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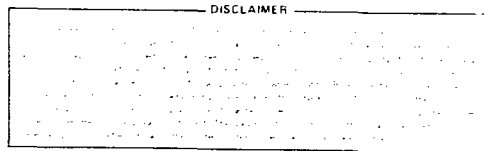
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**PHYSICS,
COMPUTER SCIENCE
and
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ANNUAL REPORT

1 January - 31 December 1979

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Editor

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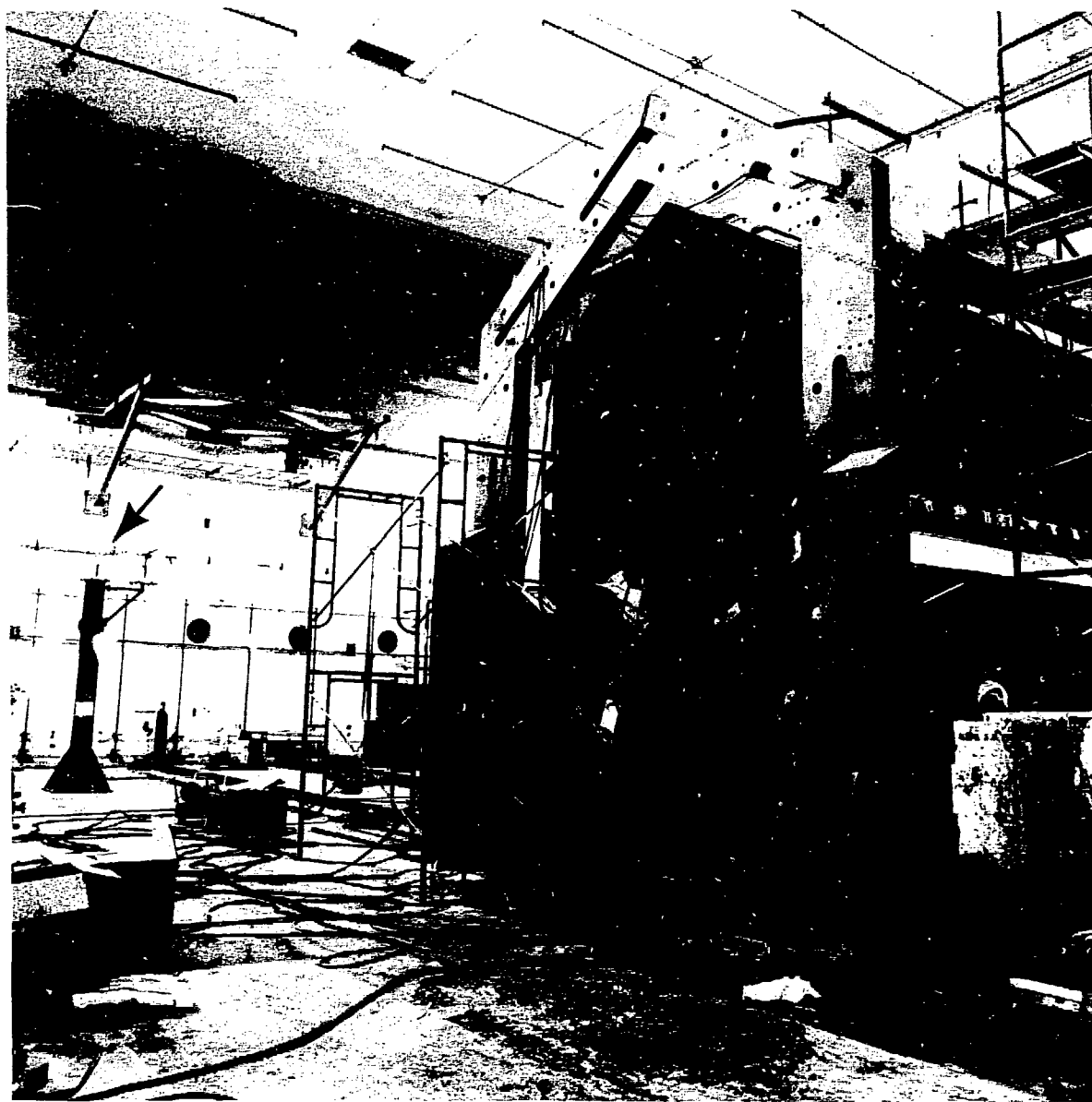
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The huge PEP-4 Detector, taking shape at SLAC, will contain the innovative Time Projection Chamber (TPC). This view shows some of the magnet legs, hadron absorber iron, and muon detectors in place as the year ended. The PEP beam pipe (arrow) is supported on the dark column near the wall at left. CBB 801-792

INTRODUCTION

This annual report describes the research work carried out by the Physics, Computer Science and Mathematics Division during 1979.

The major research effort of the Division remained High Energy Particle Physics with emphasis on preparing for experiments to be carried out at PEP. Our largest effort in this field, as well as in the Division as a whole, was for development and construction of the Time Projection Chamber, a powerful new particle detector. This work took a large fraction of the effort of the physics staff of the Division together with the equivalent of more than a hundred staff members in the Engineering Departments and shops.

Research in the Computer Science and Mathematics Department of the Division (CSAM) has been rapidly expanding during the last few years and I.B.L. now has one of the largest programs in that field funded by the Engineering Mathematics and Geosciences Division of the Department of Energy. Additionally, funds for CSAM come from other branches of DOE, from the Department of Labor (DOL), the Army Corps of Engineers, and the National Aeronautics and Space Administration. There is an especially close tie between DOE and DOL in the Computer Science work. Other funding

in the Division comes from the National Science Foundation and the University of California.

Cross fertilization of ideas and talents resulting from the diversity of effort in the Physics, Computer Science and Mathematics Division contributed in many ways to our outstanding progress in 1979. The relationship among our programs and the close association of departments stimulate new ideas and efforts which play an important role in our work. An example of the foregoing are the important contributions to the software design for the Time Projection Chamber which were made by the Computer Science and Applied Mathematics Department.

The vital and beneficial relationship which Lawrence Berkeley Laboratory has with the University of California at Berkeley continues to be a source of strength for the Laboratory. In addition, collaborations with other Universities have been beneficial and fruitful. The Physics groups at I.B.L., together with Engineering and Technical facilities at the Laboratory make it possible for outside groups to join together with us on the large projects necessary for today's advanced research at the frontier of particle physics.

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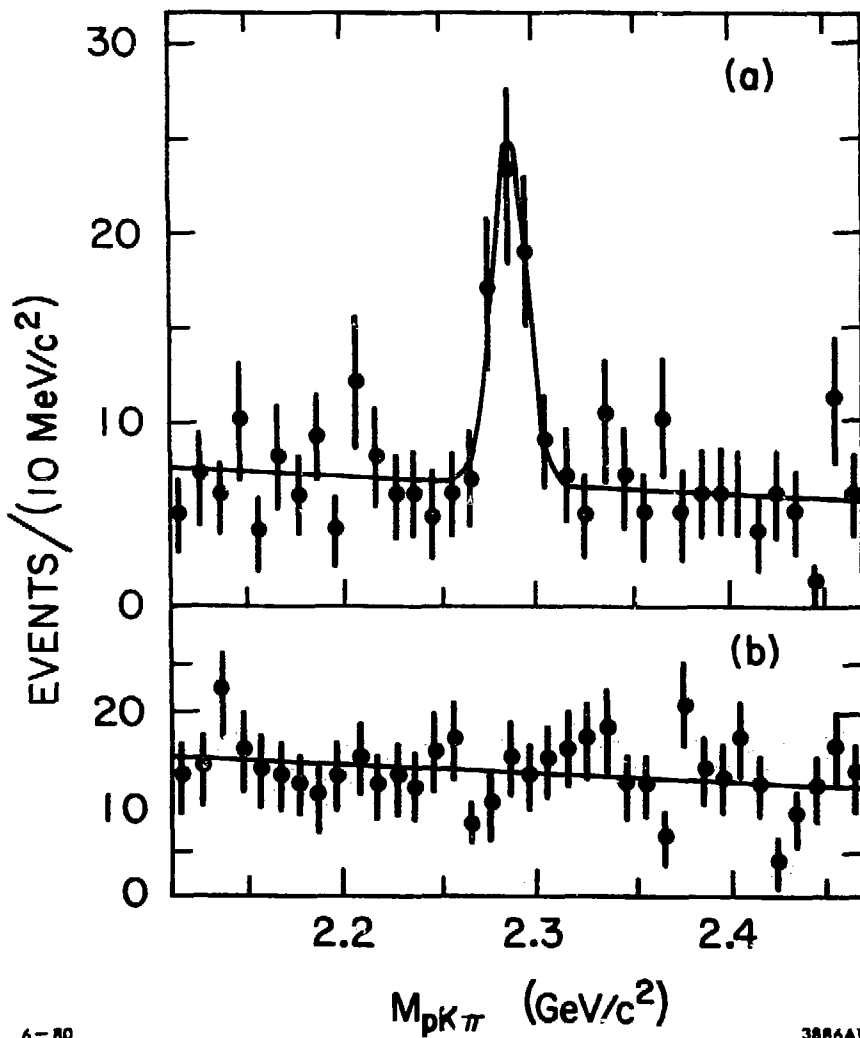
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I. EXPERIMENTAL PHYSICS



Evidence for the production of the Λ_c . The combined $pK^+\pi^-$ and $\bar{p}K^-\pi^+$ mass distribution for recoil masses greater than $2.2 \text{ GeV}/c^2$, Fig. (a), shows a peak at a mass of 2.286 GeV , while in Fig. (b) the $pK^+\pi^-$ and $pK^-\pi^-$ (and charge conjugate states) mass distribution for recoil masses greater than $2.2 \text{ GeV}/c^2$ shows no peak in the background.

I. EXPERIMENTAL PHYSICS

HIGH ENERGY PHYSICS

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

The Mark II Magnetic Detector

In collaboration with the Richter and Perl Groups at the Stanford Linear Accelerator Center (SLAC), the Mark II magnetic detector was operated at SPEAR until the middle of June 1979. Starting in late June 1979, the detector was dismantled, moved, reassembled, tested and appropriately modified for operation at PEP. We indicate recent results from the analysis of the SPEAR running at various center-of-mass energies:

(1) **3.095 GeV (mass of the ψ)**. Results from this work included the study of decays of the form

$$\psi \rightarrow \gamma + \text{all final states,}$$

$$\psi \rightarrow \gamma + \text{specific final states.}$$

These radiative decays represent several percent of the totality of ψ decays and give rise to resonances some of which are well-known and others which can be particularly well studied in this manner.

(2) **3.685 GeV (mass of the ψ')**. Analysis of these data have already disproved previous indications of a χ state at 3455 MeV, and demonstrated the existence of the rare, isospin-violating decay mode $\psi' \rightarrow \pi^0 \psi$.

(3) **3.77 GeV (mass of the ψ'')**. A large number of results on branching ratios for various decay modes of the Cabibbo-forbidden modes $D^0 \rightarrow K^+ K^-$, $\pi^+ \pi^-$, as well as good evidence for different leptonic branching ratios for D^0 and D^+ mesons. This latter

observation suggests a much shorter lifetime for the D^0 than for the D^+ .

(4) **Energy scan from 3.8 to 6 GeV, plus extended running at 5.2 GeV**. Clear evidence for the production of the lowest-lying charmed baryon Λ_c^+ and its decay to $pK^-\pi^+$ was obtained. A precise determination of the mass of this particle was obtained, as well as an estimate of its branching ratio to the above final state. The study of inclusive proton and lambda production as a function of energy confirmed unambiguously the Mark I data indicating the presence of a cross-section step near the charmed baryon threshold.

(5) **All energies**. Branching ratios for τ decay modes $\tau \rightarrow \pi\nu$, $\rho\nu$, $K\nu K^*$ have been measured and agree well with predictions from the standard theory based on the identification of the τ as a sequential lepton, confirming our present understanding of the weak interaction.

Analysis of these and many other topics is continuing.

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The Lead Glass Wall Experiment

In this experiment, a wall of lead-glass counters was 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 inclusive production of D and K mesons have been completed during this fiscal year. Studies of γ and π^0 production in e^+e^- collisions have been carried out.

In studies of inclusive γ and π^0 production in $\psi(3100)$ decay, an excess of high energy γ production over that expected from π^0 decays was discovered. Hadronic decays of the $\psi(3100)$ are

described in quantum chromodynamics (QCD) as resulting primarily from the annihilation of a charmed quark and anti-charmed quark into three gluons, which then fragment into hadrons. QCD also predicts annihilation into a γ and two gluons, with gluon fragmentation into hadrons, to occur at a significant rate (about 6 to 12% of the three gluon rate). It was found that the excess of high-energy γ 's which we observed could be explained by this QCD decay of the $\psi(3100)$ into a γ and 2 gluons.

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PUBLICATIONS

Inclusive Production of D Mesons in e^+e^- Annihilation at 7 GeV. P. A. Rapids, G. J. Feldman, G. S. Abrams, M. S. Alam, A. Barbaro-Galteri, A. M. Boyarski, M. Breidenbach, W. Chinowsky, J. M. Dorfan, R. Ely, J. M. Feller, A. Fong, B. Gobbi, G. Goldhaber, G. Hanson, J. A. Jaros, J. A. Kadyk, B. P. Kwan, R. R. Larsen, P. Lecomte, A. M. Litke, D. Luke, V. Luth, R. J. Madaras, J. E. Martin, D.

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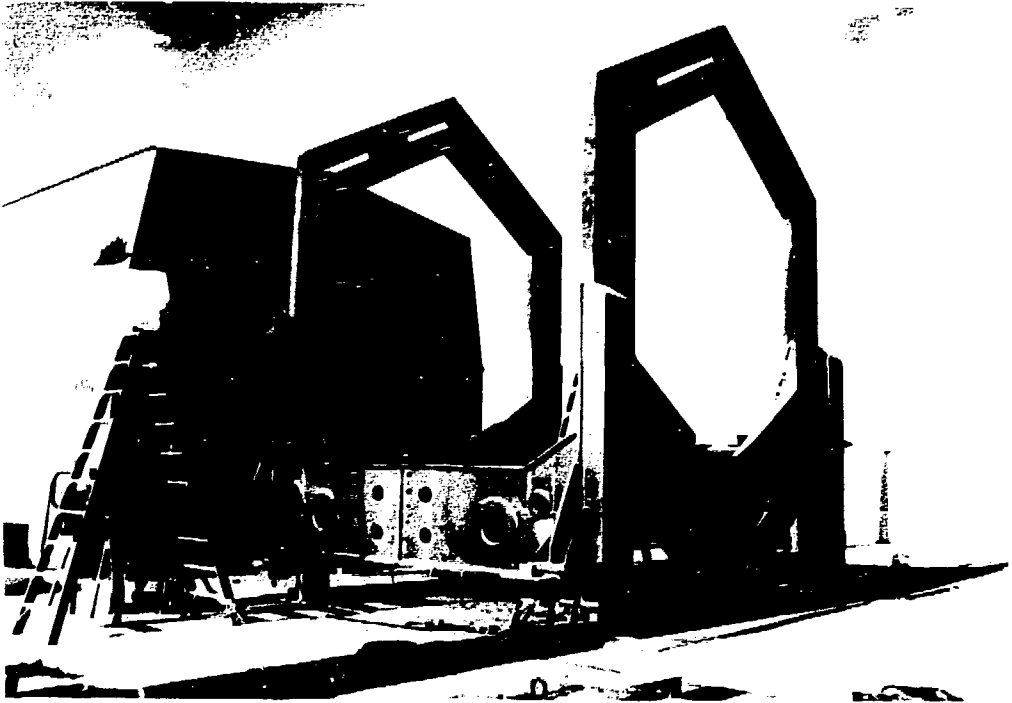
Inclusive Production of D and K Mesons in e^+e^- Annihilation. M. Piccolo, I. Peruzzi, P. A. Rapids, A. Barbaro-Galteri, J. M. Feller, D. Luke, V. Vuillemin, J. M. Dorfan, R. Ely, G. J. Feldman, A. Fong, B. Gobbi, G. Hanson, J. A. Jaros, B. P. Kwan, P. Lecomte, A. M. Litke, R. J. Madaras, D. H. Miller, S. I. Parker, I. P. Pan, M. I. Ronan, R. R. Ross, D. I. Scharre, T. G. Trippe, and D. E. Yount, IBI-7935, Phys. Letters 86B, 220 (1979).

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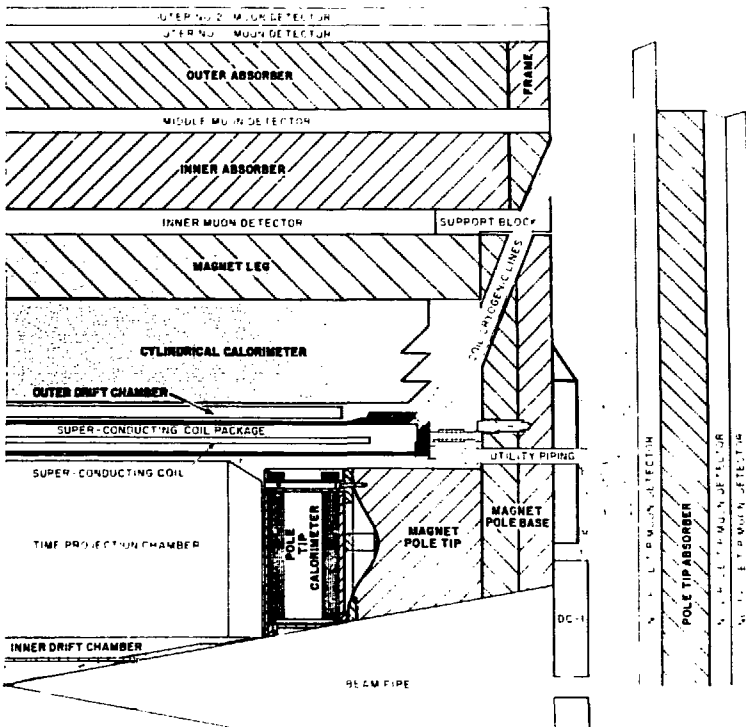
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The frame for the PEP-4 detector, as assembled on-site at SLAC; the photo was taken in September 1979. CBB 799-11468



Sectional view of upper quadrant of PEP-4 array, showing arrangement of various particle detectors. CBB 794-4616

Research and Development for e^+e^- Annihilation Experiments at PEP

Time Projection Chamber (TPC) PEP-4

As described in this Report for 1978, 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 is playing 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 highly multiplicity jet-like events, neutral reconstruction (A^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.

There has been a continuing effort during 1979 concerned with hardware development, data acquisition and processing systems and superconducting solenoid magnet research development and construction.

TPC Detector

Materials Additional testing of materials for contaminative outgassing was implemented to adjust to modifications of the fabrication processes for various components of the TPC active volume. The capability for this testing has continued to be indispensable in the final engineering and fabrication stages of the project.

Gas System The final design was completed and most of the fabrication was finished. Initial tests were in progress. Gas consumption was higher than

earlier estimates; a gas change may be required every two days. A cost-effective recirculating purifier concept was developed. Gas trailers were located from surplus sources.

High Voltage System The final design was completed and fabrication was underway. The high voltage supply was delivered and found defective. Problems were being remedied locally due to lack of confidence in the manufacturer. The graded insulation technique developed previously required some simplification due to fabrication difficulties and some schedule slippage occurred. The final insulators were partially completed, with good results. Prototype tests were very successful. The field cage fabrication is well underway and both electrical and mechanical tolerances and specifications were being met.

Readout Proportional Planes Prototype testing indicated the need for improvements in artwork design, preamp cooling system, and various detailed mechanical aspects. Performance generally met specifications well. Attention was given to maximizing reliability and stability. Final production of 16 sectors (12 needed) of the readout planes will be started soon.

Data Acquisition System and Electronics

All electronics design was complete and in preproduction or production stage. Performance specifications in all systems and components (including CCD's) were being met.

The electronics house, containing more than 400 bins of electronics, was fully equipped with wire-wrapped backplanes and power distribution. Air circulation systems were being installed. Testing of various electronic sub-systems was underway using computer controlled features.

The upper memory of the Large Data Buffer (LDB) was completed. This consists of the 36 lists of solid state memory (each up to 65k bytes) which are used to store raw data from the TPC before the data are read out by one of the on-line computers.

The LDB was extensively tested using the computer interface (Bus Controller) and the on-line computers. The computer hardware which was

installed during 1979 was refined somewhat during the testing of the LDB and an extensive library of diagnostic software was developed. A bus controller multiplexer was added so that two or more computers can share data stored in the LDB.

The hardware for interrupting the on-line computers on an event interrupt was built and tested with software drivers written for this purpose in each of the on-line computers. The hardware is also used for transmitting brief messages between the computers.

The message capability is augmented with DECNET communication for the transfer of large messages, data files, and program libraries. The Network has been extended to include other computer systems at LBL and UCLA which are not used as on-line computers.

A hardware monitoring system has been developed using a PDP 11 04 and multiplexed DVM's. The 11 04 is run as a slave to the PDP 11 70 which runs the PEP-4 experiment. A program has been developed for the 11 04 which permits periodic checking of hardware parameters such as voltage, current, temperature, and pressure, and can report errors, or keep a history of failing items. This program can also write selected data to the data tape to provide a permanent history of hardware performance.

In order to test the detector electronics during operation, and to set thresholds and other bias levels in the system, a Test Pulse Unit Register Control Unit (TPU/RCU) was developed. This system was installed in the electronics system during the year. Extensive PDP 11/70 software also was developed to use this hardware for testing the electronics.

The VAX 11/780 data acquisition program has been extensively tested using Monte Carlo data as input. These tests used the LDB, the Bus Controller, and the trigger interrupt. The data taking program was completed, ready for running in a real data-taking mode, although continued work will optimize the programs and increase their execution speed. The VAX system will be used for continued software development and hardware testing at PEP.

Development was started on a fast micro-processor for use with the LDB.

Cylindrical Calorimeter for PEP-4

A new technique for electromagnetic calorimetry has been developed. The resolution of gas shower counters can be improved by reducing the fluctuations due to heavily ionizing tracks by operating the gas gain in the Geiger regime.

Conventional wire proportional planes will operate in the Geiger mode with an appropriate gas mixture. Segmentation along the wires can be achieved by interrupting the Geiger streamer with a thin nylon monofilament, resulting in a plane of small, discrete cells. A prototype shower counter has been constructed of 72 lead plates of 0.2 radiation length thickness interspersed with Geiger cell detector planes. The shower counter was tested with electrons at SLAC and showed excellent energy resolution in the desired range. The design is complete and potential fabricators of the lead-fiberglass laminate have been found. Small samples of the laminate have been successfully produced. Data from the successful beam test last year of a small module have been analyzed. The Monte Carlo shower program has been extended to model shower development at large angles of incidence. Electronics and trigger requirements have been established. All electronics components will be ordered by spring 1980. Fabrication of full size modules will begin during spring and summer 1980.

Superconducting Solenoid Magnet Coil

The PEP-4 magnet coil has been constructed. Peripheral cryogenic equipment has been built and tested satisfactorily. Electronic equipment necessary for quench protection and for monitoring has been built and partially tested. The entire system will be tested first at LBL then at SLAC in the spring and summer of 1980.

The construction of the compensating solenoids for the PEP-4 and PEP-9 experiments will begin soon. A short sample test of the wire is being performed.

Structural Assembly at IR2

All of the steel is available onsite and erection has proceeded through the step of welding the magnet yoke. Tolerances achieved and rate of progress have been excellent.

Miscellaneous

The TPC test vessel has been utilized as planned in several manufacturing stages for other components, such as the feedthrough rings and inner pressure containment system. The interface and coordination with the PEP-9 collaboration has been proceeding without difficulty. The other detector systems that are the responsibility of the other university collaborators, i.e., poletip calorimeters, inner and outer drift chambers, and muon chambers are either complete or in the final states of fabrication.

