Gurtu, S. O. Holmgren, M. J. Losty, J. C. Marin, M. Mazzucato, L. Montanet, M. Banting, R. Blokzijl, A. J. DeGroot, B. Jongejans, J. C. Kluyver, W. M. Van Leeuwen, G. G. G. Massaro, A. G. Tenner, G. F. Wolters, P. M. Heinen, E. W. Kittel, W. J. Metzger, H. G. J. M. Tiecke, J. J. M. Timmermans, R. T. Van de Walle, B. Foster, P. Grossman, P. R. Lamb, J. L. Lloyd, J. Wells, Nucl. Phys. B142, 205 (1978).
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- A Spin Determination of the $XI^*(1820)$ Resonance*, D. Teodoro, J. Diaz, C. Dionisi, J. B. Gay, R. J. Hemingway, M. J. Losty, M. Mazzucato, R. Blokzijl, G. G. G. Massaro, H. Voorthuis, W. J. Metzger, J. J. M. Timmermans, R. T. Van de Walle, B. Foster, P. Grossman, W. L. McDowell, Phys. Letts. 77B, 451 (1978).

Astrophysics, Astronomy and Cosmic Rays

Primordial Blackbody Radiation

The experiment to detect anisotropies in the cosmic background (3°K blackbody) radiation has continued. We have measured an anisotropy at the 10^{-3} level which we interpret as due to the cosmological motion of the Milky Way galaxy. Plans are being made to check this effect by flying the microwave radiometer in the southern hemisphere aboard a U-2 aircraft. We are presently searching for polarization in the radiation from a ground-based instrument. We are currently designing a satellite version (the Cosmic Background Explorer Satellite) of the anisotropy experiment.

Neutron Stars, White Dwarfs, Blackholes

The binary radio pulsar PSR 1913+ 16 has been suggested as a uniquely valuable laboratory to test General Relativity. These tests can be made only if the companion to the pulsar is a compact object (a white dwarf or a neutron star). To check the possibility that the companion is not compact, a sensitive search for the light of the companion was undertaken. We have found a star at the position of the pulsar, with a 97% probability that it is associated with the pulsar and a 3% chance it is an accidental superposition of a field star. If one accepts this result, the tidal effects of the observed star will prohibit the observation of the general relativistic effects sought. This extremely important result will surely be carefully scrutinized in the next year.

Time resolved photometry and time resolved spectrophotometry were used to study several white dwarfs and neutron stars. WZ Sge, a recurrent nova was carefully studied to determine if its pulsations were truly coherent. They seem to be, and thus the underlying clock is the rotation period of the object (28 sec.).

Simultaneous observations of HZ Her/Her X-1 in optical and x-rays were made and analyzed. The

results show the source of optical pulsations from near the x-ray source is indeed excitation of a part of the accretion disk by the pulsed x-rays; a result predicted by us two years ago. A search for optical pulsations from another x-ray source, 3U0900-40 was made and negative results obtained. This is in contrast to a report of pulsations made by J. Steiner.

Several white dwarfs are known to pulsate in a complex manner. One theory to explain this result assumes the white dwarfs are rotating. We made an experiment to test for rotation and the results are being analyzed.

Optical Astronomy—The Rubber Mirror Telescope

In early work with the small (12") telescope, diffraction limited star images (0.5 arc sec) and diffraction limited double star images (2 arc sec separation) were obtained in the presence of bad seeing (5 arc sec) which made their resolution impossible without the rubber mirror. The angular size of the field of view that can be made distortion free at a given time had also been determined. These results were obtained at Mt. Wilson.

The telescope was modified so that it could be used with the 30" solar telescope at Sacramento Peak, New Mexico. A star guider was also designed, built, and successfully tested which, for the first time, allows the solar telescope to be automatically guided on stars (to 1 arc sec), enabling it to be used for a nighttime observing program. The rubber-mirror telescope was taken to Sacramento Peak and was used to successfully obtain diffraction-limited stellar images (1/4 arc sec) in the presence of 2 arc sec seeing. Now under study are selected double stars with separations less than 1 arc sec, including several that are of interest to astrophysics and are previously unresolved.



Experiment on polarization of 3°K blackbody radiation on roof of Bldg. 50 at LBL. George Smoot (LBL, standing) adjusts the instrument while Phil Lubin (UCB) monitors the electronics. CBB 788-10165

Ten Meter Telescope

The design study for the UC 10 meter telescope has been an important effort. In particular, the design of a segmented primary mirror has undergone substantial development. A control system has been developed and modeled on the computer. The needed mirror segment actuators and displacement sensors for the control of the primary mirror array have been designed and prototypes developed and tested. The results have been quite successful. The problem of fabrication of the mirrors has also received considerable attention, and a new technique for making off-axis parabolic mirrors is under test.

Cosmic Rays

The analysis of data from a balloon-borne superconducting-magnetic-spectrometer measurement of the abundances of the Be isotopes was completed and published. The fraction of ^{10}Be was used to obtain a mean life of the cosmic rays, but more significantly we observed a dramatic and unexpected change in the $^7\text{Be}/^9\text{Be}$ ratio with energy. This may have substantial impact on models of cosmic ray acceleration and propagation. An analysis of previously obtained data on the high energy Li through Fe cosmic rays was completed and published, showing systematic behavior in the spectra. The design and initial calculations were made for a new experiment to search for antimatter in the cosmic rays.

We are preparing for the July 1979 flight experiment to search for the expected anti-proton flux in the cosmic rays, and also to improve by a factor of 100 the sensitivity of past searches for anti-helium. The lack of anti-matter in the universe has been speculated to be due to anti-proton decay; if the anti-proton is not observed in the cosmic rays, this will imply that their lifetime is less than 10^6 years. The Pb-plate spark chamber, which is of crucial importance in the experiment, has been fabricated and tested, and other components are near completion.

PHYSICISTS

L. W. Alvarez	T. Mast
A. Buffington	S. Peterson
F. S. Crawford	J. Middleditch

R. A. Muller
J. Nelson

C. Pennypacker
G. Smoot

Graduate Student Research Assistants

S. Fridman
L. Hunt

P. Lubin
S. Pollaine

PUBLICATIONS

Pattern Measurement of a Low-Sidelobe Horn Antenna, Michael A. Janssen, Steve M. Bednarczyk, Samuel Gulkis, Harold W. Marlin, George F. Smoot, LBL-7546, submitted to IEEE Transactions on Antenna and Propagation, March 1978.

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Optical Pulsations in 4U0900-40: Do They Exist, Jerry Nelson, France Cordova, John Middleditch, to be published in April 1979 Astrophysical Journal.

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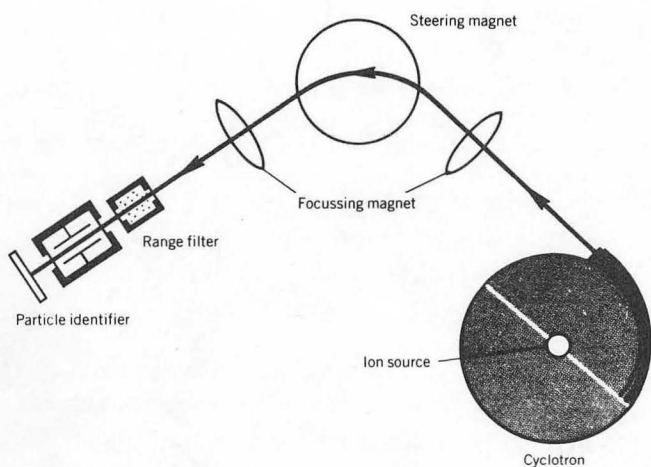
Radioisotope Dating

By considering radioisotope dating as a problem in trace-element analysis, and by using the LBL 88"-diameter cyclotron as a high-energy mass-spectrometer for this purpose, one can greatly increase the maximum age which can be dated while simultaneously reducing the size of the sample required. For carbon-14 dating one can go back 40 to 100 thousand years with 10 to 100 milligram carbon samples. In collaboration with several radioisotope-dating laboratories at other universities, we have been developing the cyclotron-dating technique in order to turn it into a practical analytical tool.

PHYSICISTS

R. A. Muller
T. S. Mast

E. J. Stephenson



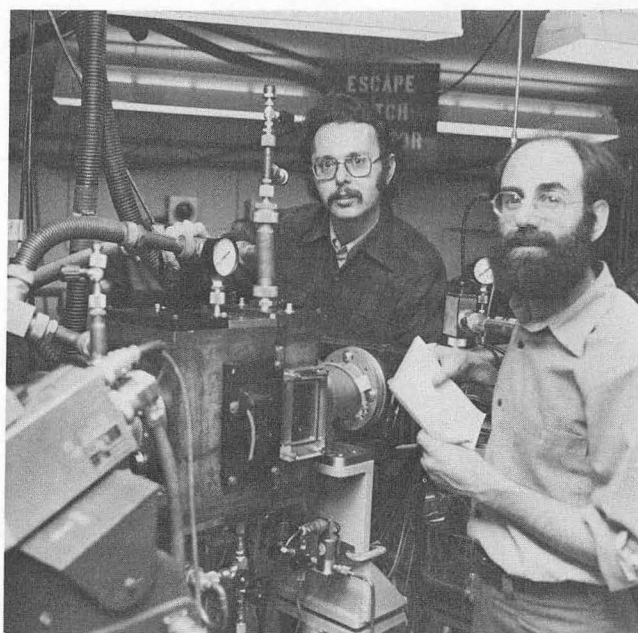
In this dating system, positive ions are accelerated by the cyclotron, which separates particles according to their mass ratios. The range filter removes much of the background ion current. Remaining particles are identified by their energy loss rate and total energy. XBL-798-11179

PUBLICATIONS

Radioisotope Dating with an Accelerator: A Blind Measurement, R. A. Muller, E. J. Stephenson, and T. S. Mast, LBL-7249 (Dec. 1977), *Science*, 201, 347 (1978).

Paper Presented at the Rochester Conference on Radiocarbon Dating with Accelerators, April 20-21, 1978, LBL-7585.

Radiocarbon Dating with a Cyclotron, E. J. Stephenson, R. A. Muller, T. S. Mast, LBL-7579, submitted to *Nuclear Instruments and Methods* (1978).



Particle filter and identifier system of the cyclotron dating apparatus is checked out by Richard Muller (left) and Terry Mast. Nitrogen background is reduced by better than 10^{-14} by the filter. XBB 783-2768.

Instruments and Instrumentation Systems

This work is concerned with the development engineering of instruments and of instrumentation systems which have broad and general applications in experiments conducted at high energy physics laboratories. Also included are research and development of particle detectors and detector methods and the evaluation of commercially available devices and instruments.

Instrumentation research has concentrated on developing various combinations of drift and multi-wire proportional chambers, various readout schemes and their associated electronics. Also under study are position-sensitive detectors using the light emitted from electron ion pairs (produced by incident charged particles or gammas), which drift in D. C. and pulsed electric fields.

Position-sensitive devices that detect and amplify the light, such as microchannel plates, CCD (charge collection devices) or CID (charge injection devices), are under consideration. Various combinations of these detectors are also under development as ultrafast avalanche counters and as detectors capable of recording large multiplicity events from high energy elementary particle interactions and from heavy ion collisions.

The gamma ray detection capability of these detectors finds applications in both accelerator and cosmic ray physics, as well as in imaging devices for nuclear medicine, x-ray crystallography and general x-ray detection. Operating manuals, maintenance, and support of previously designed system, of instruments in the Counting Pool, and of computers and peripherals used for data acquisition in high energy physics experiments are provided by this effort. In addition, inventory records of all equipment are maintained, new equipment is procured and consulting service is provided on all aspects of instruments and detectors used in research programs.

Large Scale Digitizer System

The large scale digitizer (LSD) system, an economical modular system for simultaneous digitization of analog data from hundreds of signal channels has been a continuing activity of our group since 1976. Improvements to the LSD include a control mother board printed circuit card for lower fabrication costs, and the use of a non-linear clock to extend the energy range of the LSD by more than a factor of four with no loss in resolution at the lower energy range. Techniques used in the LSD have been successfully transferred to PEP-4 to extend energy and time ranges for smaller and lower cost data ways.

The LSD system digitizer has been modified to perform with the free quark search (PEP-14, multi-wire proportional chamber) so that, with a non-linear clock, the dataway-limited system of the LSD can accommodate an energy range four times greater than what the present system allows, while maintaining high resolution for $Q/3$ and $2Q/3$ in quark studies. A programmable trigger logic has been developed for PEP-14 use.

Multiwire Proportional Chambers

A number of multiwire proportional chambers (MWPC) systems have been assembled in this past year. Improvements in several areas have been made. A new preamplifier has been developed specifically for the PEP-14 project, as well as a summing amplifier; these precede discriminators. Preliminary work has been completed for a "first in, first out" buffer memory for a MWPC readout system.

Charge Coupled Device

The development of a 16 channel charge coupled device (CCD) prototype system was instru-

mental in proving the feasibility of using CCD's for PEP-4 Time Projection Chamber (TPC) applications. Evaluation and characterization of CCD's and optimization of clock drivers for the CCD's in terms of circuit design and layout have continued.

Microcomputer Systems

The two LSI-11 systems are functioning and have replaced the old IBM 1130 computer unit. Software programs are being written for the LSI-11

systems to replace programs previously used on the IBM 1130. New programs must also be written to take advantage of the higher speeds afforded by the LSI-11 system.

A very low cost computer sold by Commodore (PET Computer) has been interfaced to a tester unit for rapidly testing a large number of digitizer cards. This unit can be sent to vendor companies which build printed circuit cards for LBL, and these vendors can pre-test the digitizer cards for us. The PET computer has many other capabilities which are being investigated.



Small enough to travel "to the field" to check instrumentation system problems, this LSI-II Computer system is shown here being connected by K. L. Lee to a multiwire proportional chamber (MWPC) register-latch system for checkout. The LSI-II is faster, has four times the memory, and is 5 to 7 times smaller than the IBM 1130 computer system originally used for this type of analysis. CBB 790-14047

Electro-Optical Device Evaluation Program

Evaluation and lifetime studies were made of prototype microchannel plate photomultipliers. Because of proximity focussing, these compact devices exhibit very good timing and pulse height resolution capabilities as well as a very low sensitivity to ambient magnetic fields.

Further improvements have been made in the high accuracy photomultiplier measuring system and the system for long time studies of the stability of microchannel plate gain. It had become apparent that operational lifetime is one of the most critical characteristics of microchannel plate photomultipliers. Several inexpensive versions of conventionally designed photomultipliers have been evaluated.

Commercial development and availability of devices appropriate for high energy physics instrumentation by major manufacturers is encouraged. Manufacturers have supplied LBL with prototype devices without charge and a commitment has been made to advise them about their evaluation at LBL and to offer suggestions concerning the design criteria for development of a new generation of these devices with improved characteristics. Based on these evaluation results, some manufacturers will incorporate in their new designs, microchannel plates with better secondary emitters than presently available. New emitters will allow a higher channel wall current which is important for high repetition rate applications.

Technical Support and Pool Operations

General services are provided in connection with all electronic instruments used in Physics Division programs. In addition to maintenance of the electronics shared within the Division, operation of an equipment pool is performed which includes maintenance of inventory records, procurement of new equipment, providing operating manuals and providing consulting services on all aspects of instruments and detectors used in research programs.

Special effort has been made to strengthen the equipment pool with those serving other LBL

Divisions. A single pool is now operating with advantage to all Divisions, along with better utilization of equipment.

PHYSICISTS & ENGINEERS

V. Perez-Mendez	P. Wiedenbeck
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B. Leskovar	M. Nakamura
E. J. Lampo	C. Nunnally
K. L. Lee	S. R. Olson
C. C. Lo	

PUBLICATIONS

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- Three-Dimensional Reconstruction in Planar Positron Cameras Using Fourier Deconvolution of Generalized Tomograms*, K. C. Tam, G. Chu, V. Perez-Mendez, LBL 6774 - IEEE Trans. Nuc. Sci. NS-25 (1978) 142-159.
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MEDIUM ENERGY PHYSICS

Radiative Pion Capture in Nuclei and Nuclear Structure

The photon spectra associated with the capture of negative pions by nuclei is being measured at LAMPF using a high resolution electron-positron pair spectrometer. Previous research by LBL has demonstrated that some of the fine-structure observed in these spectra between 100-140 MeV is due to excitation of nuclear spin-isospin dipole vibrations. In several nuclei, e.g., ^{10}B and ^{14}N , the giant magnetic dipole states also have been observed, and new evidence regarding the existence of giant quadrupole states in nuclei is now being sought. The quantitative analysis of these results has shown that the measured branching ratios can be related to the fundamental process $\pi^- + p \rightarrow n + \gamma$ without the introduction of phenomenological parameters. The data from several experiments have been analyzed. In the case of ^3He and ^6Li these experiments are serving as tests of the application of the PCAC hypotheses and soft-pion theorems to complex nuclei.

Capture of π^- Mesons by Nuclei

Tritium, $T(\pi^-, \gamma) 3n$ —The shape is consistent with the theory of Phillips and Roig¹, who analyzed the γ energy spectrum from the reaction $\pi^- + T \rightarrow 3n + \gamma$. They took account of final state interactions in the 3 neutron system due to the known two body n-n interactions between pairs of neutrons. Subsequent off-line data analysis which uses the measured magnetic field and from which spurious events have been eliminated is nearing completion.

Neon, $^{20}\text{Ne}(\pi^-, \gamma)^{20}\text{F}$ —Spectra from ^{20}Ne shows clear evidence of a weak transition at the position

where a magnetic dipole transition is expected. This measurement suggests that in the s-d nuclei, one may isolate and measure unique transitions and compare the measured branching ratios with the shell model predictions. This experiment together with preliminary ^{28}Si and ^{18}O data from SIN, are the first evidence of a sharp peak from capture on s-d shell nuclei ($16 < A \leq 40$).

For ^{20}Ne a special feature is that π^- absorption from the atomic 2p level dominates. This implies that the level width $\gamma_\lambda(2p)$ can be extracted directly from the measured branching ratio R_γ . This will provide a test of the importance of momentum-dependent terms in the fundamental interaction since they are thought to have large effects on the width.

Carbon, $^{13}\text{C}(\pi^-\gamma)^{12}\text{C}$ —Clear evidence of interesting structure in the low excitation regions has been obtained in this experiment. This data is being analyzed and comparison of the branching ratios with theory will be made.

