# PHYSICS, COMPUTER SCIENCE and MATHEMATICS DIVISION

## ANNUAL REPORT



August 1983

**Lawrence Berkeley Laboratory**
**University of California**
**Berkeley, California**

**Prepared for the U.S. Department of Energy**
**Under Contract No. DE-AC03-76SF00098**

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LBL-16140
UC-34

# PHYSICS, COMPUTER SCIENCE AND MATHEMATICS DIVISION

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Division Head

## ANNUAL REPORT

## 1 January - 31 December 1982

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Berkeley, California 94720

Major portions of this work were supported by the Office of Energy Research, Divisions of High Energy and Nuclear Physics, Basic Energy Sciences, and Health and Environmental Research, and the Energy Information Administration, Statistical Support Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098. Additional support was provided by the U.S. Department of Labor, the U.S. Department of Defense, the National Science Foundation, the National Aeronautics and Space Administration, the National Oceanographic and Atmospheric Administration, the U.S. Army Corps of Engineers, and the University of California.

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# INTRODUCTION

This report summarizes the research performed in the Physics, Computer Science and Mathematics Division of the Lawrence Berkeley Laboratory during calendar year 1982. The major activity of the Division is research in high-energy physics, both experimental and theoretical, and research and development in associated technologies. A smaller, but still significant, program is in computer science and applied mathematics. During 1982 there were approximately 160 people in the Division active in or supporting high-energy physics research, including about 40 graduate students. In computer science and mathematics, the total staff, including students and faculty, was roughly 50.

The Division draws considerable strength from a close association with the Berkeley campus of the University of California. Of the total Department of Physics faculty of 60, 25 have their research activities within the Physics, Computer Science and Mathematics Division of LBL, 17 in experiment and 8 in theory. Also from the Berkeley campus are about 35 physics graduate students, working at the Laboratory for their Ph.D. thesis research in particle physics. At the Laboratory itself, in high-energy physics there are 20 Staff Senior Scientists, roughly equivalent to tenured faculty on campus, 13 Staff Scientists with indefinite appointments, and 16 postdoctoral or equivalent term appointees. The technical and clerical/administrative staffs in high-energy physics now number 19 and 11, respectively.

In the Department of Computer Science and Mathematics there are 30 permanent Staff Scientists, 8 term appointees, and 1 Staff Senior Scientist, plus one Faculty Senior Scientist and 6 Associated Faculty and 10 graduate students. The relative size of Computer Science to Mathematics is approximately 3:1.

In addition to the subject areas of the Division's title, research is pursued in astrophysics, geoscience, and pure astronomy.

During the year under review, the Division continued its major emphasis in experimental high-energy physics on electron-positron collisions at PEP, the high-energy storage ring at SLAC. The largest project there was the TPC (PEP-4) experiment. The whole apparatus came into operation in the beam line at IR-2 early in 1982. After two months of testing and calibration, PEP-4 had approximately two months of data taking before the summer shutdown of PEP. During the summer, a new inner drift chamber and the remaining hexagonal calorimeter modules were installed so that, in the running that began in the fall of 1982, the complete detector was operational. Problems of distortions at the boundaries of the TPC volume, along with the low magnetic field of the conventional coil, limited somewhat the precision of momentum and energy-loss measurements. Even so, interesting physics results from the spring 1982 runs were presented at seminars and colloquia in the fall. Considerable progress was made in coping with the distortions and finding a solution for their elimination. Much effort went into the creation of the analysis programs to process the large number of raw-data tapes into a data-summary tape and to analyze the data-summary tape information to produce physics results. During 1982, the superconducting coil was completely rebuilt at LBL and in December was shipped to SLAC for testing in early 1983.

The other electron-positron experiment, the Mark II collaboration with SLAC and Harvard, continued its data taking at PEP. The measurement of the tau-lepton lifetime, first performed in 1981, was refined with more precise data in 1982. The lifetime of the neutral charmed meson ($D^\circ$) was measured, as were the fragmentation functions for the c and b quark. In December 1982, the proposal for an improved Mark II detector as the first detector at the Stanford Linear Collider (SLC) was approved by the SLAC Experimental Program Advisory Committee. At the end of the year, plans for construction at LBL of the new end-cap calorimeters were begun.

Another major activity in the Division is the construction of fine-grained hadronic calorimeters as part of the collaboration on the Collider Detector at Fermilab (CDF). A prototype module was tested successfully in a beam line at Fermilab in May 1982. Subsequently, the design was refined and completed by the end of the year. Construction began in the spring of 1983.

A smaller, but significant, experiment on the fundamental properties of weak interactions was conducted at the Canadian medium-energy accelerator TRIUMF. Using an elegant technique of studying the end point of the continuous energy spectrum of the positrons from positive muon decay, the experimenters sought evidence for right-handed weak currents. From the first run in April and May 1982, a limit of greater than 400 GeV was set on the mass of a possible intermediate vector meson with right-handed (instead of the customary left-handed) couplings. Eventual analysis of data taken in November and December 1982 should sharpen considerably the limit (or establish right-handed currents).

To maintain an outstanding research program in a rapidly changing field like high-energy physics, it is necessary continually to explore new experimental techniques and devices. Within the Division, detector research and development is motivated by the desire to improve the evolving existing facilities and the desire to strike out in new directions. Because the TPC was invented here, it is natural that a considerable fraction of the R & D on detectors should center around the TPC concept — high density TPC's, either liquid or very high-pressure gas, as well as improvements for the existing TPC of PEP-4. During the latter part of 1982 a table-top TPC was built to troubleshoot the field cage and other distortions discovered in the course of operation of PEP-4 for physics. Among other R & D projects during 1982 were a ring-imaging Cerenkov detector combined with a TPC, electron-photon calorimetry, very high-resolution detectors based on CCD's, and gas-filled multi-electrode detectors.

The Particle Data Group began its extensive modernization program during 1982. With the advice of the PDG Advisory Committee, a plan was proposed, funded by DOE in FY83, and began to be implemented by the end of the year. When completed, the Review of Particle Properties (which saw its twenty-fifth anniversary in 1982) will be thoroughly revised in content, format, and production methods. Its essentials will be available on the SPIRES high energy-physics data base, as will the information contained in LBL-90.

The Theoretical Physics Group was particularly active in planning for the future in 1982. A number of the members of the group participated in the DPF Summer Study in Snowmass during June and July, and in local activities in collaboration with the Accelerator and Fusion Research Division. Theoretical research was pursued in its own right, from the phenomenology of mixed quark-gluon states to supersymmetry, from studies of the field-theoretic standard model to the topological S-matrix approach.