Time Projection Chamber Staff

M. Alston-Garnjost	R. D. Majka
A. Barbaro-Galtheri	P. S. Martin
A. Barnes	J. N. Marx
A. Bross	P. Nemethy
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PUBLICATIONS

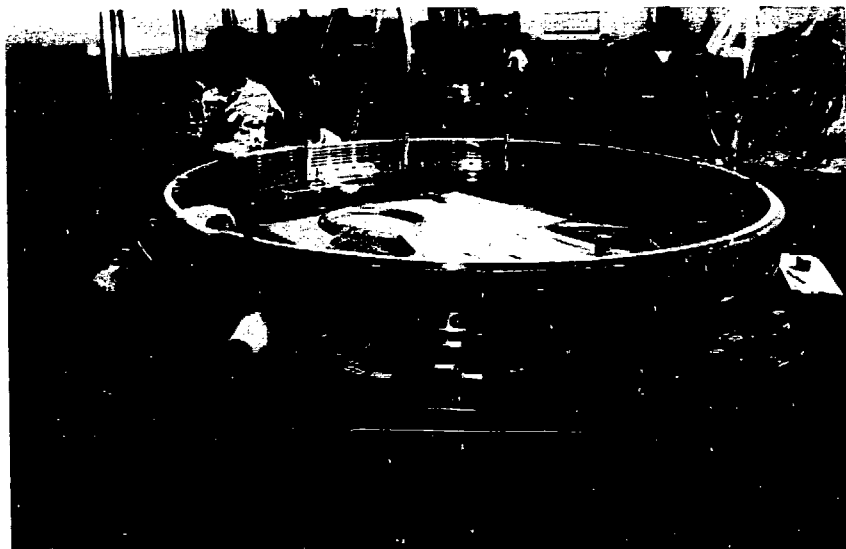
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Thousands of electrical connections from detector to readout are made with this precision-machined, vacuum-tight feed-through ring. CBB 795-7001

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The Mark II Magnetic Detector

As indicated earlier, the Mark II detector was dismantled and reassembled at LBL, Stanford Positron Electron Project (PEP) colliding beam facility. This move was accompanied by considerable modifications and improvements to the system. Those modifications to which the LBL part of the collaboration made substantial or leading contributions include:

- Upgrading of the liquid-argon shower counters, including design and construction of improved electronic cages, improved instrumentation, and improved pre-amplifier electronic design. It is expected that these changes will substantially reduce the noise level.
- Design and construction of a sophisticated vacuum pipe with appropriate masks and shielding for use with the detector.
- Development of a new improved time-of-flight calibration system.
- Improvement of tracking software for both the

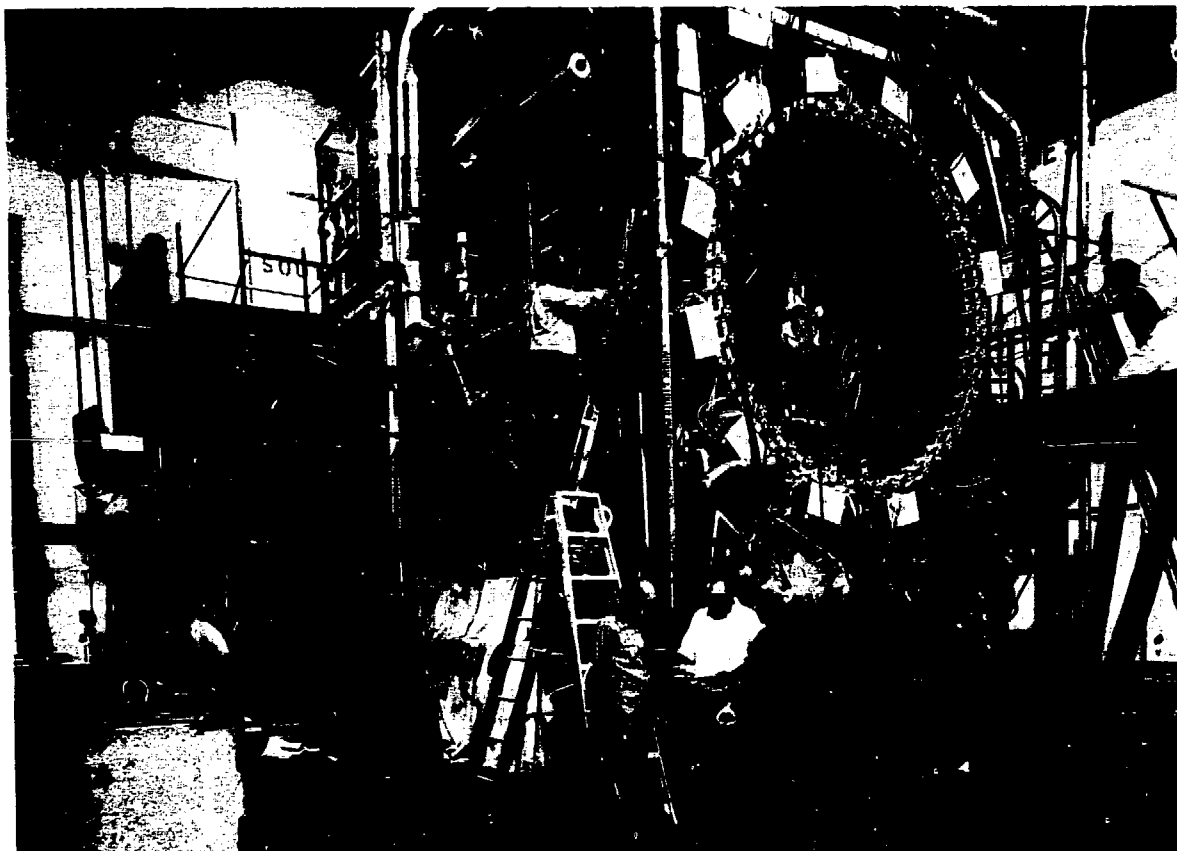
drift chamber and liquid argon systems to confront the pattern recognition problems of high energy multi-jet events.

- Development of new on-line software for diagnostic purposes.

It is anticipated that the PEP operation and data taking should begin later in the spring. Undoubtedly some of the early running will be



A two-headed monster, this tractor-trailer rig inches its way down a SLAC driveway to deliver the 400-ton central section of the Mark II detector to Interaction Region 12 on the PEP colliding beam ring.
CBB 790-13165



In place on the PEP beam line after its move from SPEAR to PEP, the Mark II was being prepared to do physics. In center foreground are Gerson Goldhaber, LBL, and Bill Davies-White and Bert Richter, SLAC. On the ladders are Gerry Abrams (left) and Andy Lankford (right), both LBL. CBB 799-13452

devoted to check out of the equipment. It is difficult to predict at this time how much real data taking will

be possible this fiscal year, but it is hoped at least to make a start.

Mark II Detector Staff

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A P Blondel
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G Gidal
G Goldhaber
J A Kadyk
A J Lankford

T A O'Halloran
C Y Pang
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Graduate Student Research Assistants

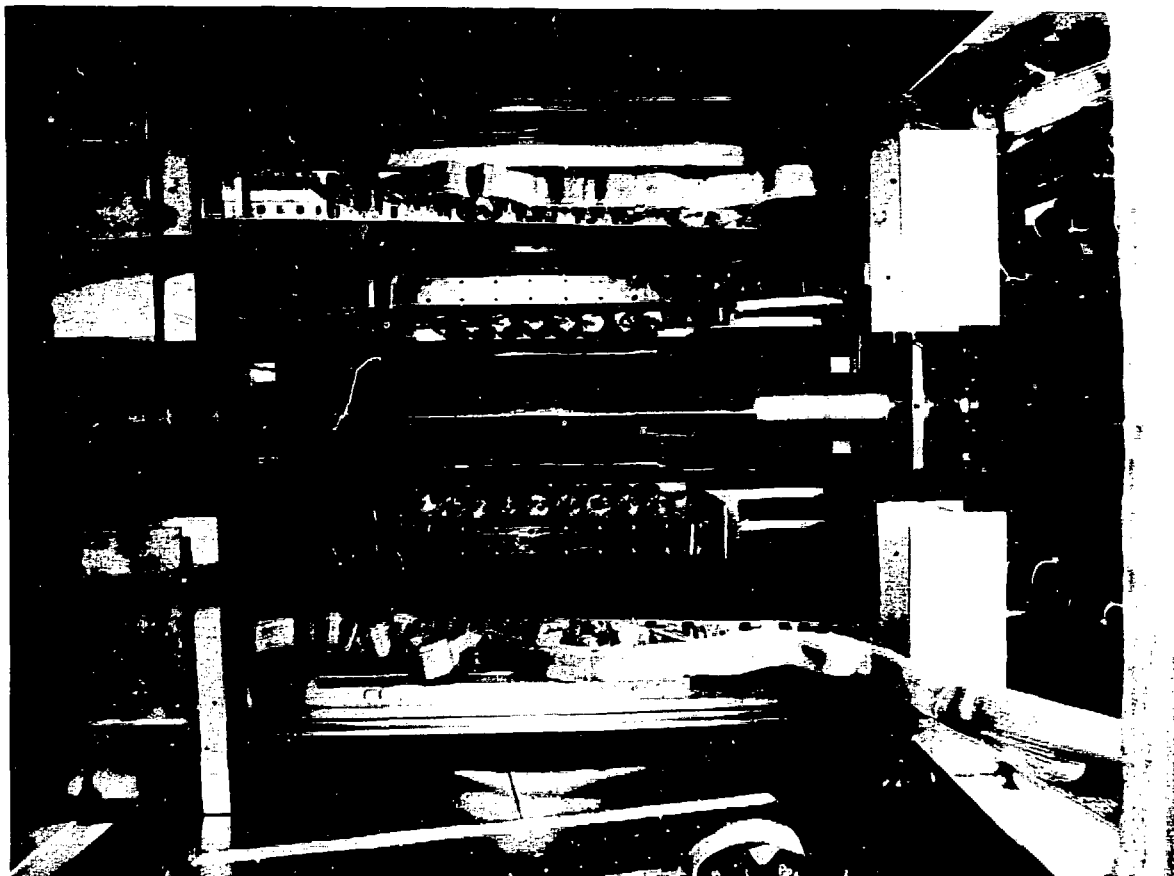
C A Blocker
M W Coles
S Cooper
W E Dieterle
J B Dillon
M W Eaton

L J Golding
R E Millikan
M E Neison
J F Patrick
H M Schellman
E N Vella

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.

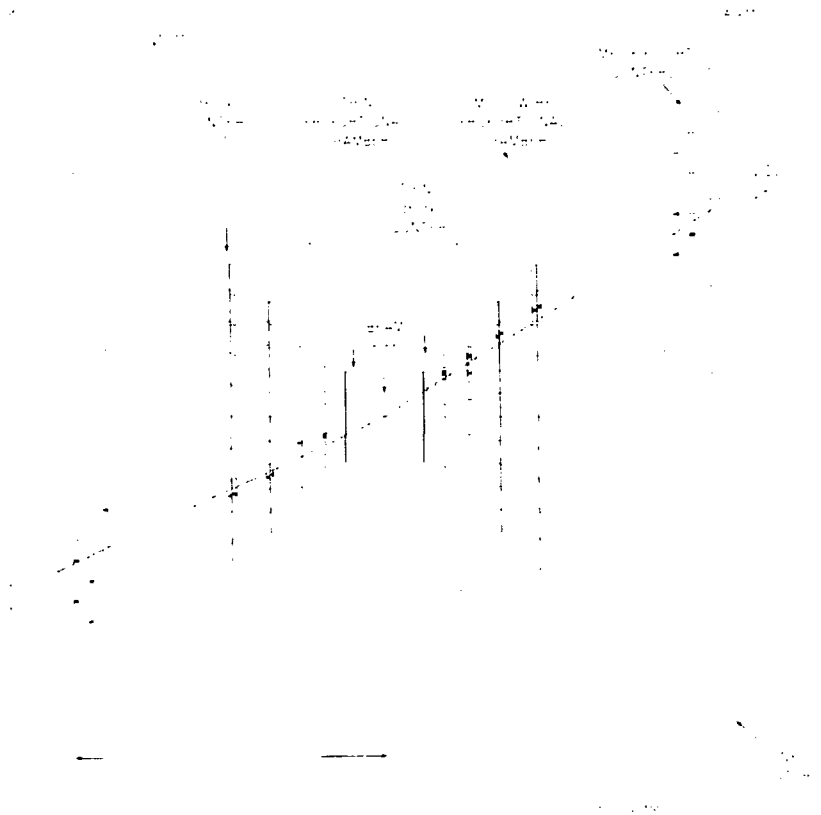
The Free Quark Search (PEP-14) depends upon the distribution of ionization of 16 layers of scintillator to distinguish particles of charge $1/3e$ and $2/3e$ from singly charged particles. Ten layers of multiwire proportional chambers (MWPC) are used for tracking the detected particle originating in the interaction region. The scintillation counters are being constructed at Northwestern University and Stanford University, and the MWPC are being built at LBL.



Ant's eye view of the PEP-14 detector, looking up from the floor of Interaction Region 6; beam pipe is at center. The pipe's wall thickness here is only 80 mils (0.080 in.). Flanking the pipe are, successively, the thin, inner, front-end scintillation counters and the proportional chambers. The dE/dx (energy loss) counters are sandwiched between them but are obscured.

CBB 801-886

Computer record of track made by cosmic ray from space, as detected by PEP-14 array during instrument checkout period, prior to beam turn-on. Principal detectors of the PEP-14 array are identified by labels applied to this computer-generated schematic.



In the past year all 10 of the MWPC were fabricated and tested. The chamber readout electronics were assembled and the system check out was completed. The different components of the experimental equipment were assembled at SLAC and interfaced to the VAX 11 780 on-line computer. Cosmic Ray data have been successfully recorded with both pulse height and time-of-flight information from the scintillator counters and position information from the MWPC. Improvements in the Trigger and data analysis are still underway.

During the latter part of the year, the overall mechanical support structures have been fabricated at LBL. The various components of the experiment were assembled to the final configuration and moved to the assigned PEP interaction region.

PEP-14 is a collaborative effort with Stanford University, Northwestern University, University of Hawaii and Frascati.

Free Quark Search Staff

Denyse Chew
Robert Ely
Robert Hamilton

Paul Madden
Ting Pun
Vincent Vuillemin

PUBLICATION

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PEP Facilities Operations

The Time Projection Chamber – PEP-4

Facility Operations this year has covered the initial testing phase of the TPC. Electronics checking and testing, cryogenics testing, magnet tests and field mapping, programming work, gas systems, high voltage systems and operations work in IR2 at PEP.

PEP Experimental Facilities Coordination

The PEP experimental coordination during FY 1980 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 areas is now about 95% complete. A total of 20 proposals have been analyzed and nine of these proposals have been approved for operation at PEP. These detectors have been assigned to experimental areas as follows:

Area 12: Mark II Detector

Area 2: TPC and Two Photon Detectors

Area 4: Magnetic Calorimeter

Area 6: High Resolution Spectrometer and Free Quark Search

Area 8: DELCO Detector, followed by the Crystal Ball

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.

aff

P. Nemethy

P. Oddone



As the year ended, construction of the PEP experimental areas was about 95% complete. Interaction halls can be seen on the perimeter of the circular service road.

CBB 806-7147

The Single Pass Linear Collider Study

The Single Pass Linear Collider (SPLC) is a colliding beam facility proposed for SLAC, for the study of high energy e^+e^- collisions (50 GeV on 50 GeV). Unlike at SPEAR or PEP, particle bunches collide only once so the facility is relatively inexpensive to construct and research may begin (if the facility is approved) as early as 1984. As a consequence LBL physicists are interested in the facility itself and the possibilities for carrying out research there.

The Single Pass Linear Collider group at LBL consists of several physicists who meet nearly every week to discuss work being done toward development of the SPLC at SLAC. The effort has thus far been solely on a voluntary basis, without any formal connection with the SLAC counterpart, except for one activity, where a specific charge has been given jointly to an LBL/SLAC two-person task force (layout and design of the experimental hall).

Activities at LBL have been based on individual interest in various problems associated with the SPLC, many of which are of natures never previously encountered, at least not in high energy physics. Specific contributions to date include:

- Development of a fast Monte Carlo program for simulating the detail behavior in bunch-

bunch collisions of the e^+e^- beams, as a function of various input parameters, such as beam size or shape, particle density distribution within bunch, offset in impact parameter, etc.

- A scheme for beam matching which, in an idealized case, leads to much less "disruption" (smaller exiting angles) of bunches during collision without loss in luminosity. Work continues on the study of the less idealized cases, closer to what is expected in practice.
- A new idea for constructing permanent magnet quadrupoles from rare-earth cobalt material, which has the virtue of very high gradients over the small SPLC beam pipe (≈ 50 T m) at the detector without any appreciable distortion of the detector field.
- A design study of the experimental hall with regard to flexibility of interchanging two experiments in the beam area on a relatively short time scale (≈ 3 weeks).

Single Pass Linear Collider Study Group

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R. Sah

Research at FNAL on Muon and Neutrino Reactions

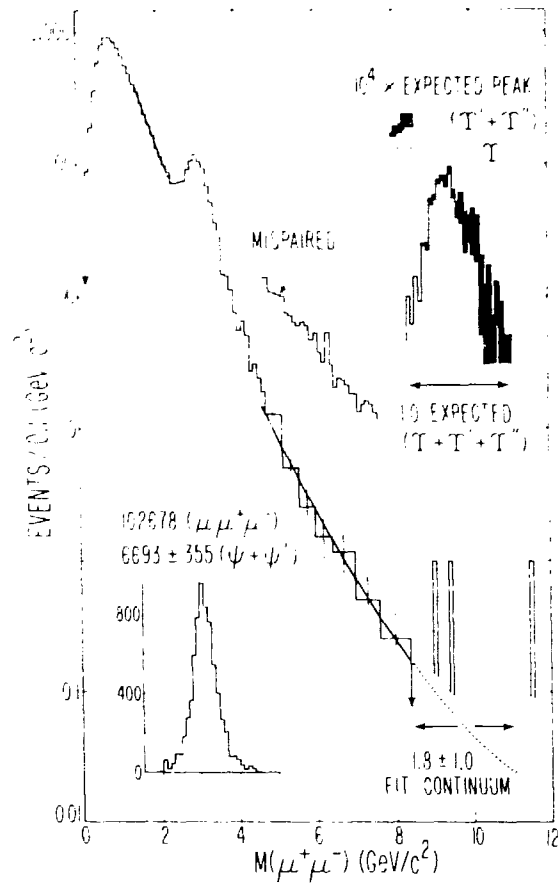
Muon Reactions

Experiments on rare muon induced reactions have been carried out at FNAL. Electronic techniques are used for particle identification and measurement. A 470 ton spectrometer magnet was constructed for use in this experiment.

During this year summary tapes were created for all the Fermilab E203 391 data and a broad range of physics results were reported at conferences and submitted for publication. All of the event-reconstruction software was developed and the majority of data were analyzed on the LBL CDC 7600 computer.

Results have been obtained for muon scattering into 1, 2, 3, 4, and 5-muon final states, as described in the following paragraphs:

- From single muon final states the inelastic structure function F_2 has been measured over the range 4-150 GeV-squared in momentum-transfer-squared and over the range of 0.045-0.65 in x , with errors as small as 10% for most of the data. This is the first of the current generation of muon experiments to measure a range large enough to confirm in detail the pattern of scale-noninvariance originally observed in muon scattering and recently measured in neutrino-scattering experiments.
 - From two muon final states the total cross section for muoproduction and for photoproduction of charmed quark pairs has been extracted. The signature of this process is the appearance in the final state of an extra muon from the decay of one of the charmed quarks. While consistent with QCD estimates, the observed charm production rates fall well below vector-dominance expectations and account for only about 1/4 of the observed rise with energy of the photon-nucleon total cross section. The measured momentum-transfer and energy-dependence of the muon data impose constraints on the quark mass and gluon x -distribution in the photon-gluon fusion model.
 - The analysis of 3-muon final states arising from $\psi(3100)$ production and dimuon decay has been extensively developed. The data set upon which it has been exercised contains more than 90% of the world sample of fully-reconstructed events of this type. The energy-dependence published on the basis of a portion of these data disagreed with an early photon-gluon fusion calculation performed at DESY. That calculation has since been repeated by others (including this group) and the earlier results found to be in error; the agreement between data and QCD is excellent. The polarization of produced ψ 's has been studied using the dimuon axis as an analyzer. Polarization transverse to the lepton scattering plane has been observed at the expected level. However, polarization along the ψ direction exhibits an unexpected transition from unit helicity to zero helicity as the momentum transfer increases.
 - Dozens of four- and five-muon-final-state candidates are under intensive analysis. Of the few which have completed this process, attention has been focused on a five-muon and a four-muon event in which several secondaries possess unusually large transverse momentum. Tentatively, the four-muon event has been identified as a candidate for associated bottom quark decay through a ψ intermediate state.
- This effort is a collaboration between LBL and physicists from Fermilab and Princeton.



Spectrum of 102 678 dimuon masses from the Berkeley-Fermilab-Princeton trimuon data. The mass continuum, due primarily to electromagnetic tridents, is fit in the regions of the solid curve and extrapolated along the dotted curve. Subtraction of the continuum yields 6693 ± 355 ($\psi+\psi'$) states centered at $3.1 \text{ GeV}/c^2$ (lower inset). These data have provided the primary basis for study of mechanisms for ψ production by virtual photons. Only one event from the T ($9.46 \text{ GeV}/c^2$) family is expected in this sample (upper inset), because of its high mass and the weaker coupling of its charge-1/3 constituents to muons.

XBL 805-966

Muon Reactions Staff

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PUBLICATIONS

Observation of $J/\Psi(3100)$ Production by 209-GeV Muons, A. R. Clark, K. J. Johnson, L. T. Kerth, S. C. Loken, T. W. Markiewicz, P. D. Meyers, W. H. Smith, M. Strovink, W. A. Wenzel, R. P. Johnson, C. Moore, M. Mugge, R. E. Shafer, G. D. Gollin, F. C. Shoemaker, and P. Surko, Phys. Rev. Letters 43, 187 (1979), and I.B.I.-9125

First Results from the Berkeley-Fermilab-Princeton Muon Spectrometer, M. Strovink, Proceedings of the Seminar on Probing Hadrons with Leptons, Erice, Trapani, Sicily, March 13-21, 1979, edited by G. Preparata and J. J. Aubert (Plenum, New York, 1979), and I.B.I.-9234

Study of Rare Muon Induced Processes, A. R. Clark, K. J. Johnson, L. T. Kerth, S. C. Loken, T. W. Markiewicz, P. D. Meyers, W. H. Smith, M. Strovink, W. A. Wenzel, R. P. Johnson, C. Moore, M. Mugge, R. E. Shafer, G. D. Gollin, F. C. Shoemaker and P. Surko, to be published in the Proceedings of the European Physical Society, International Conference on High Energy Physics, Geneva, Switzerland, June 27-July 4, 1979, and I.B.I.-9348.

Muon Scattering into 1-5 Muon Final States, A. R. Clark, K. J. Johnson, L. T. Kerth, S. C. Loken, T. W. Markiewicz, P. D. Meyers, W. H. Smith, M. Strovink, W. A. Wenzel, R. P. Johnson, C. Moore, M. Mugge, R. E. Shafer, G. D. Gollin, F. C. Shoemaker, and P. Surko, Proceedings of the 1979 International Symposium on Lepton and Photon Interactions at High Energies, Batavia, Illinois, August 23-29, 1979, edited by T. B. W. Kirk, Fermilab, and I.B.I.-9912.

Muonproduction of $\Psi(3100)$, T. W. Markiewicz, A. R. Clark, Karl J. Johnson, L. T. Kerth, S. C. Loken, P. D. Meyers, W. H. Smith, M. Strovink, W. A. Wenzel, R. P. Johnson, C. Moore, M. Mugge, R. E. Shafer, G. D. Gollin, F. C. Shoemaker, P. Surko, Abstract submitted to the April 1979 Meeting of the American Physical Society.

Muon-Nucleon Deep Inelastic Scattering, P. D. Meyers, A. R. Clark, Karl J. Johnson, L. T. Kerth, S. C. Loken, T. W. Markiewicz, W. H. Smith, M. Strovink, W. A. Wenzel, R. P. Johnson, C. Moore, M. Mugge, R. E. Shafer, G. D. Gollin, F. C. Shoemaker, P. Surko, Abstract submitted to the April 1979 meeting of the American Physical Society.

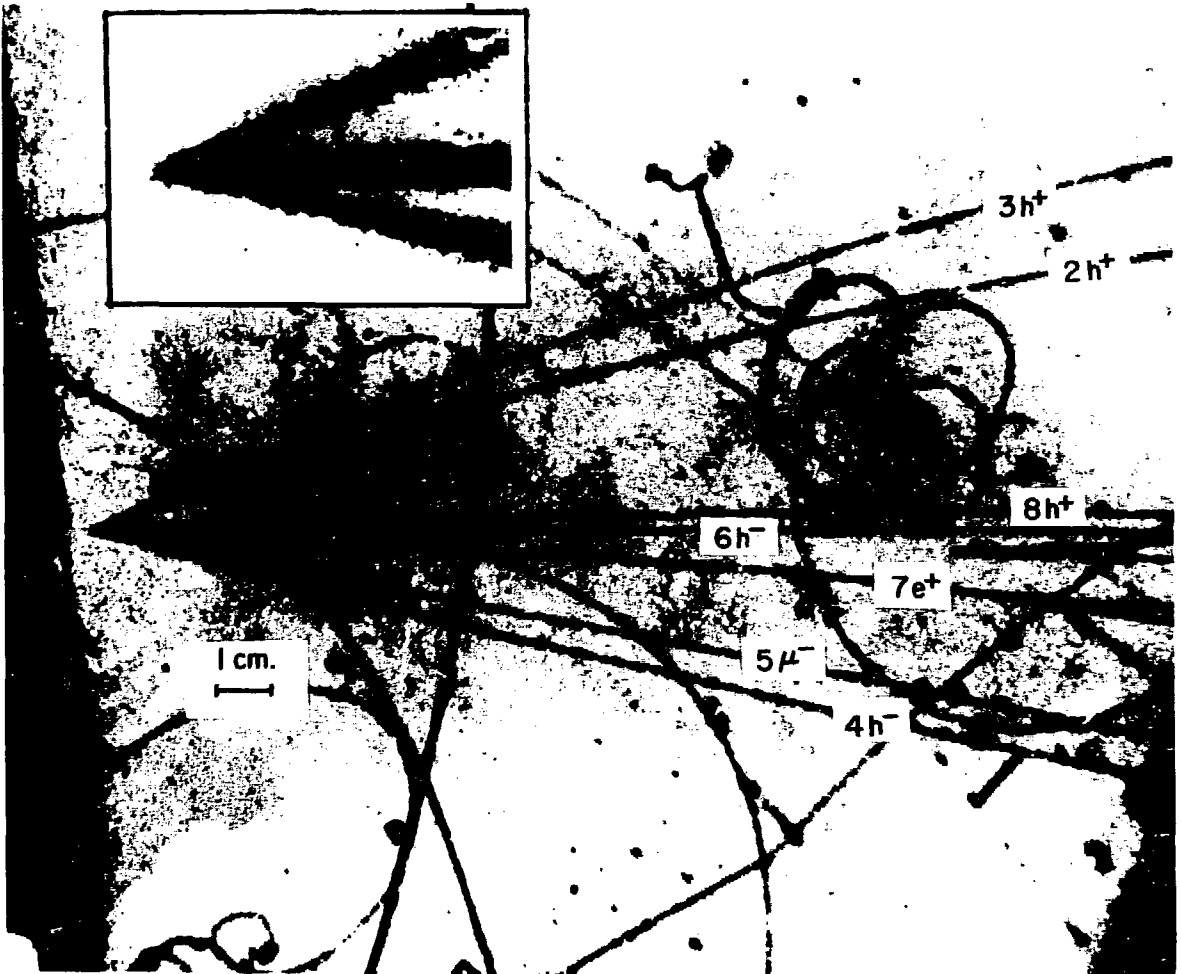
Neutrino and Anti-Neutrino Reactions

Neutrino and antineutrino studies have been carried out in the Ne-H filled bubble chamber at Fermilab.