Fluorine, $^{19}\text{F}(\pi^-\gamma)^{19}\text{O}$ —Shell model calculations in the impulse approximation with 1p-1h and 2p-2h excitations in $^{16}\text{O}(\pi^-, \gamma)^{16}\text{N}$, predict a large number of resonance levels. Since in the simplest shell model picture, ^{19}F is ^{18}O with an $s_{1/2}$ proton added outside the closed proton core, one expects the $s_{1/2}$ proton to couple to each of the dipole excitations to produce two levels with $J^\pi = J^-$ and $(J-1)^-$ which would appear either as broadened peaks or split peaks. Theoretical estimates suggest that the centroids of the split peaks occur at 9.5 and 16.5 MeV excitation in ^{19}O . There is a sparsity of data in this region, so that the observation of the speculated levels would provide ^{19}O level scheme information as well as test the extension of the ^{18}O results based on simple arguments. Data analysis is beginning.

¹A.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.

Zirconium, $^{90}\text{Zr}(\pi^-, \gamma)^{90}\text{Y}$ —Interest in this reaction centers on the possibility of providing evidence for the existence of the $T >$ component of the giant dipole resonance. In ^{90}Zr the $T >$ component is thought to exist at $E_x = 30$ MeV. Establishing the T for states of high excitation is difficult in most experiments; in π^- capture it is automatic, since $\Delta T = \Delta T > = 1$. Theoretically it is predicted that μ^- capture excites the analog of the (GDR) $T >$, but no calculations are published for (π^-, γ) . Based on the similarity of the reactions we expect the theoretical predictions to be similar as well. Of course the (μ^-, ν_μ) capture transitions to unbound nuclear states cannot be observed directly, since only ν_μ is emitted. Therefore, an interesting, unique test of these predictions is afforded by (π^-, γ) . The data from this experiment is being analyzed.

PHYSICISTS

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PUBLICATIONS

Radiative π^- Capture in Liquid Tritium, J. A. Bistirlich, K. M. Crowe, J. Miller, S. S. Rosenblum, P. C. Rowe, W. A. Zajc, F. T. Shively, G. Strassner, P. Truol, H. Brandle, E. R. Grilly, E. C. Kerr, J. Novak, R. H. Sherman, submitted to General Meeting, American Physical Society San Francisco, CA., January 23-26, 1978.

Study of Isobar Analogs of ^{13}C GDR by Radiative π^- Capture, C. J. Martoff, J. A. Bistirlich, K. M. Crowe, J. P. Miller, S. S. Rosenblum, W. A. Zajc, H. W. Baer, G. Strassner, Truol, A. H. Wapstra, submitted to General Meeting, American Physical Society, Washington, D.C., April 23-26, 1979.

Structure in Hard γ Spectra from π^- Radiative Capture in ^{20}Ne , ^{19}F , ^{90}Zr and In-flight π^+ Radiative Capture in ^{12}C , J. P. Miller, J. A. Bistirlich, K. M. Crowe, C. J. Martoff, S. S. Rosenblum, W. A. Zajc, H. W. Baer, G. Strassner, P. Truol, A. H. Wapstra, submitted to General Meeting, American Physical Society, Washington, D.C., April 23-26, 1979.

Experimental Determination of the Relativistic Fine Structure Splitting in a Pionic Atom, K. -C. Wang, F. Boehm, H. E. Henrikson, J. P. Miller, R. J. Powers, P. Vogel, J. -L. Vuilleumier, R. Kunselman, Phys. Lett. **79B**, 170 (1978).

Scattering of Mesons, Nuclei and Light Nuclei by Light Nuclei and Nuclear Structure

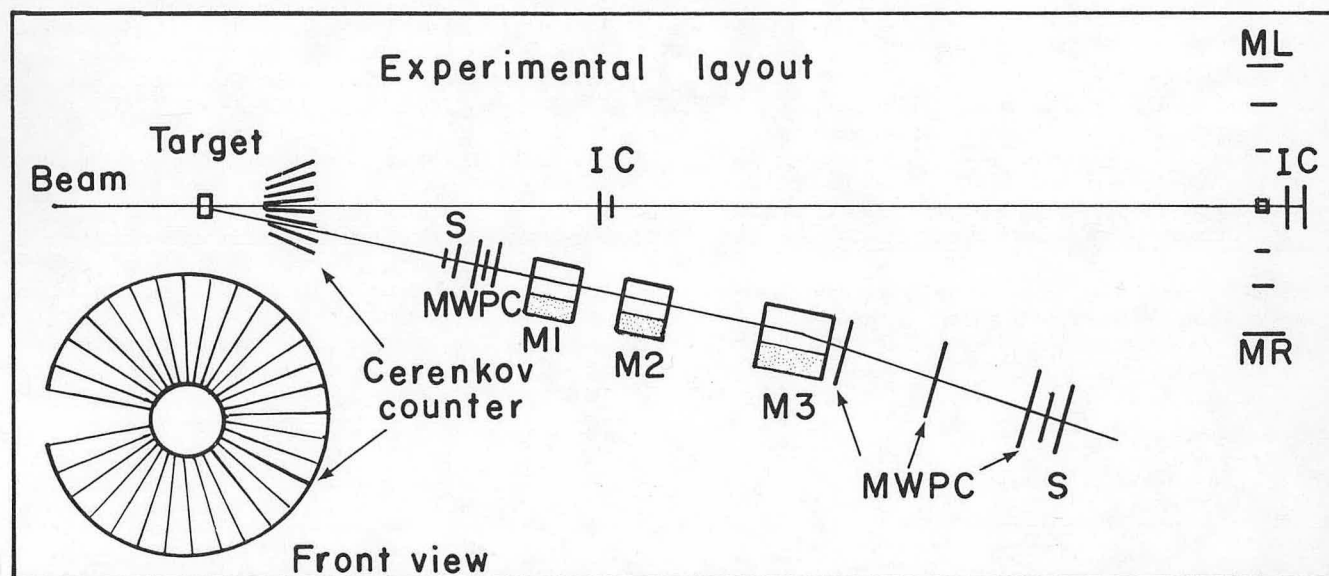


Diagram of spectrometer used at the Bevatron for proton-helium elastic scattering experiments. The segmented Cerenkov counter was used in the same configuration for heavy ion experiments.
XBL 782-189

Elastic Scattering

A comprehensive paper including all the final results from our measurements of forward elastic scattering in the p - ${}^4\text{He}$ system at $T_p = 0.4, 1.0, 2.7$ and 4.9 GeV has been submitted for publication. This paper includes detailed discussions of experimental techniques and systematic errors. The consistent and well understood absolute normalization of the cross-sections should make this data very useful in studying both the helium wave function and the behavior of the NN amplitudes.

Work has continued on the analysis of the p - ${}^3\text{He}$ and d - d forward elastic scattering data. Preliminary results from the d - d experiment show a more rapid fall-off of $d\sigma/dt$ beyond the double scattering region than seen in earlier experiments in this energy range.

Polarization Experiments

Final results from collaborative measurements at ANL of the analyzing power in backward elastic Pd scattering ($T_p = 0.68, 1.03$ and 1.53 GeV) are consistent with an interpretation in which the dominant process in the region of the shoulder in the backward cross-section is pion exchange through $N^*(1232)$ formation.

As an extension of the above work we plan to study pd scattering in which both participants are polarized. Negotiations with collaborators from the polarized target groups at ANL are in progress.

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PUBLICATIONS

p-⁴He Elastic Scattering at 5.75 GeV/c, M. A. Nasser, M. M. Gazzaly, J. V. Geaga, B. Hoistad, G. Igo, J. G. McClelland, A. L. Sagle, and H. Spinka, J. B. Carroll, V. Perez-Mendez, E. t. B. Whipple, Phys., Rev. Lett. *C17*, 1748-1751 (1978).

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d-d Elastic Scattering at 5.75 GeV/c, E. Whipple, A. Sagle, R. Talaga, V. Perez-Mendez, F. Zarbakhsh, J. B. Carroll, G. Igo, J. McClelland, J. Oostens, Nucl. Phys. Div. Meeting, Asilomar, November 1978.

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Polarization in Elastic p-p and p-n Scattering at 1.03 GeV, M. L. Marshak, W. A. Peterson, K. Ruddick, J. Lesikar, T. Mulera, J. Roberts, R. Klem, R. Talaga, W. Wriekat, Phys. Rev. *C18*, 331 (1978).

Mesonic Atoms

A measurement was made of the absorption coefficient of kaonic potassium x-rays 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 were analyzed and preparation of a report was begun.

In cooperation with the University of Victoria group at TRIUMF, the pionic x-ray intensities of 60 chemical elements were measured and the data were analyzed.

PHYSICIST

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PUBLICATIONS

Variation of Pionic X-Ray Intensity with Atomic Number, G. A. Beer, M. S. Dixit, J. A. Macdonald, G. R. Mason, A. Olin, R. M. Pearce, C. Sabev, W. C. Sperry, C. Wiegand, Asilomar Meeting, American Physical Society, November 1, 1978.

Variation of Pionic X-Ray Intensity with Atomic Number, G. A. Beer, M. S. Dixit, J. A. Macdonald, G. R. Mason, A. Olin, R. M. Pearce, C. Sabev, W. C. Sperry, C. Wiegand, CAP Congress, London, Ontario, June 12-15, 1978.

Kaon Mass by Critical Absorption of Kaonic Atom X-Rays, G. K. Lum, C. E. Wiegand, San Francisco Meeting, American Physical Society, January 23-26, 1978.

Muon Induced Fission

The software development on the data acquisition system was completed and two runs were made at TRIUMF on μ^- capture parameters in U-238. The measurements were designed to enable identification, through γ - γ and γ -fission time correlations, of excitation of the shape isomer by non-radiative muonic K-shell transitions, and to measure the lifetime and branching ratios for the subsequent spontaneous decay of this isomer. A short γ - γ run with U-238 measuring time correlations and energies of multiple γ -ray events yielded 10^7 such events. Event-by-event analysis is being carried out in Chalk River. Because of high electron background in the present muon beam, further such measurements are being deferred until the electrostatic separator is installed. This will probably not be before late FY-80. A second run, using multiplate avalanche fission chambers measured absolute

fission yields and x-ray-correlated fission lifetimes in U-235 and U-238. This data is still under analysis, but preliminary results seem to indicate a much lower absolute fission yield than that recently reported from a radiochemical measurement at SIN.

PHYSICISTS

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Multiple Pion Production in Heavy Ion Collisions

A Bevalac experiment to study the Hanbury-Brown-Twiss effect for like charged pions made by heavy ion ion collisions in events where many pions are produced is in its initial stage. Observations will be made of the production of a pair of closely related pions, +,+ or -,- in the lab angle range 40° to 120° . In the past ten years, such exotic phenomena as pion condensate, pionic lasing and nuclear antiferromagnetism have been predicted as possible states for nuclear matter in a heavy ion collision.

Recently Gyulassy and others have pointed out that one way to observe the effect of pion instabilities in heavy ion collisions is to look for the correlation of like pions in the situation when the relative momentum is extrapolated to zero.

More quantitatively, one studies the correlation function $C_m(\vec{k}, \dots, \vec{k}_m)$ for m pions. For the case of two pions, $C_2(\vec{k}, \vec{k}) = 1$ for a chaotic source while $C_2(\vec{k}, \vec{k}) = 0$ for coherent sources. Highly coherent pions will have a different distribution in relative momenta than that expected for chaotically produced pions, and the range of coherence depends on the size of the interaction region. Significant coherence may extend to $|\vec{P}_{\pi 1} - \vec{P}_{\pi 2}| < 5 \text{ MeV}/c$ for 300 MeV pions. Work is underway to instrument and set up the detection system to observe the momentum distribution of two pions made in Argon-KCI central collisions at 2.1 gev/nucleon.

The relative momentum is obtained both longitudinal and transverse by measurement of the trajectories in the magnetic field. A 2% accuracy can be expected, so that the N^* decay kinematics, pions

will have $\sim 150 \text{ MeV}/c \pm 3 \text{ MeV}/c$. The events can be collected and the correlation function obtained with pions produced in the resonance energy, i.e.,

$$\frac{\vec{K}_1 + \vec{K}_2}{2} \approx 150 \text{ MeV}/c,$$

and the distribution in relative momentum $q = (K_1 - K_2)$, with both \perp and \parallel to the average momentum. The angle of deflection in the magnet will be used to determine the momentum of each of the pions. The spectrometer/spectrograph apparatus consists of the Janus magnet, wire chambers and counters (most of which were developed in connection with the pair spectrometer program). The collaboration between LBL and the Tokyo-Michigan State University-University of Zurich is being set up in March 1979, and in summer 1979 a preliminary run will be made. This work is also reported in FY 1979 WPAS for Nuclear Science.

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II. THEORETICAL PHYSICS

II. THEORETICAL PHYSICS

The theory of interactions of fundamental particles is the principal area of research of the Theoretical Physics Group. Other areas of importance are statistical mechanics and the theoretical study of high energy particle accelerators. Many Group members have actively supported experimental programs of the Laboratory from the theoretical side.

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

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-eight 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. The summer program is usually also enriched by a bonus of self-supporting visitors who are active in LBL research areas. The laboratory offers them hospitality and is rewarded by seminars on their current research and often by direct contributions to our work.

During the academic year visitors, eager to participate in LBL research, frequently make significant contributions to this work. They are supported by their own institutions or by special research grants or fellowships. The laboratory cooperates with these theorists by supplying office space, limited computing facilities and secretarial help.

Participating Guests

Jeeva Anandan	University of Pittsburg
Thomas Applequist	Yale University
Louis Balazs	Purdue University
V. Z. Baluni	Massachusetts Inst. of Technology
Robert N. Cahn	University of Michigan/UC-Davis
Fritjof Capra	Berkeley, California
Louis Clavelli	University of Maryland
John C. Collins	Princeton University
Shmuel Elitzur	Institute for Advanced Study/NSF
Glennys Farrar	California Institute of Technology
Kurt Gottfried	Cornell University
T. Hagiwara	Ohio State University
Haim Harari	Weizmann Institute/UC Berkeley
Charlie Harper	California State University/Hayward
A. W. Hendry	Indiana University
Satish Joglekar	University of California-Berkeley
Stanley T. Jones	University of Alabama
Joe Kiskis	Inst. for Advanced Study
Moshe Kugler	SUNY-Stony Brook/Weizmann Inst.
Kenneth Lane	Harvard University
William J. Marciano	Rockefeller University
Harry L. Morrison	University of California, Berkeley
Basarab Nicolescu	CNRS-(IN2PE) Grant, Paris
Nicolas Papanicolaou	University of California, Berkeley
Chris Quigg	Fermi National Accelerator Laboratory
Neil Pomphrey	University of California, Berkeley (ONR Grant)
William R. Rarita	Retired Brooklyn College, NY
Christoph Schmid	ETH-Zurich, Switzerland
Robert Warnock	Illinois Inst. of Tech.

Doctoral Theses

During the year, two graduate students were awarded the Ph.D. degree:

Jean-Pierre Sursock, *Mathematical Foundations of the General Ordered S-Matrix and its Topological Expansion*, Ph.D. thesis (University of California-Berkeley), May 10, 1978.

George Weissman, *Particle Order: A New Fundamental Concept in Hadron Physics*, Ph.D. thesis (University of California-Berkeley), May 25, 1978.

Research in particle theory encompasses the strong, electromagnetic weak, and gravitational interactions. They are investigated both by field theoretical methods and by S-matrix methods.

Bootstrap S-matrix theory based on combinatorial topology made dramatic progress in 1978. The way now appears open to a quantitative understanding of all particle phenomena in terms of self consistency. It is about to encompass even weak interactions. The singularity structure of S-matrix elements has been investigated by a new mathematical approach in collaboration with mathematicians and mathematical physicists.

In parallel to the S-matrix approach, a large number of Group members studied strong interactions by field theoretical methods. A central issue is to explain the confining mechanism of quarks and gluons in the non-Abelian gauge theories. Toward this goal, many aspects of different Abelian and non-Abelian gauge theories were examined including the charge-monopole duality, the magnetic Wilson loop, technical problems in evaluation of Wilson loops, construction of infrared finite states, Gribov's copy problem, phase structure and symmetry breakdown, a local field theory of solutions, and a generalized nonlinear σ -model in an arbitrary compact manifold.

The other issue is how the quantum chromodynamics manifests itself in lepton-hadron processes and heavy quark systems. The effect of instantons was investigated for processes at short distances. Compton scattering was also examined in a simple non-Abelian gauge theory. Instantons in the gravitational field theory have also been investigated.

Weak interactions were investigated in the framework of gauge models and also more generally. Studies were made of low-energy manifestation of super-heavy fermions, theoretical and experimental aspects of Higgs particles, and gluon corrections to heavy quark decays, and weak interactions of strange and charmed hadrons. In this area of research, much contact with experimentalists was made in the course of this research. The properties of heavy particles with new quantum numbers continued to be a subject of interest. The baryonium spectra were studied systematically. Considerable effort was made in the area of statistical mechanics. Nonlinear interaction of waves was studied using the techniques of statistical mechanics together with numerical calculations using high-speed computers. Field theoretical techniques were introduced to study a many-vortex phase of the two-dimensional Bose fluid and other forms of two-dimensional statistical mechanics such as the Ising model.

The research in accelerator theory and design has focused on heavy-ion fusion. The ion optics of a quasi-telescopic lens system and eddy current problems in magnet design of the Time-Projection-Chamber Group of the Laboratory were also studied. Atomic physics in a strong electric field was also a subject of research during the year.

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, 9 graduate students supported by the Laboratory and 4 graduate students supported by grants and contracts are working under the direction of members of the Theoretical Group.

FACULTY

K. Bardakci
G. F. Chew
M. B. Halpern
J. D. Jackson
S. Mandelstam
M. Suzuki
K. M. Watson

SENIOR STAFF

D. L. Judd
J. V. Lepore
R. J. Riddell, Jr.
H. P. Stapp

TERM APPOINTMENTS

M. Chanowitz
(Divisional Fellow)
M. Furman
H. Haber
I. Hinchliffe
E. Rabinovici

Particle Theory

Analytic S-matrix elements are obtained entirely from the quantum superposition principle and the Cartesian view of reality, namely, isolated causally-connected events in space-time. Their singularities are associated with singularity graphs whose self-consistency can be analyzed through the topology of 2-dimensional manifolds (surfaces). The origin not only of quarks but of baryon number and flavor has been explained in terms of surface triangulation, and broken symmetry as a general phenomenon has been related to a topological expansion. Weak interactions now promise to become bootstrapped through the nonorientable components of the expansion. (Chew, Stapp, Surssock, Weissmann)

Chew and Stapp have shown that schemes may be constructed which apparently avoid the mathematical inconsistencies of earlier attempts. The new theory will give predictions regarding the hadron spectrum that go far beyond any existing theory, and will presumably also give detailed conditions on the hadron Regge trajectories. The theory is an S-matrix version of the dual resonance model in which, however, unitarity and analyticity are maintained throughout, at each level of the topological expansion scheme. Although starting from very different ideas and premises the new theory has interesting similarities to Q.C.D. However, being an S-matrix theory it has no confinement problem, and it deals exclusively with physical amplitudes, or more precisely, with the parts of the physical amplitude corresponding to the various levels of topological complexity of the singularity structure. (Chew, Stapp)

An extension of the notion of the Singularities of an analytic function has been developed in the past several years by a group of Japanese mathematicians working with M. Sato in Kyoto, and independently by the French mathematical physicists Jagolnitzer and Bros, working with Stapp. The new concept, called "singularity spectrum" by the Japanese group and "essential support" by the French group, gives more information than the real

singularity structure, and knowledge of the singularity spectrum of functions allows one to know the singularity spectrums of products of these functions, and hence also the singularity structures of the products.