One research project in astrophysics during 1982 was the automated supernova search, using the 36-inch telescope at the Monterey Institute for Research in Astronomy. The apparatus was completed, assembled, and tested during 1982, and computer programs were written to analyze the images. Actual data taking will occur in 1983. The other main astrophysics effort was a continuation of study of the cosmic background radiation. Balloon data taken in April 1982 at a wavelength of 3 mm showed the well known dipole anisotropy, but no evidence for higher multipoles, as had been reported by some investigators. A collaborative experiment in July 1982 at the University of California's White Mountain High Altitude Research Station measured the spectrum of the primordial radiation at five wavelengths from 12 cm to 0.3 cm. The results indicate no distortion of the spectrum, but further measurements will be performed in 1983.

Work on the Ten Meter Telescope (TMT) concentrated on a technical demonstration prototype encompassing all aspects of the system. During 1983 the mirror and the support and control systems will be tested completely.

The activities of the Computer Science and Mathematics Department (CSAM) cover basic and applied research in mathematics, computer science, and statistics. The mathematics research emphasizes applied analysis (capillarity and inverse problems), computational mathematics (elliptic partial differential equations and dynamical theory of tridiagonal matrices), and numerical methods for partial differential equations (vortices, turbulence, combustion). The research in computer science spans four major areas: data management, database machines, distributed systems and networks, and graphics. The statistics program addresses questions of statistically valid data extrapolation and projection techniques.

The Division's activities were subjected to considerable scrutiny during 1982. The year began with a review of the high-energy physics program by a DOE Technical Assessment Panel, chaired by Charles Baltay. The Panel had been charged with reviewing LBL, ANL, and four university groups to assess the special qualities of each institution and its worth to the national high-energy physics effort. LBL's program was judged to be excellent, with an appropriate mixture of small (university-sized) projects and large projects beyond the reach of a typical university users group. Our size and location inside a large laboratory with extensive technical support capabilities permitted us, indeed required us, to mount appreciable R & D efforts on new detector developments. Similarly, we were charged with the proper support of the Particle Data Group as a resource of benefit to the worldwide high-energy physics community. The Panel recommended roughly constant effort at LBL in high-energy physics, with expansion only with approved new initiatives.

In April 1982, the Director's Review Committee for CSAM spent two days reviewing the research program in Computer Science, while in August the PDG Advisory Committee met to review that group's past activities and future plans.

Several aspects of the Division's organization were strengthened during 1982. A Physics Planning Panel ($P^3$) was initiated with the purpose of guiding and planning the research program in the short-term and long-term. Initial

membership of $P^3$ was D.R. Nygren, M. Pripstein, M.A. Strovink, and G.H. Trilling, plus R.W. Birge and J.D. Jackson. The Physics Staff Committee was formally expanded to be the Divisional Staff Committee with Physics members M.S. Chanowitz (from 1 October), W. Chinowsky, M.A. Garnjost, G. Goldhaber (from 1 October), J. Kadyk, H.P. Stapp (to 30 September), and M.A. Strovink (to 30 September) and CSAM members P. Concus (from 1 October) and C. Quong. To strengthen scientific participation in the Particle Data Group, a Steering Committee of R.N. Cahn, G. Gidal, and T.D. Trippe was named in September 1982. At about the same time, the conduct of the weekly Research Progress Meetings, an important aspect of the intellectual life of the Division, was assigned to the troika of G.S. Abrams, A. Galtieri, and I. Hinchliffe. The long list of speakers and titles in the appendix attests to the vigorous efforts of this team and their predecessor, C. Day.

It is hoped that these pages give the reader at least a glimpse at the research activities at LBL in high-energy physics, in astrophysics, in associated research and development, and in mathematics and computer science. A sense of the excitement and the stimulus of curiosity is difficult to capture on the printed page. Perhaps it is enough if the reader pauses in wonder at why we make such immense efforts to do our research, yet trusts we are not fools. If the reader is stimulated to look further, to come around and ask, so much the better. The high-energy physicist is always willing to explain why what he is doing is exciting, fundamental, profound, and one of the greatest intellectual endeavors of man!

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# EXPERIMENTAL PHYSICS

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# EXPERIMENTAL PHYSICS

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

Experiments at the PEP electron-positron storage ring at the Stanford Linear Accelerator Center continued during 1982 to occupy a dominant place in the research program of the Physics Division. The largest single effort was on the PEP-4 experiment, mounted by a collaboration of physicists from LBL, UCLA, UCR, Johns Hopkins, Yale, and Tokyo. The year began with installation of the TPC, the magnet, and associated calorimeters and muon chambers in the beam line at interaction region 2 (IR-2) at PEP. Shakedown and some data taking occurred in the spring, final installation of calorimeters in the summer, and more running at the end of the year. The second major involvement at PEP was with the Mark II magnetic detector, continuing a long and fruitful collaboration with physicists from SLAC and Harvard.

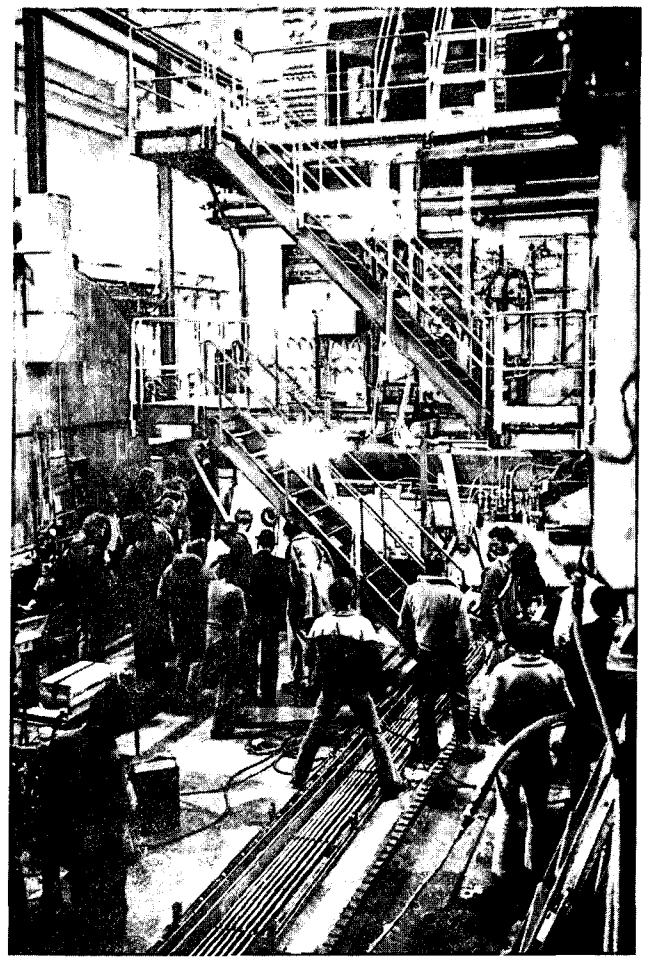
## The Time Projection Chamber (PEP-4)

### Overview

In 1982 the PEP-4 detector, with the advanced-design Time Projection Chamber (TPC) as its central component, reached a major milestone in becoming fully operational, collecting high-quality $e^+e^-$ data at PEP, with excellent spatial resolution and the best dE/dx resolution achieved by a large-scale detector to date.