- In FNAL experiment E-546 evidence for visible decay lengths of several charmed mesons that decayed semileptonically was obtained in a sample of 89 dilepton events. An average lifetime of $3.1^{+1.5}_{-1.1} \times 10^{-13}$ sec was established.
- The behavior of the hadronic final state of the

89 dilepton events was also studied. Partial results (only of the $\mu^+\mu^-$ events) have been obtained. Analysis of the μe events is not yet complete.

- In addition, measurement and analysis of an enriched sample of high- Q^2 events in this same experiment continued, in a search for evidence of gluon radiation in the hadronic final states as predicted by quantum chromodynamics.



On the trail of the D-meson. LBL physicists analyzing film from a high-energy neutrino experiment at Fermilab reported the observation of short-lived particles and, assuming that these were examples of D-meson decay, made a rough measurement of the D-meson lifetime. One of these reported events is shown in this photo. (Fermilab photo)

- This work is a collaboration with FNAL and the University of Washington.
- In FNAL experiment E-172 a search was made in ν and $\bar{\nu}$ interactions for confirmation of a reported narrow resonance at 1.9 GeV c. No evidence was found for this or any other neutral heavy lepton up to a mass of 6 GeV c².
- This experiment is a collaboration with the University of California at Berkeley and the University of Washington.
- In FNAL experiment E-388 the exposure of the bubble chamber to a dichromatic *anti* neutrino beam of various energies was completed and the analysis begun. A full-scale Internal Picket Fence, operating in addition to the External Muon Identifier, will permit a better analysis of neutral-current interactions than was possible before.
- This experiment is a collaboration with the University of Hawaii, the University of California at Berkeley, and FNAL.

Staff for These Neutrino Experiments

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J Lys
M. L. Stevenson

Neutrino Experiment E-45 — Studies have also been carried out in the hydrogen filled bubble chamber at Fermilab.

Inclusive production of non-strange reso-

nances in high energy νp charged-current interactions has been observed. For example, $(21 \pm 4)\%$ of the events contain a ρ^0 meson.

This experiment, FNAL E-45, is a collaboration with the University of California at Berkeley, the University of Michigan, and the University of Hawaii.

Staff for Neutrino Experiment E-45

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PUBLICATIONS

Dimuon Production by Neutrinos in the Fermilab 15-foot Bubble Chamber, H. C. Ballagh, H. H. Bingham, W. B. Fretter, T. Lawry, G. R. Lynch, J. Lys, J. P. Marriner, J. Orthel, M. D. Sokoloff, M. L. Stevenson, G. P. Yost, B. Chrisman, D. Gee, A. Greene, G. Harigel, F. F. Huson, T. Murphy, E. Schmidt, W. Smart, E. Treadwell, J. Wolfson, R. J. Cence, F. A. Harris, M. D. Jones, S. I. Parker, M. W. Peters, V. Z. Peterson, T. H. Burnett, L. Fluri, D. Holmgren, H. J. Lubatti, K. Moriyasu, D. Rees, H. Rudnicka, G. M. Swider, E. Wolin, R. Benada, U. Camerini, M. Dully, W. Fry, R. J. Loveless, P. McCabe, D. D. Reeder, Fermilab-Pub-79 57 (July 1979), submitted to Phys. Rev.

Observation of Short-Lived Particles Produced in High-Energy Neutrino Interactions, H. C. Ballagh, H. H. Bingham, W. B. Fretter, T. Lawry, G. R. Lynch, J. Lys, J. Orthel, M. D. Sokoloff, M. L. Stevenson, G. P. Yost, B. Chrisman, D. Gee, G. Harigel, F. R. Huson, E. Schmidt, W. Smart, E. Treadwell, J. Wolfson, R. J. Cence, F. A. Harris, M. D. Jones, S. I. Parker, M. W. Peters, V. Z. Peterson, V. J. Stenger, T. H. Burnett, L. Fluri, D. Holmgren, H. J. Lubatti, K. Moriyasu, D. Rees, H. Rudnicka, G. M. Swider, E. Wolin, R. Benada, U. Camerini, M. Duffy, W. Fry, R. J. Loveless, P. McCabe, M. Ngai, D. D. Reeder, UH-511-351-79, (July 1979).

Strong Interaction Experiments at FNAL

Elastic Scattering from a Polarized Proton Target

Polarization measurements have been made with π^+ , π^- , and protons on a polarized proton target. The analysis of all data has been completed and is being published. This experiment, FNAL E-61, is a collaborative effort involving physicists from Harvard, Yale, Argonne National Laboratory, Fermi National Accelerator Laboratory, and LBL.

O Chamberlain

H Steiner

G Shapiro

Inclusive Production of π^0 Mesons In $\pi^- p$ and pp Interactions

The final data on FNAL experiment, E-350, ($\pi^- p \rightarrow \pi^0 X$) at 200 GeV are still being reduced at Cal Tech by students. Rosemary Kennett has completed her Ph.D. thesis (CALT-68-742) on the subject "Experimental Tests of Triple Regge Theory" and two senior level theses have been written as well. The entire project will be concluded in FY 81, requiring only funds for computing, partial support coming from LBL and the remainder from CIT. The LBL support will be divided equally between the Kenney-Helmholz Group and Group A. All manpower will be supplied by Cal Tech throughout the remainder of the work.

R Kenney

O Dahl

M Garnjost

PUBLICATION

Polarization Parameters and Angular Distributions in $\pi^\pm p$ Elastic Scattering at 100 GeV/c, and in pp Elastic Scattering at 100 and 300 GeV/c, R. V. Kline, M. F. Law, and F. M. Pipkin, and I. P. Auer, D. Hill, B. Sandler, D. Underwood, A. Yokosawa, A. Jonckheere, P. F. M. Koehler, W. Bruckner, O. Chamberlain, G. Shapiro, H. Steiner, W. Johnson, J. H. Snyder, and M. E. Zeller, submitted to Phys. Rev.

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 of this experiment is now complete and publication of the results will soon follow. This is experiment E-69 at FNAL and is a collaboration with FNAL and Yale.

R Majka

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J Marx

Search for Massive, Long-Lived, Fractionally Charged Particles

A search has been made for massive, long-lived, weakly interacting particles of fractional charge that could be produced by 300-GeV protons striking an aluminum target. The search was most sensitive to particles with a lifetime of about 100 μ seconds. If present, such particles would have come to rest in the Caltech neutrino detector that was located halfway down the muon shield and, if they were massive enough and decayed into at least 5 GeV of visible energy in the calorimeter, they could have been detected. None were found. The 90%-confidence-level upper limit to the invariant cross section (times branching ratio R), $REd^3\sigma/dp^3[\text{cm}^2(\text{GeV } c)^2]$, is 4×10^{-39} (5×10^{-38}) for charge (2/3)e ($1/3$)e.

M. L. Stevenson

PUBLICATION

Search for Massive, Long-lived, Fractionally Charged Particles Produced by 300-GeV Protons, M. L. Stevenson, Physics Today, January 1979.

Research and Development for Experiments at FNAL

Muon Reactions at the Tevatron

Fermilab plans to build a new high intensity muon beam for use with the Tevatron. A proposal has been submitted to Fermilab to move the multimMuon spectrometer to this new beam. The physics objectives of a new muon experiment includes the following:

a. A measurement of the parity-violating asymmetry

$$\frac{\sigma_{\mu_L^+} - \sigma_{\mu_R^+}}{\sigma_{\mu_L^+} + \sigma_{\mu_R^+}}$$

which is due to weak-electromagnetic interference and yields a linear combination of Z^0 -quark and Z^0 -lepton structure functions. This experiment utilizes the important feature that we can control the helicity of the new muon beam. It is possible to achieve precision similar to the polarized electron experiment at SLAC and to extend the measurements over an extended range of Q^2 and $Y = \nu, E$.

b. A measurement of the asymmetry

$$\frac{\sigma_{\mu_L^+} - \sigma_{\mu_R^-}}{\sigma_{\mu_L^+} + \sigma_{\mu_R^-}}$$

which results from two contributions. The first (independent of muon helicity) is due to two-photon processes and the second is due to weak-electromagnetic interference and yields a linear combination of Z^0 coupling constants different from the P-violating asymmetry. These effects can be separated by their differing dependence on Q^2 and Y .

c. A measurement of the nuclear structure functions in deep inelastic muon scattering ($\mu N \rightarrow \mu X$). The proposed experiment will extend the measurement of W_2 to momentum transfers of 1000 (GeV/c)². In addition, by making measurements

over a wide range of incident energies it will be possible to determine the value of the function $R = \sigma_1 / \sigma_2$, over a broad range in Q^2 and $X = 2M^2 / Q^2$.

d. A measurement of dimuon final states

$$\mu N \rightarrow \mu \mu X$$

New data at higher energy will permit study of heavy quark production at large momentum transfer. The data will be used for detailed comparison with theoretical models.

e. A high sensitivity search for a neutral heavy lepton.

$$\mu N \rightarrow M^0 X$$

$$\quad \quad \quad \downarrow$$

$$\quad \quad \quad \mu^+ \mu^- \nu$$

The cross section for this process increases linearly with incident energy so that a new experiment can improve the sensitivity of this search. In addition, by varying the helicity of the incident muon beam (as in a.), the spin structure of the M^0 coupling can be studied.

f. A measurement of high mass vector meson production by virtual photons

$$\mu N \rightarrow \mu \psi X \rightarrow \mu \mu^+ \mu^- X$$

or

$$\mu N \rightarrow \mu \gamma X \rightarrow \mu \mu^+ \mu^- X$$

Diffractional ψ production is now being studied using data taken with 225 GeV incident muons. A sample of data at higher energy will provide higher statistical precision, and will permit study of increased range of photon energy and momentum transfer. In addition, it will be possible to study the nondiffractive component of the production process. The cross section for production is expected to be low even at 600 GeV. The proposed experiment using the high luminosity target of the multimMuon

spectrometer will, however, permit a measurement of the cross section and determination of the Q dependence.

g. A study of final states of more than 3 muons. The data taken at 225 GeV show clear evidence for the existence of exotic final states with 4 and 5 muons in the final state. Running at higher energy should significantly increase the number of exotic events and should permit a study of the production mechanism for these final states.

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Experiments Using Polarized Proton and Anti-proton Beams

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. Construction of such a facility is proposed for a study of the substructure of hadrons through the spin effects at high energy. The group expects to measure total cross-section differences and high x_F low- p_\perp inclusive pion production using a polarized beam and a polarized target. Fermilab has approved construction of a polarized beam facility as proposed by the group. Design of the polarized beam facility is being finalized by consultation between members of our collaboration and Fermilab personnel. This will be a collaborative effort involving physicists from Argonne National Laboratory; LAPP, Annecy, France; Rice University; INFN, Sezione di Trieste, Italy; and LBL.

O Chamberlain	H Steiner	G Shapiro
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$\bar{p}p$ Interactions at the Fermilab Collider

Preliminary feasibility studies have begun for the design of a detector to study $\bar{p}p$ interactions at the proposed Fermilab collider. Proton-antiproton collisions at $s = (2\text{TeV})^2$ and luminosities exceeding $10^{30} \text{ cm}^{-2} \text{ sec}^{-1}$ might be available by 1984. Current theoretical notions expect a cornucopia of new phenomena in this regime including weak intermediate boson (Z^0 , W), possible Higgs mesons, and high transverse momentum QCD effects.

William Carithers

Strong Interaction Experiments at BNL

Elastic Scattering and Σ^- Production in K^-p Interactions at 180°

The measurement of the differential cross section for the elastic scattering $K^-p \rightarrow K^-p$ and $\Sigma^- \pi^-$ at 180° , covering the momentum range 476–1084 MeV/c, has been made. This backward region has been investigated previously 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 K^-p data show a bump near 815 MeV/c which has not been observed previously. A new partial wave analysis (PWA) has been performed including our latest data. This PWA shows the probable existence of a D13 resonance of mass 1708 MeV. This may be one of the resonances reported by Carroll et al., PRL 37, 806 (1976). However, other structures observed by Carroll et al. cannot be reconciled with our new PWA. This is a collaboration with BNL and Mt. Holyoke College.

Staff

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PUBLICATION

Backward K^-p Elastic Scattering and Forward $\Sigma^- \pi^-$ Production, M. Alston-Garnjost, R. Hamilton, R. Kenney, D. Pollard, R. Tripp, H. Nicholson, and D. Lazarus, (LBL-9083), Physical Review in press.

$\bar{p}p$ Elastic Scattering at 180°

$\bar{p}p$ elastic scattering at 180° below 1000 MeV/c has been measured. This experiment is a search for baryonium states, and it was conducted at a scattering angle of 180° for the same reason given above in connection with the K^-p investigation. Data obtained show no evidence for the narrow S meson at 1936 MeV, nor a resonance at 2020 MeV reported previously.

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PUBLICATION

Measurement of $\bar{p}p$ Backward Elastic Scattering Cross-section from 406 to 922 MeV/c, M. Alston-Garnjost, R. Hamilton, R. Kenney, D. Pollard, R. Tripp, H. Nicholson, and D. Lazarus, (LBL-9466), Phys. Rev. Letts. 43, 1901 (1979).

Search for Baryon Resonances

Measurements of the total cross section for $\bar{p}p$ and pd , and the $\bar{p}p$ charge exchange total cross section have been made. Baryon resonances con-

tinue to be a subject of great interest, so this year the previous (1976) search for the S meson and the "2020" resonance was extended. Both the total cross section and charge exchange experiments showed no evidence for these structures. There is some evidence of a broad and gentle enhancement in the pp data centered at 1939 MeV. However, no structure has been observed in the pd reaction.

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PUBLICATIONS

Measurement of the pp Charge Exchange Cross-section from 0.119 to 1.046 GeV/c. R. P. Hamilton, T. P. Pun, R. D. Tripp, H. Nicholson, and D. M. Lazarus, submitted to Phys. Rev. Letts.

In Search of the S Meson. R. P. Hamilton, T. P. Pun, R. D. Tripp, D. M. Lazarus, and H. Nicholson, submitted to Phys. Rev. Letts.

Barrelet Moment Analysis of πN Scattering

A πN partial wave analysis has been performed using the Barrelet formula for the amplitude together with data zeros from Barrelet-moment analysis of the data (performed in 1978). The results for Δ parameters are rather interesting: all Δ resonances are found with a width of the order of 100 MeV. Also there are hints of resonance degeneracy between S31 and P31 resonances (LBL-5306, August 1979).

The Barrelet Amplitude formula has been verified by checking it against a widely accepted standard analysis ("Cutkosky76"). This check also

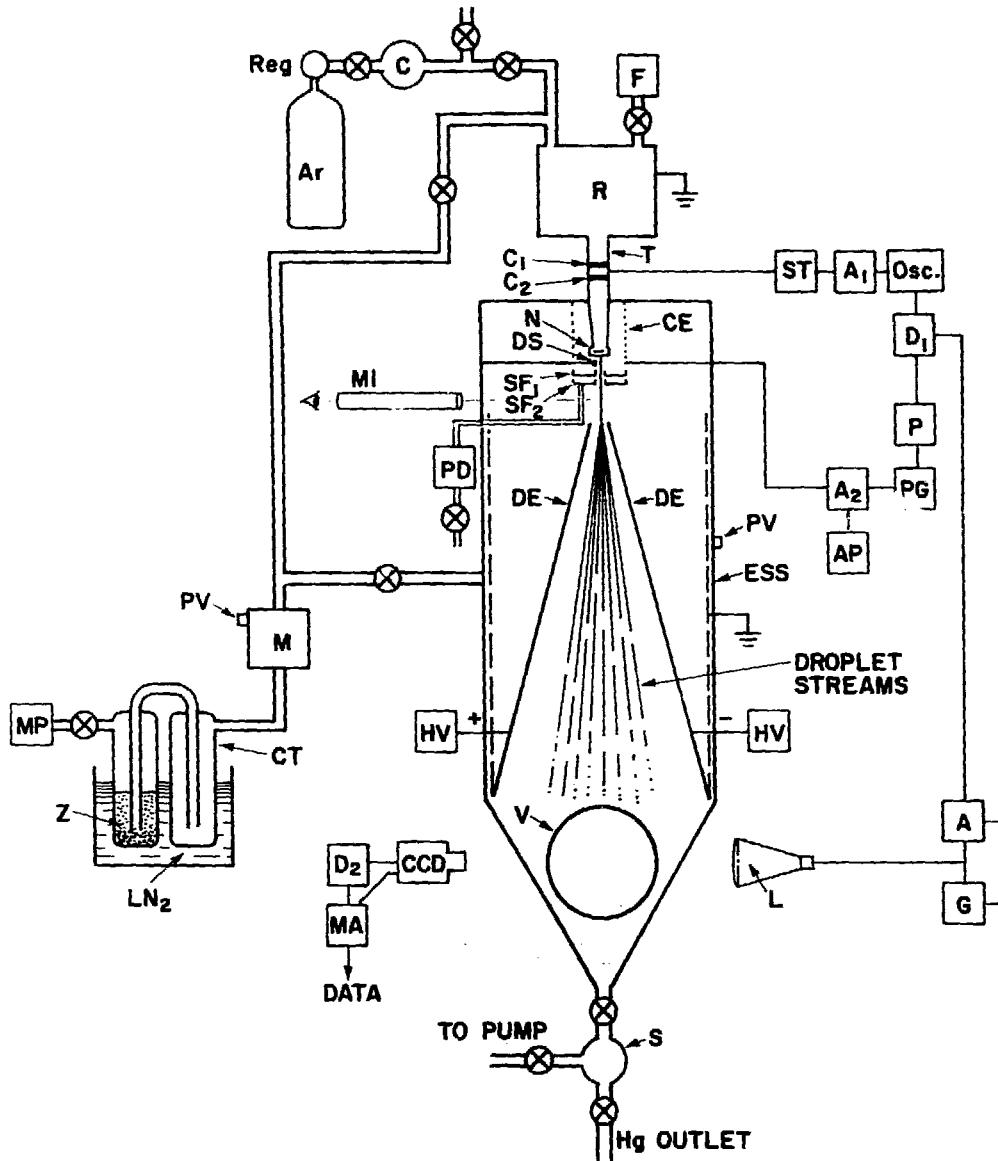
illuminates the reasons that standard partial wave analyses fail to find narrow resonance widths.

D. Chew

PUBLICATIONS

Barrelet Moment Analysis of πN Scattering

New Δ Barion Parameters from a Barrelet Analysis of Elastic $\pi^+ p$ Data Between 0.6 and 2.3 GeV. D. Chew, LBL-5306, August 23, 1979.



This apparatus can analyze droplets of matter for stable fractional charges down to 0.02 e in quantities of about one gram. More conventional droplet-analyzing apparatuses are limited to measuring a few milligrams. Diagram shows charged mercury droplets deflected by an electrostatic field. XBL 802-329

Search for Stable Fractional Charges on Matter

Work on a device to search for stable fractional charges, if they exist, is underway. The apparatus works by means of producing a highly stable liquid droplet stream, passing this stream between electrodes producing a static electric field and then measuring the resulting deflections. This particular technique appears to be quite superior in performance to all presently existing techniques; the entire amount of matter searched to date by all earlier investigators amounts to a few milligrams. Straightforward improvements to the present apparatus which should allow sensitivities approaching one fractional charge per kilogram are being developed.

The apparatus consists of a reservoir of mercury which is acted upon by the pressure of some inert gas. This pressure causes the liquid to be expelled from a tiny orifice at the bottom of the reservoir. This produces a stream of liquid which emerges in a roughly cylindrical jet. Such a jet breaks up spontaneously into droplets of roughly equal sizes. This breakup into droplets is standardized in our apparatus by imposing a sinusoidally varying acoustic perturbation within the reservoir. This technique produces streams of droplets which can have mass uniformity at the level of 0.01% and velocity regularity at the level of 0.0001%. The charges on these droplets may be placed to near zero, thermal variations amounting to about 20e. The droplet stream passes between deflecting electrodes so that, by measuring the spatial deflection of any droplet we may estimate its charge. The design goals are to process 10^{-4} g/sec with one accidental fractional charge candidate per 10 gm at a charge resolution of 0.02e.

The physics design of the apparatus was completed in April 1979. The apparatus is now complete. All work, with the exception of welding and occasional glasswork, was done by physicists.

Testing and calibration are now in progress. A subsystem which is still needed is an automatic data storage system to allow handling of large quantities of data. At present, the data handling capacity of the apparatus limits the searchable quantity of matter to the level of about 10^{-4} gm. Testing and calibration of the apparatus is ahead of schedule, and there is every reason to believe that a demonstration of actual resolution of separate integer charges will be soon achieved.

Earlier searches for fractional charges have been of three separate classes: accelerator searches, cosmic ray searches, and stable matter searches. The stable matter searches may be further subdivided into two classes: enriched searches and non-enriched searches. The cosmic ray searches imply that there is little interest in searching for fractional charges originating from cosmic rays unless one may search quantities of matter in excess of 0.01 gm. The enriched stable matter searches indicate a threshold of 0.10 gm. for observing fractional charges. It should be noted that the direct, non-enriched searches amount to only a few milligrams, so that these efforts do not even equal the level of sensitivity which would be considered to be interesting in comparison to the cosmic ray and enriched matter searches. The accelerator searches for fractional charges search a realm of parameters as yet quite separate from the other search methods.

Ray Hagstrom

PUBLICATION

A Sensitive Method for Detecting Stable Fractional Charges on Matter, Greg Hirsch, Ray Hagstrom, Charles Hendricks, LBL-9350, (1979)

Particle Data Center

The Particle Data Center compiles high energy physics data, and makes it available to the physics community in easily usable form. The Review of Particle Properties and other publications are distributed to the community periodically, and computer searchable databases are also being made publicly available. Most members of the group are also active in research projects at LBL and elsewhere (see section "c" below).

(a) Major revisions were made to existing sections of the 'Review of Particle Properties' and additional new sections were added. The changes included a new section on Quarks and Weak Interactions and revisions to the Relativistic Kinematics and SI (3) sections. The Data Card Listings were updated in anticipation of publishing in early 1980. The listings of particle properties continue to grow at a rate of 10 per cent per annum.

(b) During 1979 the updating of our document and proposal databases continued. Outside collaborators in Japan and the USSR were added to our list of encoders for the document database. Various software systems to streamline this encoding were developed. In conjunction with SLAC, we amalgamated two databases running on the SLAC SPIRES system into one; these were the SLAC Preprints in Particles and Fields database and the DESY High Energy Physics database. The proposal database was updated, increasing the number of laboratories covered, in anticipation of publishing the third edition of LBL-91, *Compilation of Current High Energy Physics Experiments*, in early 1980.

(c) Outside collaborators at Cal Tech, Durham University, Glasgow University, and Rutherford Laboratory continued to input information into the database for experimental reaction data. A highly versatile Particle Physics Encoding Language program was developed for this purpose. This

database is publicly accessible on the Rutherford Computer system, and is widely used by British physicists.

(d) The second generation of the Berkeley Database Management System has continued to be used to maintain our various databases, and allow for complex queries to be carried out on these databases. BDMS was made to run on a VAX11 780, and version 2.2 was installed on the Rutherford IBM 360 195. A few outside users were allowed to interrogate our document database for their own special needs.

(e) Most members of the group are active in research projects, both with other LBL and with outside collaborators. Kelly is active in the 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 published in 1979. Plans for 1979-80 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.

Yost holds a joint appointment with the Bingham Group, which is participating in photon and (anti)neutrino beam bubble chamber experiments at SLAC and FNAL. Progress was made on the project to improve reconstruction of electron and positron tracks in the presence of substantial bremsstrahlung. A new program to determine optical constants for the FNAL 15-foot chamber was written.

Yost also worked on the design and testing of a high-resolution camera system for the SLAC 40 inch bubble chamber. This camera will allow charmed particle tracks, normally too short to be

seen in a bubble chamber, to be photographed and therefore analyzed in detail. This experiment hopes to see an order of magnitude more identified charmed particle decays than the sum of all emulsion experiments, (only LEBC at CERN will be competitive, and the SLAC experiment has several practical advantages), with consequent great improvement in the determination of charmed particle lifetimes and decay modes and identification of new types of charmed particles. Trippe participated in the Lead-Glass Wall Experiment at SPEAR to study neutral particle production and anomalous electron production in e^+e^- annihilation. Trippe was involved in the analysis of inclusive production in (3100) decay.

Losty and Horne were involved in the PEP-14 Quark Search Experiment, making contributions to the software packages. 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.