For some years now the problem of determining the analytic structure of the S-matrix has been blocked by our lack of understanding of the singularity spectrum of the S-matrix. The recently finished work of Kawai, Kashiwara and Stapp has used powerful recently proved mathematical theorems to derive the singularity spectrum of the phase space factors, whose singularities are closely related to the S-matrix, and to make on the basis of these results, a reasonable conjecture for the singularity spectrum of the S-matrix. This should clear the way for a satisfactory understanding of the analytic structure of the S-matrix. (Stapp)

Warnock's principal work is concerned with a new formulation of the crossing-unitarity equations in S-matrix theory, carried out entirely in terms of partial-wave quantities at complex l . The formulation leads to dynamical equations for construction of a crossing-symmetric unitary Regge theory, and also to a new definition of Reggeon exchange at low energy, which may be significant in phenomenology.

This physical view is somewhat similar to that of dual unitarization and the topological expansion (Chew, Rosenzweig, Veneziano et al.), but there is a heavier emphasis on exact crossing symmetry and analyticity properties. The main effort has been to extend the scheme to allow n coupled two-body channels with exact crossing symmetry. This is an essential step toward a dynamical study of particle symmetries and issues surrounding Zweig's rule, exchange degeneracy, and the explanation of approximate planarity.

A long-standing problem that arises with coupled channels with large mass differences is to solve the unitarity equations with overlapping left and right cuts. A very simple solution is obtained. It provides a tool for phenomenological study of

unitarity effects in systems such as the S^* resonance and NN. Further investigation will be carried out to investigate absorption in baryonium, as well as the S^* , with the help of this method. (Warnock)

Calculations with the Regge scheme described above require fast computation of Legendre functions in the entire space $\text{Re } \nu \geq -1/2, z > 1$. That turns out to be a harder problem than appears at first sight, since there are regions in which standard expansions converge too slowly. Using special devices to accelerate convergence, Warnock has written a computer program which calculates $P_\nu(z)$ and $Q_\nu(z)$ to 10 significant figures with good speed, over the entire space. (Warnock)

Warnock has studied a non-linear integral equation that arises in a simplified multi-peripheral model. The model has limited physical interest, but a detailed study of the equation has provided clues on how to proceed in computing solutions of more realistic crossing-unitarity equations. By a careful numerical study using the Newton-Kantorovich method, and an Ansatz of Ball-Zachariasen, a bootstrap solution of the homogeneous integral equation was found. This may be the first genuine example of a bootstrap solution of a non-trivial S-matrix model. (Warnock)

Field Theory of Hadrons

Non-Abelian gauge theories have been investigated to clarify the confining mechanism of quarks and gluons.

Mandelstam has been studying the problem of charge-monopole duality in non-Abelian gauge theories. It has been shown that, analogously to the ordinary magnetic vector potentials, one can construct "electric vector potentials," gauge-invariant combinations of which constitute the physical variables. However, while the Hamiltonian could in principle be expressed in terms of such variables, it would be very complicated; the definition of the potentials is thus not unique. The $O(3)$ magnetic gauge group is separate from the ordinary electric gauge group. One can also formulate the theory in terms of electric (Wilson) or magnetic (Nielsen-Olesen) flux loops; the property of the loops which identifies the electric or magnetic gauge group as $O(3)$ is studied. The possible phase of Abelian gauge

theories have been discussed and related to the above work. The relation between the Wilson condition, applied to loops at a fixed time, and the confinement of infinitely massive quarks has been studied; it is hoped that the analysis will be helpful in constructing wave functions for hadronic states with confined quarks. (Mandelstam)

The vortex loops of 't Hooft and Mandelstam's construction of the "magnetic Wilson loop" are being studied by Polchinski, a student of Mandelstam. Mandelstam's construction has been generalized from $SU(2)$ to a general gauge group. (Polchinski)

Kaymakcalan, a student of Mandelstam, has constructed infrared finite-energy, local gauge invariant states for the Abelian-Higgs model in 4 dimensions by using a smearing procedure for ultraviolet infinities. Extension to non-Abelian models is being made. (Kaymakcalan)

Moore, a student of Mandelstam, has been studying techniques for describing a nonrelativistic quark-antiquark bound state in the path-dependent gauge-invariant formulation of quantum chromodynamics. By regularizing the path-ordered exponential of the non-Abelian gauge field along a fixed path between the fermion field endpoints and then averaging over all paths with a suitably chosen weighting function one arrives at a sensible, physical meson wave function. The approach has been first to decompose the product of gauge fields order by order into pieces of definite symmetry, then select combinations of paths which cancel the ultraviolet divergences occurring when several fields are evaluated at a point, and finally estimate the weighting function by using the constraints imposed by measurability over the infinite dimensional space of paths and by the expected infrared (confining) behavior of the effective quark-antiquark potential. The expectation value of the energy between the trial meson states is minimized to determine free parameters in the weighting function. (Moore)

Rabinovici has studied the phase structure of the Abelian-Higgs lattice gauge theory at zero and finite temperatures. It has been found that for the Higgs boson in the fundamental representation of charge one, there exists two phases at zero temperature, a normal QED-like phase and a total screening phase incorporating both confining and Higgs mechanisms. For other representations, three phases form as a result of the separation of the total

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screening phase. Also a mapping has been derived of the theory into a theory of electric charges and magnetic monopoles. For finite temperature the charge-one theory does not undergo phase transitions, while in the case of higher charges one finds a transition into a plasma phase from both the confining and Higgs phases. This result is applied to the structure of the Hagedorn spectrum and also to the Weinberg-Salam model. (Rabinovici)

Samuel, a student of Bardakci, discussed the proper classical evaluation scheme for Wilson loops and presented a formalism to overcome the difficulties of a phenomenon called color zitterbewegung by resorting to integrals over anticommuting variables. He concludes that an infinite number of configurations contribute to an amplitude, each corresponding to fixing the color degree of freedom along the loop. (Samuel)

Samuel showed how calculations can be done for topological symmetry breakdown leading to confinement in the $(2 + 1)$ dimensional model. In the $(3 + 1)$ dimensional model, an explicit calculation cannot be done, but the behavior of monopoles was investigated and compared with Mandelstam's construction of the vacuum. (Samuel)

Bardakci has been working on the problem of constructing local field theories for the soliton solutions of various field theoretical models. Several theoretical models of current interest possess stable classical solutions called solitons, which can be thought of as new particles, which do not explicitly appear in the original Lagrangian. Partly in collaboration with his student, Samuel, he has been able to enlarge the original Lagrangian to take this new degree of freedom into account. The resulting theory is still local and of a fairly simple form, so it appears possible to investigate some important problems concerning the different phases of these theories. The method works for solitons, topological in character, for which the topological charge is point-like. It is applied to vortices in the $(2 + 1)$ dimensional Abelian Higgs model and to monopoles in the $(3 + 1)$ dimensional Georgi-Glashow model. (Bardakci, Samuel)

The Gribov copy problem was investigated and a new formulation of gauge theories was obtained.

Halpern constructed a large class of "field-strength copies" including all copies with finite

action, which occur entirely in the sector of zero winding number. Noticing that the notion of field copy is not gauge invariant, he generalized it to "action copy" and showed that the set of all action copies in the non-Abelian theories is roughly as large as the number of field copies in an average gauge times the number of possible gauge choices. He investigated the details of the inverse transformation from field strengths to potential in such gauges and found the field-strength formulation of gauge theory. The dual potentials can be easily introduced in this formulation, leading to a dual formulation of gauge theory. (Halpern)

Classical solutions of nonzero topological numbers were investigated in the gravitational theory. As analogs of Yang-Mills pseudoparticles, two classes of dual solutions of the Euclidian Einstein equations were obtained. These metrics are free from singularities and approach a flat metric at infinity. It is also suggested that the absence of torsion in conventional gravity could be dynamical. A gravitational Meissner effect might produce instanton-like vortices of nonzero torsion concentrated at four-dimensional points. (Hanson)

Friedan studied a generalization of the nonlinear sigma model in which the field takes values in an arbitrary compact manifold and in which the coupling is given by a positive definite Riemannian metric. He proved renormalizability of the perturbation series in $d = 2 + \epsilon$ dimensions and found the renormalization group equation. The fixed points are given by couplings corresponding to Einstein metrics and yield at $d = 2$ new theories which are asymptotically free at small distances. These generalizations capture the critical behavior of a large class of statistical systems: all those whose critical temperature goes to zero as the dimension of space approaches 2 and which can be characterized by a smoothly varying bounded order parameter. The renormalization group equation yields expansions in $\epsilon = d - 2$ for the critical indices and the equation of state and makes possible investigations of stability and crossover effects. The study of this sort of critical system is thus reduced to a collection of problems in differential geometry. (Friedan)

Chanowitz, Furman, and Hinchliffe found a simple prescription for γ_5 in dimensional regularization such that all non-anomalous Ward identities are respected, and such that the well-known

anomalies are reproduced in anomalous identities. They have tested the prescription to one-loop level. (Chanowitz, Furman, Hinchliffe)

In the massless free field theory, Eylon showed that if one treats the symmetry mode of the model in the same way as the gauge theories, the symmetry is not spontaneously broken. He concluded that the non-linear σ -model with the U(1) symmetry is essentially equivalent to the massless free field in the continuum. The U(1)-symmetry of this model is also not spontaneously broken. He gave indications that continuous symmetries of boson fields are not spontaneously broken in more realistic and unsolvable models. (Eylon)

Furman, Hinchliffe, and Haber have been investigating QCD corrections to parton processes for which the renormalization group methods are not applicable, such as at high transverse momentum hadron scattering. In particular, they are trying to verify the properties of factorization and universality of mass singularities for quark-quark scattering. They are in the process of calculating high-energy quark-quark scattering at fixed angle to order g^4 in QCD with careful attention to non-leading terms. (Furman, Hinchliffe, Haber)

Higher energy and short distance behaviors of hadrons were investigated in the quantum chromodynamics.

Suzuki investigated how significant numerically the effect of instantons is in electron-positron annihilation, the anomalous magnetic moment of a heavy quark, and in the potential between a heavy quark and a heavy anti-quark. The calculation was done by expanding the dressed quark propagator in the instanton field and retaining the lowest order terms. The numerical results depend critically on the cutoff value of the instanton size, but it is concluded that the part of instanton effects which is calculable with reasonable reliability is too small to be clearly detected by experiment. The part which may become large at long distances cannot be estimated accurately with the present knowledge of quark confinement. (Suzuki)

For deep inelastic scattering, Flory, a student of Suzuki calculated without instanton size cutoff the instanton contribution to the "x-moments" of the hadronic structure functions by replacing free internal quark propagators with propagators in a

background instanton field. He found that the effects should become observable for higher moments of these structure functions. (Flory)

Fleishon, a student of Chanowitz, calculated the Compton scattering matrix element in two-dimensional quantum chromodynamics and, by looking at various kinematic and photon mass limits, has found that the use of parton model ideas outside the region of their theoretical validity is justified, that the "photon" is totally dominated by the negative parity mesons in the theory with the amplitude described by Regge exchange ideas in the forward limit, and that dimensional counting rules which characterize the fixed angle high energy scattering are modified by small factors connected with confinement. (Fleishon)

Theory of Weak Interactions

Chanowitz, Furman, and Hinchliffe investigated the weak interactions of quarks and leptons which are much heavier than 100 GeV, the mass scale of the W and Z bosons in the standard SU(2) x U(1) model. For critical masses, which they computed, the weak interactions cause strong binding and scattering of ultra-heavy fermions. They also found all the low energy processes of ordinary, light fermions which would received one loop radiative corrections as large as the leading order tree diagram if ultra-heavy fermions exist. One of these processes implies an experimental upper bound of 500 GeV for a heavy lepton in an isodoublet with a massless or very light neutrino. (Chanowitz, Furman, Hinchliffe)

Chanowitz and Fleishon in collaboration with Cahn (UC-Davis) have computed the rate for $Z \rightarrow H\gamma$ because it could provide a very clean signal in $e^+e^- \rightarrow Z \rightarrow H\gamma$. Only the monochromatic photon need be detected. This is a decided advantage since the decays of the H could be difficult to reconstruct. The amplitude vanishes in lowest order and occurs by virtue of W and fermion loops, which we computed. The main contribution is from the W loop, unless there are several generations of fermions at or above the Z mass. In the latter case the rate for $Z \rightarrow H\gamma$ would enable us to determine the number of such heavy fermion species. (Chanowitz, Fleishon)

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Haber investigated in collaboration with Kane (University of Michigan) a modification of the standard Weinberg-Salam $SU(2) \times U(1)$ model of weak interactions. Specifically, they studied the model with two Higgs doublets such that the ratio of two non-zero vacuum expectation values, β , obeys the condition $\beta \ll 1$. In addition, by imposing an appropriate discrete symmetry on the Higgs potential, they could insure that fermions couple only to the Higgs doublet with the small vacuum expectation value. The result is that the smallness of the fermion mass scale as compared with the mass scale of the intermediate vector bosons is a result of the smallness of one of the vacuum expectation values. In addition, they found some of the Higgs-fermion couplings enhanced by a factor of β^{-1} over those in the standard model. This would make it experimentally feasible to see Higgs effects in the near future. Currently (with some assumption about Higgs masses), one can only restrict β to be larger than 10^{-2} based on available experimental evidence. (Haber)

Suzuki calculated gluon corrections to the semileptonic decays of heavy quarks to the order g^2 . It was found that in spite of the opening of gluon emission channels, the total semileptonic decay rates decrease, as much as 35% for the charmed quark decay, and that the energy distribution of the emitted lepton is softened and is closer to what has been observed for the charmed mesons produced in the electron-positron annihilation. Therefore, a relatively small value (8 — 9%) for the observed semileptonic branching ratio of the charmed meson decays may be attributed to the suppression of the semileptonic decays as well as to the small enhancement of the nonleptonic decays. (Suzuki)

Oliver has worked mainly on the weak interactions of strange and charmed particles, semileptonic and nonleptonic. Specifically, he has concerned himself with the large $SU(4)$ -breaking in neutrino-production of charmed baryons, the relative magnitude of S- and P-waves in nonleptonic hyperon decays, and the search for tests to confirm or exclude the existence of right-handed currents. He also has been studying the lowest order radiative (gluon) corrections to the current-current interaction—"hard" gluons, and also the vertex correction, self energy, and one-body operators, including "penguin" diagrams. (Oliver)

Works were continued by Jackson and his student deForcrand on the properties of heavy quark-antiquark systems in the nonrelativistic limit, and corrections to that limit. Subjects studied were the effects of tensor forces and other first-order relativistic corrections on the Wigner-Kirkwood sum rules (used originally in estimating total widths of the χ states in charmonium), and corrections to the relations between Γ_c and $|\psi(0)|^2$ for the 3S_1 states. A detailed survey was made of the theoretical spectroscopy of charmonium for the Tokyo Conference. Some preliminary work with deForcrand was made on systematics of weak decays of charmed mesons and baryons, and also on the "classical" problem of an electron interacting with a magnetic dipole made of magnetic monopoles. (deForcrand, Jackson)

Hinchliffe, in collaboration with Hendry (Indiana University), worked on the spectroscopy of baryonium states. They attempted to reconcile the experimental candidates with theoretical predictions based on the assumption that they are $qq\bar{q}\bar{q}$ bound states. Several experimental tests were suggested to test this assumption. (Hendry, Hinchliffe)

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Statistical Physics

Studies of interaction waves have been made by Watson and his students, Lerner and Meiss. In particular, wave propagation with non-linear couplings have been studied by using the methods of statistical mechanics. Examples of such waves with nonlinear couplings include plasma waves, water waves, laser beams propagating through matter, etc. The dynamical theory is expressed in Hamiltonian form. Hamilton's equations are used to obtain Langevin and Fokker-Planck equations. From these the transport of energy in wave-number and coordinate space can be studied. Numerical integration of the dynamical equations provides a test of approximations used in obtaining a Langevin and transport equation. Detailed analysis for internal waves has been completed. Accomplishments include numerical indications of complete integrability for the internal wave soliton system and for a system describing nonlinear wave-wave interactions. (Lerner, Meiss, Watson)

Morrison's work has centered on the question of ordering in two dimensional macroscopic systems. He has demonstrated the existence of a many-vortex phase of the two dimensional Bose fluid. At lowest order the partition function of this system factorizes into two parts. One part characterizes the fluid as a quasi-particle system and the second part reveals a system of interacting vortices. Such factorization was suggested on heuristic grounds by Kosterlitz and Thouless and was more recently studied in the context of a phenomenological hydrodynamic theory by Nelson and Kosterlitz. He finds that the path-integral representation of the many-body system leads directly to this picture. One can go further, however, and obtain the evolution equations of the individual pseudo-particles, the vortices. These evolution equations are first order and have the form of a dynamical system studied by Nambu in a different context. (Morrison)

Samuel introduced a new method in two dimensional statistical mechanics, such as the Ising model, the free-fermion model, and a class of close-packed dimer problems. He used integrals over anticommuting variables to relate the problems to fermionic-like field theories. He was able to relate hitherto unrelated models, organize unruly algebra, and make rapid calculations, often in a few steps. A series of graphical rules was derived which allowed the computation of partition functions and anticommuting variable correlations by solving miniature dimer problems. This provided a quick and simple graphical approach. Many models were solved by drawing a few diagrams. An easy method was derived for obtaining the vacuum expectation value of an arbitrary product of Ising spin variables. (Samuel)

A new two-dimensional statistical mechanics model was solved using the methods described above. It is a general model with 18 free parameters and includes many Ising-like spin systems and ferroelectric systems as subcases. It is probably the most encompassing two-dimensional statistical mechanics model ever solved. Simplifying tricks reduced the algebra by a factor of about seven. (Samuel)

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Accelerator Theory

PEP Accelerator Studies

Work has continued on problems of coupling and emittance growth in PEP due to various types of misalignments. Improved formulas have been derived for chromaticity calculations. These improvements are being incorporated in the SYNCH computer program. Various studies were directed toward chromaticity correction problems. Sextupole configurations were developed and studied over a wide range of operating parameters. Control programs were developed for operation control of the PEP dextupoles. The theory of non-linear chromatic effects was developed with the emphasis on obtaining efficient computational algorithms for calculating and controlling non-linear chromaticity.