The entire detector was rolled into the PEP beamline in Interaction Region 2 (IR2) at SLAC in January 1982 (Fig. 1). The only incomplete subsystem then was the hexagonal calorimeter, which had only two out of the eventual six modules installed. The next few months were spent primarily in de-bugging and calibrating the apparatus in beam conditions, and improving the performance of the various subsystems. Smooth data taking began in late April, and in the two-month period before the summer shutdown, approximately 4 inverse picobarns ($pb^{-1}$) of integrated luminosity were accumulated. The data trigger was hampered during this time by the loss of the inner drift chamber (IDC) due to growth of impurities ("whiskers") on some of the wires. Fortunately, the development of an ingenious charged-particle trigger using the TPC information enabled the data taking to continue effectively. All the other subsystems performed well.

During the summer shutdown, various improvements were made to the detector. A new inner drift chamber was installed, the remaining four hexagonal calorimeter modules were put into place, and some modifications (described below) to the electronics were completed. In addition, a gas recirculator system was installed in the TPC gas system that reduced



(XBB 837-6081)

Fig. 1. PEP-4 detector being rolled into the beam line at PEP.

considerably the gas consumption (and cost) and impurities in the gas. The latter improvement changed the drift-electron capture rate from 32% per meter to 4% per meter.

Data taking resumed in November 1982, and by the end of December another 5.5 $pb^{-1}$ of integrated luminosity were accumulated. During this period further modifications continued to be made to the trigger system and online software that improved the efficiency of data collection significantly. These improvements, together with those implemented in the summer shutdown, yielded much cleaner data, with fewer background events and very few spurious points in bona fide events from $e^+e^-$ collisions.

In January 1983 new machine-tune conditions for PEP were implemented which increased the PEP luminosity to record levels (e.g., to a peak luminosity of $3\times10^{31}$ $cm^{-2}$ $sec^{-1}$). This, coupled with the more effective performance of the PEP-4 detector, resulted in approximately a 700% increase in integrated luminosity accumulated per week over that in the spring of 1982 — to more than 5 $pb^{-1}$ per week, for several weeks at a time. If this level of performance can be maintained, then the PEP-4 detector may collect a total of nearly 90 $pb^{-1}$ of integrated luminosity (with about 30,000 hadronic events) by the end of the spring 1983 cycle.

## TPC Chamber

Figures 2 and 3 demonstrate the capability of the TPC detector to measure complex final states in multihadron events and to identify the reaction products by the simultaneous measurement of momentum and specific energy loss (dE/dx). The extremely high density of information from the dE/dx wires (i.e., sense wires) allows the identification of secondary vertices

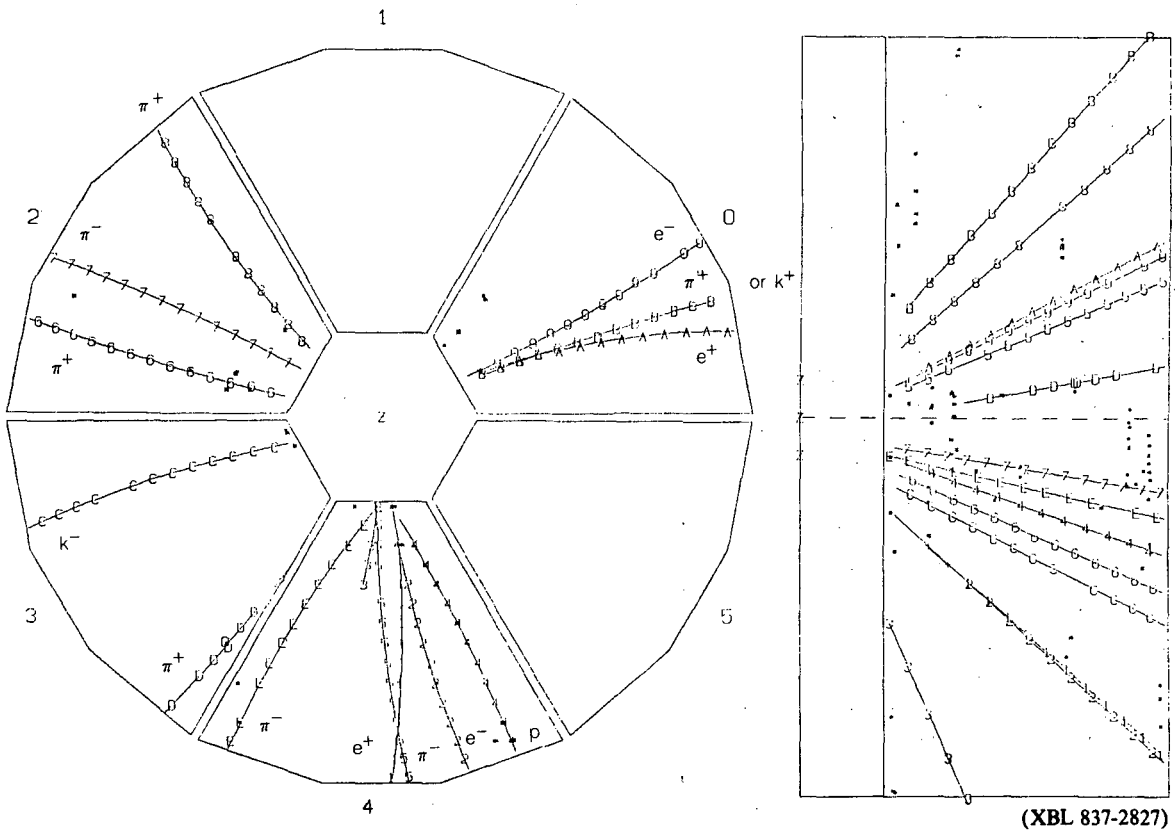
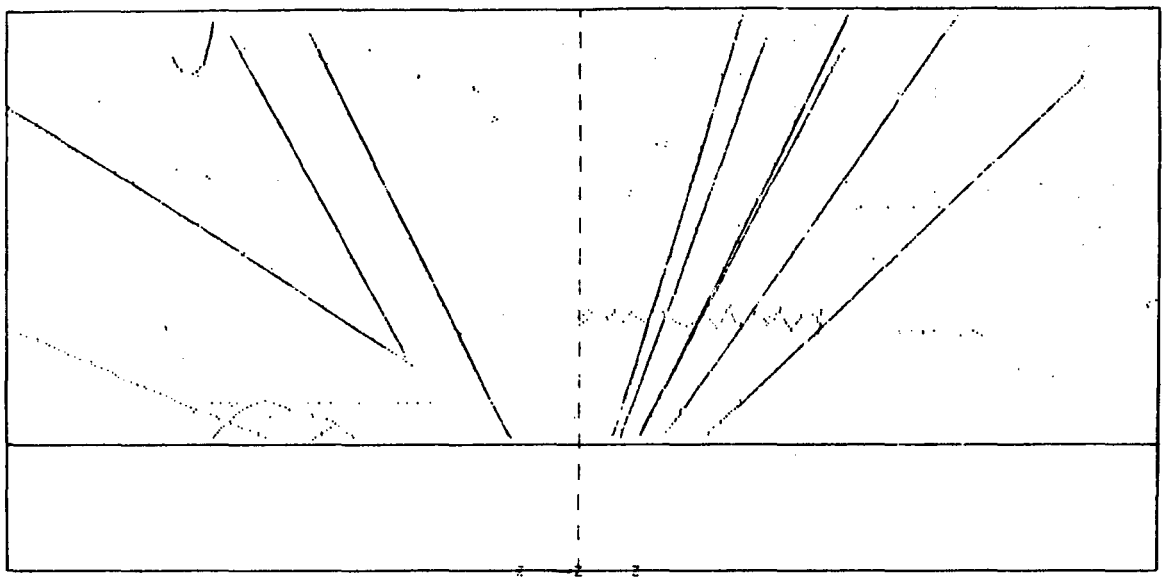