LBL-92, an index to and listing of our reaction-data database, will be published. The group will continue to refine and upgrade the systems for maintaining and accessing its various databases, and will also work to keep these databases up to date. The *Review of Particle Properties* will be issued, as will a new edition of LBL-91. As the Particle Physics Data System and the underlying Berkeley Database Management System programs become more sophisticated, access to the stored data by interested users should become simpler and easier. It is planned to make the data available to the physics community via interactive access, and or

tape distributions. Pion-nucleon data amalgamation and partial-wave analysis will continue, increasing the energy range and including new data as it becomes available.

Particle Data Group

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Instrument Development and Engineering for High Energy Physics

Development Research

Development work was done on various forms of gas-filled multi-electrode detectors. A program to study switching properties of thin films as possible multi-electrode particle detectors was initiated and some measurements on V_2O_5 layers were made. Measurements were done on the following configurations of gas-filled detectors with the aims as given below.

a. A prototype three grid wire chamber for detecting high multiplicity events was built. Elimination of the x,y ambiguity from orthogonal direction readout was accomplished by maintaining secondary glow discharges between two of the grids at locations where a primary spark occurred due to the passage of charged particles. Unambiguous x,y pairing of the coordinates is obtained by sequentially pulsing the x lines and recording the signals on the corresponding y lines attached to the memory-glow pair of grids.

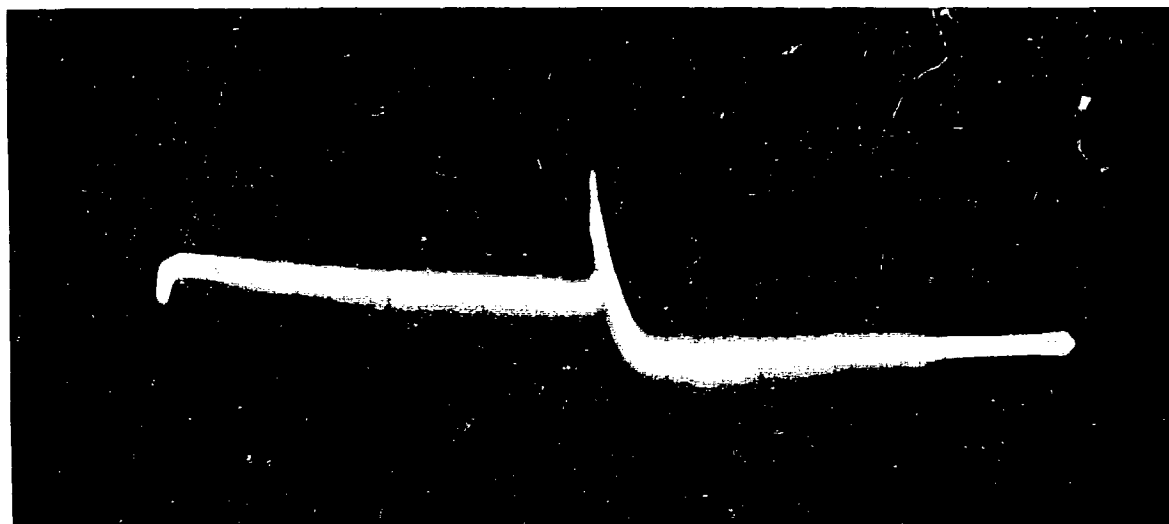
b. Low pressure parallel plate (grid wires) avalanche chambers for fast timing are being developed. Various schemes have been investigated to increase the signal-to-noise ratio so that minimum ionizing particles can be detected with good time resolution ($<300 \mu\text{sec}$). These schemes include the use of multiple grids inter-connected to have transmission line characteristics, and the use of avalanche gain on small diameter anode wires with analogue electronics to correct for time differences in the rise time of the anode signal, due to the different trajectories of the incoming particles relative to the closest anode wire.

c. An investigation has been started on the use of the U.V. light produced in very pure argon or krypton, when charged particles produce secondary electrons in high field regions between parallel wire

grids. This U.V. light can be used to transfer the signal information from one region of the detector through an optically transparent barrier to another region of the chamber which may contain a different gas mixture and at a different gas pressure. This can be used in various applications; the main interests here are in (1) use of the U.V. light to initiate glow discharges for multi-track chambers instead of sparks, and (2) as a means of eliminating the positive space charge effects which would be created in TPC-like devices. In this scheme, signal position information in the main tank is carried by the localized U.V. light across the optically transparent barrier to a shallow MWPC. This is filled with argon and a small admixture of an organic vapor and will signal the position of the particles by the conventional avalanche ionization methods since the argon gas vapor mixture has an ionization potential below the U.V. light.

d. Some measurements have been made together with R. Hagstrom on the properties of V_2O_5 layers to investigate switching properties triggered by the ionization produced by the passage of charged particles through the layers. Since these layers switch from one current-conducting state to a different current state they can also be used as memory devices.

e. Gas-filled detectors developed in this program have also found biomedical and biophysical applications. Lead glass converters for high efficiency detection of gamma rays in the energy range 200 keV - 20 MeV have been made with high density ($\tau = 6.3 \text{ gms/cc}$) out of fused lead glass tubing. The fused lead glass matrices are made surface-conducting by high temperature reduction in a hydrogen furnace. Interaction electrons produced by incident gamma rays are drifted out of the glass matrix and



Oscilloscope trace showing current flowing in a glow discharge ignited by a charged particle in a prototype glow memory chamber. XBB 808-9662

into the wire plane region of a MWPC, thus providing position resolution. Applications of these to medical position imaging cameras, and to position imaging of electron distributions within crystals, are proposed. Work was also continued on computer methods to solve for the electron density distribution within three-dimensional objects by imaging with annihilation gammas from positron capture or by single gamma-emitting radioisotope distributions within the object. These computer methods are applicable to MWPC detectors covering finite angles or in completely different fields such as electron microscopy.

Staff

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PUBLICATIONS

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Engineering, Evaluation and Support Operations

The development engineering of instruments and instrumentation systems which have specific as well as broad and general applications is a continuing task. Other tasks include the research and development of particle detectors and the evaluation of commercially available devices. Operating manuals are supplied, and maintenance and support of instruments in the Counting Pool, as well as in previously designed systems used in HEP experiments, are provided. In addition, inventory records of all equipment are maintained, new equipment is procured, and consulting service on all aspects of instruments and detectors used in research programs is provided.

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 is a continuing activity. Improvements to the LSD include 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. This improvement has been successfully implemented for the PEP-14 (Free Quark Search) experiment. Techniques used in the LSD have successfully been transferred to PEP-4 (Time Projection Chamber) instrumentation to keep costs of digitization to a minimum. Non-linear clock techniques have also been transferred to PEP-4 to extend energy and time ranges for smaller and lower cost data ways and space-limited printed circuit cards.

Multiwire Proportional Chambers A number of multiwire proportion chamber (MWPC) systems have been assembled in this past year. Improvements in several areas have been made. A new preamplifier has been designed and checked out for the PEP-14 project as well as a summing amplifier which precedes some discriminators. Work has been completed for a "first-in, first-out" buffer memory for a MWPC Readout system. A new MWPC system has been delivered for experiments at the Bevalac.

The Large Scale Digitizer (LSD) system has been modified to perform with the PEP-14 MWPC so that, with a non-linear clock in the digitizer, the

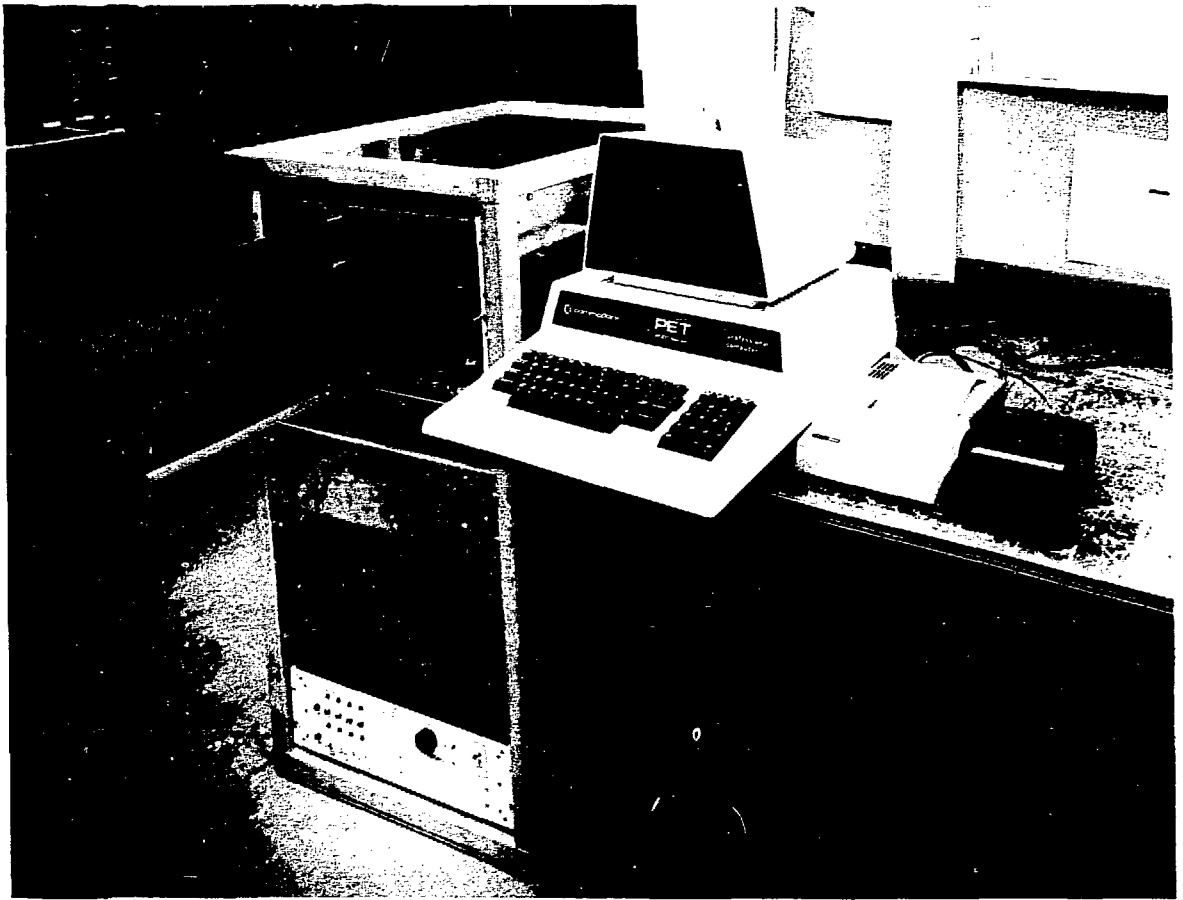
dataway-limited system of the LSD can accommodate an energy range four times greater than what the present system allows while maintaining high resolution for Q 3 and 2Q 3 in Quark studies. A programmable trigger logic has been designed and installed for PEP-14 use.

Microcomputer Systems – The two LSI-11 systems are functioning and have replaced the old IBM 1130 computer unit. Software programs have been written for the LSI-11 systems to replace programs previously used on the IBM 1130. New programs have also been written to take advantage of the higher speeds afforded by the LSI-11 system. A Basic interpretive language has successfully been implemented to work with CAMAC. The portability of the LSI-11 system has been instrumental in our ability to rapidly troubleshoot complex systems in the field when problems are often obscured by dependence on unfamiliar computers and software programs.

A low cost computer has been interfaced to a tester unit for rapidly checking a large number of digitizer cards. This unit was sent to a vendor, which had built printed circuit cards for LBL, so that the cards can now be pre-tested. This small computer has many other capabilities which are being investigated.

Electro-Optical Device Evaluation Program - Evaluation and lifetime studies were made of the prototype micro-channel plate photomultipliers. Further improvements were made in the high-accuracy photomultiplier measuring system, and in the system for long time studies of the stability of microchannel plate gain, because 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. Some manufacturers have supplied prototype devices without charge, with an LBL commitment only to advise them about our findings and to offer suggestions concerning the design criteria for development of a new generation of these devices with improved characteristics.



This microcomputer system for testing digitizers, control cards, and backplanes provides a 23-second checkout of 20,000 signal channels per card for Time Projection Chamber's (TPC) electronics. The TPC is the principal detector at the heart of the PEP-4 array.
CBB 807-8046

Technical Support and Pool Operations — The base of the equipment pool was effectively expanded by coordinating it with those serving still other LBL Divisions. The operation of this combined multi-division equipment pool is providing efficiencies, convenience and better utilization of equipment than the previous separate pools.

Staff

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PUBLICATIONS

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Astrophysics and Astronomy

Cosmic Background Radiation

This research group is involved in a number of experiments designed to determine the properties of the cosmic background (3°K blackbody) radiation. Using a 33-GHz differential microwave radiometer flown aboard a U2 aircraft, measurement was made of a first-order anisotropy in the background radiation at the 10^{-3} level. Confirmation of this result with more recent southern hemisphere measurements was obtained. The dipole anisotropy was interpreted as resulting from the local cosmological motion of the Milky Way galaxy -- a 500 km/sec velocity with respect to the cosmic background.

Additional U2 or balloon flights have been planned to search for higher order (intrinsic) anisotropy, and design of a more sensitive four-frequency satellite version of the anisotropy experiment as part of the Cosmic Background Explorer (COBE) Satellite was in progress. The existence of either intrinsic anisotropy or polarization in the cosmic background radiation would provide the first evidence for large scale structure in the early universe.

In a ground-based experiment, this group is searching for possible polarization of the background radiation. Using a Dicke-type microwave polarimeter, the upper limit was set for a polarized component at below the 0.2 mK (10^{-4}) level. Plans to expand the experiment to include polarimeters at three frequencies have been made.

Physical processes in the early universe, including intrinsic anisotropy, inhomogeneities or turbulence, should also affect the spectrum of the background radiation. A report by Dave Woody and Paul Richards of a high-frequency distortion in the blackbody spectrum, and theoretical predictions of possible distortions at low frequencies has motivated the group to begin an experiment to measure

the spectrum of the background radiation at long wavelengths.

Cosmic Background Radiation Staff

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Supernovae Detection and Observation

A search to discover and observe supernovae early in their explosions was being planned. Supernovae (SN) play a fundamental role in many areas of astrophysics: they are the progenitors of black holes, neutron stars, and pulsars; they probably make all elements heavier than iron; stars, planets, and interstellar grains are made on supernova shockwaves; cosmic-rays are accelerated on the shockwaves either at the explosion itself or in interstellar space, or in the enormous electric fields at the pulsar. The remnants of SN explosions are strong sources of radio, optical, and x-ray and γ -ray radiation.

Although about 400 SN observations have been reported in the last 6,000 years, only five were seen before maximum light. Calculations indicate substantial differences in the pre-maximum light curve, depending on the details of the explosion; yet this section of the light curve is where there is no data. The present search should detect one SN every three to six days at 10% to 40% of maximum light before the peak.

A plan has been made to couple an RCA CCD (charge-coupled imaging device) to either a 24" or 36" automated telescope and to scan about 7500 galaxies, cycling through this sample every three days. The image of the galaxy will be compared to a standard (no SN present) image of the galaxy, and checked for a brightness increase in any one image

High-altitude measurements by physicists Phil Lubin (left) and George Smoot confirmed the existence of a first-order anisotropy at the 10^{-3} level in the cosmic background (3° K blackbody) radiation in the southern hemisphere. Here they are preparing to check their instrument, a 33 GHz differential microwave radiometer installed aboard a NASA-Ames U-2 aircraft, before plane took off from the Jorge Chavez International Airport, Lima, Peru.

CBB 794-4316



element. A dedicated mini-computer, either a PDP 11 44 or equivalent, will be used for controlling the device and calculating the brightness differences. When a supernova is discovered it will be studied in detail with existing ground-based and orbiting satellites to take optical, U.V., and γ -ray spectra.

Purchase of parts for the detector was underway and it was targeted to have an operating detector by the end of the fiscal year. A study of software needs to better define computer needs was underway.

Supernovae Staff

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Compact Stellar Objects (Neutron Stars, White Dwarfs, Black Holes)

Our optical observations of the pulsating x-ray source, 4V1626-67, have finally revealed the elusive binary period for this object, with a period of 42 minutes. The x-ray pulsations have a negligible doppler shift, consistent with an isolated star, yet the presence of modulated x-rays strongly suggests a spinning (7 second period) neutron star accreting matter in a binary system. These optical observations of the pulsations revealed that some of the x-

rays heat the surface of the companion star, and the optical pulsations experience a detectable doppler shift due to the binary motion. The binary period is the second shortest known, and by far the shortest of any x-ray binary.

Observations of optical pulsations from the recurrent nova Wz Sge, taken both before and after the December 1978 nova, have revealed a strange phenomenon. The period of pulsations has changed from 27.87 sec to 28.96 sec. Because of this, the widely held view that the pulsations represent the rotation period of a spinning white dwarf must be rejected, and another explanation must be sought to explain the extremely stable oscillations.

Our survey of the x-ray behavior of Cataclysmic variables (with Cordova and Mason) using the satellite x-ray observatory HEAO-2 has revealed an exciting richness. Virtually all of the sources examined (~ 15) have proven to be previously undetected x-ray sources. The x-ray spectrum (0.5 - 4.0 keV) suggests that the sources are extremely hot ($T > 10^6$).

Along with the x-ray observations, the group has made ultraviolet observations using the IUE satellite telescope of a similar set of Cataclysmic variables with emphasis on the Dwarf novae. These observations are showing evidence for very hot, highly ionized gas in the systems.

Compact Stellar Objects Staff

J. Neison

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UC Ten-Meter Telescope Project

During the past year, great progress has been made developing the methods for making a very high quality segmented primary mirror. A method for making high quality off-axis mirrors has been developed and successfully tested which should allow the economical fabrication of the segments. A method for controlling the mirror positions to optical tolerances has been explored and modeled on the computer with quite positive results. The apparatus needed to sense and move the segments has also been designed and the prototypes easily satisfy the specifications needed to properly position the mirrors.

U.C. Ten-Meter Telescope Staff

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The Rubber Mirror Telescope

In earlier work at Mt. Wilson with the small (12") telescope, diffraction-limited stellar images (0.5 arc sec) and diffraction-limited double star images (2 arc second separation) were obtained in the presence of bad seeing (5 arc sec) which made their resolution impossible without the rubber mirror. The "rubber" telescope was then modified and used with the 30" solar telescope at Sacramento Peak, New Mexico. A star guider was built which guided the solar telescope automatically on stars (to one arc sec) enabling the solar telescope to be used for the first time in a night-time observing program. Using the "rubberized" solar telescope, nearly-diffraction-limited images (1.4 arc sec) of bright stars were obtained when the uncorrected "seeing" was 2 arc sec. Based on the first measurements of "speckle time" at Sac Peak (which indicated there were about 25 milliseconds available for adjusting mirrors), the group expected to study selected double stars with separations of less than one arc sec, including several that were previously unresolved, or controversial. To accomplish this (for these non-bright stars) the observed 15 millisecond

speckle times were required (to obtain enough light for mirror-move decisions).

Unfortunately, the 15 millisecond result turned out not to be typical; speckle times of more than about 5 millisecond turned out to be rare, and the double-star program was not accomplished. Future progress requires redesign so as to restore images of dimmer stars in less than the 5 millisecond that is typical of all sites examined. This redesign would require a new optical system and a new information-processing system to make use of one of the parallel processing schemes. This redesign is not being pursued at present.

Rubber Mirror Telescope Staff

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PUBLICATIONS

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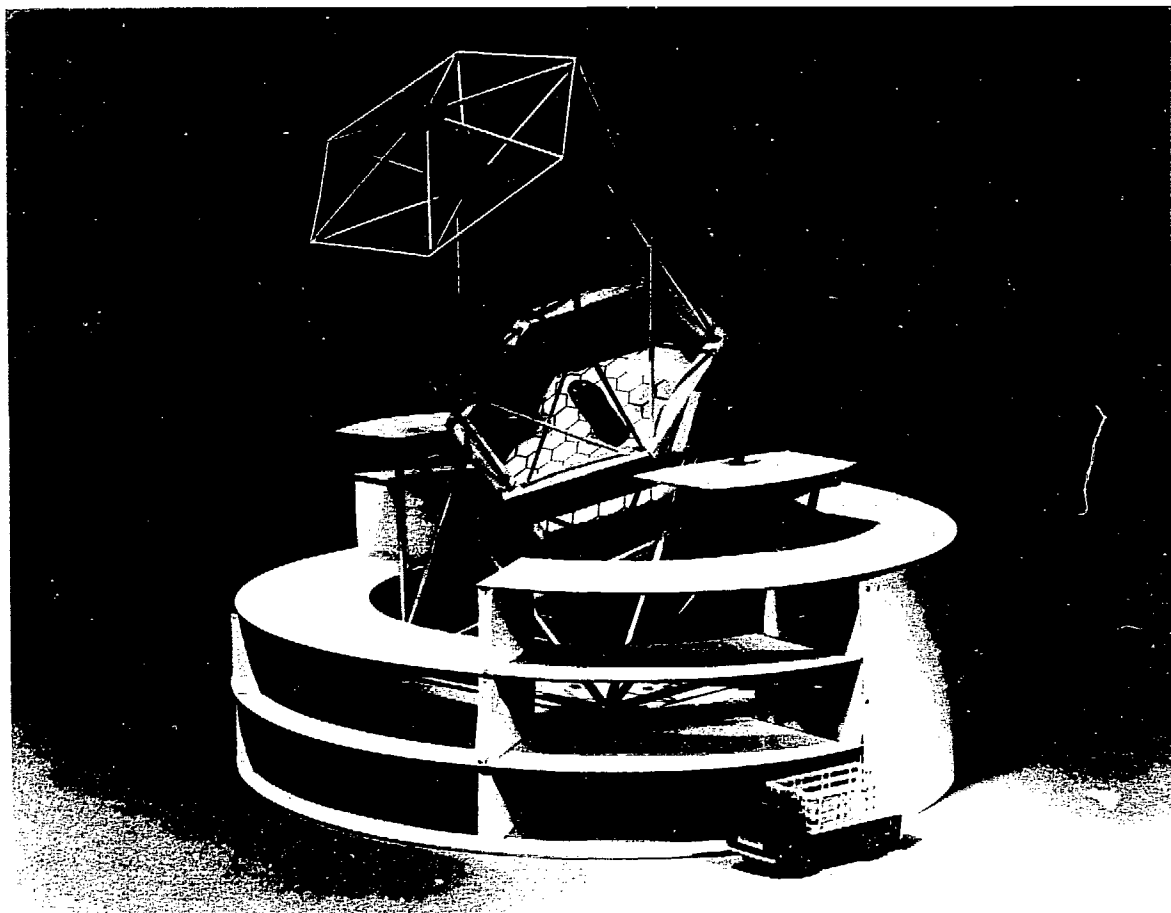
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Methods were developed for making and controlling a high quality segmented primary mirror for the UC Ten-Meter Telescope. This model shows the array of individual mirrors. These are computer controlled for continuous alignment to maintain the figure of the primary mirror, thus preserving the image against distortions induced by wind, gravity, and temperature.

CBB 807-8322A

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High Energy

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Earth Studies

Atmospheric CO₂ Concentration

The rise in the atmospheric CO₂ concentration due at least in part to the combustion of fossil fuels is expected to have a profound impact on the climate everywhere on earth. The credibility of current predictions of the future rise of atmospheric CO₂ is seriously impaired by the fact that the present CO₂ budget does not seem to be in balance. Very precise measurements of changes in the global atmospheric O₂ N₂ ratio in the course of a few years could provide the key to the solution of the "missing CO₂" problem.

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Extraterrestrial Cause for the Cretaceous-Tertiary Extinction

Platinum metals are depleted in the earth's crust relative to their cosmic abundance; concentrations of these elements in deep-sea sediments may thus indicate influxes of extraterrestrial material.

Deep-sea limestones exposed in Italy and Denmark show iridium increases of about 30 and 160 times, respectively, above the background level at precisely the time of the Cretaceous Tertiary extinctions, 65 million years ago. There are indications that this iridium is of extraterrestrial origin, but did not come from a nearby supernova.

An hypothesis to account for the extinctions and the iridium observations was made. Impact of a large Apollo object would inject about 100 times the object's mass into the atmosphere as pulverized rock; about 10 percent of this dust would stay in the stratosphere for 3–5 years and be distributed worldwide. The resulting darkness would suppress photosynthesis and the expected biological consequences match quite closely the extinctions observed in the paleontological record.

One prediction of the above hypothesis has been verified: the chemical composition of the boundary clay is markedly different from that of clay mixed with the Cretaceous and Tertiary limestones, which are chemically similar to each other. Four different and quite independent estimates of the diameter of the asteroid give values that lie in the range 10 ± 4 km.

L. W. Alvarez

MEDIUM ENERGY PHYSICS

Radiative Pion Capture in Nuclei and Nuclear Structure

In these experiments the photon energy is measured with a high resolution pair spectrometer. This allows a determination of the final state mass spectrum.

1. ${}^3\text{H}(\pi^-, \gamma)3n$

The trineutron mass spectrum was observed in the reaction ${}^3\text{H}(\pi^-, \gamma)3n$ by measuring the photon energy with high resolution. It exhibits no structure beyond that predicted by the interaction of two of the outgoing nucleons considered in the framework of the Amado model. Thus the absence of $T = 3/2$ resonances in the $A = 3$ system as well as the non-existence of a bound trineutron now seems firmly established.