Experiments were conducted at SPEAR to investigate the flip-flop beam-beam effect to ascertain the potential limitation which this effect would have on PEP beam intensities. The understanding of the instability of one beam due to the presence of the other is a continuing investigation.

With regard to future additions to PEP, a new conceptual design for a possible PEP proton-electron system has been developed. It includes a 300 GeV superconducting proton ring in the present PEP tunnel, situated above and below the present electron ring, which it crosses in four of the six straight sections. The beams cross at a small angle, and are separated beyond the interaction region by a septum-magnet system acting on the proton beam. Crossing of the electron ring by the proton ring, rather than the reverse, is chosen in order to avoid synchrotron radiation in the experimental areas, which would result if the electrons were bent away from the protons. A preliminary set of general parameters and lattices has been determined.

A lattice system for a small electron storage ring to cool protons in the Fermilab accelerator was designed. The ring includes wiggler magnets to

shorten the synchrotron-radiation damping times, and thus better cool the protons. This type of research has potential application to a proton-electron facility in PEP, where cooling protons by an electron storage ring could help make the protons better able to tolerate the beam-beam effect that occurs at the collision points between the proton and main electron storage ring, and thus lead to higher luminosity.

Stochastic Cooling

Development of stochastic cooling techniques have been undertaken in order to produce more intense beams. Experiments will be carried out on the newly constructed electron cooling ring at FNAL with the immediate purpose of contributing to the design of a $p\bar{p}$ colliding beam facility at FNAL. The role of the Theoretical Group has been to assist in the design of the experiment, participate in the development of design of the facility in collaboration with FNAL and other laboratories and to develop a theoretical framework, including a computational program, which will help to interpret results of the experiments.

Transport of Intense Beams

An analytic study of the limitations encountered in attempting to transport high current beams without degradation in beam quality was carried out by the technique of examining the linearized Vlasov equation for unstable modes in a quadrupole transport channel. A number of regions of instability have been identified in the general parameter space, the most serious ones corresponding to a time

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depression of a factor of two or more due to the space charge force of the beam on itself. Excellent agreement with a simulation computation by I. Haber of the Naval Research Laboratory of a particular mode isolated from all others was obtained (usually a number of modes are unstable simultaneously, making comparison almost impossible). Aside from the verification of the theory, we believe that the agreement shows that simulation computations should be valid for more general situations.

Some of the previous work has been concerned with "heavy-ion fusion," a national program of DOE, of which the LBL program is a part, to explore the design of high-energy heavy-ion accelerator systems as igniters for inertial-confinement fusion power plants. Conceptual designs of systems based on the induction linac, the rf linac, and the synchrotron have been studied with particular emphasis on six-dimensional phase space volume requirements and on ion dynamics in the induction linac. In connection with this work D. L. Judd gave eight general lectures and three topical lectures to a

variety of audiences and served on the committee to evaluate systems designs developed at all the National Laboratories participating in the program.

PHYSICISTS

A. Garren
L. J. Laslett
L. Smith

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**III. COMPUTER SCIENCE and
APPLIED MATHEMATICS**



Teleconferencing and telecommunications via the ARPANET are used extensively in collaborative research with DOE laboratory and university contractors in research planning and review management. Carle Quong, CSAM Department Head, and Lesta Nadel, Administrator, respond to messages via electronic mail on the network (see ARPANET, page 59). XBB 791-740

III. COMPUTER SCIENCE and APPLIED MATHEMATICS

The Computer Science and Applied Mathematics (CSAM) Department conducts basic and applied research in a variety of computer science and mathematics disciplines. In addition to the development of computational and information management tools applicable to a wide range of laboratory and DOE programs, CSAM staff collaborate with or provide applications support to other research and support groups in almost every division of the laboratory.

Activities highlighting research, development and demonstration programs and projects during 1978 included:

- A demonstration of the Socio-Economic Environmental Demographic Information System (SEEDIS) sponsored by DOE's Office of Energy Research, in Washington, D.C. in September. The demonstration of SEEDIS was seen by over 100 attendees from a wide variety of federal agencies.
- Participation in the DOE Applied Mathematical Sciences (AMS) research planning and review activities, including serving as host for the AMS Research Planning Conference held in Berkeley in April.
- LBL/DOE sponsorship of the Third Berkeley Workshop on Distributed Data Management and Computer Networks. The workshop was attended by more than 300 participants from six nations, in August.
- Implementation of a prototype homogeneous minicomputer network as the basis for the development of distributed information

techniques. This work is jointly supported by DOE and the U.S. Department of Labor as a logical extension and enhancement of SEEDIS.

The CSAM staff is comprised of over 80 computer scientists, mathematicians, engineers, physicists, computer technicians, and administrative personnel. UC Berkeley faculty, post doctoral appointees and graduate students are included in the staff, adding to an environment supportive of the exchange of ideas and experiences. CSAM sponsors workshops, colloquia and seminars and provides supervision of graduate students in the master's and doctoral programs in applied mathematics and computer science at UCB.

Research, development and demonstration areas in 1978 included:

- SEEDIS and component database projects, advanced computer system development
- Data management research
- Applied mathematics and computational modeling
- Computer graphics.

CSAM collaborates with and provides applications support for other LBL research groups, including high energy physics, accelerator design, epidemiological studies, biomedical applications, and geochemical simulation studies. CSAM also provides assistance in laboratory support functions such as program budgeting and accounting, bibliographic information, personnel management, and project planning and management.

RESEARCH

Applied Mathematics

Research in applied mathematics includes the program categories of applied analysis, computational mathematics, and software engineering. This research emphasizes the problem areas of numerical studies of laminar and turbulent combustion and fluid flow, numerical computation of two-phase flow in reservoirs, numerical methods for elliptical equations, capillary phenomena, image reconstruction from projections, and mathematical software development. The staff also provides consulting services to LBL staff members and supervises the Computer Center mathematical software library.

Applied Analysis

Work in applied analysis emphasizes the numerical solution of hyperbolic partial differential equations, development of numerical methods applicable to problems in fluid flow and combustion, the study of capillary phenomena, the reconstruction of an image from projection data, and the analysis of the equations for two-phase flow.

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 perturbed by a singular (parabolic) perturbation.

These studies are of substantial importance because:

—discontinuous and nearly discontinuous so-

lutions 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.

It is anticipated that research developments will prove useful in a number of physical applications, including turbulence theory, multi-phase flow and turbulent flame propagation.

Numerical Studies of Laminar and Turbulent Combustion and Fluid Flow—A detailed analysis of the accuracy of vortex methods near a boundary was performed. This is an important question in applications to combustion theory. On the basis of this analysis a new higher accuracy version of the vortex creation operator used in our programs was developed.

Glimm's method for reacting gas flow was extended by including a deflagration with given velocity in the solution of the Riemann problem. This reduces the amount of computing labor required for problems in which a reaction proceeds slowly.

Capillary Phenomena—Work continued on the capillary free-surface problem. New analytic estimates for the shape of pendent liquid drops were obtained, improving previous estimates by an order of magnitude. These improved estimates made possible a proof of results on convergence to the singular pendent drop as the vertex height extends downward to infinity. The design of related physical experiments to explore questions of stability may now be carried out.

The stability of capillary surfaces in an inverted circular cylindrical container with a spheroidal bottom was studied for the case in which the bottom is not completely covered by liquid. New results were obtained for the limiting form of the boundary conditions for neutral stability for the case of perfectly wetting liquids. In addition, the analytical bounds which were developed earlier for the limits of existence for capillary surfaces on curved domains were found to be in close accord with the critical values observed from numerical experiments on an ellipse. The block successive over-relaxation-Newton method and the generalized conjugate gradient method for solving the capillary surface equation on a uniform square mesh in a square domain were compared. Some of the numerical methods which have been 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 bi-quadratic elements.

Image Reconstruction from Projections—Improvements were made in algorithms for reconstructing the image of an object from projection data of its transverse sections. A convolution algorithm for arbitrary location of the angles of view was obtained. This is particularly relevant in the case of limited angles of view. The main result is that in the noise-free case there is no inherent geometrical limitation to reconstruction. The effect of noise has been analyzed, and codes which compute the optimal filters for an arbitrary set of angles have been written and run. New reconstruction algorithms are under development for a variety of non-invasive detection problems including computerized tomography.

Computational Modeling

Work in computational modeling centers on numerical studies of combustion and fluid flow and on the numerical computation of two-phase flow in reservoirs.

Numerical Studies of Laminar and 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 hindered application of other numerical techniques to the study of physical combustion phenomena. Unlike others, these methods 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.

A pilot program for studying the flow in a motored internal combustion engine was written, using a hybrid method which incorporates random choice and vortex methods. This program is being used by several other groups. Detailed documentation of this program has been written and published. A second hybrid program has been written by Gary A. Sod at North Carolina State University.

Numerical Computation of Two-Phase Flow in Reservoirs—The Buckley-Leverett equation, which describes two-phase immiscible flow in porous media such as petroleum reservoirs, was solved numerically for the one and two dimensional cases excluding the effects of capillary pressure and gravitation. The Piecewise Sampling Method was used to develop a numerical technique for the sharp tracking of the discontinuities, such as the interfaces between immiscible liquids, that occur in these flows. This method is unconditionally stable, approaches being first order accurate, and propagates discontinuities (shocks) sharply without dissi-

pation. The sampling method introduces a small amount of statistical uncertainty into the solution, but this is within the accuracy limits imposed by the discretization.

It was found that the method is computationally efficient for solving a numerical example of the five-spot configuration for the water flooding of a petroleum reservoir. In numerical experiments the van der Corput equidistributed sampling procedure was compared with a procedure containing a random element. The former sampling was found generally to give more satisfactory results.

Computational Mathematics

Work in computational mathematics focuses on numerical methods for 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.

Numerical Methods for Elliptic Equations—An updating technique was developed for quasi-Newton methods for solving highly structured systems of nonlinear equations, such as those that arise in the numerical solution of elliptic partial differential equations. The technique allows a known or desired structure of the Jacobian matrix to be imposed during updating. A particular application to a neutron diffusion eigenproblem in nuclear reactor analysis has been solved successfully.

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 systems 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 interior mesh points.

Mathematical Software and Consulting Services

In addition to its research activities, the Applied Mathematics Group supervises the management of the Computer Center software library, which covers essentially all the major areas of contemporary numerical methods. In connection with this activity, consulting services to Computer Center users is provided in numerical mathematics, applied analysis, and statistics.

Several areas of the mathematical software library were strengthened by the incorporation of an extensive, general purpose program library (SANDIA), and several state-of-the-art software packages (EPISODE, GEARIB, PSASVA3, GMA, NNLS). The subscription to a major commercial software vendor (NAG) was initiated, which should provide a wider choice of routines for most Computer Center users.

The efforts in software development continued. An especially useful set of solvers, based on the method of capacitance matrix, was developed for the solution of the Helmholtz equation on irregular planar regions.

The consulting service in numerical mathematics, applied analysis, and statistics was expanded significantly. Assistance was made available for problems arising from virtually all stages of a

program's development. Services such as problem formulation, selection and use of software, and analysis of failures were routinely provided.

A library improvement project was initiated. The objective was to provide the software library with a clear structure and quality documentation.

There were three tasks involved: the compilation of a complete catalog of mathematical software available locally, the establishment of a "core" collection of frequently used software, and the preparation of a comprehensive user's guide. This project, when complete, will make the software library much easier to use.

Advanced Systems

Throughout 1978, Advanced Systems conducted research and development in distributed systems technology. A distributed system is a collection of computing components (e.g. software, cpu's, memory, printers, terminals, etc.) connected by a communications network. An integrated distributed system is a distributed system which may be regarded by the user as a single, unified computational resource. This year's effort was primarily concentrated on techniques for making such systems easy to use, control, and understand. As a measure of success, Advanced Systems personnel were assigned leadership roles in both the DOE-AMS sponsored distributed systems research program and in the ANSI technical committee on system command languages (X3H1). Active participation in the ANSI Fortran technical committee (X3J1) continued.

Four development projects were undertaken—the software tools project, the network front-ending project, a prototype local network implementation, and connection to the ARPANET. These provided basic tools for conducting distributed systems research as well as initial design criteria for a prototype integrated distributed system. University based research into file migration in a distributed environment was also supported.

Software Tools

The software tools project (started in October 1977) has as its primary goal the implementation of standardized software development tools on a

variety of different systems. These provide powerful capabilities (editors, text formatters, code converters, etc.) in a stand-alone environment, and form the basis of a prototype integrated distributed system when the host machines are connected by a network.

The base software was obtained from Addison-Wesley publishers and installed on three local systems. Through contact with other purchasers, implementations on a total of 38 distinct systems were located. Contact with these individuals was expected to evolve into an international software tools user group by mid 1979.

To maximize utility, three types of manuals were developed — novice, journeyman, and system maintainer. These were made available both as printed manuals, and as part of an online help facility. In addition, a "cookbook" was developed as a guide for installing the tools on new systems, and a guideline was created for developing and documenting new tools.

Once the base software was installed and documentation completed, a portable shell was written. A shell, also called a command language or job control language, is the software which transforms user requests into system actions. Thus a shell forms the primary interface between the user and the system. The existence of a common shell on all systems removes one of the most significant barriers to resource sharing through networks. By late 1978, work on two important extensions to the shell had begun. These are the ability to capture user requests and system responses for statistical analysis, and extension of the shell syntax to include access to remote resources.

In December 1978 a DOE-wide working group on user interface methodology was formed within the DOE-AMS program. Its purpose was to use the software tools to make computational resource sharing easier in DOE. Participating DOE sites included ANL, BNL, LBL, MIT, NYU, PNL, UCB, and UCLA. Communication was maintained on a daily basis through the "planet" computer conferencing system.

For 1979, software tools development effort will be focused on extending the primitive system functions to a distributed environment, a source code maintenance tool, and a portable hierarchical file system. Extending the system primitives to a distributed environment requires development of a kernel emulator to provide access to remote resources. Kernel design will be carried out in close collaboration with developers of NLTSS at LLL, and with developers of the prototype local network at UC Berkeley. NLTSS is designed to be a network operating system from the ground up. As such it has especially simple and elegant mechanisms for accessing remote capabilities. The software tools kernel will emulate these mechanisms on arbitrary systems.

A source code maintenance tool is essential for distributing and maintaining portable software. A review of existing source code maintainers is planned so that one can either be purchased directly or developed from the best features of several.

A portable hierarchical file system is another necessity for an integrated distributed system. A hierarchical file system allows the user to arrange files into directories of related items, greatly reducing the mental effort of associating the contents of each file with a single name. Code for this project was obtained from the University of Arizona and will be modified to be more readily portable. A common file naming scheme allows users to easily access files at remote sites without having to remember the arbitrary syntactical conventions at each host.

Network Front-Ending

The network front-ending project has as its primary goal use of a dedicated minicomputer to translate user requests into the native tongue of a

remote computational resource. In contrast to the software tools approach, front-ending requires no additional software development on the target system. Instead, a high-level language is provided in the minicomputer by which the user specifies dialogs or "agents" which handle the irksome aspects of translation automatically.

The "agents" listed below were developed on the LLL "network access machine" (NAM), a PDP 11/70 running UNIX with software originally obtained from the National Bureau of Standards:

- DOC—Online read access to NAM agent user documentation.
- NEWS—Latest news about NAM agent developments.
- NIC—Access to the ARPANET Network Information Center
- OPEN—Connect and log in to another host.
- PARAP—Access to the "Population-at-risk-to-air-pollution" database.
- PLANET—Access to a computer conferencing system.

The NAM environment includes a monitoring capability for tracking use of agents. For 1979, work will continue on emulating the software tools shell on various host machines. Also, another piece of existing software for UNIX minicomputers will be imported to the CSAM ARPANET machine. It is the "Rule Directed Intelligent Transaction Agent" (RITA) developed at RAND. Its approach to front-ending allows experimentation with AI techniques, leading to more intelligent user agents.

Prototype Local Network

By late 1978, a prototype packet switched local network was under development at UC Berkeley with support from the DOE-AMS program in distributed systems. This network will provide a highly transparent form of resource sharing by extending local file naming conventions to a multi-host environment. The technique, based on the UNIX file pathname concept, consists of allowing file names to be optionally qualified by the name of the system on which the file resides. Programs thus will be able to process remote files by simply using

changed file names. All system requests will be implemented for these remote references, allowing existing utilities to remain unchanged. Interprocess communication channels which can be named by a creating process will provide an efficient mechanism to pass data between cooperating processes. Finally, a completely new form of broadcast will be implemented to provide efficient communication between a processor and any subset of a previously designated set of processors. This broadcast mechanism is being used in a design of the distributed version of the INGRES database system.

By mid 1979, the network kernel will be coded and debugged. Error free communication "channels" will be operational, as well as a kernel implemented notion of process "location" in the network name space (possibly differing from the machine on which the process is executing). The network will also support both message oriented and stream oriented communication, routing, broadcasts, a low overhead flow control algorithm, and a security mechanism. The security mechanism will be based on a distinction between clusters of processors within which user identifications are global, and remote processors on which access must be validated using encrypted "login" messages. The network kernel will include drivers for a number of very high speed devices, including a new ring communication device which can be connected to multiple processors.

The PDP-11 UNIX system will be modified to interface to the network kernel. Because the network handles all communication activities, this is not a very difficult problem. In fact a similar kernel will be developed for the PDP-11/780 VMS system. It is expected that the set of devices useable on the network will expand, and that support for non-local protocols, for example ARPANET and DECNET, can be provided. Eventually, a fully distributed network operating system supporting many types of machines and processing environments is expected.

ARPANET

The first two months of 1978 were spent stabilizing the programs on the LBL 6000/7000s. This included "freezing" the ARPANET programs,

after incorporating various timeout mechanisms to detect inactive connections. All non-ARPANET related codes for the CDC machine were delivered to the LBL computer center for maintenance. Both design and user documentation were provided as well as personal instruction in maintenance techniques.

With this out of the way, attention focused on ARPANET software for the PDP 11/34. Extensive modifications and additions were required to provide better security checks, adaptation to new peripherals, and system optimizations developed by UC Berkeley. Additionally, several user programs were partially or completely rewritten, and assorted new codes were developed. A large amount of new software was imported via the ARPANET. Effort was also expended in assisting the LBL computer center in bringing up their PDP 11/70, and in coordinating and assisting UC Berkeley in attaching their 11/70 to the ARPANET.

Research

In addition to development of research tools, Advanced Systems supported University based research in distributed file systems. Work on the automatic management of file migration between levels of a storage hierarchy, e.g. between disk and tape, or between sites on a computer network was started. The goal was to relieve the programmer of the need to explicitly control the location of files by providing the illusion of a single level file store.