Fig. 2. Multihadron event as seen in the TPC detector, with particle types determined from dE/dx measurements. Left-hand picture is an end view and right-hand picture is a radius-versus-Z (beam direction) plot. Note that 12 out of 13 tracks are uniquely identified.



(XBL 837-2828)

Fig. 3. Tracks of charged particles, as detected by the dE/dx wires, for a typical multihadron event. The decay vertex in the left endcap is identified as a $K^0$ decay.

and kinks in the ionization tracks due to particle decays.

The TPC has been operating reliably and well, with performance characteristics close to design values. The wire signal gain was quite stable and reproducible (to approximately 1%) and was uniform among the sense wires to within about 2%. The chamber resolutions are summarized in Table 1. The spatial resolution in both the X-Y bending plane and in the beam (Z) direction are just about at the design limit. Similarly, the dE/dx ionization resolution of 3% for a single track is at the expected value, which means that the electronics is performing at design specifications. On the other hand, the dE/dx resolution for minimum-ionizing tracks in jet events is slightly worse than expected (3.8% compared to 2.9%), indicating that not all the systematic effects are fully understood yet, but we are close. Nonetheless, this is a major milestone for large solid-angle, high-granularity, ionization detectors.

The present value of the momentum resolution is poorer than the design value, especially for that from the TPC alone (without vertex information), despite the excellent spatial resolution. This is due to some track distortions (up to several mm radial displacement at the inner radius) in the TPC caused by electrostatic non-uniformities from both positive-ion space-charge and error potentials in the drift-field shaping electrode structure (field cage). A model has been developed to correct for the longer-range space-charge distortion in the software, but it doesn't eliminate entirely the effect of this distortion. Extensive R&D during 1982 has led to a solution for both types of distortion, and the necessary modifications will be implemented in the 1983 summer shutdown. This is described more fully below in the section TPC R&D.

Thus, except for track distortions at the edges of the chamber, the TPC is operating at very nearly design specifications, providing precise 3-dimensional spatial information along with accurate dE/dx measurement.

## Trigger

A versatile and relatively unrestricted trigger, yet with low trigger rate (2 Hz), has been developed, which is highly efficient for $e^+e^-$ events and effectively cuts out background events. This has been achievable because of the high density of information in this detector. The trigger defines five requirements that an $e^+e^-$ interaction may satisfy: (1) at least two charged tracks in the drift chamber and the TPC; (2) at least one charged track and neutral energy deposited in the electromagnetic-shower (e.m.) calorimeter; (3) a minimal amount of neutral energy deposited in the e.m. calorimeter; (4) two coplanar (colinear) charged tracks; (5) a Bhabha event in the pole-tip calorimeter. Any one of these five conditions provides an event-trigger. This loose trigger allows for an unbiased data collection of a wide variety of $e^+e^-$ events.

## Electronics

The PEP-4 electronics system was completed early in the year with the installation of the final CCD

Table 1. TPC performance characteristics and operating conditions.

| | *Currently at PEP* | *Expected at PEP* |
|---|---|---|
| *Performance Characteristics*: | | |
| Spatial resolution in bending ($xy$) plane | 180 $\mu$m | 150 $\mu$m |
| Spatial resolution in axial ($z$) direction | 350 $\mu$m | 350 $\mu$m |
| Track pair resolution dE/dx resolution: | 1–2 cm | 1–2 cm |
| single track | 3% | 3% |
| tracks from jets | 3.8% | 3% |
| Momentum resolution $dp/p^2$ (for $B = 4$ kG): | | |
| — with vertex and 12 pad rows | 3.5% | 2.4% |
| — no vertex and 12 pad rows | 6% | 4.1% |
| — with vertex and 15 pad rows | – | ~1.5% |
| *Operating Conditions:* | | |
| Gas = 8.5 atm of 80% argon, 20% methane | | |
| E-field = 75 kV over 1 meter | | |
| B-field = 4 kG | | |
| Drift velocity = 5.0 cm/$\mu$s | | |

boards in the TPC system. Under normal operating conditions the system has proven to be quite stable (to within 1%) and reliable. The TPC system normally has about 97% of the 16,000 channels operating. Of the dead channels, approximately 170 (1.1%) are down because of failures of preamps or cables inside the detector that can only be repaired while the detector is rolled out and open. The remaining dead channels are due to component failures in the electronics house, which are repaired as they are detected.