2. ${}^{13}\text{C}(\pi^-, \gamma){}^{13}\text{B}^*$, ${}^{20}\text{Ne}(\pi^-, \gamma){}^{20}\text{F}^*$, ${}^{18}\text{F}(\pi^-, \gamma){}^{18}\text{O}^*$

Each of these reactions has been investigated. Clear evidence for a giant magnetic dipole (M1) resonance in ${}^{13}\text{C}(\pi^-, \gamma){}^{13}\text{B}^*$ at 125 MeV was obtained. Satisfactory agreement with theory was found for the positions and strengths of resonances.

Evidence for an M1 transition in ${}^{20}\text{Ne}$ is shown by a small peak at 130 MeV.

Analysis of data from these reactions is underway.

3. ${}^{12}\text{C}(\pi^+, \gamma){}^{12}\text{N}^*$

Capture in flight of 45 MeV π^+ mesons has been studied. This allows determination of changes in transition mechanisms as the momentum transfer is changed. Work is continuing.

Weak Interactions Studies at LAMPF and TRIUMF

A precise measurement of the positron spectrum in the decay

$$\mu^+ \rightarrow e^+ + \nu_e + \nu_\mu$$

will allow accurate determination of the positron helicity and Michel parameters, η and δ . This is the only process in which the weak interactions are independent of strong interactions and nuclear structure. Two experiments have been planned, one at LAMPF the other at TRIUMF. A final experiment will be completed at the Laboratory where circumstances are most favorable.

Staff

K. Crowe J. Jansen S. Rosenblum

Graduate Student Research Assistants

C. Martoff W Zajc C Clawson

Technician

J. Bistirlich

PUBLICATIONS

Muonium Chemistry — A Review, K. M. Crowe, with D. G. Fleming, D. M. Garner, L. C. Vaz, D. C. Walker, J. H. Brewer. In *Positronium and Muonium Chemistry*, Advances in Chemistry Series #174, Ed. Hans J. Ache (1979).

Experimental Physics
Medium Energy

Study of Isobar Analogs of ^{13}C GDR by Radiative π Capture, (K. M. Crowe, with C. J. Martoff, J. A. Bistirlich, J. P. Miller, S. S. Rosenblum, W. A. Zajc, H. W. Baer, G. Strassner, P. Truol and A. H. Wapstra). Abstract for American Physical Society Meeting, Washington, D.C. April 23-26, 1979; Bull. Am. Phys. Soc. 24, 4, p. 647 (1979).

Structure in Hard γ Spectra from π Radiative Capture in ^{20}Ne , ^{29}F , ^{90}Zr and In-flight π^- Radiative Capture in ^{12}C , (K. M. Crowe, with J. P. Miller, J. A. Bistirlich, C. J. Martoff, S. S. Rosenblum, W. A. Zajc, H. W. Baer, G. Strassner, P. Truol and A. H. Wapstra). Abstract for American Physical Society Meeting, Washington, D.C. April 23-26, 1979; Bull. Am. Phys. Soc. 24, p. 647 (1979).

Exotic Atoms '79: Fundamental Interactions and Structure of Matter, Ed. Kenneth Crowe, Jean Duclos, G. Fiorentini.

G. Torelli. Ettore Majorana International Science Series, Vol. 4 Plenum Press, New York (1980).

Upper Limits for Bound States and Resonance Behavior in the Tri-neutron System, (K. M. Crowe, with J. P. Miller, J. A. Bistirlich, S. S. Rosenblum, P. C. Rowe, F. T. Shively, E. R. Grilly, E. C. Kerr, J. Novak, R. H. Sherman, H. Brandle, G. Strassner, P. Truol) Submitted to Nuclear Physics A (1980).

Elementary Excitations Involving Spin Flip Studied in ^{13}C and ^{20}Ne by the (π, γ) Reaction, (K. M. Crowe with C. J. Martoff, J. A. Bistirlich, J. P. Miller, S. S. Rosenblum, W. A. Zajc, H. W. Baer, G. Strassner, P. Truol, A. H. Wapstra, M. Koike). Contributed to Nuclear Structure with Intermediate Energy Probes Workshop, Los Alamos Scientific Laboratory, January 14-16, 1980.

Mesonic Atoms

Kaon Mass Measurement

If the kaon mass were $493.669 \text{ MeV } c^{-2}$ the $n = 6 \rightarrow 5$ transition in potassium-39 would result in kaonic atom x rays of 57462.0 eV . The element erbium has a critical absorption K-edge at 57485.6 eV measured to high precision at the National Bureau of Standards. Using a beam of kaons from the JBL Bevatron a measurement was made of the attenuation of the 39K x-rays in a set of calibrated Er foils. The transmission measurements determined the energy of the x-rays, which translated into a kaon mass of $493.64 \pm 0.05 \text{ MeV}/c^2$. Heretofore the kaon mass had been determined by using kaonic x-rays of the heavy elements (Pb and U) where high order radiative and electron screening corrections are difficult to calculate. These results are in agreement with the previous kaon mass measurements 493.67 ± 0.02 and verify certain theoretical calculations.

Staff for Kaon
Mass Measurement

C Wiegand

Graduate Student
Research Assistant

Gary Lum

Pionic X-ray Intensities

At the TRIUMF laboratory pionic atom x-ray intensities were measured for 57 targets of chemical elements. The experiment surveyed these intensities over the range of elements from $Z = 3$ to $Z = 92$, as was done earlier at LBL for kaonic atoms. The pionic x-ray intensity pattern of transition $|\Delta n = 1|$ as a function of Z showed maxima near Z values of closed atomic shells as had the kaonic intensities, but the intensity variations were not as pronounced as those for kaonic atoms. In contrast, however, the pionic intensities for transitions $|\Delta n = 2|$ showed large variations. The $n = 6 \rightarrow 4$ intensities showed a well-defined maxima around $Z = 34$. A satisfactory theory for the atomic effects in mesonic atoms has not yet been devised.

C Wiegand

Task Description

A program to study the interactions of muons with fissile nuclides is underway. Nuclei whose fission-barrier heights are comparable to the $K\alpha$

transition energies of atomically captured muons are used. The primary motivation is to attempt to use the muon to probe the fission barrier, particularly the double-hump barrier which produces the so-called shape isomeric state.

If the atomic cascade of the muon excites the shape isomer, then the ground state energy of the isomer as well as the transmission rate through both the forward and backward barriers may be measured. Although the barrier shape is perturbed by the coulomb interaction of the muon in the atomic K shell, this interaction is well understood so that the measured results may be interpreted in terms of the unperturbed nucleus.

Although there have been many previous efforts to study this problem, no clear demonstration has been found for the existence of this isomer production mechanism.

Analysis of absolute fission-yield measurements have been completed following efficiency calibrations of the ^{235}U and ^{238}U fission chambers at the UCB Research Reactor. Because of large and not fully understood atomic-transfer mechanisms in the slowing-down process, normalizing such fission-yield measurements to atomic capture by U, particularly when it is in the form of thin fission chamber depositions, is subject to large uncertainties. Such uncertainties were overcome in these

measurements by requiring fission to be preceded by muonic $K\alpha$ x-rays. These yield results, which in addition to having intrinsic interest, are necessary for normalizing, or setting limits on subsequent measurements.

Concurrent theoretical calculations have been made. As a first step, the mesic-x-ray-energy programs of Rinker from LASL (MUON and RURP), have been used at LBL and are being modified to calculate muon energies in a highly distorted nucleus.

Selig Kaplan

PUBLICATIONS

Absolute Fission Yields per Muon Capture in ^{235}U and ^{238}U . S. Ahmad, G. A. Beer, M. S. Dixit, J. A. Macdonald, G. R. Mason, A. Olin, R. M. Pearce, O. Häusser, S. N. Kaplan, Paper 5B15 (Abstract), 8th International Conference on High Energy Physics and Nuclear Structure (August 13-17, 1979).

Fission Yields and Lifetimes for Muon Induced Fission in ^{235}U S. Ahmad, G. A. Beer, M. S. Dixit, J. A. Macdonald, G. R. Mason, A. Olin, R. M. Pearce, O. Häusser, and S. N. Kaplan LBL-10458 (1980) and *Physics Letters*, 92B, 83 (1980).

II. THEORETICAL PHYSICS



A joint experimental-theoretical physics seminar in which the discussion is being led by a theorist. These sessions are aimed at finding directions for profitable research.

XBB 805-7069

II. THEORETICAL PHYSICS

The major thrust of the theoretical physics research in the Physics, Computer Science and Mathematics Division at LBL is in the field of particle physics.

The Berkeley (LBL,UCB) particle physics research program is concerned with all aspects of particle physics — the strong, electromagnetic, weak and superweak, and gravitational interactions. They are investigated by the techniques of S-Matrix theory and quantum field theory. Our Group is especially noted for its contributions to the development of the S-matrix approach to the theory of strong interactions. This method deals more directly with experimental quantities than the traditional field theoretic approach and is based on very general assumptions such as Lorentz invariance, analyticity properties of scattering amplitudes, and probability conservation. Over the years the S-matrix approach has been placed on a very firm foundation by members of our Group.

In addition to our concern with fundamental theoretical work, members of our group are actively concerned with the Laboratory's experimental program through the analysis and interpretation of experimental data.

Minor areas of research include statistical mechanics and nonlinear wave phenomena. This work is funded by agencies such as the National Science Foundation, the Office of Naval Research and the Advanced Research Projects Agency; those engaged in it have the status of participating guests in the Theoretical Physics Group.

An important adjunct of our research program is in the training of graduate students working for

the doctorate in theoretical physics. These students make important contributions to our research in the course of fulfilling requirements for the degree.

Theoretical Physics Group

The Theoretical Physics Group is now composed of 7 Faculty Senior Scientists, 5 Staff Senior Scientists, 2 Divisional Fellows, and 6 Postdoctoral Research Associates. These titles and categories are slightly different than those which have been given in earlier reports and they reflect the approval by President David Saxon of the University of California of a policy statement on professional research staff for LBL. Divisional Fellows are experienced scientists of exceptional ability who are appointed for a term of five years with the expectation that they will eventually be promoted to become Staff Senior Scientists. The Postdoctoral Research Associates are persons who have shown unusual ability and promise but have only recently been awarded the doctorate. They are appointed for terms of one or two years.

At the present time there are nine Graduate Student Research Assistants (GRSA) supported by DOE and three supported by other grants who are working under the direction of members of the Theoretical Physics Group.

Doctoral Theses

During the year, two graduate students were awarded the Ph.D. degree: Neil L. Fleishon, *Vector Current Scattering in Two Dimensional Quantum Chromodynamics*, Ph. D. thesis (University of

Theoretical Physics

California–Berkeley), May 23, 1979. Stuart Samuel, *Statistical Mechanics and Field Theory*, Ph.D. thesis (University of California–Berkeley), May 23, 1979.

Members of Theoretical Physics Group

The present composition of the Theoretical Physics Group is given in the following list:

Faculty Senior Scientists

Korkut Bardakci	Stanley Mandelstam
Geoffrey F. Chew (on sabbatical leave 6/78-9/79)	(on sabbatical leave 9/79-6/80)
Martin B. Halpern	Mahiko Suzuki
J. David Jackson	Kenneth M. Watson (on sabbatical leave 7/79-7/80)

Staff Senior Scientists

Michael Chanowitz	Robert J. Riddell, Jr.
David L. Judd	(on leave of absence during 1979)
Joseph V. Lepore	Henry P. Stapp

Divisional Fellows

Robert N. Cahn	Ian Hinchliffe
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Postdoctoral Research Associates

Daniel Caldi	Eliezer Rabinovici
Miguel Furman	Jonathan Sheiman
Howard Haber	Ken-ichi Shizuya

Graduate Student Research Assistants

Alan Axelrod	Mark Levinson
Philippe de Forcrand	Leonard Mlodinow
Neil Fleishon	Susan Moore
Curt Flory	Joseph Polchinski
Daniel Friedan	Stuart Samuel
Omer Kaymakcalan	Stephen Sharpe
	Philip Yau

GSRA Participating Guests

Jeffrey Lerner	James Meiss	Henry Warchall
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Summer Program

For almost thirty years the Theoretical Physics Group has maintained a stimulating summer program. The vigor and variety of Berkeley physics research and the unusual features of the Bay Area have made it relatively easy for us to attract outstanding scientists from all over the world at modest expense. Both theoretical and experimental programs at the Laboratory benefit from these visitors who often interact as much with experimentalists as with theorists. In addition to the participation of those few which are given some support, our summer program is enriched by a bonus of self-supporting visitors who are active in our research areas. We offer them our hospitality and are rewarded by seminars on their current work and often by direct contributions to ours.

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

Participating Guests

Brower, Richard	University of California, Santa Cruz
Capra, Fritjof	Berkeley, California
Coster, Joseph	Western Illinois University
Das, Kamala	University of Oregon
Dash, Jan	Centre National de la Recherche Scientifique, Marseille, France
Deshpande, N. G.	University of Oregon
Duncan, Anthony	Columbia University
Eguchi, Tohru	University of Chicago
Einhorn, Martin	University of Michigan
Ellis, John	CERN, Geneva, Switzerland
Ellis, R. K.	California Institute of Technology
Eylon, Yoav	Weizmann Institute
Finkelstein, Jerome	Columbia University
Garczynski, H. W.	University of Wroclaw
Gronau, Michael	Technion, Haifa, Israel
Harper, Charlie	California State University at Hayward
Holland, Peter	City College of San Francisco

Theoretical Physics

Joglekar, Satish	University of California, Berkeley/NSF	Rarita, William R.	Retired - Brooklyn College, New York
Langacker, Paul	University of Pennsylvania	Robel, Michael	Niels Bohr Institute
Li, Ling-Fong	Carnegie-Mellon	Ross, G. G.	Oxford University, England
Matsuda, Satoshi	Kyoto University	Strock, Robert L.	State University of New York, Stony Brook
Morrison, Harry L.	University of California, Berkeley	Sursock, Jean-Pierre	Electric Power Research Institute
Moshe, Moshe	Tel-Aviv University	Sutherland, David	University of Glasgow
Neuberger, Herbert	University of California, Berkeley/NSF	Tan, Chung-I	Brown University
Oliver, Luis	Laboratoire de Physique Theorique, Orsay, France	Truong, Tran N.	Ecole Polytechnique, Palaiseau, France
Palmer, William F.	Ohio State University	Uchiyama, Fumiyo	University of Tsukuba, Sakura, Japan
Papanicolaou, Nicolas	University of California Berkeley/NSF	Wada, Walter	Ohio State University
Peskin, Michael	Harvard University	Warnock, Robert	Illinois Institute of Technology
Pomphrey, Neil	University of California, Berkeley/ONR	Weiler, Thomas	Northeastern University
Pusterla, Modesto	Universita Padova, Italy	White, Alan	CERN, Geneva, Switzerland
		Yan, Tung-Mo	Cornell University
		Yao, Y. P.	University of Michigan

Scattering Matrix Theory

Topological Bootstrap Theory of Hadrons

A topological bootstrap theory of hadrons and strong interactions based on combinatorial topology has been developed. Reaction amplitudes (S-matrix elements) are associated with 2-dimensional surfaces and particles with discs covering the surfaces. The controlling principle is consistency with a causal, unitary, Poincare-invariant S-matrix within a surface hierarchy of increasing complexity (entropy) — a topological bootstrap. The bootstrap solution yields 3 families of elementary hadrons — mesons, baryons, and baryoniums — each corresponding to discs built from oriented triangles. Baryon number, 3 colors, and 8 flavors emerge. An individual triangle cannot be a hadron but on

strong-interaction surfaces may be identified as a quark. On surfaces corresponding to electromagnetic and weak interactions, it is believed that individual triangles are associated with leptons. Hence a total of 8 leptons is predicted.

Present work concentrates on the spin dependence of strong interactions. It appears that there is a chiral structure in zeroth approximation which will produce spin-flavor multiplets. Looming in the immediate future is extension of the theory to electromagnetic and weak interactions.

G. F. Chew

M. Levinson

Unitary Regge Amplitudes

A systematic program¹ for construction of a crossing-symmetric unitary Regge theory is being pursued. The scheme is based on a new formulation of the crossing-unitarity equations in terms of partial-wave quantities alone. It overcomes mathematical difficulties occurring in earlier formulations, in particular the problem of apparent high-energy divergences. A key element is the Watson-Sommerfeld representation of spectral functions.

The main effort of the past year was to extend the scheme to allow several coupled two-body channels, still with exact crossing symmetry. Unitarity in the extended scheme will involve the channels treated explicitly, but will also include many-particle absorptive effects of multi-peripheral type, arising from crossed two-particle processes.

There are two novel technical problems which arise in the coupled-channel set-up. First, one must find a coupled-channel N/D method allowing arbitrary absorption parameters and overlapping left and right cuts in the energy plane. Second, a

Watson-Sommerfeld representation of spectral functions is needed, but off-diagonal Froissart-Gribov amplitudes $A_{ij}(l,s)$ increase exponentially in $\text{Im } l$ in the energy region where channel i is open but channel j is closed; consequently, the usual Watson-Sommerfeld integral diverges. Solutions to these problems are proposed in several papers.^{1,2,3}

Robert Warnock

Meson-Meson Scattering

Work currently underway is focused on development of a meson-meson scattering theory consistent with quark model spectroscopy. It is conjectured that quark model Regge trajectories can be introduced through the central spectral function (i.e., through their couplings to inelastic states) in such a way that the same Regge poles appear in elastic amplitudes, and so that crossing symmetry and unitarity are maintained.

Robert Warnock

¹P. W. Johnson and R. L. Warnock, Phys. Rev. D15, 2354 (1977); *ibid.* 16, 482 (1977); R. L. Warnock, Physica 96A, 321 (1979).

²R. L. Warnock, "Matrix N/D Method with Absorption and the Unitarity Problem in Coupled-Channel Regge Theory," I.B.I.-10196, November 1979

³R. L. Warnock, "Dynamical Equations for a Regge Theory with Crossing Symmetry and Unitarity. Part IV: Coupled Channels," preprint, February 1980

Quantum Chromodynamics

Meson Masses in QCD

An approximation scheme is proposed for calculating masses of $Q\bar{Q}$ mesons in QCD. The vacuum instability is removed, not by giving the magnetic field an expectation value, but by enhancing the amplitude of the low-frequency components of the virtual magnetic field. A simple truncation of the Schwinger-Dyson equations incorporates such an effect. Rough numerical calculations indicate that the equations for the gluon propagator have a solution which increases logarithmically at large distances. Clustering does not hold for multi-gluon Green's functions. Instead, if generally believed properties are found to be true for the two-gluon function, they are assumed to be true for the higher functions. Equations for the quark propagator and the $Q\bar{Q}$ bound states are set up. The ladder approximation is totally inadequate in the confinement region, but we can make a reasonable approximation which leads to static forces at large distances. Corrections probably involve vibrational modes of the dual string. At high energy, linearly rising $Q\bar{Q}$ Regge trajectories with the expected quantum numbers are found. The scheme is free from dimensionless parameters if the quarks have zero bare mass. Our equations possess the possibility of chiral symmetry breaking. Massless "pions" would then appear as $Q\bar{Q}$ bound states; massless "etas" would not appear if closed quark loops were included.

Stanley Mandelstam

Quark-Quark Scattering

Quark-quark scattering has been studied beyond the leading order in perturbative QCD. All one-loop Feynman diagrams contributing to the scattering of two quarks of different flavors were

calculated. Massless quarks and gluons were assumed and the infrared and collinear divergences were regularized using dimensional regularization. MACSYMA (the MIT computer programming system used for performing symbolic mathematical manipulations) was used to cope with the enormous number of algebraic manipulations required by the calculation. By factorizing the (leading log) singularities into unknown distribution and fragmentation functions and by comparing with previous calculations of $ep \rightarrow eX$ and $e^+e^- \rightarrow hX$ ($h = \text{hadron}$), the order g^2 correction to the standard parton model formula for $pp \rightarrow hX$ was obtained. The corrections were found to be large, implying that QCD perturbation theory may not be reliable for large transverse momentum hadron physics.

M. A. Furman
H. E. Haber

I. Hinchliffe
R. K. Ellis (Cal Tech)

Target Mass Effects

A general procedure for including target mass effects in the QCD parton model has been invented. The algorithm reproduces the ξ scaling analysis of inclusive lepton production. Applying it to semi-inclusive lepton production gives rise to double moments which are target mass independent, and which have simple scaling violations and factorization breaking.

Jonathan Sheiman

Quarkonium-Gluon Interactions

The interaction of a very heavy quarkonium with soft gluons is being studied within the

framework of perturbative QCD. By use of a unitary transformation analogous to the Foldy-Wouthuysen transformation, interactions are classified according to the softness of color gluons which interact with the quarkonium.

Ken-ichi Shizuya

Heavy Quark Meson Wavefunction

As a model exercise in the gauge-invariant loop space formulation of quantum chromodynamics, the heavy quark meson wavefunction was determined variationally. The bare loop space meson operator is the ordered exponential of the gauge field integrated along a path between fixed quark-antiquark endpoints. The trial wavefunction is constructed by averaging over the unphysical paths with an ansatz weighting functional. Assuming the usual area law behavior of the Wilson loop, it is found that a finite width, stringlike distribution of color electric flux is the preferred ground state configuration.

Susan Moore

Instanton Effects on Boson Masses in QCD

An investigation of the fate of the would-be scalar Goldstone Boson associated with the spontaneous breaking of scale symmetry has been made. In the absence of anomalies spontaneous breaking of chiral symmetry would imply that scale invariance is also spontaneously broken and that there should be a light scalar meson. The absence of such a scalar meson in the observed spectrum is expected as a consequence of the anomalies that do exist in quantum chromodynamics. In particular, instantons may elevate the mass of the scalar boson because of the anomaly in the trace of the stress tensor, just as they are thought to elevate the flavor singlet pseudoscalar boson because of the anomaly in the divergence of the axial current. Instantons must exist in QCD but no experimental tests of their existence have been devised. This analysis may lead to a testable statement about the effect of instantons on the observed spectrum of scalar mesons.

M. Chanowitz

R. Peccei (Max-Planck Inst.)

Field Theory of Hadrons

Field-Strength Formulation of Gauge Theories

Work on an unambiguous field-strength formulation of gauge theories, Abelian and non-Abelian, was completed. The field-strength formulation emphasized that there exist gauges in which Wu-Yang ambiguities are totally absent, and in which Bohn-Aharanov effects can be traced entirely to the field strength. The formulation also leads naturally to another formulation of gauge theories in terms of the "dual potentials." Such potentials, like the magnetic scalar potential of Maxwell's equations, are canonically conjugate to the magnetic fields, instead of the electric, and are thus closely related to 't Hooft's disorder operators.

Martin B. Halpern

Ground State of Non-Abelian Gauge Theories

Gauge theories with positive mass-squared scalar particles and with arbitrary (i.e. non-perturbative) coupling constants are considered. The quantization is done in the axial-gauge for which the quantization procedure is simplest in non-Abelian gauge theories.

The axial-gauge bare vacuum is not a good trial wavefunction for the vacuum of such a theory. Certain coherent state trial wavefunctions which spontaneously break the symmetry of these theories are considered. Performing a variational calculation, it is then shown that a broken symmetry wavefunction gives a lowering of the energy compared to the energy of the bare vacuum for which the symmetry is unbroken.

This indicates that in non-Abelian gauge theories, a phase with partial Higgs-symmetry breaking may be a better approximation to the ground state than the symmetric phase with real massless gluons.

Omer Kaymakçalan

Topological Excitations

The topological excitations in the two-dimensional Abelian Higgs model are studied in both the continuum and the Villain lattice version, and the results are compared. Using a singular gauge transformation, it is shown that there is an exact equivalence between the dual form of both versions. A fermion form of the theory is useful in studying its confinement properties beyond the dilute gas limit. Also, the correct measure factor for the continuum version is derived.

Korkut Bardakcı

Renormalizable Non-linear Field Theory

New renormalizable non-linear field theories in two dimensions and the large N limit of non-Abelian gauge theory were studied. This work was directed towards understanding the possibilities for critical phenomena in two and three dimensions and towards understanding QCD. A description of a new class of models for critical systems and a

substantiation of a phase transition in $U(\infty)$ lattice gauge theory through explicit calculations for small lattices were found.

Daniel Friedan

Two-dimensional CP^{N-1} Models

Two-dimensional CP^{N-1} models have been investigated. These models are generalized non-linear sigma models, and have many properties in common with QCD. The specific problem is how to calculate the effects of a dense plasma of instantons and anti-instantons together. These instantons are certain configurations which are solutions to the classical equations of motion. It appears that the instantons and anti-instantons break up into vortices, and one ends up with a plasma of these vortices. These topological excitations lead to confinement. Confinement is also seen by calculating in the $1/N$ expansion, and it can be shown that it is the topological excitations we have identified which drive the confinement in both cases. In addition, the problem of generalizing these methods to 4-dimensional QCD is currently under investigation.

Daniel Caldwell Herbert Neuberger Korkut Bardacki

Variables for CP^{N-1} Models

Various aspects of the two dimensional CP^{N-1} model were studied. By transforming to new variables, which are unconstrained, a Lagrangian and Hamiltonian were obtained which were studied to gain an insight into the confinement that this model exhibits. In the Lagrangian formulation the appearance of a dynamically generated gauge field leads directly to the confinement. The Hamiltonian had a singularity (similar to the Gribov ambiguity of QCD) whose presence is an immediate indication of quark confinement.

H. Haber

J. Hinchliffe

E. Rabinovici

't Hooft Vortex Operator

The 't Hooft vortex operator has been intensively studied. The possible phases of a gauge theory without quarks have been classified in terms of the cluster properties of the vortex and Wilson loops. The effect of quarks on the vortex operator has been determined; the operator is no longer "local looplike" and the algebra of the vortex and Wilson operators no longer restricts the possible phases. Some problems of the renormalization and equations of motion of vortex operators have also been examined. This research will soon be completed.