At the present time, effort is concentrated on collecting traces of file access from several sites. The traces will be used for trace-driven simulation studies of proposed memory management policies. This trace driven modeling will be combined with statistical analyses to provide both a practical and theoretical understanding of the problems involved.

Long-term file access measurements are currently available only from SLAC. A variety of possible long term file migration algorithms were tested. The results of both the analysis and testing are available as LBL reports. Presented in one of these reports are some algorithms suitable for implementation in existing and future file systems.

Data Management

Summary

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 will be primarily concentrated in the following areas:

- *Human Oriented Interfaces*—Development of logical data models and query languages that minimize the burden on users to have a detailed knowledge of physical data structures. Also involved is research on techniques to accommodate users who are not computer specialists, who cannot afford the investment of learning new programming languages. This includes production of data dictionary/directory techniques for organizing summary information on very large databases.
- *Specialized Access Methods*—This area includes the study and development of techniques which are particularly suitable for very large databases. Emphasis is on techniques for encoding data in a way which facilitates efficient search of the encoded data, and on techniques for re-organizing databases with inherent redundancy into efficient, non-redundant data structures.
- *Query Optimization*—Focuses on development of techniques for choosing an optimal way of accessing a database given the data characteristics and its physical organization. Such techniques will spare the end user the need to make detailed data access queries in terms specific to the complex characteristics of physical database organization.
- *Distributed Database Techniques* — Research in this area facilitates the development of an environment in which related databases

existing on disparate hardware/software systems can be integrated into a single system.

Data management tools are necessary to many applications which otherwise support their own data management in an overlapping and wasteful manner. Some of the application areas important to DOE which benefit from data management tools are as follows:

- *Data Analysis and Modeling* — This includes statistical analysis of data gathered from the monitoring of experiments and the development of models based on the analyzed data.
- *Data Display* — A large number of applications require reports, graphical displays, or interactive access. An underlying data management facility is required to generate these displays.
- *Data Selection* — Selection of a subset of a large data collection is often necessary. Efficient database retrieval can avoid expensive creation of special purpose software for each application.
- *Data Sharing* — Databases are valuable resources which should be made available to a large number of users in distant and dispersed geographic locations. Additionally, since databases are growing so large, it is not cost effective to require that all data reside on the same machine. Computer networking is emerging as the most promising method of achieving data sharing. However, extensive research and development is required to accommodate the diversity of systems on which databases reside.

It is in DOE's programmatic interest to support research in these areas. The process of decision making on energy and environmental issues depends heavily on processed information. DOE requires data management facilities that can handle

large databases (on the order of ten billion characters), facilities designed to interface to existing software, which can handle scientific data efficiently, and which are oriented to non-computer specialists. By and large, currently available commercial systems do not emphasize and poorly support these needs.

The following sections describe in some detail the work accomplished during 1978.

Logical Data Model and Query Languages

As a result of preliminary work performed during 1977, research is focussing on a logical data model which is rich in semantics (the entity-relationship model). This model facilitates the definition of a query language independent of the physical organization of data, with semantics closer to those known to the user. During 1978 the model was refined to include structures to enhance its semantic clarity. A preliminary data definition language (DDL) was defined for specifying databases for this enhanced model. In parallel, the query language (called CABLE), specified in general terms previously, has been enhanced to include many desirable features. Several existing query languages were studied and compared with CABLE. A stable version of the language is expected in early 1979.

Translation Between Query Languages — Researchers conducted the experimental translation of a version of CABLE into QUEL — the query language of the INGRES relational data management system. This experiment proved the generality of the research approach by establishing a correspondence between the entity - relationship model and the relational model. The translator was not interfaced to INGRES, but this can be done when access to INGRES is facilitated. This technique can provide a way to experiment with CABLE before other parts of the system are implemented.

Installation of a Parser Generator—In order to experiment easily and efficiently with new versions of query languages, a parser generator (meta-compiler) was installed on the VAX/VMS system. The parser was received from Lawrence Livermore Laboratory. It accepts a context-free syntax description and generates efficient LR(1) parsers.

Initially, a parser produced by the generator contained only the syntactic component. The parser generator was modified so that the semantics of the target language could be specified with the syntax. It now produces parsers that contain the semantic routines along with the syntactic component.

Data Dictionaries/Directories

When dealing with data contained in very large databases, it is particularly difficult for users to remember (or even find out) which summary matrices have been created and the names for those matrices with aggregate elements. Summary data is necessary because it is not possible to efficiently search a very large database for each possible query.

A tool for organizing summary information in the form of a data dictionary/directory which organizes categories of information in a hierarchical form will be developed. A user who is not familiar with available databases can start at the top of the D/D hierarchy as a help facility, and successively refine his area of interest, to the point of specifying a query. The more experienced user could proceed from an intermediate node of the hierarchy. Implementation of the dictionary/directory mechanism will allow experimentation and user feedback. An added advantage of this approach is that it integrates naturally with an access method for summary data, as explained below.

Special Access Methods for Very Large Databases

Although there are many known conventional organizations and access methods for very large databases (VLDB's), they all add to the storage requirements for efficient searching of the data. Research is therefore focussing on techniques which are efficient in storage but still permit "reasonable" data searching. Three such methods have been identified.

The first method, which we call a "computation scheme" is suitable for databases that have many of the data values repeating, such as values for "sex" or "race". The idea is to "factor out" these data values into a dictionary and leave only non-repeating

values. To access the data organized in this way one starts with the dictionary and computes the locations of the desired data values in the database. This method fits directly with the data dictionary/directory described above and can be considered an extension of it. Work on the design of this method has already started.

The second method involves an "encoding scheme" that permits a search of encoded data rather than decoding it before searching. The gain is in storage of the data because of the encoding, and the search of a smaller amount of data. A few existing schemes have been studied and their suitability to this purpose is being investigated. This scheme is also related to the third method, which is called "vertical partitioning".

Vertical partitioning is intended to provide a mechanism for searching only the data relevant to the query. Conventional methods organize data into records, and searching on a condition requires examining entire records. In the "vertical partitioning" method, data is organized by individual fields. Each data set contains the data of a given field for all records. Thus, to search on a condition, only the data sets of involved fields have to be examined. There are trade-offs involved in using such a method, and experiments with them will continue in 1979.

Study of Requirements for Portable Software

One of the goals of the data management research program is to develop software that is portable to other machines and operating systems. Unlike application programs, software for data management interacts with the operating system at a much lower level, especially for input and output. Experiments during the year included an effort to

install on the VAX/VMS system a data management system developed at Lawrence Livermore Laboratory. The task proved too tedious and expensive (in terms of effort). However, the experience pointed out pitfalls that should be avoided in designing transportable software.

Modular Design and Inter-module Communication

Another goal of a data management system design is flexibility for the following purposes: easy interface to existing software, easy addition and deletion of capabilities, and expandability to a network environment. Several options were considered and the "data stream" design was evaluated as the most desirable. It offers autonomy of modules, and their interconnection through separately defined control networks. Detailed design of the method is in progress and is coordinated with the work of the distributed systems group.

Ventilation Database Support

Researchers in data management have continued to support the Ventilation Project jointly with the Energy and Environment Division. The purpose of the project is the development of ventilation databases and software for their access using the INGRES data management system on a DEC PDP-11/70. The effort included defining the logical structure of the databases, support in the development of data entry programs, and the formulation and evaluation of search routines. Data entry programs are needed for efficient and correct loading of the database and search routines are needed for prototype reports and interactive keyword search. CSAM personnel continued in the role of consultants on the use of the INGRES system.

Computer Graphics

Work in computer graphics included development of graphics software, evaluation of computer graphics hardware, image analysis, and vision research.

The Integrated Data Display System (IDDS) is a general scientific graphics package widely used at LBL. In addition to routine development, maintenance and documentation, new areas were addressed in investigation of generalized coordinate transformation techniques, contouring of sparse data and three dimensional hidden line algorithms. In particular, the generalized coordinate transformation concept is intended to allow all types of plotting to be done through complex, non-linear transformations, for example map projections. This preliminary work resulted in displaying a contour plot projected through an Aitoff-Hammer map projection.

GRAFPAC is the low-level, device independent graphics driver system developed at LBL. A great deal of work was done on GRAFPAC in the areas of investigating and implementing user interfaces to color and raster scan devices. In conjunction with GRAFPAC development, work was done toward defining a standard graphics interface. Most of the standards effort is involved with the ACM SIGGRAPH work on the 'CORE' standard.

Research in the area of vision is being done investigating the connections between computer and human vision. The areas of direct relevance to computer graphics involve the study of color space transformation, uniform perceptual color spaces and human visual characteristics in relation to the design of improved display algorithms.

Work in image processing focuses on attempts to use remote sensed imagery of study earthquake prone geographic areas; and on biomedical applications including three-dimensional display of a beating heart, reconstructed from x-ray data. In conjunction with the latter, work on color displays

of smoothly shaded, three dimensional objects was accomplished. Exploration of the use of video frame buffers for video art and bio-feedback applications was also undertaken.

Technical specifications were developed for a high quality color information display system suitable for rapid display of color coded thematic maps and charts. This is directed toward enhancing the hardware resources supporting the SEEDIS project. Other SEEDIS support work included further development of CHART, a program for interactive analysis and graphical display of tabular data; of MAPEDIT, a program for manipulation of geographic files; and of CARTE, a program for the interactive design and display of thematic maps.

Researchers working in the area of computer graphics serve as a resource available to computer users throughout the laboratory and actively participate in the following forums:

- DOE Computer Graphics Forum
- SIGGRAPH/ANSI Graphics Standards Meetings
- Auto-Carto III
- Harvard University Computer Graphics Week
- ACM/SIGGRAPH '78
- Optical Society of America Meeting
- NRCC Workshops on State-of-the-Art Computer Techniques
- COMTECH, presentation on color perception
- Image Processing, Human Vision and Computer Graphics Seminars
- Council on Social Graphics, First Annual Meeting

PROJECTS AND APPLICATIONS

SEEDIS

The Socio-Economic-Environmental-Demographic Information System (SEEDIS) consists of a very large integrated database and sophisticated analytical and display capabilities. The objective of the SEEDIS program 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 SEEDIS system contains a variety of large databases, such as the 1970 census, air quality data, censuses of agriculture, business, mining and mineral industries, manufacturers, energy production and consumption, and geographic base files. SEEDIS contains approximately 20,000 different data elements for geographic area records: states, Standard Metropolitan Statistical Areas (SMSA's), counties, census tracts, etc.

A uniform dictionary for the 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 ARPA network, dial-up terminals, and remote batch stations. A comprehensive set of user-oriented software modules provides data in tabular format, charts, and maps, both on interactive terminals and on high-quality hardcopy devices.

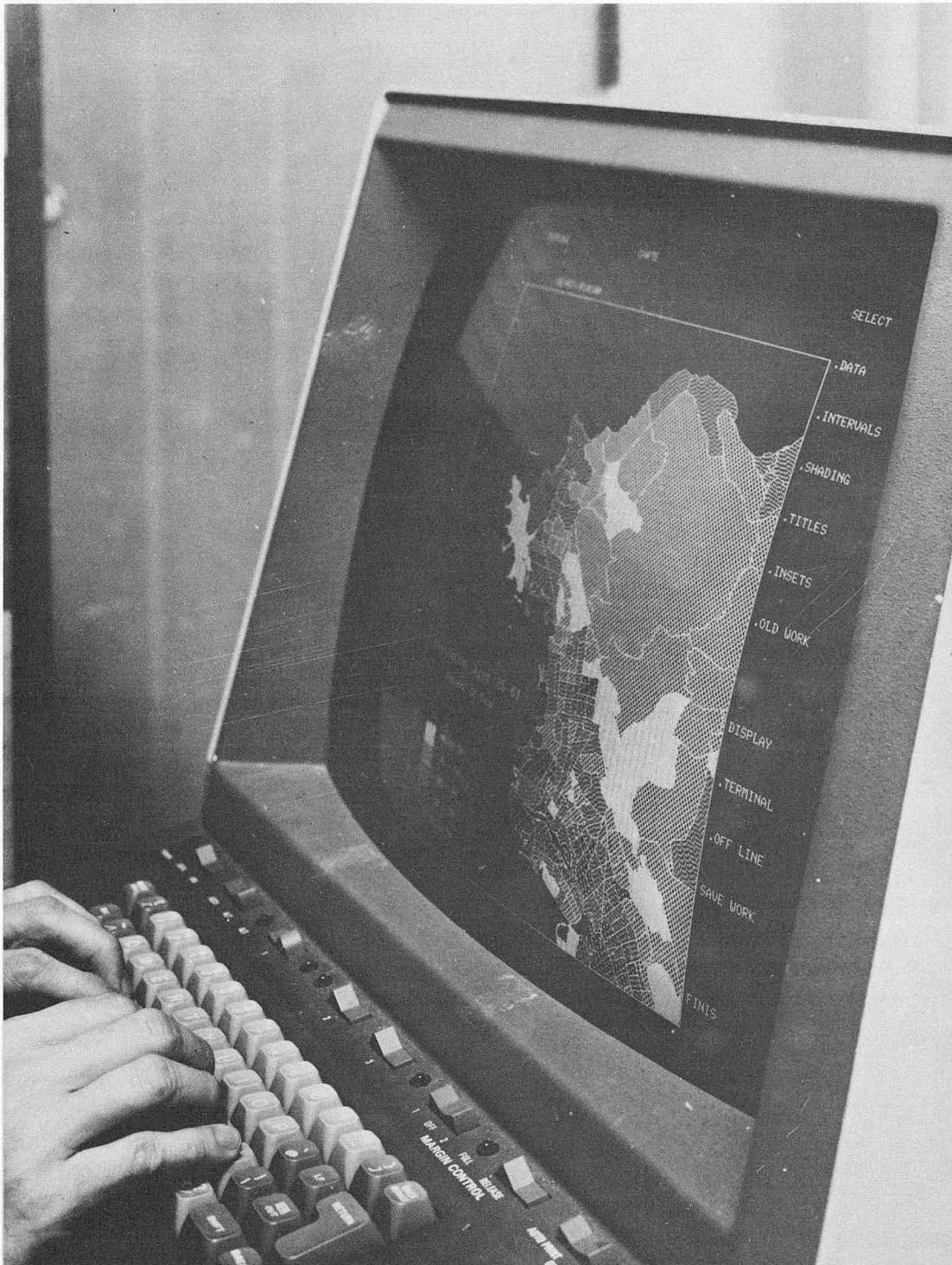
Computer science techniques involved include very large databases, mass storage systems, distributed data management, computer networks, image processing, and computer graphics. Work has

begun on interfacing the system to a distributed mini-computer 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.

SEEDIS System Integration

The primary objective of the SEEDIS effort during 1978 was aimed at a comprehensive integration of widely disparate functional modules. To this end a uniform method of data communication was developed, and all modules revised to read and/or write in the communication data format. The SEEDIS Monitor was completely revised to provide a uniform, user-oriented interactive front-end to insulate the user from the individual languages of different retrieval modules. The components of system integration are described below:

CODATA (COmmon DATA File) —This is the uniform standard data file format for communication between modules of SEEDIS. CODATA belongs to the class of data files called "self-describing"; i.e., the semantic definition of the meaning and structure of the data on the file is also stored on the file as a Data Definition File (DDF) or data description. CODATA was designed and implemented so that the files could be examined and, if necessary, modified by using the system text editor. Since CODATA was designed to include free-format (as well as fixed format) data, user-created data files are easily integrated into the



A map of SEEDIS data is composed at the terminal for quick-view analysis, or refined interactively to achieve the most effective display of analytical results before a final hardcopy version is produced.

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system. Since line images or punch card files are special cases of CODATA, databases of this form brought from outside SEEDIS can be entered into the system (for mapping and display) with minimal effort. Finally CODATA files serve as user "work files" for regional collections of only those data sets of interest to a particular user.

SEEDIS MONITOR — This functions as a hierarchical menu selection/option system, wherein each level in the hierarchy will produce for the user a new sub-menu until he reaches a low-level (known as a leaf) and enters a module. The major menu items, which will be described in detail below, are

- AREA, geographical area selection;
- DATA, database and element selection;
- EXTRACT, retrieval of data for specified areas;
- NEWDATA, data entry;
- MERGE, merge of separate databases into a single database
- TABLES, data manipulation, bar, pie charts, line graphs;
- MAP, on-line thematic mapping.

SEEDIS AREA — The SEEDIS AREA module was written to provide regional area selection by common name instead of FIPS (Federal Information Processing Standard) geographic code. Common name recognition has been provided for:

- states
- counties
- SMSA's (standard Metropolitan Statistical Areas) cities or towns of 2,500 or greater population.

In addition, selection is available for census tracts by number. The AREA module writes geographic code intermediate files to drive data retrieval (extraction) and thematic mapping modules.

SEEDIS DATA — The SEEDIS DATA module provides for uniform on-line browsing and concomitant data item selection for all SEEDIS databases. DATA allows the user to examine a database dictionary at the terminal much as he might look at a printed copy at home, by entering commands like

TABLE to print the Table of Contents, or 27 to print page 27 of the dictionary.

SEEDIS EXTRACT — The EXTRACT module is the work horse of SEEDIS modules, accessing and retrieving data from each user-specified data-base to form a sequence of CODATA work files. EXTRACT insulates the user from the complex processes of very large data management over different mass storage hardware devices which have evolved out of a progressive five year development effort to manage multi-billion item databases.

SEEDIS NEWDATA — The NEWDATA module offers the user a straight forward method of entering his personal data (for example, timely administrative data) for integration with data already within SEEDIS.

SEEDIS MERGE — The MERGE module was developed to integrate data retrieved from multiple database sources into a single integrated database (CODATA) work file. In the terminology of relational database management models, MERGE performs a "relational join" of SEEDIS databases.

SEEDIS TABLES — The TABLES module consists of the table manipulation, report preparation, statistical analysis, bar chart, pie chart and line graph facilities of the LBL CHART system.

SEEDIS MAP — The MAP module derives from the LBL CARTE thematic mapping system. MAP provides for automatic bin generation (for shade selections), computation of new variables, zoom and inset capabilities, color hardcopy output, and a variety of character fonts and labelling options. Mapping may be done for polygon, line, point, or symbol specifications.

MISCELLANEOUS — In addition, the SEEDIS monitor provides miscellaneous functions for testing new versions of modules, for archiving extracted work files, and logging SEEDIS runs.