The various electronics subsystems have received a number of modifications during the year in order to improve performance or reliability. The major efforts included:

1. The "streaker" fix: The pulse-shaping circuit in the TPC shaper/amplifier board was modified to shorten the recovery time, particularly after a large-amplitude pulse. Large pulses tended to show a long tail that remained above threshhold for many CCD buckets. These tails generated extra "noise" data that increased the data-acquisition time on-line and sometimes caused event reconstruction to fail by obscuring other tracks in the data. All 16,000 TPC channels were modified. The fix was completed during the summer and was quite successful.
2. Test-pulse system: During the summer, a redesigned test-pulse driver was installed. The new circuits show a much improved linearity and long-term stability over the previous ones and greatly simplify the task of calibrating the system. Also, new high-quality cables were installed to carry test-pulses to the TPC sectors in order to reduce crosstalk and to improve the quality of the test-pulses at the sectors.

## Computing and Data Analysis

The PEP-4 detector uses VAX-11 and PDP-11 computers for online analysis and monitoring and for offline data analysis and program development.

The experiment is controlled by an online PDP-11/70. The computer is used for hardware testing and calibration. A smaller PDP-11/04 computer is used for monitoring the many temperatures, pressures, voltages, and currents that must be watched during data taking.

A VAX-11/780 computer is used to read data from the detector and write it on tape. The online program in the VAX was substantially rewritten during 1982 to improve system efficiency and decrease dead time. The new online system includes an event filter that rejects approximately 30% of the triggers as background. The remainder are written on tape and analyzed offline.

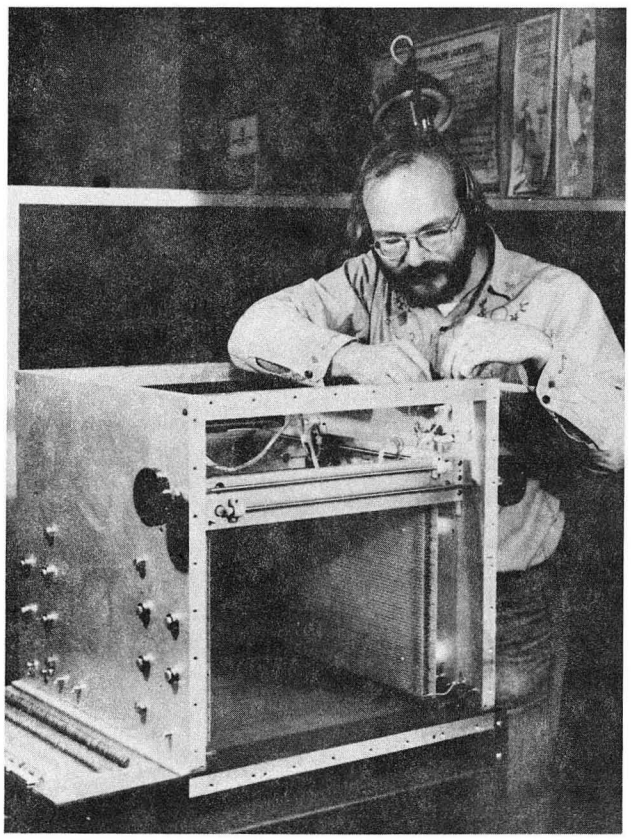
Offline analysis is carried out on VAX computers at LBL and at the universities in the PEP-4 collabora-

tion. The analysis programs have continued to evolve, and a series of data reduction steps yielded a final data sample from which physics results have been extracted.

An important aspect of the software development effort is the management of program libraries. During 1982 a new DEC software product called CMS (the Code Management System) was installed in the Physics VAX computer at LBL. This system provides tools to permit programmers or physicists to determine what changes have been made to programs and for what reason. This information significantly reduces the problems of managing large software systems and makes the members of the project function more effectively.

## Superconducting Magnet Coil

The coil was completely rebuilt in 1982. The modifications to the associated cryogenics, electronics, and quench-protection systems were also completed in this period, and the entire package was shipped to SLAC at the end of the year for further testing in early 1983 before scheduled installation in the summer of 1983.



(CBB 831-59)

Fig. 4. Mini-TPC developed for studies of track edge-distortions.

## TPC R&D

An extensive program to fix the track distortions in the TPC, mentioned earlier, was successfully pursued this past year. The primary distortion due to positive-ion space-charge feedback from the sense wires will be substantially reduced by adding an additional grid (called the gated grid) to the TPC sectors. This grid can be used as an electronic shutter preventing the positive ions from drifting back into the TPC sensitive volume. A prototype gated grid was built on a spare TPC sector and operated successfully, demonstrating that this solution works very well. Gated grids will be added to the TPC sectors during the 1983 summer shutdown.

The other principal source of distortion, caused by error potentials in the field cages, was studied in a table-top mini-TPC specifically constructed for this purpose (Fig. 4). The distortions were reproduced in this chamber. It was found that the electrostatic nonuniformities could be eliminated by applying a slightly conducting polyurethane coating to the field-cage surfaces. No evidence of outgassing from this coating in the TPC was found, even after many months. The field-cage surfaces in the PEP-4 TPC will be coated with this material during the 1983 shutdown.

## Hexagonal Calorimeter

During the winter and spring, datataking at PEP was carried out successfully using the two modules completed at that time. The remaining four modules were installed during the summer shutdown. During the fall the HEX-calorimeter signals were included in the overall PEP-4 trigger system. Data taking continued for the remainder of the year with considerably higher rates.

The Geiger-cell HEX-calorimeter is particularly well suited to self-calibration, because for any pattern of radiation the sum of the signals on the axial sense-wire channels is half that induced on each of the two sets of cathode-strip channels at $\pm$ 60 degrees to the wires. Therefore, any local source of ionization, including cosmic rays, beam secondaries, and even low-energy noise, can be used to measure the relative gains of a subset of channels from each view. With continual event sampling, the channel-to-channel sensitivities for each submodule can be regularly determined to 2% rms. The absolute energy scale is established at high energies by Bhabhas and at low energies by TPC-measured electrons. These measurements are in very good agreement with the simulated Monte Carlo results.

Data from the spring running have been analyzed to give electron, photon, and $\pi^0$ spectra. Despite confusion created by interactions in the 1.5-radiation-length-thick conventional magnet coil, the HEX-calorimeter

has been shown to have excellent reconstruction capability for particles within jets. Features of the HEX construction and experiences from early operation are described in reports submitted for publication to the 1982 Washington IEEE Conference and the FNAL Workshop on Gas Calorimetry.