J. Polchinski

"Quadratic-Building Block" Theories

Large N saddle points were found for general theories constructed out of "quadratic building blocks" — e.g. field theories whose interaction is an arbitrary function of $\bar{\Phi}\Phi$ where $\bar{\Phi}$ is an N -component vector. This will allow detailed large N expansion studies of a broad class of theories.

Martin B. Halpern

Large N Expansion for Quantum Mechanics

The large N (N = number of spatial dimensions) expansion for quantum mechanics was formulated in an algebraic manner. Contrary to many expectations the method was found to yield accurate results (after only a few terms) for a wide variety of potentials. Furthermore, in the present

formulation higher order terms of the expansion are easily calculable. In particular, spherically and axially symmetric one-particle potentials were treated and work is in progress on the treatment of two-particle potentials. The accuracy of the method is illustrated by the fact that for the linear potential ($V = e^2 r$) in three dimensions the first three terms of the expansion yield the result (in units such that $m = 1 = \hbar, e^2 = 1/2$) 1.16849 for the ground state energy, as compared to the exact numerical result of 1.16905.

The expansion was also applied to the interesting problem of the hydrogen atom in a uniform magnetic field. For the range $0-10^{11}$ Gauss, inclusion of only the first non-trivial correction gives accurate results for the ground state energy of each azimuthal angular momentum subspace. The accuracy of the method as well as the range of fields will be improved by future higher order calculations.

L. Mlodinow

N. Papanicolaou

Theory of Weak Interactions

CP Violation and the Higgs Sector

Higgs field mixing and CP violation in the Weinberg-Salam model have been investigated. The proliferation of the number of Higgs particles leads to CP violation some orders of magnitude larger than that due to the quark sector. In connection with this, research is now in progress to study CP violation due to the Higgs sector by use of the mixing matrix of Higgs particles. This mixing-matrix method gives a concise parameterization of CP-violating interactions. An article is being prepared.

Ken-ichi Shizuya

H. Tye (Cornell)

Axial Current Dimensional Regularization

Work begun last year on how to treat the axial

current in dimensional regularization has been completed. This is an important issue in the broken gauge theories of weak and electromagnetic interactions, theoretically because it figures in proving renormalizability, and practically, to have a convenient method of computing higher order corrections. It is shown that a prescription which is both correct and convenient is to assume an anti-commuting γ_5 . This prescription has been rejected in the past because no such object can be defined in n dimensions. Their analysis showed that this is not a defect of the prescription but merely the inevitable reflection of the well-known axial anomaly of Adler, Bell and Jackiw. In the broken gauge theories the anomaly is constrained to cancel so that the prescription is well-defined. Other prescriptions are either incorrect or very cumbersome.

Michael Chanowitz

Miguel Furman

Ian Hinchliffe

Particle Physics, with Direct Application to Experiment

Charmonium Chi States

Charmonium chi states, their radiative and hadronic widths and the spin of the gluon have been investigated. The dipole sum rules, used earlier to give upper and lower bounds for the radiative transitions for $\chi_J - \gamma\psi$ and so estimate the hadronic widths of the χ states, are re-examined with more general assumptions about the $Q\bar{Q}$ interaction, namely the presence of spin-spin, spin-orbit, and tensor forces. The lower and upper bounds for a specific J value are now explicitly force dependent. In fact, a useful lower bound can be established only for the J = 2 state. The inferred radiative rates and estimates of hadronic width, based on new data, are similar to those given earlier. Results from the Crystal Ball Detector reported at the Fermilab Lepton-Photon symposium in August 1979, led to the inequalities $6 < \Gamma_h(0^{**})/\Gamma_h(2^{**}) < 20$, in some disagreement with the QCD expectation of 15/4 for vector gluons, but also far from the scalar gluon value of 125/2.

J. David Jackson

Cluster Decomposition of Phase Space And High Energy Collisions

Studies have been made of the application of a cluster decomposition of many-dimensional phase space to high-energy collisions. A high-dimensional phase space is reduced in an approximate way to a much smaller dimensional phase space, by singling out a "cluster" of a smaller number of particles (e.g., two or three). This study derives the invariant mass distribution of the cluster, and, for fixed invariant mass, its c.m.s. energy distribution. The basis of the method is a two-cluster decomposition of the original phase space into the cluster of interest and

the remainder. Simple, explicit formulas are given for all particles massless, and for one particle with mass and the others massless. A recipe is stated for the application of these easily calculable distributions to practical situations where the masses of particles must be taken into account. Numerical examples illustrating the validity of the approximations and applications to high-energy elementary particle collisions are given.

Martin M. Block

J. David Jackson

Analyses of η' (958) Width

Recent experimental measurements of the width of η' (958) have been analyzed in order to distinguish between the integral and fractional charge quark models. If the color threshold of the integral charge model is assumed to be very large, then the two models are very hard to distinguish. In fact, the two-photon decays of η and η' could be the only experimental means of discriminating between the two models. Previous analyses have had to resort to dubious assumptions, such as "nonet" symmetry which manifestly fails to explain the observed η - η' mixing. The present analysis does not require these assumptions. The results strongly favor the fractional charge model.

Michael Chanowitz

One-Loop Correction for Three-Jet Events

The magnitude of the leading one loop corrections to the differential cross section for three jet

events, $e^+ e^- \rightarrow q\bar{q}g$ is being investigated. With enough data from PEP and Petra, this cross section is likely to provide the most definitive test yet of quantum chromodynamics. Knowledge of the one loop correction is essential for the interpretation of the data.

Michael Chanowitz

Stephen Sharpe

Heavy Flavor, Quarkonium Decay

Heavy flavor production in quarkonium decay has been investigated. The postulate of duality for the one-gluon production mechanism of $Q\bar{Q}$ bound states has been rejected, and the rates for desired color singlet states with soft gluon radiation have been calculated. The results indicate a large suppression of heavy quark bound state production via this mechanism. Intuitively, this is due to limited phase space and a "long-wavelength dipole coupling" between the $Q\bar{Q}$ bound state and the soft gluon. This work will be extended to $Q\bar{Q}$ bound state production in hadron-hadron collisions, and the phenomenological implications analyzed.

Curt Flory

Angular Distributions of Charmed Particles

The angular distributions in $e^+ e^- \rightarrow D^* \bar{D}^*$ have been studied. These can be measured conveniently at $\sqrt{s} = 4.028$ GeV. The angular distributions yield evidence of the mechanism by which the initially produced charmed quarks are turned into hadrons. The $D^* \bar{D}^*$ production occurs in three partial waves: $(L = 1, S = 0)$, $(L = 1, S = 2)$ and $(L = 3, S = 2)$. The last may be ignored at 4.028 GeV since it is very near threshold. Especially detailed calculations were done for the π^0 's and γ 's resulting from the D^* decays, since these particles can be measured by the Crystal Ball experiment at SPEAR.

Robert Cahn

Boris Kayser (NSF)

Fermion Families, Gauge Bosons

The puzzling occurrence of the second and third families of fundamental fermions has led to the suggestion that there may be gauge bosons connecting these different families. The various rare processes which would be induced by such bosons have been studied. These are: $K \rightarrow e\mu$, $K \rightarrow \pi e\mu$, $\mu N \rightarrow eN$, $\mu \rightarrow e\gamma$, $\mu \rightarrow 3e$, and the $K_L^0 - K_S^0$ mass difference. The mixing scheme which generalizes Cabibbo mixing in such theories has also been investigated. The most stringent limit on the new boson masses is obtained from the limit on coherent muon conversion into an electron. That lower limit is about 40 TeV. The $K_L^0 - K_S^0$ mass difference sets another stringent limit, requiring either that the new bosons be very heavy (hundreds of TeV) or that there be a near degeneracy which cancels their contribution to the mass difference.

Robert Cahn

H. Harari (Weizmann Inst.)

Radiative Decays of Charmed Mesons

The weak decay of charmed mesons was investigated in two aspects: First, the apparent anomaly in the decay rates in the Cabibbo suppressed decay processes was observed by the Mark II Collaboration of LBL-SLAC. The dynamical enhancement mechanism was examined in the standard six-quark gauge model with SU(3) symmetry for strong interactions. The mixing angles of Kobayashi-Maskawa were constrained. Secondly, the large difference in the decay rates of nonleptonic D^+ and D^0 seems to be evidenced by the largely different semileptonic branching ratios. One-gluon correction to the W-exchange diagram was calculated to be no more than a factor of two. A more intensive study is in progress.

Mahiko Suzuki

Relativistic Sum Rules for Charmonium Decays

The radiative decays of charmonium states were examined by the relativistic sum rules with

dynamical assumptions at high energies. The widths of the 3P_J ($J = 0, 1, 2$) are related among themselves by the sum rule in the simplest approximation. The work is in the final stage.

Mahiko Suzuki

Asymptotic Freedom and Charmonium Decays

The asymptotic freedom in the processes that

involve heavy quarks is less precisely formulated. The strong decays of the charmonium states and weak decays of the D mesons are studied for the validity of applying the asymptotic freedom heuristically. The work is in progress

Mahiko Suzuki

Heavy Ion Fusion Studies

Research continues on problems in accelerator theory aimed at developing high-energy heavy-ion accelerators to serve as igniters for inertial-fusion pellet targets. The goal of this program is to develop commercial-scale electric power plants. The work is carried out in collaboration with members of the Accelerator and Fusion Research Division. During 1979 attention was focused on the development of a theory of longitudinal ion dynamics in induction linear accelerators; the topic is important because previous experience with induction linacs is entirely

with the acceleration of electrons whose velocity is essentially that of light throughout acceleration, so that relative motion of electrons within a bunch cannot take place. The new degree of freedom arising in ion acceleration is very useful in that bunch compression can be performed during acceleration, but it also creates new problems, especially regarding motion of ions near the ends of bunches.

David L. Judd

Non-linear Wave Interactions

Langevin vs. Boltzmann Relaxation Rates

The investigation of non-linear interactions in water waves has been continued this year. A comparison has been made between relaxation rates derived by Langevin techniques and the more usual Boltzmann transport equations. It was shown that the transport rate is a balance between the two types of Langevin rates. The experimentally measured energy spectrum of internal waves in the ocean is a steady state over most of wavenumber space under these interactions. A simple approximation (in-

duced diffusion) allows analytical calculation of the relaxation rates.

Kenneth M. Watson James Meiss Neil Pomphrey

Solitons/Ambient Waves

Langevin techniques have also been used to compute the decay rates of solitons in the ocean due to interaction with ambient waves. These rates have been computed for various models of the ocean.

Kenneth M. Watson

Philip Yau

Wave-Current Interactions

A study of the interaction of waves with currents is in progress. The interaction is especially important at "critical layers" where the doppler shifted wave frequency goes to zero.

Kenneth M. Watson

Jeffrey Lerner

Validity of Random Phase Approximation

The induced diffusion model has been used as a dynamical model to test the validity of statistical assumptions such as the random phase hypothesis (R.P.A.). In some cases it is possible to obtain exact

solutions to the dynamics which reduce to the R.P.A. results in the weak interaction limit. These results give the contribution of non-resonant triads to relaxation rates.

Kenneth M. Watson

James Meiss

Non-linear Interaction of Vortices

The non-linear interaction of point vortices in a 2-dimensional fluid is being studied by Hamiltonian methods. An exact, explicit solution for the three vortex system has been obtained. Computer studies of the four vortex system are in progress.

Neil Pumphrey

Statistical Mechanics

Macroscopic Ordering in Bose Systems

A study is being made of macroscopic ordering in Bose systems of two spatial dimensions to obtain a better understanding of phase transitions in systems where the usual broken symmetry mechanism is precluded by long range fluctuations. The path integral representation of the partition function provides a convenient basis for such studies. The steepest-descent approximation has been used to establish the decomposition of the spectra of the Bose liquid into phonon and vortex sectors. It is known that the statistical mechanics of the interacting vortex gas provides for a phase transition. This serves to establish a microscopic basis for the Nelson-Kosterlitz theory of two dimensional superfluidity. Going further, the evolution equations for the vortices may be established. Through path integral methods it is found that the quantum vortex system is a Hamiltonian system. The evolution equations are equivalent to Kirchoff's equations in hydrodynamics, however the circulation of the vortices is quantized.

Plans have been made to study vortex structure in three spatial dimensions. There is particular interest in the possible existence of spherical vortex configurations and in the interaction between vortices and elementary excitations.

Harry L. Morrison

"Hardcore" Potentials in Statistical Mechanics

Existing formulations of quantum corrections for thermodynamics are restricted to systems with analytic interaction potentials.

The objectives of the current research are (a) to develop the classical statistical mechanics for systems in which the interaction potential of the constituent particles is a hardcore type potential by

use of a velocity-dependent potential formulation, (b) to extend the formulation of quantum corrections for thermodynamics to include hardcore type potentials, and (c) to make explicit calculations of quantum corrections for thermodynamics for specific systems by assuming that the actual two-body interaction between constituent particles has a velocity-dependent part.

Charlie Harper

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Accelerator Theory

Stochastic Cooling

A particle simulation program was used to investigate the transverse cooling mechanism under extreme conditions of a small number of particles in good and bad mixing situations, for the purpose of providing clues to a proper analytical treatment of the process. Among other things, it was shown that the scrambling of longitudinal momenta necessarily accompanying the time varying transverse deflections by the pulsed bending (kicker) magnet provides an effective mixing mechanism for small momentum spread, a point which had not been recognized in previous analyses. A theoretical model in which the Vlasov formalism was extended to include two-particle correlations was then developed to rigorously describe the various aspects of the problem in a consistent way; we believe the theory of cooling in the vertical plane is now complete.

Because of the increasing interest in accomplishing momentum cooling at an early date, a similar technique was applied to that case, and we now have a formalism to describe momentum cooling as well. The next step will be to compare theory with the results of the experiments, which will be underway next year.

Synchrotrons and Storage Rings

A substantial amount of work has been done on the design of magnet configurations, both for LBI projects and in assistance to other laboratories. In addition to preliminary work on the Variable Energy Nuclear Synchrotron (VENUS), which included a study of possible collective instabilities, a new design for a proton-electron option to be added to the Positron Electron Project (PEP) was developed. Contributions were also made to the concept of the single-pass, electron-positron collider, which is currently favored as the next step in an expansion of the accelerator facilities located at the Stanford Linear Accelerator Center (SLAC).

In collaboration with other laboratories, a low-beta (i.e. small beam size) modification of an FNAL

doubler straight section was designed for future use in a p-p colliding beam configuration, as well as a precooler-accumulator ring for collecting anti-protons. A small electron storage ring, designed for possible use at both FNAL and CERN, was developed by the Accelerator Theory group, for the purpose of cooling high energy protons and/or anti-protons in a colliding beam storage mode.

Finally, one staff member spent three months at the University of Tokyo to provide them with our computational programs and assist in refinements of the design of the proposed 4.5 GeV nucleon heavy ion synchrotron (NUMATRON).

Accelerator Theory Group

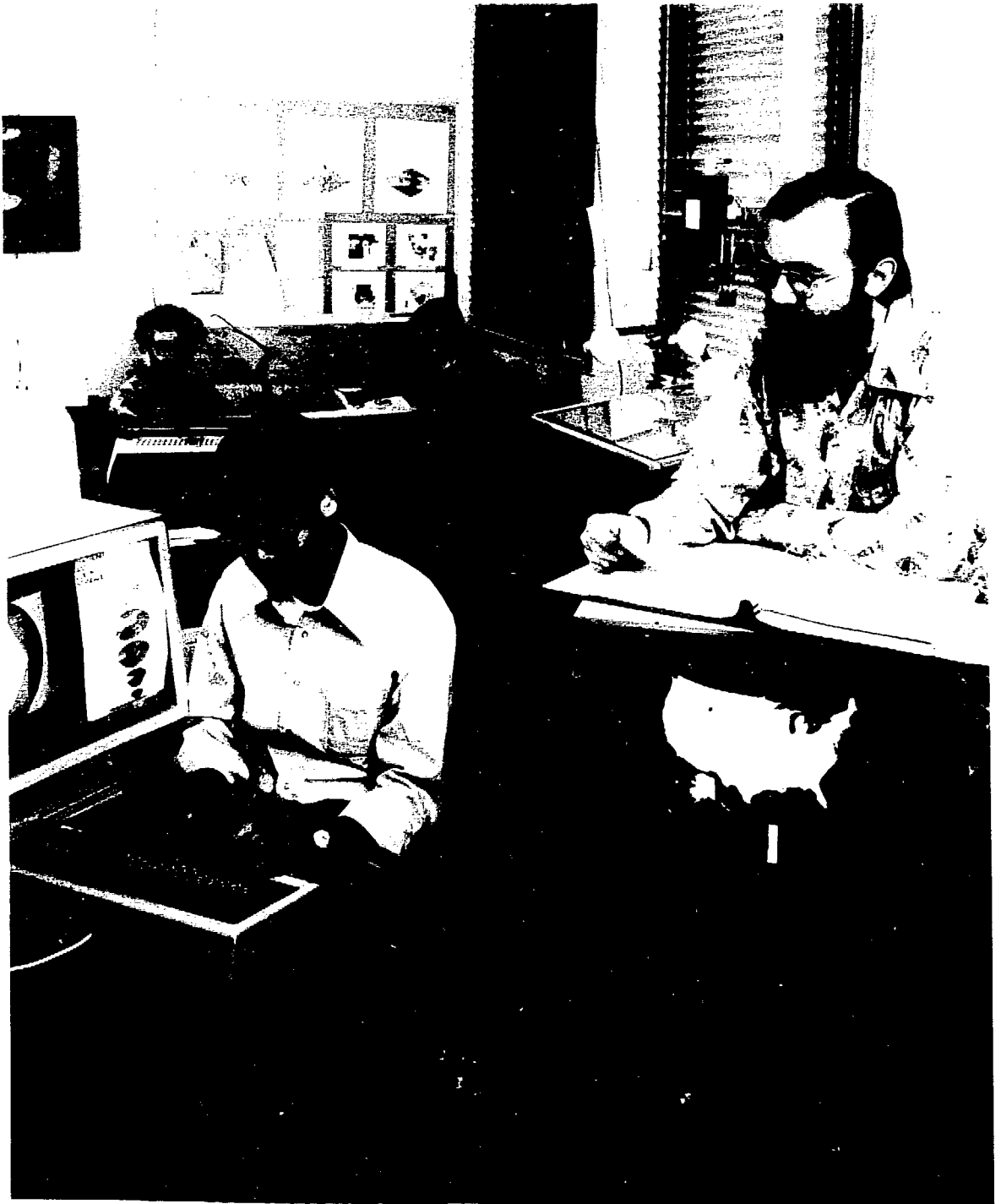
J. Bisognano
A. A. Garren

L. J. Laslett
L. Smith

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III. COMPUTER SCIENCE and APPLIED MATHEMATICS



Computer graphics capabilities in both hardware and software are expanding significantly. Research, development, and applications of graphics at LBL during the year made important contributions in several areas of work. In this photo are (foreground) Albert Yen, left, and Bill Johnston; (background) Bill Benson, left, and Ivy Kuo.

CBB 795-7624

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, CSAM staff collaborate with or provide applications support to other research and support groups in almost every division of the laboratory.

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 1979 included SEEDIS and component database projects, advanced computer system development, data management research, applied mathematics and computational modeling, and computer graphics.

RESEARCH

Applied Mathematics

Applied Analysis

Work in applied analysis centers on three areas: Sampling and Probabilistic Methods; Capillarity Phenomena; and Image Reconstruction From Projections.

Sampling and Probabilistic Methods -- The first area is in the development of numerical techniques for obtaining solutions that are discontinuous or nearly discontinuous for hyperbolic and parabolic

partial differential equations. Such solutions occur very often in applications; however, the usual tools of numerical analysis often depend on smoothness assumptions that are not realized in these cases. The numerical techniques being developed are based on sampling rather than averaging and make use of "dictionaries" of known phenomena as building blocks of probabilistic numerical schemes. These techniques are proving to be successful in a number

of physical applications, including turbulence theory, multiphase flow through a porous medium, and combustion theory.

During 1979, a method has been developed for following flame fronts based on Huyghens' principle and has been used to analyze the velocity of wrinkled flames on the Taylor microscale in a turbulent flow.

The existence of travelling wave solutions in a model of slow combustion has been proved. It also has been proved that arbitrary initial data yield solutions that converge exponentially to a sum of such waves. These facts have been used to extend Glimm's method to the parabolic equations that describe combustion in the diffusion limit.

A version of Glimm's method has been developed that can solve efficiently the problem of gas flow in a duct of variable cross section. Other studies of Glimm's method include an investigation of error growth, and applications to reacting gas flows.

Detailed chemical kinetics have been successfully incorporated into the present models of combusting gas flow. New Ordinary Differential Equation (ODE) solvers written for the specific purpose of being used in these calculations have been developed, and calculations have been extended to several space dimensions through the use of the method based on Huyghens' principle.

Capillarity Phenomena — The second area is the analysis of the nonlinear elliptic partial differential equations arising in the study of capillary free-surfaces. Here the work is concerned with questions of the existence, stability, and qualitative behavior of solutions of these equations, particularly as such questions relate to areas of physical, biological, and engineering sciences in which capillarity plays a significant role. This work has led in a rigorous manner to new results concerning the possible configuration of liquids that are freely suspended or that are confined to a space that they partially fill.

New analytic estimates for the shape of pendent liquid drops were obtained, and the most general such shape characterized. The trapezoid phenomenon for discontinuous behavior of free-surfaces as a function of boundary shape was analyzed further.

Formulation was begun of possible physical experiments to study the difference, revealed by mathematical analysis, between the trapezoid and wedge phenomena.

Image Reconstruction From Projections The third area of investigation in applied analysis is the reconstruction of images of objects from projection data of their transverse sections. The work is directed towards developing "optimal" numerical schemes as well as understanding the mathematical constraints on different forms of tomography. Special emphasis is placed on the effects of limiting the number or range of the directions defining the projections. This work is applicable to X-ray and emission tomographies, transmission electron microscopy, nondestructive testing, and the emerging area of nuclear magnetic resonance (NMR) reconstruction. New reconstruction algorithms for "limited angle" X-ray tomography have been devised and tested successfully. Work has been started on extending these codes to the three-dimensional case with a view towards specific applications to NMR reconstruction. Extensive testing of new reconstruction algorithms for a number of noninvasive detection problems including computerized X-ray and NMR tomography has been conducted.

Computational Mathematics

Research in computational mathematics emphasizes the development of mathematical, numerical, and statistical methods related to the study of energy processes, typically in cases requiring the solution of ordinary and partial differential equations. The topics of primary interest are the development of methods for the numerical solution of elliptic partial differential equations and of algorithms for array processors. 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 requirements. Furthermore, the reliability and ease of use of such methods make them generally attractive. These and related methods are being developed for the iterative solution of elliptic equations that are

nonlinear or have discontinuous coefficients.

An updating technique has been developed for quasi-Newton methods for solving highly structured systems of nonlinear equations, such as those arising from the discretization of an elliptic partial differential equation. Such a technique permits the imposition of general matrix structures suitable for efficient and rapid convergence of iterative schemes. Work was initiated on extending the previously developed updating technique for quasi-Newton methods to solving sequences of elliptic equations with discontinuous coefficients arising from time dependent problems with moving fronts.

Numerical Methods for Partial Differential Equations

In these studies computational techniques are being developed for analyzing turbulent combustion phenomena, such as those that occur in an internal combustion engine and multiphase porous flow phenomena such as those that occur in petroleum or geothermal reservoirs. The goal is the construction of realistic models that are suitable for comparison with experiments and are capable of being used for engineering purposes. The specific features of the methods that are 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 prevented application of preferred numerical techniques to studies of physical combustion phenomena and of porous flow phenomena in which there are sharp fronts. These methods, unlike others, have little or no numerical diffusion (and thus no cell Reynolds number restrictions), i.e., they can deal realistically with high-Reynolds-number fluid flow. Because the 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 for combustion models because chemical phenomena are greatly affected, even determined, by the existence of coherent eddies and will not be reasonably reproduced if such eddies are not taken into account.

Combustion — The main advances this year have been the following: A method based on Huyghens' principle has been used to implement a flame model in which the dynamical effects of a flame are represented by a distributed surface (or line) source of specific volume. The resulting computational algorithm is stable, simple, inexpensive, and realistic. Vortex models of turbulent flow have been developed further and extended to the three-dimensional case. The Piecewise Sampling Method was applied to additional studies of flow fields generated by accelerating flames.

Numerical methods for solving the systems of stiff ordinary differential equations arising in the chemical kinetics of reacting gas flow have been studied. Several techniques for improving existing state-of-the-art methods have been developed that result in up to 50% improvement in computational efficiency for simulation of realistically detailed models of chemical kinetics and flame propagation. The resulting software has been used successfully for a parametric study of the ignition of a methane-air mixture, demonstrating the validity of a greatly simplified model of the chemical kinetics.

As an application, our techniques have been applied to flow in a combustion tunnel where the flame is stabilized by a back-facing step. Numerical solutions for both non-reacting and reacting flow have been obtained; they reproduce quite satisfactorily the essential features of turbulent combustion in a lean propane-air mixture as observed in the laboratory by means of high speed schlieren cinematography.

Technical advice and computer programs have been provided to researchers in combustion and turbulence at the combustion facility at SANDIA, to the Autolab of the University of Michigan, to the combustion groups at Princeton and NYU, to the theory groups at Volvo, and elsewhere.