System Conversion

During the development of SEEDIS and its precursors, it became clear that greater use of the system would require more responsive computing facilities. Experimentation began with the use of a minicomputer for graphics in 1975. CHART was

installed on a stand-alone minicomputer in early 1977. Later in 1977, a larger minicomputer was acquired. With this experience a distributed computing network (DCN) was proposed Dept. of Labor (DOL). DCN is now using the Digital Equipment Corporation VAX computer and SEEDIS is being moved to the VAX. During the final quarter of calendar 1978, several major subsystems of SEEDIS were moved from the CDC-6000's to the VAX, as follows:

- *CHART* — The VAX version of CHART (SEEDIS display TABLES) is up and running with full capabilities.
- *MONITOR* — The SEEDIS monitor has been converted to DCL (Digital Command Language), is running and is being expanded as needed to keep pace with other systems' developments.
- *AREA* — The AREA module for the selection of a geographic study area is nearing completion. Additional geographic coded databases must be transferred before geographic retrieval below the county level can be fully operational.
- *DATA* — The DATA selection module is nearing completion and is being tested and used. Some development effort remains in the area of ultimate dictionary design, and the installation procedures for databases.
- *RETRIEVAL and MERGE* — The RETRIEVAL and MERGE modules are being designed. These two modules will be combined. They retrieve subsets of data from multiple databases for user-specified geographic areas. Together, they will replace a wide variety of modules in use on the CDC-6000's by providing a uniform data view supported by a limited number of physical data structures. Key design decisions for these modules were as follows:

The CODATA structure will be retained (with minor extensions) for the data definition files (record and element descriptions)

The file-naming conventions developed for MSS-tape transfer will be carried over

to the VAX directory structure for SEEDIS databases.

The data compression scheme used for MSS-tape transfer will be used on the VAX (it was originally formulated for both the VAX and the CDC-6000s).

The EXTRACT and MERGE modules will be combined for more efficient operation of these functions. This will also require some restrictions of the structure of the data files. In particular, data files will now be stored in ascending sort order by geocode.

- *CARTE* — A substantial rewrite of CARTE will be needed for transfer to the VAX. Factors which led to this conclusion are:

CARTE's current implementation is highly machine and operating system dependent, making use of 60-bit words and doing its own memory management.

A much cleaner implementation of CARTE can be achieved if the VAX operating system is allowed to provide the memory management using virtual memory techniques.

Data Dictionary Automation

In early 1978 a project was undertaken to make machine-readable versions of the 600 pages of SEEDIS database dictionaries, which were available only in printed form. This effort, now about 2/3 complete, was a prerequisite to installation of databases into DATA and the integrated SEEDIS monitor. In addition, the machine-readable dictionary will provide the basis for retrieval-by-subject of SEEDIS data. Finally, the centralized machine-readable dictionaries can provide the basis for distribution of SEEDIS data catalogues.

MSS-Tape Transfer

With the impending demise of the chipstore (the LBL Mass Storage System) on October 1, 1979, CSAM established a Working Group on MSS-Tape Transfer to provide for the orderly transfer of data

Computer Science and Applied Mathematics

from MSS to the new tape-based archival storage system GSS. The working group had the following objectives and tasks:

Comprehensive cataloging of the 10 billion character SEEDIS databases.

Development of archiving methodology and storage structures to take advantage of the physical characteristics of the new hardware.

Development of data structures which compressed redundant data and yet were computer independent (i.e., could be easily transferred to new CSAM computers).

These objections were met and actual MSS-tape transfer was approximately 75 percent complete at year's end. While a number of production problems have occurred (bad chips, bad tapes, errors in system software), completion is expected before October 1979.

Planning for the 1980 Census

Because of its extensive experience with the 1970 Census, LBL is serving as 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.

SEEDIS Demonstration

LBL's Computer Science and Applied Mathematics Department (CSAM) had a unique opportunity to demonstrate to managers and analysts in several government agencies the usefulness of computerized information systems. Due to the growing interest in such systems as an aid to Federal policymaking, LBL was asked to demonstrate SEEDIS in Washington, D.C. during a four day

period in September, 1978. The demonstration was sponsored by Dr. John Deutch, Director of the Office of Energy Research in the Department of Energy.

The demonstration was attended by over 100 people from various government agencies, including several divisions of the Department of Energy, the Department of Labor, the National Aeronautics and Space Administration, the Executive Office of the President, the House of Representatives, the Veterans Administration, the Army Corps of Engineers, and many others. An interesting visitor was Geoffrey Carter, the President's son. A recent graduate of George Washington University in geography, Mr. Carter, his major professor, Robert McReady, and two Secret Service agents, spent over an hour asking questions and commenting on the possibilities of SEEDIS use. Other White House staff attending included Richard Harden and Ed Zimmerman of the Executive Office Information Systems.

In order to improve the response time for running the demonstration, new technology was required. LBL engineers and computer scientists produced a very reliable system in a very short amount of time. The demonstration was held in Dr. Deutch's former office suite, on the eighth floor of DOE Headquarters at 20 Massachusetts Avenue, downtown Washington.

Staff from the LBL Computer Center Electronics Technical Support Group flew early to Washington and worked with Special Projects staff (also LBL) and with several people from AT&T, Washington, to convert the 9600 baud synchronous Digital Data Service lines running from D.C. to New York to Oakland to LBL, into the asynchronous signals required by terminal handlers on the CDC 6600 in the main computer center and the CSAM PDP 11/70. Although a host of unexpected problems were caused by the DDS lines, the group ran three Tektronix 4014 terminals at 9600 baud for four days without a noticeable interruption.

CSAM computer scientists brought a borrowed four-color plotter from Zeta Corporation on the airplane, since there was none available on the East Coast. Two Tektronix 4014 terminals were borrowed from Tektronix Inc., and a third was borrowed from DOE Headquarters. The Zeta

plotter operated over a 1200 Baud line to both the CDC 6600 and the PDP 11/70, generating four-color plots of maps and charts.

The demonstrations were more or less continuous from 9:00 a.m. to 4:00 p.m. on the four days. CSAM bought block time on the CDC 6600 during the hours of the demonstration, which, while a major inconvenience for regular users, ensured the rapid response time required for an interactive information system. The cooperation of the Computer Center staff and the Engineering and Technical Services Division staff was a major factor in the success of the demonstration.

Dr. Deutch, Dr. James Kane (Director of Basic Energy Sciences), and Dr. James Pool (head of the Applied Mathematical Sciences research program under Kane) were very pleased with the outcome of the demonstration. Dr. Deutch commented on the importance of computer science research in making information available to a wider range of decision makers and analysts throughout DOE and other agencies. Dr. Robert Birge, Associate Director of LBL and Head of the Physics, Computer Science and Mathematics Division, thanked Dr. Deutch for his support and encouragement.

Generalized Language Processors

The parser generator system LANGPAK (Heindel and Roberto, American-Elsevier, 1975) was implemented on the CDC-6600 with extensions for code generation and execution for generalized boolean selection with embedded arithmetic expressions. The first implementation was for data files defined on QWICK QUERY dictionaries. An implementation is currently underway on the VAX computer which interfaces to the CODATA subroutine library.

PAREP

A project to assess Populations at Risk to Air Pollution (PARAP) was initiated in 1976, under funding from the U.S. Environmental Protection Agency (EPA). In September 1978, under funding from the Department of Energy (DOE), the project was extended to consider other environmental hazards (including low level radiation), and was

renamed Populations at Risk to Environmental Pollution (PAREP). The PARAP-PAREP project is a collaboration between CSAM and the Energy and Environment (E&E) division, and the University of California (Berkeley) School of Public Health.

Activity in the project has involved:

1. Creation of an integrated database containing data on socioeconomic and demographic characteristics, air pollution levels for several important pollutants, and disease specific mortality data for the entire U.S. by county;
2. Conversion of the database for installation in the SYSTEM 2000 Database Management System, at LBL and in the EPA computer in Research Triangle Park, North Carolina;
3. Installation of the database and other related data into SEEDIS.
4. Analysis of possible associations between disease specific mortality, air pollutant levels, and socioeconomic and demographic indices;
5. With the use of SEEDIS, quick response to specific data requests from DOE headquarters and elsewhere.

Database Description

The integrated data file to be installed in SYSTEM 2000, when completed, will contain approximately 2800 data items for each of the 3200 counties of the United States, including the following (the number in parentheses indicates the approximate number of data items for each county):

1. Socioeconomic and demographic data:
 - (140) population by sex(2), race(3), and age(23), from 1970 Census
 - (140) corrected 1970 population by sex(2), race(3), age (23)
 - (220) 1970 (Census) population by sex(2), race(3), age (9), and marital status(4)
 - (200) 1970 socioeconomic characteristics by sex(2), race(3)

2. Air Quality data:
(500) 1974-76 (and average) air quality by year(4) and pollutant(11)
3. Mortality data:
(700) 1950-1969 cancer mortality by sex(2), race(2), site(35)
(900) 1968-1972 mortality by sex(2), race(2), cause(54)
4. Geocodes and miscellaneous data:
(30) geocodes, county centroids, climatological and emissions data

Installation in SEEDIS

The individual data files being used to construct the integrated SYSTEM 2000 database have

now been installed in SEEDIS, greatly simplifying the construction and verification of the PAREP data file. In particular, the interactive mapping facility (program CARTE) has led to the discovery of errors in data obtained from EPA.

The use of SEEDIS for the PAREP project has been of direct benefit to other SEEDIS users by providing them access to important data bases which would otherwise not have been so readily available. Within SEEDIS, these can be combined with other important SEEDIS data files, including the 1970 Census, the City/County Data Book, the U.S. Energetics Atlas, and many others.

Figures 1, 2, and 3 are examples of maps produced by SEEDIS in connection with the PAREP project. (Color maps, as well as bar charts, pie charts and other graphic displays, not presented in this annual report, may also be readily produced.)

AGE-ADJUSTED CANCER MORTALITY RATES - STANDARD DEVIATIONS FROM AVERAGE
CALIFORNIA WHITE MALES, NCI DATA 1950-69
CANCER, ALL TYPES (ICD 140-205)
TOTAL NUMBER OF DEATHS (20 YEARS) = 216761
AVERAGE MORTALITY RATE = 171.72 ± 0.37 (PER 100,000)

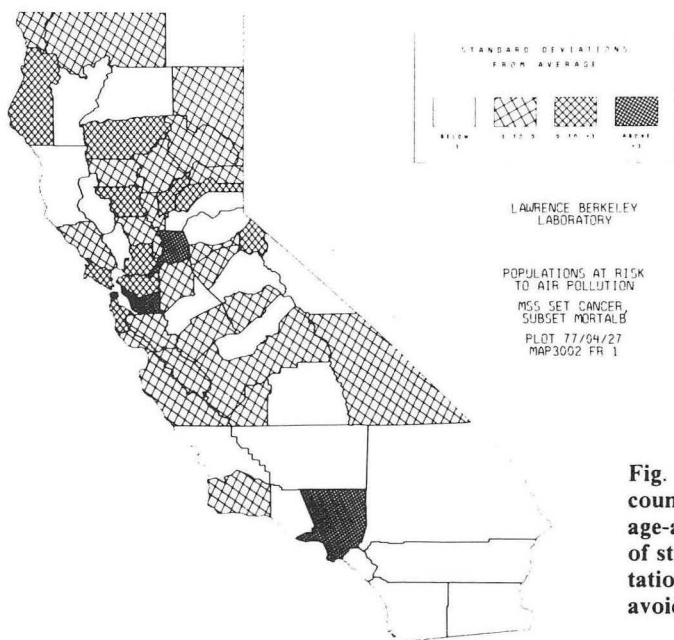


Fig. 1 —Cancer mortality rates for white males for the counties of California. The data presented are annual average age-adjusted rates for the period 1950-1969, expressed in terms of standard deviations from the California mean rate. Presentation in terms of standard deviations is a useful technique to avoid the effects of large statistical fluctuations in small counties.

XBL 775-8640

LOCATIONS OF AIR QUALITY MONITORING STATIONS
CALIFORNIA, ANY POLLUTANT, ANY YEAR (313 STATIONS TOTAL)

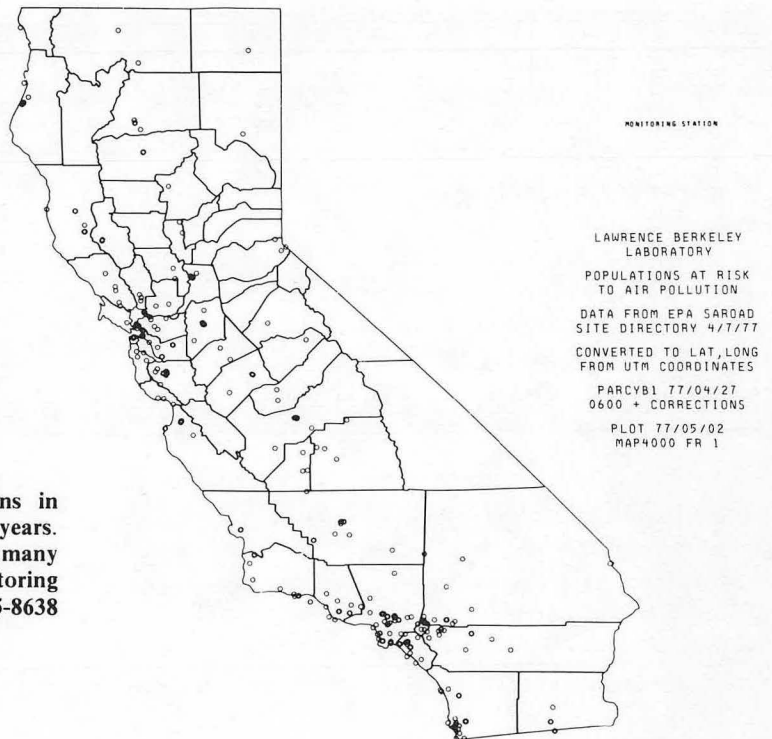


Fig. 2—Locations of air quality monitoring stations in California which were active at any time in the last ten years. Not all pollutants were measured at each station; in fact many counties in the U.S. have no active air quality monitoring stations for any pollutant. XBL 775-8638

ANNUAL GEOMETRIC MEAN POLLUTANT CONCENTRATION
CALIFORNIA, 1975 SAROAD YEARLY SUMMARIES
NITROGEN DIOXIDE (SAROAD 42602)

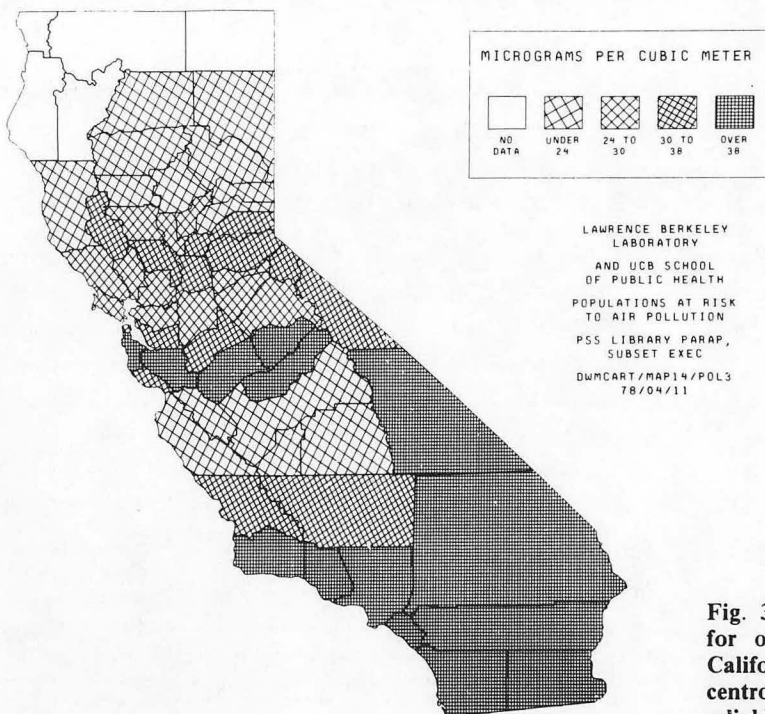


Fig. 3—Estimated (annual geometric mean) concentrations for one pollutant, nitrogen dioxide, for the counties of California, estimated at the position of the county population centroid. Five counties indicate 'no data', which means that a reliable estimate could not be made from the available data.

Air Quality Estimates

The production of county level air quality estimates is the most difficult and the most innovative aspect of the PAREP project. Most analyses of air quality data, including standard published EPA reports, provide estimates by county or AQCR (Air Quality Control Region) by simply averaging the estimates from all monitoring stations within the county or AQCR. Such an analysis ignores the actual locations of the monitoring stations as well as the distribution of the population, and does not provide a good estimate of the average air quality experienced by the population of the county or AQCR.

In the PAREP project, the county population centroid is calculated from the population distribution reported in the 1970 Census. (The same analysis can easily be performed for cities, or census tracts, or any other political division.) For the pollutant in question, the distance is calculated from the population centroid to all active monitoring stations, whether or not in the county. A weighted average (actually, geometric mean) is constructed, in which each station i receives a weight $w(i)$ equal to

$$w(i) = \exp [-0.5 (d/d_0) **2]$$

where d is the distance from the centroid to station i , and d_0 is a constant of the order of 20 kilometers. Various values of d_0 will be tested to see which gives the most reasonable results.

In the completed PAREP data file, not only calculated values of air pollutant concentrations, but also the corresponding weights will be included. Thus estimates having large uncertainty (no stations nearby) can be appropriately weighted in statistical analyses. Where the weights are extremely small, the estimates will simply be entered as 'missing data.'

System of Information Retrieval and Analysis for Planners (SIRAP)

During 1978 the U.S. Army Corps of Engineers' SIRAP system was enhanced with the following new databases made available using the QWICK QUERY system:

Freight Commodity Flows (1972)—the data are amounts of commodity traffic for 23 bulk commodity and product groups (accounting for approximately 75% of the intercity tonnage carried by all modes of transportation) between the 173 BEA (Bureau of Economic Analysis) Economic Planning Areas in the United States. BEA areas are defined as aggregates of counties which behave as a uniform regional economic unit.

County Population Centroid Area Measurement File—The Census Bureau's file of population centroids, 1970 Census total population, total county area, total land area, total water area, and population density.

Annual Housing Survey (4 Files)—The micro samples from the Bureau of the Census annual housing surveys for the following years and areas.

1974 SMSA sample

1975 SMSA sample

1975 National sample

1976 National sample

BEA Personal Income 1976—Bureau of Economic Analysis personal income estimates for the years 1971-1976 by type (wage & salary, proprietors, etc.) and industry (farm, non-farm, manufacturing transportation, trade, government, etc.) as well as derivation of income by place of residence. Data for counties, states, SMSA's and BEA areas.

BEA Employment 1976—Bureau of Economic Analysis employment time series for the years 1971-1976 by type (wage & salary) and broad industry classification (farm, non-farm, manufacturing, transportation, trade, government, etc.) Data for counties, states SMSA's and BEA areas.