## First Physics Results

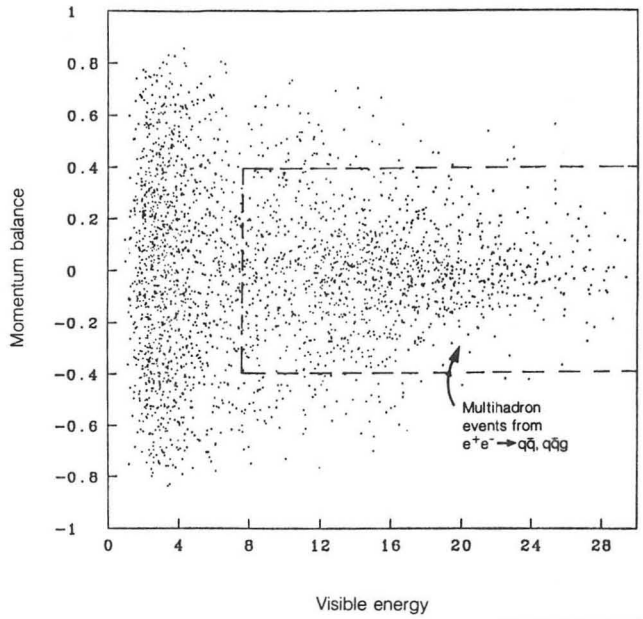
The first results from the PEP-4 TPC detector are based on a sample of events corresponding to 3.5 $pb^{-1}$, taken in May and June 1982 at center-of-mass energies of 29 GeV. The analysis concentrated mainly on multihadron events from $e^+e^-$ annihilation, with the aim of investigating the mechanisms of particle production in quark and gluon jets and studying tests of quantum chromodynamics.

To separate multihadron events from 2-photon events and beam-gas background, at least five reconstructed tracks, a minimum visible energy of 7.25 GeV (corresponding to half the beam energy) and a certain amount of momentum balance were required. As shown in Fig. 5, a relatively clean separation of multihadron and 2-photon events can be achieved with these cuts, which yield approximately 1400 multihadron events, with fewer than 6% background events.

Using the luminosity determined from Bhabha events detected in the poletip calorimeters, a value for R of 3.7 ± 0.5 was derived, in good agreement with other experiments.

The analysis of the event topology in terms of the shape-parameters sphericity and aplanarity (Fig. 6) demonstrates that most of the events are 2-jet-like, with few (approximately 10%) 3-jet events. Using the fraction of 3-jet events, the strong-coupling constant alpha-s can be determined. A detailed study of models for quark and gluon fragmentation, however, demonstrated that the result is rather model dependent; the data can accommodate almost any value for alpha-s within 0.15 to 0.3. The conclusion agrees with a study published by the CELLO collaboration at DESY and proves that a more detailed understanding of the nonperturbative hadronization processes is required. Such information can be derived, for example, from the measurement of particle production ratios in jets and from studies of multiparticle correlations.

The measurement of particle production ratios in the PEP-4 detector is based on the particle identification using dE/dx. This is demonstrated in Fig. 7. For low momenta a very clean separation of particle types can be achieved; at higher momenta, the dE/dx bands overlap, and identification is possible on a statistical basis. For this purpose, it is essential that the distribution of the dE/dx measurement shows little deviation from a Gaussian error distribution (Fig. 8); the particle fractions can then be determined from a




(XBL 837-2829)

Fig. 5. Momentum imbalance vs visible energy for events with at least five-reconstructed tracks. Events from 1-photon reactions are characterized by good momentum balance and high visible energy.

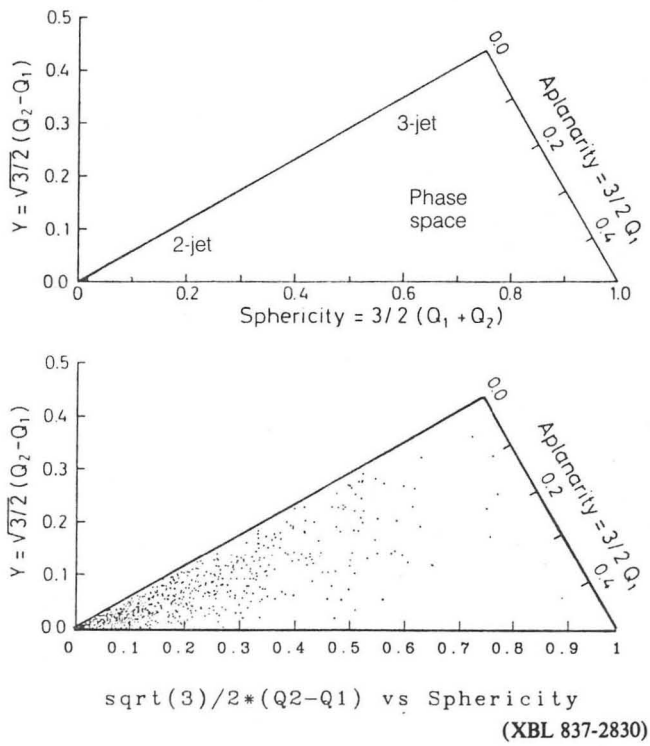



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Fig. 6. Distribution of multihadron events in the topological variables sphericity and aplanarity. The characteristic regions for 2-jet, 3-jet and isotropic events are indicated.

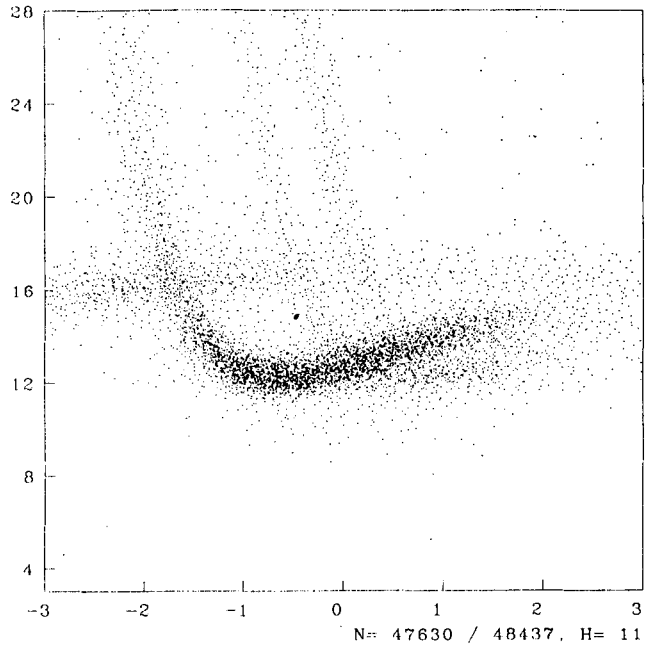


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Fig. 7. Distribution of mean energy loss dE/dx vs particle momentum for tracks in multihadron events.