Flow In Porous Media — Work continued on extending the Piecewise Sampling Method to solve the Buckley-Leverett equation for the general two-dimensional case by means of fractional splitting, including the effects of capillary pressure and non-uniform velocity. 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 and that it gives an accurate estimate of the time of breakthrough of the water front into the producing well. In numerical experiments, the van der Corput equidistributed

sampling procedure has been compared with a procedure containing a random element and the former sampling found generally to give more satisfactory results.

Information Analysis Techniques

The area of Information Analysis Techniques (IAT) serves as a general umbrella for combining the results of related research areas focusing on the end user's perception of the computer as an analytical tool. Some of the related research areas are: statistical analysis of large data sets, data management techniques, distributed systems techniques, computer graphics techniques, and human-machine interfaces.

These research efforts contribute to the development of techniques that will provide the capability of retrieving, integrating, analyzing, and displaying information. Areas covered by IAT include studies of methodologies used in socio-economic and environmental impacts, energy policy analysis, physics and biophysics data analysis, management information and program planning.

Research in data management at LBL is directed toward development of data models, data compression and fast search techniques, and data structures appropriate for statistical analysis of large data sets. Research is beginning in the development of archival mass storage systems capable of supporting information analysis and display techniques for very large data bases.

At LBL, the Socio-Economic Environmental Demographic Information System (SEEDIS) under development provides a framework and testbed for implementation and evaluation of information analysis techniques. At Pacific Northwest Laboratories (PNL), the Analysis of Large Data Sets (ALDS) project forms the basis for the development of statistical tools. At George Washington University (GWU), an effort is underway to develop the

ANSI graphics standards and to investigate user interface techniques associated with SEEDIS. Research Computing facilities at these three sites (LBL, PNL, and GWU) are linked via a computer network connecting VAX 11/780 computers and RAMTEK 9400 color display terminals. This network, managed and implemented by LBL, will provide for easy sharing of ideas and software among researchers in this area.

Data Management

The purpose of the data management research program is to develop tools and techniques tailored for applications relevant to the DOE mission. An important consideration is in the efficient handling of large amounts of data and the ability of users who are non-programmers to interface with it. Environmental, demographic, energy use and production data are typical examples of large, geographically oriented data bases important to DOE. Other sources of large data bases are statistical data bases that are the results of lengthy experiments, such as measurement of the effect of radiation on animals.

Data management research concentrated in two main areas over the last year. One is the area of efficient data storage and access. After studying the characteristics of the data typical to DOE needs, special access techniques were developed that provide a high degree of data compression, yet permit efficient access of the data.

The second area is user interfaces. Two efforts were involved. One is the development of a data dictionary/directory system that directs a user to

the data he needs and lets him specify selection requirements. This system was implemented on SEEDIS. The other effort involved the design of a query language based on a semantically rich data model. Work was also performed to enhance the data model with clearer semantic constructs that more accurately represent statistical data bases.

A critical facet of data management research is the integration of mass storage technology. We have investigated numerous possibilities for mass storage devices and concentrated on the promising technology of optical disks. Currently, there are very few companies developing this technology, and we are in contact with these developers for possible acquisition of a prototype device. Work was started to define the software support needs for such a device.

Efficient Data Storage and Access — Many data bases in the DOE environment have characteristics which require special techniques for their efficient handling. One typical characteristic is that they tend to contain a large amount of repeating data. For example, a data base on disease statistics, organized by counties, by age, by sex, and by race, would repeat each item for all possible combinations of the other three items. A similar situation occurs in data bases collected as a result of experiments, where at each stage some parameter changes while the others stay the same. We refer to such data bases as “summary data.” Another common characteristic of summary data is that it contains a large number of special values, such as null (empty) values, zeros, or specially selected values to represent a special meaning.

The compression of data often results in inefficient access because the data has to be decompressed or searched sequentially to locate each data element. Techniques were developed to allow an efficient access of the compressed data. The problem of data repetition is handled by applying array linearization techniques to value sets (e.g., all counties, all races) stored in a dictionary. This technique reduces storage requirements (a savings of up to 80–90%) while access to the data can be accomplished with a simple computation. For the purpose of compressing the “special values” out of the data, a technique was developed which employs a header describing the distribution of the “special

values” in the database. This technique avoids the need to sequentially access the compressed data. Storage savings depend on the frequency of special values, but often amount to 50–70%. In addition, the above techniques were combined to handle more general cases.

Prototype implementation of these techniques will soon commence. The purpose of the prototype is to verify the results with example data bases.

Data Dictionary/Directory for Summary Data — Another aspect of summary data is that multiple summaries of the original (very large) database are generated and stored for more efficient use. For example, county level data may be summarized to the state level, and stored for future use. In practice, hundreds and sometimes thousands of such summaries are generated, a problem that requires special attention. There is a proliferation of data element names and much duplication of data. An additional problem is in determining the availability of data elements for a given geographic level, or availability for a given subject.

The above problem was handled in two ways: first an efficient method for representing the information in summary sets has been developed. This method uses a common dictionary for all data sets so that data duplication is eliminated. For example, descriptors for U.S. counties are stored once, but used for multiple data sets. Secondly a generic structure was built to describe the data sets in a hierarchical manner. The result is a system that lets users browse through the directory in a menu-driven fashion (obviating the need to remember data element names), express selection of desired items, or search for the existence of data sets from a set of keywords. This system has been incorporated into the SEEDIS project on an experimental basis, and has been shown to be of great help to users.

Simplified Query Language — It is typical of many user interfaces that in order to express a query involving elements from more than one file, a complex construct (called “join”) had to be used in the query language. To avoid this difficulty and to provide a more meaningful data model to the user, a model called the “entity-relationship” (E-R) model was selected, and a query language called “CABLE” developed for it. Over the last year, the language has

been redesigned to be more general and powerful. The query language lets the user express implicit connections between files through a path mechanism, thus avoiding the "join" construct whenever possible.

Enhancement to the E-R Model — As a result of examining multiple examples with the E-R model, it was concluded that the model should be enhanced to include two special entity types — a "subset" entity and a "summary" entity. The subset entity type is particularly useful in describing "generic" data bases, where several subsets of the data share common properties. An example was provided in the implementation of a proposal tracking system where a proposal can be in different stages, each stage having its own distinct data requirements. For example, proposals in the review stage are linked to information on reviewers. The summary entity is designed for the description of summary data bases. Its purpose is to obviate the need for specifying an aggregate operation (such as sum or average) in the query language when this information can be inferred from the data description. For example a user can ask for the population of a state without needing to specify it as a total of populations of all counties.

A version of the query language CABLE, called STRAND, was implemented and interfaced to the INGRES data management system and made available for use with the proposal tracking example.

Mass Storage — An informal evaluation of mass storage devices was carried out. We discussed our requirements with a number of potential vendors. The most promising devices are based on optical disk recording technology, originally developed for video recording. Recording is done by laser machining of micro-sized pits in a thin metal film which has been deposited on a plastic or glass disk. Each disk has a capacity of a few billion bytes of data.

Display and Analysis Systems

In an effort to foster cooperation and communication among the agencies and organizations working toward the development of information

analysis techniques, a new project related to LBL's Socio-Economic Environmental Demographic Information System (SEEDIS) was begun. Visiting scientists from LBL and LASL spent the academic year at George Washington University in collaboration on the development of user interfaces, graphics, networks, and data management techniques. Specific research conducted cooperatively by GWU and LBL has concentrated on the implementation of the ANSI graphics standards (which is based on the SIGGRAPH GSPC effort), user interfaces, graphics design methodology, and networking techniques for distributed data bases.

The analysis and display of summary data entails many problems in the representation of the accuracy (or uncertainty) in the data. Traditional techniques, such as thematic mapping, tend to mislead the observer into assigning too rigorous a meaning to statistically uncertain data. This research project has attacked these problems by investigating color perception and specification, alternative data categorization techniques ("binning" methods), and graphics design principles. Significant progress in developing new techniques for display and analysis of data was made in the area of "fuzzy" set theory applied to graphics display and in data categorization applied to thematic mapping. These advanced techniques provide a powerful new capability to represent information in a more rigorous and unambiguous manner than formerly available in similar systems. This work was the result of collaboration with experts in fuzzy set theory at UC Berkeley, and with graphic designers.

Activities in graphics standards have concentrated on the development and identification of those areas of computer graphics suitable for standardization. These ideas are input to the ANSI graphics standards effort (ANSI X3H3 "Computer Graphics Programming Language"). Areas of research include:

- the design of a standard interface to device dependent drivers;
- specification of graphic techniques for storage tube terminals, including the treatment of default screen areas, unescorted text, and the classification and treatment of cross hair and other inputs;

- implementation strategies for raster scan terminals;
- proposed color look-up table strategies as they apply to changeable vs non-changeable color look-up tables and related transformations (an example of a device with a changeable look-up table is the Ramtek 9400 color display system; the Dicomed color COM is an example of a device with a non-changeable look-up table);
- extensions to the standard to handle “after-the-fact” changes in color via changes in the look-up tables;
- the definition of a common terminology and methodology to be used by application programs to describe hue, saturation, and intensity

or to specify red, green, blue components for a specific device. Transformation between these two specifications will be allowed.

A working document has been prepared describing the Device-Independent/Device-Dependent (DI/DD) interface specifications. Our past experience with a storage tube terminals is incorporated in work in progress on drivers for these devices. A preliminary implementation strategy for raster scan terminals has been developed. This strategy supports characters, lines, area filling, and after the fact changes in the color look-up tables, and allows both kinds of color description with transformations between them based on color perception. Further investigation on changeable vs non-changeable color look-up tables will be needed.

Computer Graphics

Work in computer graphics included development of graphics algorithms and 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. Areas of investigation included generalized coordinate transformation techniques, contouring of sparse data, three dimensional viewing transformation problems, command structures for software generated text (as used in plot annotation), and the automatic determination of fiducial or calibration points for the coordinate domains of a plot. In particular, the generalized coordinate transformation concept is intended to allow all types of plotting to be done through complex, nonlinear transformations, for example map projections.

GRAFPAC is the low-level, device-independent graphics driver system developed at LBL. Work was done on GRAFPAC in the areas of investigating and implementing user interfaces to color and raster scan devices. Research in device-independent graphics had lead to an active involvement with computer graphics standardization; in particular, LBL is represented on the ANSI Committee, X3H3 — Computer Graphics Programming Languages. Research on a general DI/DD interface (the communication between device independent graphics software and device dependent drivers) had been undertaken in conjunction with George Washington University.

Research in the area of vision explores 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. Research on border locking of luminance gaps (a phenomenon related to antialiasing algorithms) is an ongoing project.

Work in image processing focuses on attempts to use remote sensed imagery to 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 were developed.

Technical specifications and initial software design issues 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.

A new direction in research connected with the development of CHART is that of characterizing data "verbally." Linguistic expressions composed of dimensional terms such as high, medium, low, near; connectives such as and, or, but, not; and modifiers such as slightly and very, can be formulated interactively to express relationships among one or more data variables. Using quantitative techniques based on fuzzy set theory, linguistic expressions can be evaluated in terms of the degree to which the data fit. A shaded display shows where and how well the data fit the description.

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

- DOE Computer Graphics Forum — Hosted at LBL in 1979;
- ANSI — X3H3 — Technical Committee for Computer Graphics Programming Languages;
- ACM/SIGGRAPH '79 — several papers were presented and a panel was chaired;
- Optical Society of America Meeting;
- COMTECH, presentation on color perception;
- Image Processing, Human Vision and Computer Graphics Seminars.



Twenty planar C-T scans of a dog's heart, such as the two shown, are combined by a computer program to yield the three-dimensional image. This technique is being studied by researchers as an aid to visualizing internal structures. Top: CBB 808-9263 — Bottom: left, XBB 808-9213; right, XBB 808-9214

Distributed Systems

Software Engineering

Software Engineering research at LBL addresses the wide variation in commercial program development environments. These range in quality from bad to mediocre, with almost nothing in common crossing vendor boundaries. As a result, collaboration is difficult within the AMS research community, and development of portable software is inhibited. FORTRAN language development and standards activities are also supported.

Software Engineering Research — Research focused on the question of what constitutes a good user interface to a program development system. Results indicated that the methodology most likely to evolve is a set of conditions describing what constitutes a poor user interface, rather than clear cut maxims for generating good interfaces. For example, stringently columnar input formats are poor since they produce user fatigue and frustration. However, a best form for data entry cannot be specified generally since it depends strongly on both the user and the problem.

Software Tools — The "Software Tools" investigation demonstrated that a well designed program development environment can significantly reduce programming effort and increase collaboration by providing a standardized environment across vendor boundaries. Experimentation with new tools and primitive operating system functions resulted in specification of a virtual operating system (VOS). This provides a uniform view of system resources on a variety of existing systems, and is expected to form the basis for a network operating system (NOS).

Availability of a standardized environment on a number of systems accentuated the need for a portable hierarchical file system. Such a system allows users to arrange files into directories of related items, significantly reducing the effort of organizing and retrieving data. This is essential for ensuring a uniform view of files when working in a network environment. Initial measurements indicated that 13%-30% of user commands involved manipulations of the file hierarchy. An experimental hierarchical system was implemented, and directory primitives were isolated for a future portable system. The prototype system was sufficiently popular to warrant research into a more powerful version — one that could be easily ported and expanded to function in a network environment.

The software tools were modified to output statistics on command usage for user sessions at LBL. Preliminary results indicated that 87% of user requests were to the portable environment. Only 13% of the commands related to the native system. Further analysis was expected to yield a modified interface that would maximize ease of learning and ease of use while minimizing the likelihood of errors.

Portable performance measurement tools were designed and implemented. These measure the CPU time and elapsed clock time for executing programs and program segments. This allows programmers to isolate "hot spots" for subsequent optimization. It also allows determination of software efficiency on more than one system, an

important requirement for creating optimal distributed applications.

Examination of the problems involved in maintaining and distributing portable software established the need for a portable source code maintenance tool. A survey of existing software resulted in the location of a tool which would meet the requirements. Development of a public-domain version of a similar system will follow.

The feasibility of translating the software tools programming language (RATFOR) into languages other than FORTRAN was investigated. Preliminary results indicated that significant improvements in CPU load and reduction in code size could be obtained through mechanical translations. Individuals at other sites who have already begun, or are interested in, such translations were located, and an informal collaboration was established. The development of new translators will be coordinated by the Software Tools Users Group.

Technology Transfer - A Software Tools Users Group was formed to enhance communications and broaden responsibility for further design, development and distribution of the package. A newsletter was circulated to a mailing list of 250. The first meeting was held in Toronto in June, 1979, with over 100 people attending. Attention at the meeting focused on status reports from the various sites, methods for coordinating development efforts, and formation of a clearing-house for additions and modifications to the base system. Special interest groups were formed in the areas of RATFOR (preprocessor) extensions, text editing, text formatting, and networks. Distribution of the software tools package began. Project personnel assisted in the implementation of the package at several DOE sites. Supporting tapes, documentation and verbal assistance were made available to many other installations world-wide.

LBL staff visited ANL, PNL, George Washington University, and New York University, presenting lectures and course material on the philosophy and use of the software tools package. Identification of potential areas of collaboration

and cooperation on projects of mutual interest were also discussed.

Participation continued in the DOE-wide working group on user interface methodology, created to discuss the research aspects of interface design. Communication was maintained on a daily basis through the PLANET computer teleconferencing system.

Fortran Development and Standards - In October of 1976, the Advanced Computing Committee was formed by the Office of ADP Management (DOE), to provide a forum for the exchange of information regarding advanced computing environments. This committee chartered a Language Working Group to identify common language needs at sites where high performance computers were in use. During 1978 and 1979 this group identified functional requirements for extensions to the Fortran computing language. These requirements were the basis for an extended Fortran language, the design of which will be presented for review at other DOE sites during 1980.

One important feature of this set of Fortran language extensions is the emphasis on array processing. Applications that deal with large arrays of data can achieve improved performance through the use of such extensions, whether or not special array-oriented hardware is employed. Compilers will be able to exploit the higher-level algorithm description specified by the array syntax, rather than deducing array operations by analysis of lower-level description of the problem.

Array processing is one of the features also under active consideration for future standardization by the American National Standards Technical Committee on Fortran (ANSI X3J3). Since publication of the most recent Fortran standard in 1978, this committee has been engaged in the design and specification of an advanced Fortran language, intended to provide needed modern features while maintaining compatibility with former versions of Fortran. CSAM personnel have continued active participation in ANSI X3J3 activities, including serving as secretary to the committee.

Networking

Distributed Systems research at LBL focuses on the software and hardware issues relevant to the interconnection of heterogeneous computer systems via computer networks. Interconnection is necessary to promote resource sharing among the various DOE sites. The LBL efforts in distributed systems fall into three general categories.

Portability and Transparency Issues — This category involves the design and development of a logical model of computer networks which is realistically implementable on a majority of the traditional computer systems found in the DOE research community. The major purpose of the model is to promote a uniform view of the collective resources available on the network, such that user applications may exploit the shared resources of the network.

To facilitate resource sharing within heterogeneous networks, the primitives of the virtual operating system, described above, were extended to support network access to a resource in the network once the user specified its location via an extended name. The extension of the primitives has the effect of transforming all of the standard software tools utilities into network utilities. An implementation of these extensions and capabilities was performed and tested in a pair of homogeneous systems connected via a vendor-supplied network. While not testing the validity of the hypothesis that the VOS facilitates resource sharing in a heterogeneous environment, the increased functionality and utility of such an implementation over the vendor-supplied utilities was encouraging. A preliminary report of this work was presented at the Georgia Technical Institute Interprocess Communication Workshop in November 1978.

System Interconnection Techniques — This general area concerns hardware and low-level software issues in the actual interconnection of two or more machines. Significant variables in such considerations include: required bandwidth, type of carrier, protocols necessary to provide network services, and impact of network load on host processing power.

The connection of the DEC PDP-11/70

running UNIX as a host on the ARPANET was completed. In addition, a simplistic DECNET link between the PDP-11/70 and VAX 11/780 was established.

Collaboration and support for the local network between UNIX machines at UC Berkeley continued. Major portions of the software had been designed and implemented on a single machine, as well as software tested.

The Fourth Berkeley Conference on Distributed Data Management and Computer Networks was sponsored in August 1979. The best data management papers were published in IEEE Transactions on Software Engineering, and the best network papers were published in Computer Networks. A total of 35 papers was submitted, of which 21 were published in the proceedings.

Automatic File Migration — The automatic file migration research is concerned with 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. The goal is to relieve the programmer of the need to explicitly control the location of files, by providing the illusion of a single level file store. The plan of research is to collect measurements (traces of file system activity) and use that data for both experimental and theoretical studies of file migration and related problems.

Efforts to obtain file traces and reduce them to useful form continued. One new raw trace (2 months) was obtained from NASA Johnson Space Flight Center. One short (2 week) trace obtained earlier (from SLAC) was reduced and statistical characterization studies begun. The studies showed that shared user files (the primary candidates for file migration on networks) accounted for about 10% of file opens.

Work on a linear programming model of file system activity continued. This model is intended to incorporate the effects of fixed size caches, and time dependent file system activity. The choice of a highly aggregated, discrete time, deterministic, linearized model was made for the sake of tractability. Even so, a large LP (Linear Programming) problem results. However, this appears amenable to decomposition.

PROJECTS

The Socio-Economic Environmental Demographic Information System (SEEDIS)

The Socio-Economic-Environmental-Demographic Information System (SEEDIS) consists of sophisticated analytical and information display capabilities and a very large integrated database. 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. Ongoing effort includes research, development and demonstration of data retrieval, analysis and display programs; the integration of new data sources; and the investigation and implementation of distributed information and networking techniques.

The system currently contains a variety of databases --

- socio-economic data, including portions of the 1970 Census of Population and Housing;
- the 1976 Survey of Income and Education;
- Current Population Surveys and econometric models projecting population and employment patterns;
- data describing land use;
- industrial and business patterns, for example the 1947-1977 City-County data books and Censuses of Agriculture;
- environmental quality data including air quality measurements from EPA and state agencies;

- energy production and consumption statistics and projections from the Brookhaven Energetics Atlas and the Federal Energy Regulatory Commissions Generating Unit Reference File;
- health effects data including mortality rates and cancer incidence; and
- geographic base files.

VAX Implementation

During 1979 major components of the SEEDIS system were implemented on DEC VAX-11 780 computers, a major step in the investigation of distributed information technology. This included the user interface and the modules for geographic area selection, data selection, data extraction, and display. The installation of SEEDIS on the experimental network provided the anticipated benefits of improved response time, ease of use, and greater flexibility. This improved response time allows the planner or analyst to quickly produce the necessary reports and graphs, to perform in-depth analysis, and to refine the presentation until the desired results are obtained.

The major components of SEEDIS which were converted to DEC's VMS operating system were:

- a) The SEEDIS Monitor: The user-oriented Monitor allows the user to gain access to



TOP
RIGHT

An interactive map design session on a Tektronix 4027 color terminal having eight selectable colors. It is connected to a Xerox 6500 color graphics printer through a laser control unit.
CBB 806-7471

TOP
LEFT

The Tektronix 4016 is a large-screen, high-resolution storage-tube terminal used for preparation and display of black and white computer graphics. A thematic map with shaded-circle symbols is shown here.
CBB 806-7467

LEFT

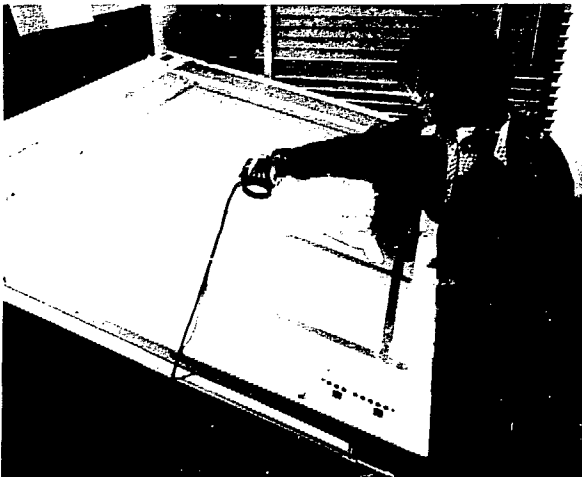
The Ramtek terminal produces detailed thematic maps. Other applications yield digital images, such as satellite data or digitized radiographic images.
CBB 806-7469

BOTTOM
LEFT

The Talos digitizer is shown digitizing New England SMSAs for use with SEEDIS. Almost any drawing or other graphic material can be entered into the computer.
CBB 806-7465

BOTTOM
RIGHT

The DUNN camera makes high quality color prints and slides from computer color-graphics terminals, directly from the video signals. The camera accepts images of up to 1024 x 1280 pixel resolution.
CBB 806-7473



the very large data bases and the data analysis and display programs in SEEDIS. The monitor was completely rewritten for the VAX computers.

- b) The Area module: The Area module permits the selection of a geographic study area. The module was generalized to allow the addition of administrative districts, such as prime sponsors or congressional districts.
- c) The Data Selection module: The Data Selection module provides on-line browsing and data item selection for all installed SEEDIS data bases.
- d) The Extract module: The Extract module retrieves subsets of data from multiple data bases for user-specified geographic areas. Extract procedures operate automatically and create user work files which are accessed by the SEEDIS display and analysis modules.

During the transfer of SEEDIS software to the VAX, many improvements were made to the functional capabilities. Based on experience with earlier versions of SEEDIS, the mapping module (CARTE) was completely redesigned to take advantage of features provided by the VAX VMS operating system. Significant developments have occurred for the data analysis and display modules CHART, QUERY, and SUBJECT.

The principal changes and improvements in CARTE were to modularize the user interface, the control logic and graphic design portions of the system, and the graphics display functions. The new user interface provides a script facility, better control of graphics display parameters, and much more flexibility in adding new features.

The CHART system has been enhanced to incorporate commands to manipulate imprecise user data. This work is based on fuzzy set theory and provides an understanding of data qualifying phrases such as "high," "very high," etc. These phrases can be combined with boolean conjunctions such as "and," "or," and "not." For example, areas which have "high unemployment" and "low popu-

lation" can be represented graphically. Other improvements to CHART include better arithmetic capabilities, a better intermodule interface, better display techniques, and more precise control of color. Consultations with a graphic designer have provided insight into improved effectiveness in the visual presentation of data.

An experimental selective query facility has been implemented. This facility (QUERY) provides:

- selective retrieval by user specified boolean conditions;
- arithmetic computation and creation of new variables from existing variables;
- some statistical functions (SUM, MAX, MIN, AVERAGE).

The new SUBJECT module satisfies the need for a subject-oriented search facility for the vast number of data elements available in SEEDIS. SUBJECT supports a directed-graph-structured representation of the data elements. By means of simple menu selection the user proceeds from general to more detailed specification. When the specific category of interest is reached, a request is made for the retrieval of all data elements included in this category. For tabular data arrays, the user may select data elements by specifying a subset of each axis independently.

Another capability provided by the SUBJECT module is keyword searches within the data element category descriptions. The user specifies the desired keywords and the system responds with the data bases and categories which contain the specified term, or conjunction of specified terms.