Retrieval, aggregation and report generation programs were written to access the 1970 Fifth Count data at the enumeration district-block group and census tract levels of geography. These reports provide the most detailed small area profiles yet available through SIRAP and SEEDIS.

Labor Market Projections Model

The affiliated State Employment Security Agencies (SESAs) of the Department of Labor – Employment and Training Administration (DOL-ETA) supply local planners in CETA projects with estimates of persons in need of manpower services. To be of maximum use, these estimates should reflect “current” local needs. The Labor Market Projections Model was developed in collaboration with DOL-ETA to provide an estimation procedure. The goal of the LMPM project is to provide a comprehensive modeling system to be used by local 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. Updated Census tabulations were 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, by sex, and by race for a particular area. Labor force and unemployment projections are based on the labor force and unemployment of the geosarea 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 considerable effort has been put into improving the population projections. Sub-models to take into account the special populations (college students and the military) were included. Net migration totals for 1970-1975 from the 1975 Revenue Sharing tapes were used to improve the net migration rates for 1960-1970 previously used. Lastly, as the projections are now being done from 1970 to 1980, the model does this in two steps—projecting first to 1975 and then to 1980. With these changes, the population projections model has been greatly strengthened. As a result, the labor force and unemployment projections are equally improved.

Furthermore, this past year, the projections model was made interactive. Not only may the user alter the various control totals, but may also change some of the input parameters and aggregate across racial categories. A user’s guide for running the interactive version was started.

At the end of the calendar year, both models are run for all states, SMSA’s and prime sponsors. The results are then mailed to the State Employment Security Agencies in each of the fifty states.

The survey of Income and Education (SIE) data have been installed at LBL. The Survey of Income and Education was carried out between April and July 1976 to determine the number of children in certain areas living in families with incomes below poverty. The sample design is quite similar to that of the CPS but the sample size of the SIE is about four times larger. Many tabulations of the SIE data were obtained at the state level.

Data from the 1975 and 1976 Revenue Sharing Files have been installed in the SEEDIS Monitor. These files contain current estimates of population below the county level and per capita money income. These estimates were prompted by the enactment of the State and Local Fiscal Assistance Act of 1972.

Regional Management Information System (RMIS)

This project was initially funded by the Department of Labor in 1974 to integrate and test aspects of SEEDIS development: interactive data retrieval systems, computer graphics, report generation systems, and computer mapping. The project enables managers at all levels to access DOL-Employment (ESARS) data easily in a form which they readily understand. Consequently, the planning and management information gathering effort can be done much more efficiently. Development of the prototype “RMIS” has proven the feasibility and value of an integrated information system and has provided long term research results in understanding the requirements of the user community and tools which meet them.

During 1978, RMIS development consisted of:

1. Implementation of October and December 1977 ESAR’s format changes,

2. Provision of high density tape as one of the storage devices in the file management system and
3. Reviewing patterns of system utilization for planning transfer of the system and data to a distributed minicomputer environment.

Endangered Plants Information System (EPIS)

Section VIII of the Endangered Species Act of 1973 prohibits federal projects in conflict with

protected species. As similar legislation is passed at state and local levels, the process of power plant site selection will increasingly require readily retrievable rare-species information. Rare, endangered and protected plants are as numerous and as widely distributed as rare animals; yet while two rare animal databases are available at LBL, there is none for rare plants. An excellent publication of endangered plants data, by the Biota of North America Committee (BONAC) is available in machine-readable form, and will be obtained for conversion and integration into SEEDIS. BONAC data is the most comprehensive and useful currently available.

Distributed Computer Network

CSAM is developing an experimental network of minicomputers for distributed data management functions. This Distributed Computer Network (DCN) project is funded by the Department of Labor's Employment and Training Administration (DOL-ETA) under a Memorandum of Understanding with the Department of Energy. Since the major goal of the DCN is to provide shared access to socio-economic, environmental and demographic databases, and sophisticated data retrieval, analysis, and display systems, it is appropriate to consider this joint DOE-DOL project as a prototype system for future development to serve similar functions for various DOE programs.

The DCN is designed to provide local processing power for each of the Regional Offices of DOL, including data management, analysis, graphics displays, report generation, etc. In addition, the DCN nodes (minicomputers with mass storage peripherals and network communication interfaces) will be connected to a general distributed network providing access to other Regional nodes and to large scale computer systems, such as the LBL Computer Center and the U.S. Labor Department Computer Center. This will allow the installation of large, archival databases, such as the 1970 and 1980 Censuses of Population and Housing, to be maintained at the large scale centers.

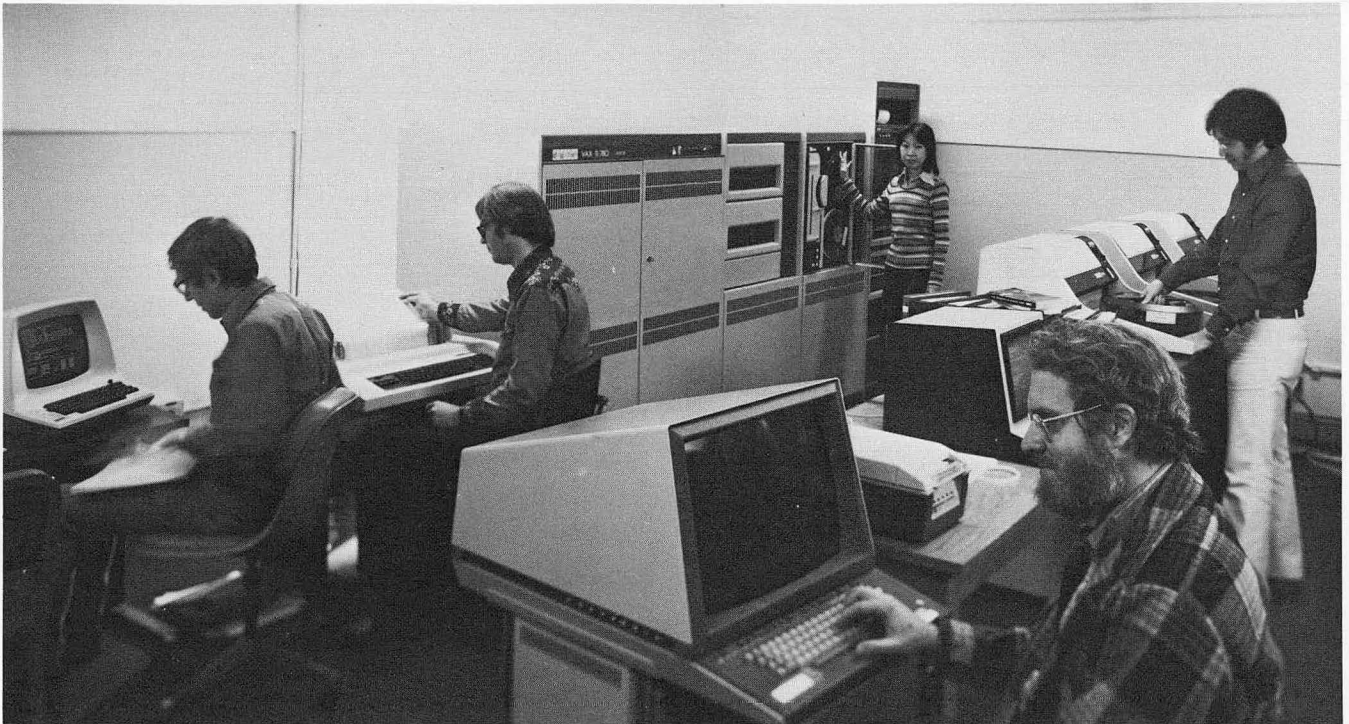
The Regional nodes will have access to small subsets of these large databases on demand, without having to permanently store and maintain such large databases at each node on the network. In addition, local databases can be combined with portions of the large databases and analyzed; required reports can be generated and sent over the network to other nodes, including the main computer system in D.C. (or elsewhere, as appropriate).

During 1978 three Digital Equipment Corporation PDP-11/70 minicomputer systems were acquired. A prototype network was developed as part of the feasibility study for the nationwide network. The first regional installation was concluded late in the summer at the Region IX offices in San Francisco. Two systems remained at LBL for developmental work in networking and communications.

Site Preparation—In addition to site preparation efforts in-house, LBL personnel coordinated pre-installation check-out, shipping and installation of the Region IX node.

Software and Utilities—The IAS operating system and the following utilities or application programs were provided:

- a. RMS-11 Record Management System



The Distributed Computing Network (DCN) project focuses on development and evaluation of a prototype homogeneous network of DEC-VAX-11/780 computer systems.

XBB 791-738

- b. DATATRIEVE Query Language
- c. COBOL, FORTRAN IV-Plus and Basic-11 programming languages
- d. CHART graphics display program
- e. ED file editing utility
- f. ROFF test formatter
- g. CAT file copy program
- h. LPR print program to convert from terminal output to line printer

installing nodes will coordinate training through LBL and Digital Equipment Corporation's Western Regional Training Office in order to benefit from this specialized development.

A procedural guide for day-to-day operations was prepared at LBL and provided as a part of DCN system documentation. This guide differs from DEC documentation in that it summarizes routine operations specific to the DCN configuration and is directed to the less technically experienced operations staff.

Training and Systems Management

LBL personnel worked with personnel from Region IX and Digital Equipment Corporation's Western Regional Training Office to develop a curriculum that focuses uniquely on DCN hardware and software configurations. It is anticipated that Region IX and the other offices which will be

Technical Assistance, Applications Development

LBL personnel met with DOL regional personnel to define the scope of potential application program development and to evaluate the feasibility of various development scenarios. This effort included detailed work with users of RMS-11 and

DATATRIEVE as well as a general overview of potential automation of some regional office procedures.

Data Management

The RMS-11 Record Management System and associated query language DATATRIEVE were installed on each system. Extensive work was done in evaluating these programs for their applicability to DOL regional office applications and determining their limitations. Other data management systems such as DBMS-11, SEED, ADMINS-11, and INFORM-11 are being evaluated for their potential applicability as data management systems on the network.

Evaluation of System Upgrade

An option to upgrade the prototype systems to VAX-11/780 configurations was included in the procurement action. A critical evaluation of the VAX 11/780 hardware and the Virtual Memory Operating System (VMS) was made. The hardware architecture and the design and features of the operating system were carefully studied. LBL participated in several benchmarks which demonstrated hardware performance and software capabilities.

Development on the SEEDIS VAX system confirmed the results of the evaluation. The VAX/VMS system provides capabilities which are crucial to the development of DOL applications. The PDP 11/70 system provided the basic capability for prototype development as the design of the VAX/VMS system was still in progress.

Computational Physics

During 1978, the Computational Physics Group provided research support to the following groups:

Advanced Accelerator Theory

This project relates to a continuing effort to study the transport of heavy ions. In particular, research activities have been directed towards studying the transverse stability of a beam of heavy ions moving uniformly in a periodic magnetic solenoidal focussing system. The resulting computer simulation is used sparingly because of the large number of particles required for meaningful results. It is hoped that the results obtained will correlate with those theoretically derived for a particular initial particle distribution.

A project to investigate the economics of building a linear induction accelerator is also under consideration. The resulting simulation is directed towards calculating a minimum such machine by varying certain construction and performance parameters.

LBL/SLAC Proton-Electron Project (PEP)

The PEP project at SLAC is presently in its final construction stage with all the components having been designed and built. CSAM staff contribution in this continuing research effort is geared towards investigating alignment problems and correction of displaced equilibrium orbits. Specifically, research efforts have been directed towards determining the correct strength positions and monitor positions for the closed orbit correction in the PEP ring. Various correction schemes were also investigated and consequently reported.

The computer simulation designed to fulfill these research goals (Program ALIGN) has been constantly updated and a user's guide is being prepared. Presently, the program ALIGN has been converted to run on the SLAC IBM 370 computer. Various modifications to the program have been incorporated and presented at a workshop at SLAC.

Some of the results obtained with ALIGN were compared with those obtained with the program SYNCH, in particular those relating to various orbit properties.

CTR Tokamak Fusion Test Reactor (TFTR)

Studies for the calculation of the ion densities in neutral beam ion sources continued with emphasis on computing rate coefficients from experimental cross-section data. The procedure involves the simultaneous solution of a set of particle balance equations yielding neutral and ion species densities in terms of electron density.

Concurrently, extensive calculations are carried out in computing trajectories of secondary ions and electrons in a 120 Kev TFTR accelerator structure with the WOLF code. The principal motivation is a desire to understand the origin of the heat loads on the accelerator grids, and to minimize them if possible.

A third area of concern has been the measurement of the species and parasitic component of a neutral beam by Doppler shift spectroscopy. Preliminary results of this effort were presented at the Annual American Physics Society meeting held on October 30, 1978.

CTR TORMAC

Developmental work for the TORMAC (Toroïdal MAGnetic Cusp) project continued with research efforts directed towards:

- o Designing coil systems and performing plasma equilibrium calculations for the new TORMAC-PUFFER experiment. Some of the results have been reported at the 20th annual APS meeting of the Plasma Physics division.
- o Developing computer simulations for plasma behavior such as MHD-Shock.
- o Developing multiparameter theory to explain experimental results, such as plasma gun magnetic field interactions for plasma trapping.

These efforts will continue, focussing on

extension of simulations, particularly those relating to MHD shock extending from one-dimension to two dimensions, and continued calculation for support of future experimental developments.

Magnetic Fusion Test Facility (MFTF - LLL)

This project relates to the design and construction of a large superconducting magnetic fusion device to investigate microinstabilities and scaling laws of such devices. CSAM staff contribution has been investigating the degree of magnetic field penetration in the neutral beam enclosures, identifying the magnitude and behavior of the penetration, and establishing criteria for its reduction to accepted theoretical minima. Simulations presently under development have supported the redesign of these enclosures to a predicted optimal shape.

FXR Accelerator (LLL)

Research in the design of the FXR accelerator was greatly enhanced by the preparation of a computer program EBQ used to provide sufficiently accurate calculation to model the cancellation that occurs between the radial electric and magnetic self-forces in a relativistic beam.

EBQ has also been applied to the design of the Electron Test Accelerator (ETA) at Livermore.

This code is a two dimensional simulation of steady-state problems involving space charge transport of charged particles in cylindrically symmetric devices specified by the externally applied electric and magnetic fields. The electric and magnetic self-fields of the particles are used to obtain a self-consistent azimuthally symmetric charge and current distribution. The program follows the three dimensional particle trajectories in the two dimensional external structure employing a unique method of assigning values of charge density to grid points.

This research has led to a better understanding of the methodology required to properly model high current beam from space-charge-limited cathodes.

Donner Laboratory – Epidemiology of Magnetic Fields on Humans

This project relates to the investigation of the epidemiological effects, if any, of magnetic fields on humans. In particular the study is directed towards correlating the medical records of people who have been exposed to magnetic fields of various strengths, with those of a “control group”. The project is presently at the data collection stage. However, various computer programs such as MDTST have been prepared to read “patient” medical records which contain coded medical history and magnetic exposure data as well as other related information. The data may then be translated from coded form, printed, plotted, histogrammed, T-tested, sorted, filtered, normalized, combined and/or selected and listed under the control of various options, print formats and appendices. It may be statistically analyzed under control of the GRASS system options.

Support of Research for Evaluation of BART

This research effort was directed towards analysis of braking data for Bay Area Rapid Transit (BART). Analysis was performed on digital data which have been converted from analog signals recorded on a multitrack analog tape recorder. The recorder is carried on board the train under test. The set of signals converted in the A/D conversion are those from accelerometers, metal detectors, open-loop braking indicators and tachometers. The timing waveform is inherent in the sampling of the four channels. The BRAKES program converts the readings from voltage to the proper units, by use of calibration signals recorded on the tape, determines the effective deceleration, and calculates velocities at various times over the entire braking cycle. The program prints these results along with specified times and distances and plots various results for each braking sequence.

Physics

A Supervisory System to Control Data Collection from the Time Projection Chamber

The proposed PEP-4 experiment, with its Time Projection Chamber and associated detectors, presents an extreme challenge to the concept of computerized experimental control. The estimate of one high multiplicity event every 20 seconds (approximately 50,000 bytes of information), together with three to five low multiplicity events every second, requires an extremely efficient control scheme to maximize the on-line information gathered as well as to minimize the processing dead-time incurred.

The digitized data from the detectors for each event are accumulated in a large bank of semiconductor memory (the Large Data Buffer). During the experiment, two PEP-4 computers have access to this data:

1. a PDP-11/70 running the RSX-11M operating system, the primary purpose of which is to control the experiment. Two of its main functions are to control the Test Pulser and to monitor the physical constants of the detectors.
2. a PDP-11/780 running the VAX/VMS operating system, the primary purpose of which is to write the data to tape and to perform on-line data analysis.

CSAM personnel participated in development of the control system devised for the 11/70: A similar system is being considered for the 11/780.

In order to satisfy the two boundary conditions described above, two supervisory processes have been written for the 11/70:

1. The LDB supervisor is the only process capable of reading the data from the LDB

into the 11/70 memory. It also controls access to the data once in memory by user processes.

2. The TP supervisor is the only process capable of communication with the test pulse hardware.

The interface between the user's process and these supervisory processes is via well-documented subroutine calls which are linked with the user's image from the system library at task-build time. This allows the implementors to use various mechanisms for the Inter-Process Communication, while the user interface remains constant. Currently the IPC is achieved through a combination of short messages passed by the executive and shared memory.

The LDB supervisor has been designed to use any of three possible data access control mechanisms:

1. While user processes are active on the current event's data in main memory, it ignores subsequent events.
2. If users are active when a new event's data are ready, it interrupts the processes, giving them some short time interval (dt) to clean up their processing.
3. User processes which are habitually active long after a new event is ready are aborted, with a message appearing at the user's terminal describing the reason for the termination.

Depending upon the actual data rate encountered, either mechanism 1 or 2 may be used in conjunction with 3. Also, if mechanism 2 is chosen, dt may be varied to minimize dead-time.

In summary, a supervisory control scheme has been implemented on the PEP-4 11/70 to minimize the processing dead-time and to allow controlled access by user processes to the data taken. A similar system is being considered for the 11/780. Documentation concerning the subroutine interface, as well as user process templates, are available.

SPEAR Mark II

Work has continued on programming support

for the MARK II detector at SPEAR. The track-finding and reconstruction for charged particles now is about 95 percent efficient, and the spatial resolution is approaching 200 micrometers RMS, which is near the design limit. Problems remain with the very steep and highly curved tracks; these are being studied.