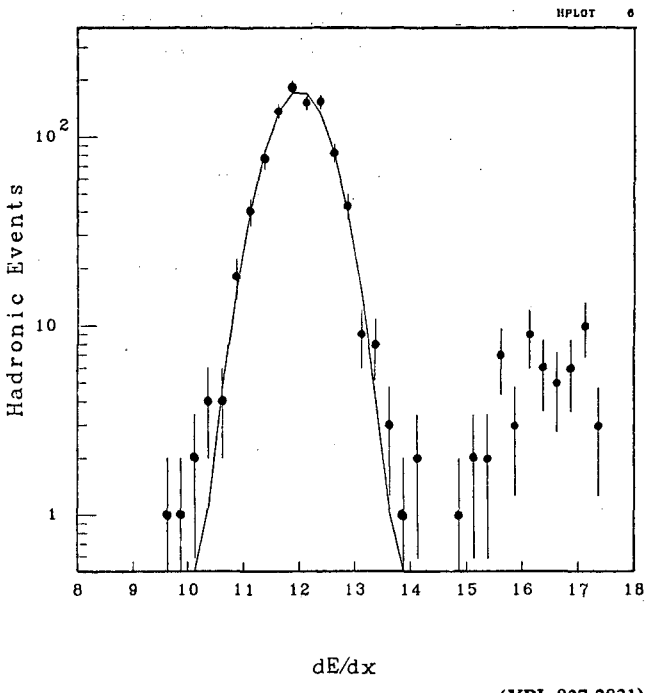


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Fig. 8. Distribution of mean energy loss for minimum ionizing pions. The rms resolution is 3.8%; non-Gaussian tails of the distribution are below 1%. The enhancement at higher dE/dx is due to electron tracks.

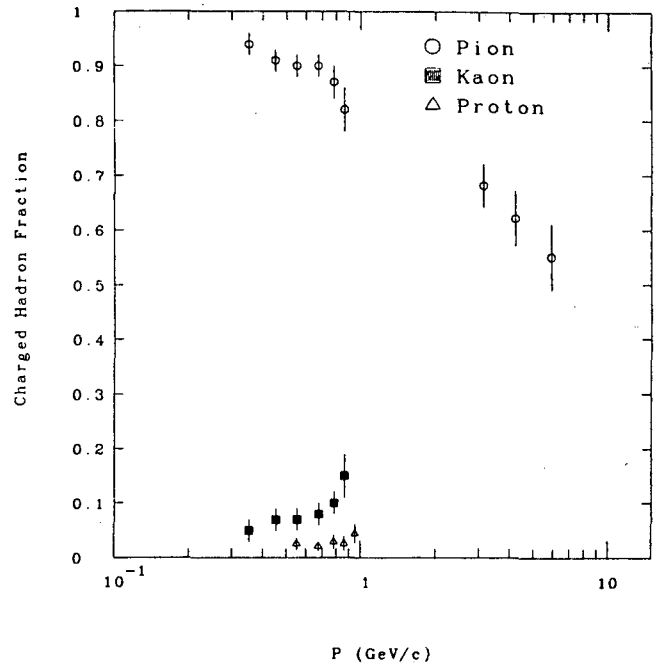


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Fig. 9. Fraction of pions, kaons, and protons as a function of momentum for multihadron events.

simultaneous fit of several Gaussian distributions (for pions, kaons, and protons) to the distribution of dE/dx in a given momentum band.

The resulting particle ratios are shown in Fig. 9. It is worth noting that the error bars are approximately equal to the errors given for earlier measurements by the TASSO group at DESY, although the latter experiment used about 20,000 events in the analysis compared to our 1400-event sample.

First studies of charge and multiplicity correlations in jets yielded evidence for copious resonance production and fragmentation mechanisms providing local conservation of charge in quark jets, in agreement with standard fragmentation models (Fig. 10).

More detailed information on these mechanisms and refined studies of particle fractions and of the flavor dependence of multiparticle correlations will be possible, once the data collected in 1983 have been analyzed, corresponding to a 20-fold increase in statistics.

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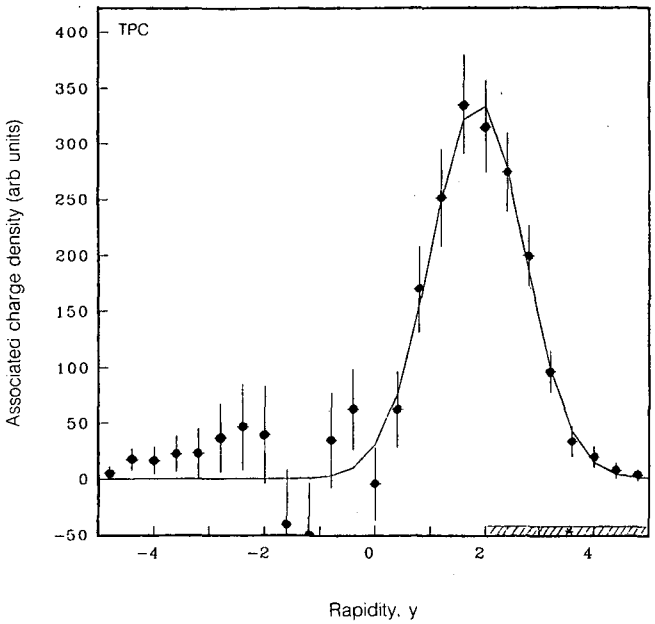


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Fig. 10. Distribution of net charge density in multihadron events selected by requiring a negative "test particle" at large rapidity (shaded region in the plot), as a function of rapidity. The local charge of the charge density in the vicinity of the test particle demonstrates the local conservation of charge in quark jets.

Hadley, W. Hofmann, J. E. Huth, H. Iwasaki, T. Kamae, R. W. Kenney, L. T. Kerth, W. Koellner, R. Kofler, S. C. Loken, G. London, G. R. Lynch, R. J. Madaras, J. N. Marx, W. Moses, P. Nemethy, D. R. Nygren, P. J. Oddone, M. Pripstein, P. R. Robrish, M. T. Ronan, R. R. Ross, F. R. Rouse, R. Sauerwein, G. Schnurmacher, G. Shapiro, M. D. Shapiro, R. G. Smits, M. L. Stevenson, J. D. Taylor, N. Toge, H. Van Slyke, R. Van Tyen, W. A. Wenzel, E. T. Whipple, H. Yamamoto, M. Yamauchi.

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Geiger Mode Calorimeter for PEP-4, PEP-4 TPC Collaboration, presented by M. Yamauchi, IEEE Transactions on Nuclear Science, to be published.