Archiving the SEEDIS Data Bases

The UBL mass storage device which housed the majority of the component SEEDIS data bases was removed from service during the first quarter of fiscal year 1979. CSAM began a project to transfer this data to a new archive on high density (6250 characters per inch) magnetic tape. The identification and development of new storage structures

led to the following accomplishments:

- a. Archiving on high density tape of the entire 1970 Census of Population, the geographic base map files, State Industry-Occupation matrices developed under a project for the Bureau of Labor Statistics, the FIPS code identification files, data from the 1972 Economic Censuses and the City-County Data Books, and other important data bases;
- b. Development of a computer-independent data compression scheme which saved an average of 66 percent of the original size of the data files;
- c. Development of a generalized Data Definition File (DDF) facility for characterizing all SEEDIS data;
- d. A rewrite of the Manpower report package software for the new storage structure, to maintain access to this data resource by DOL, CETA prime sponsors, and the general public.

New Data Files

During 1979, new data files from DOE and other agencies were integrated in SEEDIS for interactive access, analysis and display in the form of maps and tables. The data included the April 1979 Federal Energy Regulatory Commission Generating Unit Reference File, 1970 Housing and Heating Characteristics obtained from Brookhaven National Laboratory, air quality measurements from individual monitoring stations, air quality estimates for counties and census tracts, locations of places defined by the Bureau of the Census and the Environmental Protection Agency, and Bureau of the Census county population estimates through 1975.

Geocode files and base maps for a variety of geographic areas were added to permit aggregation of county level data to larger geographic units including Standard Metropolitan Statistical Areas, EPA Air Quality Control Regions, BEA Economic Areas, Water Resource Council Areas, Federal Regions, Census Regions, Petroleum Allocation Districts, Bechtel Energy Model Regions, National Center for Health Statistics county groups, and National Cancer Institute county groups.

The ESARS Data Project

The ESARS project is a test application of SEEDIS data integration, analysis and display functions in a distributed environment. DOL Employment Security (ESARS) data are generated at the local level, reported and aggregated at the state and regional levels for extensive analysis, and submitted to a centralized database for national reporting and comparative studies across regional boundaries.

A major development during 1979 was the

installation of ESARS data on VAX-11/780 computers. Design specification and implementation of the ESARS tape conversion programs were completed. As currently implemented, the programs create a master data tape which contains regional ESARS data. From this tape the user can create a subset of the data which will be disk-resident for rapid access in report generation. The conversion programs achieve a significant reduction in storage space, and allow an estimated 1250 master data sets to reside on one 200 MB disk pack.

Labor Market Projections Model

The Labor Market Projections Model (LMPM) provides estimates of current requirements for employment and training services in local areas. 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) data and the

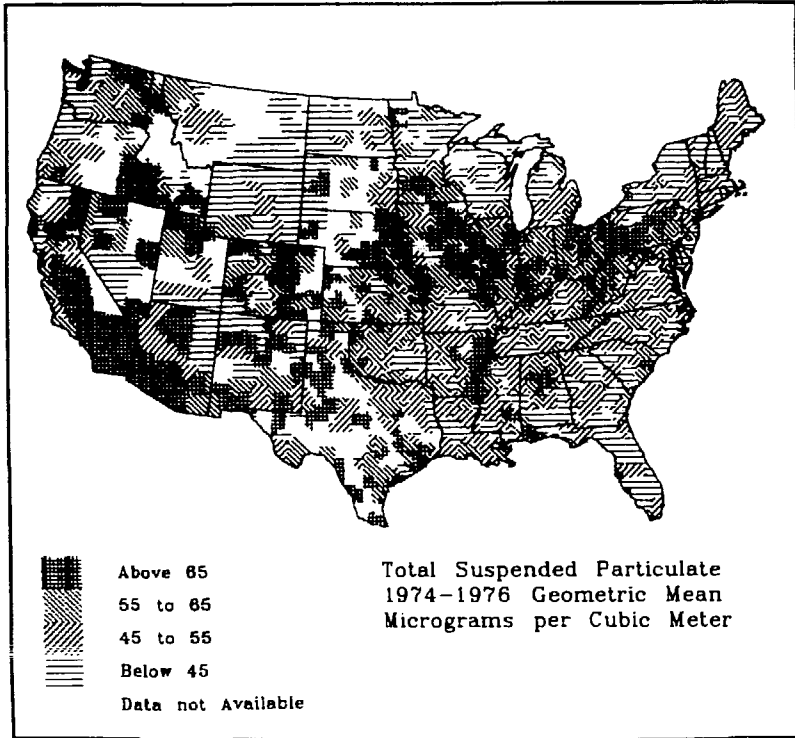


Estimating "current" local labor needs with the Labor Market Projections Model (LMPM), using census data and refining the population projections are concerns of Esther Schroeder (left), LMPM project leader, and Linda Kwok, statistician.

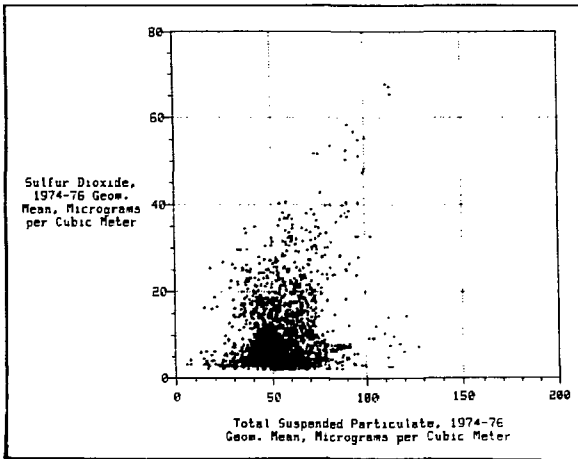
CBB 796-7917

latest CPS data. 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, sex, and race for a particular area. Submodels are used to handle the military and collegiate populations separately. Labor force and unemployment projections are based on the labor force and unemployment of the gearea in the base year, national changes in the labor force and unemployment from the base year to the target year, and the population projections for the target year as calculated previously.

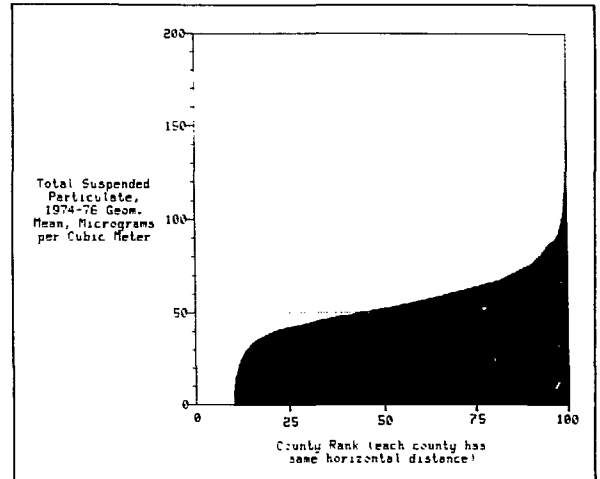
Several improvements were made to the population projections model. More current mortality rates and fertility rates were introduced. Furthermore, the fertility rates are now defined at the state level, instead of the national, as previously. The submodel for the military was improved considerably. In 1970, the total military in an area are estimated, not just those in military barracks as was done before. Data on station strength in 1975 and 1977 were obtained at the county level from the Bureau of the Census. Thus the general decline in military strength across the county was taken into account. To accommodate those states which must use state generated population projections by law, a provision was made for them to insert their own population estimates to obtain labor force and unemployment projections.



The 1974-1976 geometric mean level of total suspended particulate (TSP), estimated at the position of county population centroids from measurements at individual monitoring stations, is shown.



Graph showing a positive correlation between levels of TSP and sulfur dioxide, another significant and widely measured pollutant. Such a relationship is important, because the combined effect of these two pollutants is believed to be more harmful than the simple sum of their separate effects.



The distribution of estimated TSP levels among the 3000-odd counties of the United States. Levels could not be estimated for about 15% of the counties, as shown at left end of this plot. Most of the remaining counties have estimated levels between 45 and 65 micrograms per cubic meter; a few counties have levels in excess of 100 micrograms per cubic meter. The primary national ambient air quality standard is 75 micrograms per cubic meter. Counties with levels above this limit are in violation of EPA regulations and are required to take action to bring the levels down.

Populations at Risk to Environmental Pollution

The Populations at Risk to Environmental Pollution (PAREP) project is expanding the existing environmental database at the Lawrence Berkeley Laboratory for the purpose of making epidemiologic investigations into the relationship between disease (particularly cancer) and environmental pollution. The PAREP project encompasses development and evaluation of analytical methodologies as well as specific investigations. The database contains, for each county in the United States, information on air quality, human mortality, geographic location, and a number of socioeconomic indicators. In 1979 the database was supplemented with more inclusive air-quality data and with information on age-specific mortality and cancer incidence.

A typical epidemiologic study focuses on the individual as the unit of investigation. The PAREP project has begun to analyze data for which the basic unit is a group of individuals; this approach is called an ecological study. Since the methodology for analyzing this type of data is not well developed, and is limited to only a few techniques, the PAREP project is developing specialized statistical techniques to deal with ecological data. Without such statistical tools, the utility of ecological data is much reduced.

A comprehensive set of geocode files and geographic base-map files was needed so that data files based on different geocoding schemes could be combined. The problem was not simply one of nomenclature, but of finding a means of combining data from different areas that partially overlap each other. Software was implemented to automate the combination of data archived at different geographic levels by providing proxy variable files. Consequently, when such geographic inconsistencies are encountered in future work, the files can be easily integrated with the existing database.

A major task was the development of a file containing corrected latitudinal and longitudinal coordinates for all the active air-quality-monitoring stations in the United States. Station locations were visually checked against county boundaries, an exercise that would have been extremely difficult without the graphic-display capabilities of SEEDIS.

County-level air-quality estimates were calculated as a weighted average of measurements from nearby stations, with the nearest stations being weighted most heavily. This method has yielded estimates that are more precise than those made in other projects, which have relied on simple averages of the measurements taken within the county. The new method involves some assumptions, including the empirical choice of a distance-weighting function for each station. Still, a reasonable choice was made, and the results were carefully checked for consistency against those obtained by other methods. Again, the interactive mapping capability of SEEDIS was indispensable in detecting errors.

Portions of PAREP, especially the air quality estimates developed at LBL, have been requested by the President's Council on Environmental Quality for the UPGRADE project, and by Brookhaven National Laboratory, Pacific Northwest Laboratory, and Oak Ridge National Laboratory. Self-documenting data files have been prepared that allow the data to be distributed with a minimum of personnel effort. Resources are being shared with other DOE installations, and it is expected that, in exchange, data will be acquired that will be valuable in future projects.

A complete integrated file, containing all of the PAREP data in SYSTEM-2000 load format, is being put together for installation in the Research Triangle Park computer of the Environmental Protection Agency. Based on the PAREP data, a

series of epidemiologic hypotheses has been tested, and further hypotheses will be generated as use of the database continues. The computer software and statistical tools are being developed in parallel, a fact that has made the database more serviceable in exploring epidemiologic issues.

The project has explored and implemented

methods for estimating the missing portions of censored or truncated data sets so that parameters can be estimated and statistical tests performed. Moreover, the computer software has been developed for efficiently accessing age-specific mortality data. Consequently, it will be possible to cover age-specific as well as age-adjusted mortality rates for 53 specific causes in future studies.

Distributed Computer Network (DCN)

An experimental network of minicomputers has been established as a framework and test bed for basic research in networking techniques, user interface and environment, and distributed information technology. This Distributed Computer Network (DCN) project is funded jointly by the Department of Labor's Employment and Training Administration (DOL, ETA) and 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, this joint DOE-DOL project is considered to be a prototype for future development of systems to serve similar functions for DOE programs.

During 1979 the network was upgraded to Digital Equipment Corporation (DEC) VAX-11/780 computer systems located at LBL and DOL-ETA field test sites with links planned to DOE research sites specializing in certain areas of information analysis research. The network, shown in the Figure, is based on DECNET software. Work was done in establishing DECNET links and exploring networking capacities and shortcomings.

The LBL Computer Science staff worked cooperatively with Digital software support personnel to establish DECNET connections between the LBL-VAX and Digital's Santa Clara VAX and between the LBL-VAX and Digital's Oakland PDP 11/70.

Point-to-point connections, utilizing dial-up

telephone links, were established between DCN nodes and used for transfer of small data files, minor software updates, and rudimentary electronic mail functions. Design of network links utilizing dedicated lines was completed and the implementation effort was initiated during 1979.

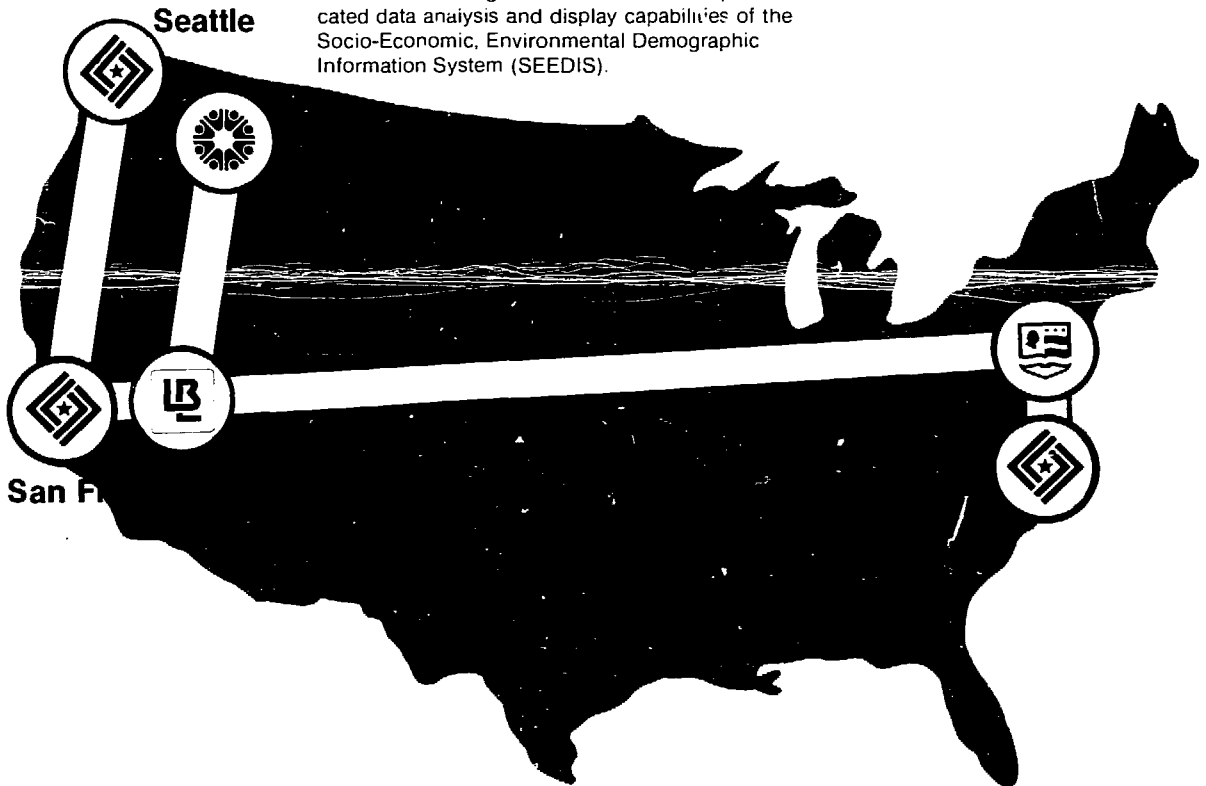
A set of preliminary benchmarks was designed and run on DECNET Version 1 software. The network configuration under test was a 9600 baud full-duplex link between two VAX systems at LBL and a 4800 baud half-duplex link between systems at LBL and DOL-ETA Region IX office in San Francisco. The benchmark results indicated areas of inefficiencies in the software. LBL worked with Digital to address resolution of these areas in later versions of the networking software.

In addition to development and conversion of SEEDIS software modules, CSAM is developing software on the VAXES to meet the following functional requirements:

- Text processing tools, including a text editor, text formatter, and ancillary text manipulation programs;
- A mail system on each node. Users within each node can communicate meeting notices, letters, memoranda, etc.;
- A UNIX[®]-like shell which allows inter-process communication.

The Distributed Computer Network

An experimental network of homogeneous mini-computers serves as a framework for research in networking techniques, and distributed information systems technology. LBL is linked to demonstration sites at Department of Labor Employment and Training Administration offices and to other DOE research sites. The network provides shared access to the integrated databases and sophisticated data analysis and display capabilities of the Socio-Economic, Environmental Demographic Information System (SEEDIS).



Department of Energy Research Laboratories



Berkeley: Lawrence Berkeley Laboratory



Richland: BATTELLE Pacific Northwest Laboratories



Washington, D.C.: George Washington University

Department of Labor, Employment & Training Administration



Seattle: Federal Region X Office



San Francisco: Federal Region IX Office



Washington, D.C.: National Office

System of Information Retrieval and Analysis for Planners

The System of Information Retrieval and Analysis for Planners (SIRAP) is a component of SEEDIS focusing on the development of detailed small area profiles and other analytical capabilities of particular use to civil works planners.

All data files retrievable via the QWICK QUERY and REAP system were moved from the chipstore (the LBL mass storage device, which was discontinued on October 1, 1979) and placed on high density magnetic tape. QWICK QUERY access to these and other files was maintained and QWICK QUERY remained as a software product available on the LBL main computer center.

The retrieval and report programs for the 1970 Fifth Count Census have been documented and tested. Data from this file provides report profiles at the Census Enumeration District or Block Group, the finest geographic detail for demographic data provided by the Census Bureau.

A new file containing the 1977 City-County Data Book was installed for access via QWICK QUERY. This file contains a time series of data from 1947-1977, consolidated from all City-County Data Books of that period. The file will also be available for on-line retrieval on the minicomputer version of SEEDIS.

A substantial number of modules and data bases have been transferred from the LBL Computer Center mainframe computers (CDC-6600 and CDC-7600) to the VAX-11/780 computer. These include the following data bases:

1947-1977 City-County Data Book

1974 & 1969 Census of Agriculture

1972 Energetics Data Base (Brookhaven Laboratories)

1971-1976 BEA Employment Data Base

APPLICATIONS

Computational Physics

Development and applications support was provided by the computational physics group to the following projects:

Accelerator Theory

Work continued on the theoretical and practical aspects of design for an induction linac to be used for acceleration of heavy ions for inertial fusion. The problems of transverse stability of a beam in a quadrupole focusing channel was studied and compared with results from analytical theory. Investigation of the optimum accelerator with

respect to various design parameters to minimize total cost was undertaken with the newly written computer program *LIACEP*.

A new circular boundary condition for magnets with quadrant symmetry has been incorporated into the computer program *TRIM*.

Advanced Technology Accelerators

The Experimental Test Accelerator (ETA) at LLNL has been modeled with various computer simulation codes. The main thrust of this effort has been directed at understanding the beam dynamics including the self electric and magnetic forces in the presence of the externally applied magnetic focusing elements and electrode structures. The calculations have been compared with experimental results with emphasis on understanding the actual operation of the ETA and providing the basis for future improvements over the original design goals. This has resulted in improved methods of tuning the machine and understanding the observed beam loss mechanisms. The beam emittance introduced by passage through finite grid wires has been studied by computer simulations. These results compare well with the experimentally measured values of the beam emittance and provide confidence in our understanding of the contributing factors to the beam phase space volume and growth.



Accelerator design and fusion energy technology are among the principal programs of the Computational Physics Group. In this photo are (top) Victor Brady and Jim Miller; (center) John Colonias, Jos Polman, Art Paul, Ludmilla Soroka, Elon Close, and Mark Friedman; (front) David Soroka. XBC 798-10795

Controlled Thermonuclear Reaction (CTR) Mirror Fusion Test Facility (MFTF)

Magnetic field computations were performed to determine the extent of attenuation in the magnetic field inside the MFTF neutral beam

injector modules, since operation of the neutral beam injectors must be in an environment as free of magnetic fields as possible. The complexities of the geometry necessitated the revision of standard ways of zoning magnet geometries with boundary conditions. Numerical computations and a 1/10th-scale prototype model were used to arrive at a three-layer shield design.

A large class of problems in physics and engineering is formulatable in the confines of the non-linear Poisson's equation which, with modern digital computers and advanced methods of numerical analysis, has been solved for a variety of geometrical configurations of extreme complexity and various boundary conditions. Work has been undertaken to find the proper formulation and solution of the non-linear "magnetostatic equation", for the design and implementation of a computer program to solve this equation efficiently.

CTR Tokamak Fusion Test Reactor (TFTR)

Self-consistent calculations of the primary electron energy distribution and secondary electron temperature have been included in the computer model for hydrogen and deuterium ion source plasmas. Solution of the rate equations for the production and loss of atomic and molecular ions yields the calculated ion current density at the accelerator and the beam composition as functions of the source geometry, gas flow, and arc current and voltage. Predictions made in this model show reasonable agreement with measured data for TFTR and MFTF sources.

CTR-TORMAC

Tormac (Toroidal Magnetic Cusp) is a new experimental magnetic configuration concept for confining a fusion plasma. Computational support was provided for the Puffer experiment where a gun-injected plasma expands radially outward with very

high velocity and is stopped and trapped by the main bi-cusp Tormac magnetic field.

A two-dimensional magnetohydrodynamics (MHD) skin current equilibrium code was used to calculate the MHD plasma equilibrium. Two models of the equilibrium were considered: a) plasma is mirror-trapped on an open magnetic field and b) plasma is trapped in a cusp equilibrium with bulk of plasma on closed field lines. Experimental measurements support the cusp model.

Calculations were made for an MHD shock wave concept for trapping and heating of the plasma. The plasma parameters in front and behind the shock wave were calculated for a range of experimental conditions. The final plasma temperature and density calculated were in good agreement with the experimental data.

CTR-Neutral Beams

The LBL neutral beam sources have been designed based on calculations with the WOLF code. This ion optic code is being improved to include cylindrical geometry, and better numerical convergence schemes. Consideration is being given to writing a new simulation program for the CRAY-1 computer.

Epidemiology of Magnetic Fields

An epidemiological study has been under way at Donner Laboratory for several years to investigate the health effects, if any, resulting from the occupational exposure produced by various nuclear instruments such as cyclotrons, bubble chambers, and spectrometers. The methodology involved in determining the magnetic field exposure of such instruments has been applied to statistical study designed to evaluate potential health effects in groups of scientists and industrial workers who have been occupationally exposed to high magnetic fields.

LASL-PSR

Los Alamos Scientific Laboratory is designing a Proton Storage Ring for use with the Los Alamos Meson Production Facility (LAMPF). At LBL we have worked on the problems of beam injection and extraction from this ring.

Injection of protons into the PSR uses a unique method of negative hydrogen ion stripping to neutrals, injection into the ring and stripping to protons to complete the capture process. A long injection line transports the negative ion beam horizontally and vertically from LAMPF to the PSR. The dispersion produced by the dipole magnets in the injection line from a spread in the beam momentum must be chromatically compensated while allowing a varied tune of the line so that programmable beam injection stacking processes can be used.

The extraction system of the PSR serves to extract the stored beam from the PSR and transport that beam to either a beam dump or a line reinserting it for transport to a target.

LBL/SLAC Positron-Electron Project (PEP)

Further development of the *ALIGN* program was made. This program is used to correct simulated survey and position errors and generate an appropriate orbit correction scheme and to determine the corresponding corrector strengths. *ALIGN* was also used in conjunction with the program *SYNCH* to study the orbit properties of the corrected machine and compare it with those of a perfect machine that contained no errors.

The successful use of the *ALIGN* program at SLAC prompted the ISR (Intersecting Storage Ring) division of CERN to request this program for use with their design study for the proposed large electron-positron colliding beam machine, LEP.

Interest in the beam-beam interaction problem encountered in colliding beam storage rings has been renewed by the proposed construction of ISABELLE at BNL. Much of the unpublished work done over the last several years was documented and presented at a symposium on Non Linear Dynamics and the Beam-Beam Interaction.

Physics

PEP 5: the Mark II Detector

When the PEP accelerator becomes operational, the MARK II magnetic detector is expected to be the first fully operational system for detecting and measuring multi-particle final-state events. The detector itself was moved from SPEAR, and an inner set of drift chambers is being installed. This additional improvement, along with the increased complexity of the events to be analyzed, required upgrading of the software for event reconstruction.

The pattern-recognition program has been augmented so that readouts from the non-paraxial chambers are combined with the paraxial data to improve efficiency of track finding. This involves a two-dimensional histogram search, which is time-consuming. Running times on the IBM triplex

computer at SLAC and on a Floating-Point Systems array processor were compared, and it was found that no distinct advantage could be gained by use of the array processor in this application. The study will be continued to see whether reorganization of the routine to take advantage of the unique capabilities of the Array Processor will make it competitive.

A track reconstruction program which runs interactively on the IBM computer at SLAC has been implemented to allow human-guided reconstruction of difficult events. An event is displayed on a CRT and a light-pen is used to select points to be fitted to a track. Options in the program allow for modifications of the preliminary results of the automatic track-finding and fitting routines, modifications such as the deletion of points and the re-

fitting of tracks using different lists of points.

Monte Carlo programs for simulation of experiments have been improved, and a version of the current SLAC program is being implemented on the LBL computers.

Programs which enable LBL physicists to analyze SPEAR data from the data-summary tapes originally written at SLAC — but especially designed so that they can be read (and copied) on the CDC 7600 at Berkeley — continue to be developed and improved. At present, for example, a program is nearly completed which will allow BKY users to select, merge, and partially sort MARK II data on the 7600, using multiple input and output tapes.

Maintenance of the HYDROX version of the general data-display program KIOWA requires occasional programming time (the HYDROX version is widely used by both local and remote users). Work is currently being done to provide greater sophistication to that part of the program which allows the plotter to superimpose function-curves on top of the histograms.

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