Kinematics programs at LBL (SQUAW) have been used to analyze several classes of events from SPEAR. The pi-zero decay of the psi meson has been used to calibrate the liquid-argon neutral detector by comparing measured gamma-ray energies with those obtained by fitting. This comparison has also been useful for recognition of spurious neutral particles, so that both the energy resolution and detection efficiency have been improved for neutral particles.

A new constraint class has been incorporated in the kinematics program. This is a constraint that the mass of a cluster of particles in the final state have the same mass as the recoiling particle group, and is particularly useful in searching for particle-anti-particle pairs. Several such efforts are underway at various energies. At the D, D threshold (3.77 GeV) the method works well, but, although several candidate events have been found, it has not been possible to establish higher-mass charmed particles.

Support for the MARK II experiment also included continued development of programs that effect the transport of data from the SLAC computer systems to LBL systems. Improvements were made to the program that writes a data summary tape at SLAC containing information to be read and analyzed at Berkeley. The complementary BKY package which reads the tape on the CDC 7600 was completed. This package unpacks subsets of physics information as requested, converting the values from internal IBM formats to CDC format. Additionally, improvements to the KIOWA plotting program contained on the PSS HYDROX library were made to make more sophisticated use of LCM for storage, and general programming support was provided to members of the Trilling-Goldhaber Physics Group.

Administrative Information Systems

Bibliographic Information Systems

LBL's Reports Issued System (LBLRIS) was developed to maintain Bibliographic data on laboratory reports and publications. The primary users of the system are the Technical Information Department, responsible for input and report generation, and the Library, concerned with index searching. The users access the system through an interactive monitor, which supports data input and update, batch and interactive searches of the Reports Issued Database, and textual report generation including multiple key sorts. The data may be generated on the IRATE system, and may contain Roman and Greek fonts, italic and bold typeface, subscripts, superscripts, and mathematical symbols; or it may be entered through an ASCII terminal in BDMS form, in batch or interactive mode. Output can be made available for ASCII printers or for film and microfiche, as generated with the OPTIK system. A user's manual was written detailing the procedures for input, search and report generation.

The computer system supporting the library's Energy Database-related activities was reorganized to streamline processing by implementing a systematic job submission scheme which minimizes human interaction. The machine-readable bibliographic Energy Database (EDB) tape is received bi-monthly from Oak Ridge National Laboratory, and is processed here to provide a variety of services. Users, including laboratory staff, the LBL library, DOE contractors, other federal users and private consultants, may subscribe to on-going selective dissemination of information, request one-time searches of the database, or receive cumulative keyword, report number and author indexes.

Fiscal Management Systems

Considerable progress was made on the coordination of all fiscal management planning and monitoring. The Fiscal Activities Management Information System (FAMIS) allows administrators to do fiscal planning with a personalized database. The Coordinated Accounting Reports Distribution System (CARDS) supplies fiscal information to others who do not need the planning capabilities. Both FAMIS and CARDS are integrated into the Labwide Accounting Files System (LAFS) and use the Accounting Report Generation System (ARGS).

The Accounting Department uses CARDS to maintain a coordinated distribution list. The profile for each recipient includes name and address, desired ranges of accounts, and the selection of reports. By gathering together the data for non-contiguous accounts and addressing each selection, the system has minimized manual procedures in distributing accounting reports.

The users of FAMIS may keep more elaborate profiles containing not only selection criteria but also aggregation, sequencing, and formatting specifications for personalized reports. FAMIS users may access information directly from an interactive terminal and enter plan data for comparison to actual charges. Data may be entered and/or reported in a variety of units; the basic ones are dollars, man-months, and full time equivalents. A master table of conversion factors is now maintained to eliminate duplication of effort in entering projected values and thus to ensure that all fiscal planning uses the same parameters.

The conversion factors for historical months can be obtained from accounting databases. The

effort rate for each payroll department is the ratio of total payroll costs (dollars) to total effort charges (man-months) multiplied by a factor to collect funds to cover leave and other fringe benefits. The productive work factor for each department is the ratio of effort charges excluding leave to total effort charges. The Budget Office provides the effort rates and productive work factors projected to the end of the fiscal year and for subsequent fiscal years. A new RATES program was designed and implemented to facilitate this activity.

The accounting data processing is still done at Lawrence Livermore Laboratory. Tapes are received at Berkeley, some weekly, others monthly, and processed by LAFS into the files used by ARGS. Some of these files are identical to the Livermore tapes, but restricted to LBL data for more efficient processing. Other files are cumulative: month to date for weekly data, year to date for monthly data. LAFS was converted to use the Computer Center's GETTAPE/STOTAPE System (GSS) for all handling of Berkeley files. The control of job flow was massively reorganized to minimize manual procedures: each job concludes by submitting other jobs requiring the availability of the new data. Thus all the jobs which generate the reports automatically distributed through FAMIS or CARDS are themselves automatically triggered by the arrival of a new Livermore tape.

Several new reports were developed, and some old ones modified, to use the ARGS standard job flow. This consists of five distinct phases: extract the selection criteria (one module for FAMIS, another for CARDS); attach the appropriate data file; process the file, selecting and tagging desired records; sort the selected records, primarily by the grouping tag, then by other criteria; read the ordered records and format the desired reports. Such a standard job flow permits great flexibility and power while minimizing maintenance, due to the combinatorial possibilities of stringing together individually simple procedures.

A new facility was developed to facilitate effort planning for individual employees. An administrator may choose to plan for whole payroll groups and/or specific individuals. The resulting plan data may be aggregated for entry into the fiscal planning files of FAMIS users.

The library offers a service of bibliographic searches on databases maintained on line by a number of companies. COSTU, the database and program for recharging the costs to the end user, was extensively revised to accommodate an increasing number of companies and databases.

Personnel Management Systems

Personnel information is available to authorized departments through offline reports and online interrogation. The database of current data is maintained by Livermore Data Processing, with a copy encrypted for storage at the Berkeley Computer Center. The programs for encrypting and deciphering the data were improved and documented, both to make them more cost effective and to allow the Personnel Department to take control of processing.

After some preliminary investigation, the Personnel Department decided to switch to use of the NOMAD database management system at a commercial service bureau. Major factors were security and better interactive response. A system, including programs and procedures, was developed to enter all historical personnel data into the database.

Until NOMAD is fully functioning, however, many specialized reports must be prepared here. In particular, major improvements were made in processing the 252 Report for the Affirmative Action Department. The reorganization of manual procedures and computer processing resulted in a vast improvement in the quality of the report and a significant savings in report preparation time.

Special Projects

Geochemical Simulation Program

A new family of chemical simulation programs (EQS, EQ3, and EQ6) has been obtained from T. Wollery of LLL and implemented on the BKY system to replace FASTPATH. These codes model mass transfer in geochemical processes involving aqueous species, minerals, gases, and solid phases using the theoretical approach to chemical processes developed by H. C. Helgeson.

The new programs contain expanded modeling tools and use more robust numerical methods. EQS checks the specie compositions and reaction coefficients from the database. EQ3 computes full or partial equilibrium distribution of species in an aqueous solution at a specified temperature and pressure with ion association reactions and user designated oxidation-reduction reactions assumed to be in equilibrium. EQ6 computes the path of one of several equilibrium or partial equilibrium reaction models, which describes mass transfers between a reactant subsystem, an equilibrium subsystem and a physically removed subsystem; the path need not be isothermal.

Modifications made at LBL include an improved user interface and a restructured database which is more easily read, updated, and expanded. SHOWTELL is a new interactive graphics program written at LBL to process EQ6 results. It will allow on-line construction and display of overlaid curves and make hard copies with color options.

Project Planning and Management

POSSUM is the newest version (formerly CPMG) of LBL's network based program designed to assist in project planning and management. From the detailed information about the many activities that comprise a project, POSSUM can provide the project manager with selected information, detailed or summarized, to make the project as a whole comprehensible. Areas of potential difficulty, such as deadlines that cannot be met or overallocation of

resources, can be identified early in the planning stage.

The program can then be used to investigate various solution strategies. POSSUM determines the critical path and optionally does resource constrained scheduling in several ways. The graphical presentation of scheduling and resource information can be presented on each graph. A link with the accounting information provides interesting graphical comparisons of actual expenditures with those planned. The increasing use of POSSUM as an ongoing aid to project control has demonstrated the importance of the flexible free-form input provided. Extensions and modifications continue to be made based in part on user experience and computer resources available.

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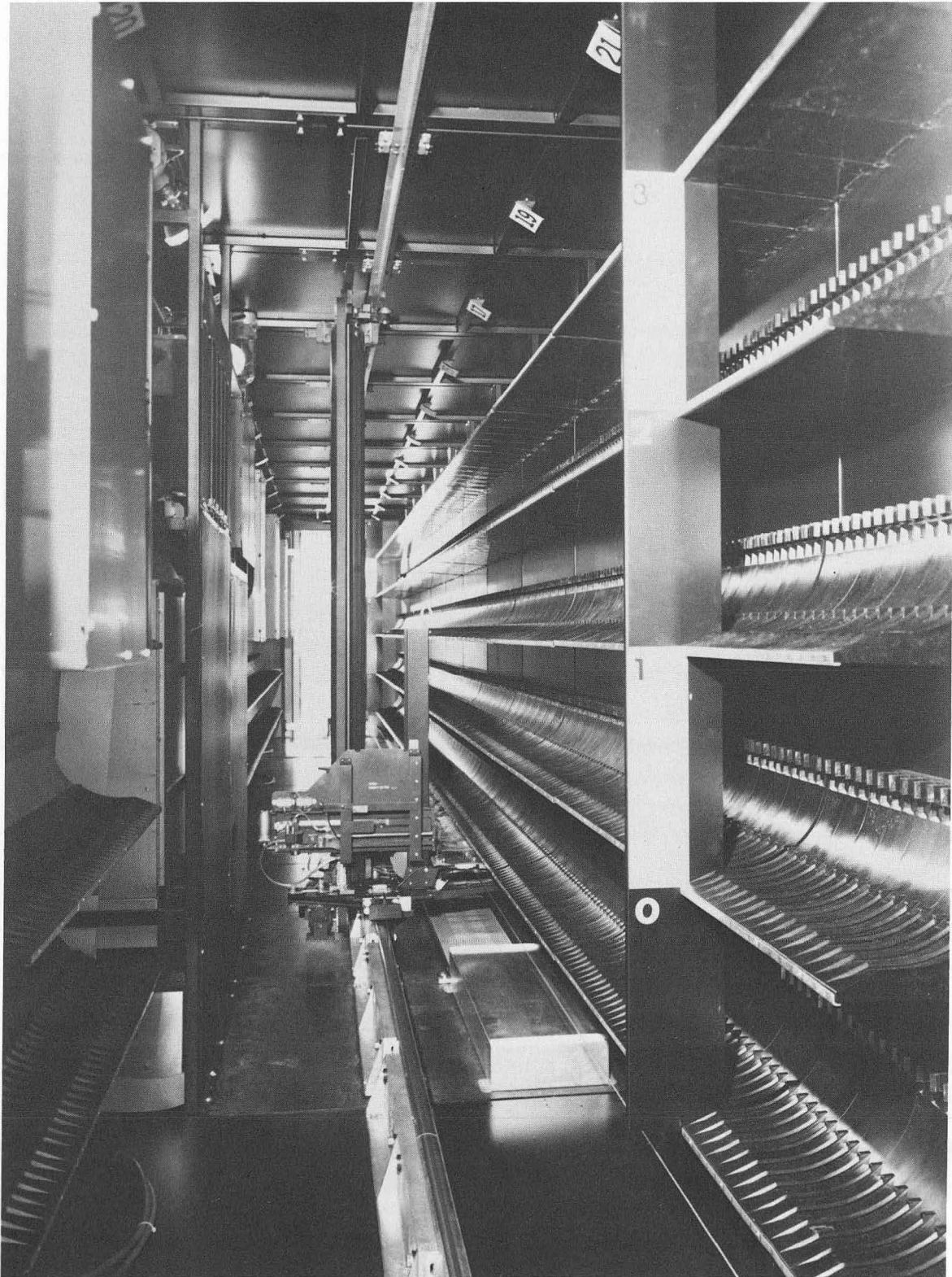
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IV. COMPUTER CENTER



Interior view of the Automatic Tape Library (ATL)—prior to loading with reels of computer tape. The device in the middle is the robot which retrieves tapes from the bins along the walls and delivers them to one of the automatic reel mounters.XBB 789-12770

IV. COMPUTER CENTER

The principal responsibility of the Computer Center is the provision of large-scale computational support to LBL's scientific program. This includes access to an extremely powerful computer (a CDC 7600), to a very large mass storage system (an IBM Photodigital Store, containing 3×10^{11} bits of on-line storage), and to a complete selection of peripheral devices. Large numbers of jobs are processed (almost 1.25 million in 1978) with excellent turnaround (about 71% were turned around within 20 minutes).

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 the TYMNET commercial network.

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. A number of university physics groups 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 six briefly described below:

- *Hyperchannel Progress Report*—Work has begun on implementing the Computer Center local network using NSC hyperchannel adapters connecting the various machines in the Center. In summer 1978, we acquired two NSC adapters, one for the 6600B and one for the PDP-11/34N, and wrote a preliminary acceptance test verifying that the equipment was suitable for use in our network. After the completion of the feasibility study, work was begun on the software protocol that would be used on our network, and an additional two adapters (7600Z and 6400C), as well as an additional port on the PDP-11/34N adapter (for PDP11/70T), were acquired so that all of the current Computer Center machines now have the hardware necessary for the implementation of the network.

Software design is progressing on schedule.

A preliminary document describing the network protocol, THC, has been prepared, and the network executive has been implemented on the 7600Z, the 6600B, and the 6400C. A test program which may be used to verify the correct performance of the hardware and software has been written and debugged. Preliminary design of the features and commands necessary for a complete network operating system is underway and expected to be completed by the end of 1979.

- *The Automated Tape Library*—The impending demise of the Computer Center's

Computer Center



Exterior view of the ATL showing the three tape drives (center). Located adjacent to the ATL, these drives automatically load and thread the tapes delivered by the robot. Pat Gillenwater (right) is inserting a tape into an ATL input port. Systems Programmer Jerry Knight (seated) is responsible for some elements of the software which control the ATL from the 6400 and 6600 computers. Don Dumpit (standing) is one of the people responsible for operation of the ATL. XBB 789-12768

largest data storage device, the IBM Photodigital Chipstore, has prompted the acquisition of a California Computer Products Automated Tape Library (ATL) as a temporary answer to the need for mass storage. Similar in function to a large juke box, the ATL can automatically mount reels of magnetic tape for use by programs running in the Center's various computers.

The ATL is contained in a steel box some 34 feet long lined with shelves holding about 2,500 reels of high density (6250 bytes per inch) tape. A "robot", which travels on a rail the length of the unit, selects a requested reel and delivers it to one of the 5 tape drives

connected to the system. A separate mechanical device at each drive mounts the reel on the hub and, since the new STC drives are self threading, the tape is made ready for use without human intervention. The entire process takes about 30 seconds.

- *PEPNET*—The first phase of the PEPNET implementation was achieved with the delivery and acceptance of the NSC hyperchannel adapters and also the installation of a PDP-11 Network Access Machine (NAM). The NAM will provide a gateway to the Computer Center's hyperchannel via DECNET, Digital Equipment Corporation's protocol.

At this time, development of the hyperchannel is underway and approval for the telecommunication equipment has been secured.

- *Interactive Computing*—Interactive computing at LBL is swiftly becoming the preferred mode of operation for our community of computer users. The interactive system which multiplexes approximately 400 terminals into the CDC 6000's is a system known as RECC. The present configuration consists of two DEC PDP-8/E minicomputers and locally written code. The hardware permits many flavors of terminals from 10 characters per second teletypes to 1000 CPS "glass" terminals. In addition, many users use RECC to input data from micro and minicomputers in fact, all commands to, and all responses from, the new ATL pass through RECC. It appears that RECC has sufficient bandwidth so as not to be the bottleneck in the current saturation of the 6000's.
- *Terminal Switch*—The Computer Center has procured and installed a Gandalf, Inc. Terminal Switch to allow interactive terminals to be dynamically switched to different host computers (e.g., BKY/CDC 6000s, UNIX/PDP 11-70, VMS/VAX 11-70, etc.). The Gandalf, now completely full, allows 250 terminals to be switched among 120 different computer terminal ports. This capability (i.e., terminal switching or networking) is essential for allowing the use of multiple small frontend computers. An enhancement to this terminal switch capability is planned for 4Q FY79 and FY80.
- *Gettape/Stotape System*—During 1978, the User Services Group at the Computer Center produced a highly efficient magnetic tape storage system called GSS (the Gettape/Stotape System). A replacement for the obsolete Chipstore device (MSS), GSS also many unrelated sets of information to be put on the same high-density (6250 BPI) magnetic tape. Previously it was very inconvenient to add data to a tape without destroying the existing information on the tape; consequently, separate tapes were often used, wasting much potential storage space.

With GSS, tapes can be used to their optimal storage capacity.

User Services has maintained all existing Computer Center documentation and has produced extensive new documentation on graphics. The group has also adapted documentation for the new UNIX system, and continues to produce two Computer Center news documents, BKYNEWS and the monthly Newsletter, on a regular basis. The group regularly offers classes for new users of BKY, and has, of course, kept the consulting service available for BKY users seven days (and five nights) a week.

American National Standards for Computers and Information Processing

The LBL Computer Center continues to be a significant participant in setting computer standards for ANSI (the American National Standards Institute). Our participation includes an institutional vote at the X3 level, the highest level committee in the USA for setting voluntary computer standards, plus technical participation in the X3T9 I/O Interface and X3H1 Operating System Command and Response Language Technical Committees. (These Technical Committees are the bodies which define the standards which are considered by the parent X3 committee.)

IBM 1360 "Chipstore" Writer Departs

The Chipstore writer (see Fig.) was dismantled shortly after October 1, 1978, never to write again. It had served LBL Computer Center users well, but had been overcome by the ravages of old age. During its approximately 10 year life it had written over 530,000 chips (2.5×10^{12} bits). The remainder of the Chipstore system (i.e. reader and cell store) will be turned off during October of this year.

Computer Center to ETS

The Computer Center's farewells for 1978 include saying goodbye to the Physics Division. On

Computer Center

January 1, 1979, after a long, productive relationship with Physics, the Computer Center moved to the Engineering and Technical Services Division. The Computer Center was born and raised under the wing of the Physics Division, from the purchase of the first digital computer (IBM 650, 1954) to the last major computer purchase (CDC 7600, 1970). The Center's present excellence is due to their encouragement and support. Goodbye and thanks to the Physics Division.

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"Goodbyes" to the 10-year old 1360 "Chipstore" Writer were said by Margaret Garnjost, LBL physicist who originally specified a need for the facility, and Robert Fink, Head of Hardware Development and Technical Services. Bob holds aloft a digital storage cell.

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