Measurement of Ionization Loss in the Relativistic Rise Region with the Time Projection Chamber, PEP-4 TPC Collaboration, presented by B. Gabioud, IEEE Transactions of Nuclear Science, to be published.

Performance of the Signal Processing System for the Time Projection Chamber, PEP-4 TPC Collaboration, presented by S. Loken, IEEE Transactions on Nuclear Science, to be published.

Spatial Resolution of the PEP-4 Time Projection Chamber, PEP-4 TPC Collaboration, presented by R.J. Madaras, IEEE Transactions on Nuclear Science, to be published.

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# The Mark II Magnetic Detector

The continuing experiment of the Mark II detector at PEP is a collaboration consisting of physicists from LBL, SLAC, and Harvard University. During the past year the experiment has benefited from the improved luminosity of PEP and from the data collected with the new secondary vertex detector, yielding an accurate measurement of the $\tau$ lepton lifetime. The principal achievements of the experiment during this time were:

1. The operation of the Mark II detector at PEP, with the new secondary vertex detector. The Mark II accumulated data corresponding to an integrated luminosity of 29 $nb^{-1}$, a factor two more than previously accumulated at PEP.
2. Analysis of the PEP data, including the following new results:
   a. A new, improved measurement of the $\tau$ lepton lifetme, in agreement with with the predictions of theory.

b. Observation of a $D^{*+} \rightarrow D^{\circ}\pi+$ signal and study of the charmed quark fragmentation function;

c. A measurement of the $D^{\circ}$ lifetime;

d. Observation of semielectronic decays of the B meson and the corresponding b-quark fragmentation function.

3. The continuing analysis of data taken with the detector at SPEAR during the period March 1978 to June 1979. In particular, the Baryonic decays of the $\psi$ were studied.

4. Detailed study of modifications to the Mark II for use at the SLC (SLAC Linear Collider). The Mark II detector was eventually chosen as the first detector at the SLC. In particular, the end cap calorimeters will be constructed at LBL for use at PEP and at the SLC.

## Operations at PEP

During the calendar year 1982, the Mark II detector continued its operation at PEP. A short in the Magnet Coil forced us to reduce the magnetic field from 4.6 to 2.3 kG. A new coil is under construction at SLAC. The improvement in resolution that we obtained by the introduction of the vertex chamber was just about offset by the decrease in magnetic field. Thus, the resolution remained about the same as in 1981.

During 1982 we obtained an integrated luminosity of about 29 inverse picobarns ($pb^{-1}$). The quadrupole magnets next to the interaction regions were moved closer (a new mini-beta configuration), and this resulted in a considerable improvement in the luminosity (up to $1.5 \times 10^{31}$ $cm^{-2}$ $sec^{-1}$ by December 1982).

The vertex chamber is a high resolution drift chamber that allows more precise track measurements. This vertex chamber was designed to detect and measure particles with short lifetimes; it has a space resolution $< 100$ $\mu$m and is a unique feature of the Mark II detector.

## Analysis of PEP Data

Elaborated here are a few of the new topics studied in the Mark II detector.

1. Vertex chamber measurement of the $\tau$ lifetime: With the help of the vertex chamber we were able to get a much more precise measurement of the $\tau$-lepton lifetime. Figure 11 shows a distribution of measured decay lengths for three charged particle decay modes of the $\tau$. We find an average decay length of $710 \pm 120\mu$m, which corresponds to a lifetime $\tau_\tau = 3.31 \pm 0.57 \pm 0.60 \times 10^{-13}$ sec. This is perfectly consistent with the theoretical estimate of $\tau_\tau = 2.8 \pm 0.2 \times 10^{-13}$ sec, based on the $\mu$-lepton lifetime and our measured branching ratio for $\tau \rightarrow e\bar{\nu}_e\nu_\tau$. This implies (within our accuracy) that the $\tau$ couples to the charged weak current like the $\mu$-lepton and electron, or more simply, that the $\tau$ is a heavier version of the $\mu$.

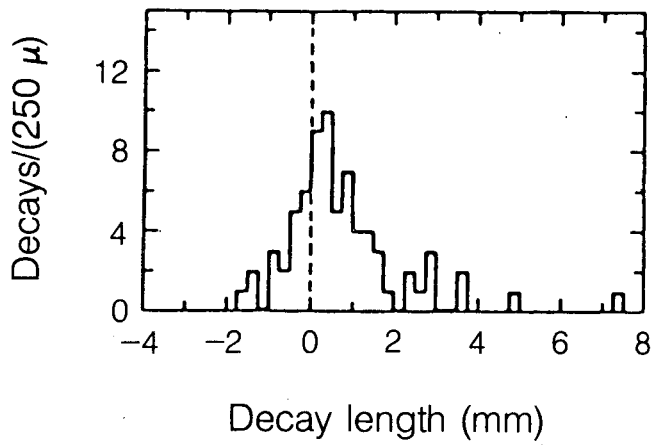


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Fig. 11. Measured decay lengths of $\tau$ leptons.

2. Charmed quark fragmentation function: We have identified the reaction $D^{*+} \rightarrow D^{\circ}\pi^+$ in the PEP data. Because of the very tight kinematical constraints in this decay mode, namely the mass difference $\Delta = M(D^{*+}) - M(D^{\circ}) = 145$ MeV, we are able to identify such events even in cases in which the K identification from time of flight in the decay $D^{\circ} \rightarrow K^-\pi^+$ is not available. Figure 12 shows this mass difference $\Delta$ for $z > 0.4$ and $z > 0.6$, where z is the D* energy in units of the PEP beam energy for $K^-\pi^+$ masses in a $D^{\circ}$ "mass band." Figure 13 shows the corresponding $K^-\pi^+$ masses for a cut on the mass difference $\Delta$. From these data, we learned that the charmed quark fragmentation function peaks at large z values, with $\langle z \rangle = 0.6 \pm 0.1$.

3. The $D^{\circ}$ lifetime: We measure the $D^{\circ}$ lifetime using $D^{\circ}(\bar{D}^{\circ})$ from $D^{*+}(D^{*-})$ decays from about half the above data taken with the vertex chamber in place. For the $D^{\circ}$ lifetime we have the additional requirement that the vertex chamber measurements are of high quality. For seven events with $z > 0.6$ we find $\tau = (3.7^{+2.5}_{-1.5} \pm 1) \times 10^{-13}$ sec using a maximum likelihood fit in which the exponential decay is convoluted with a Gaussian error function.

4. Bottom quark fragmentation function: We have measured the total momentum and transverse momentum spectra for prompt electrons in hadronic events in $e^+e^-$ annihilation at 29 GeV. By utilizing the differences in the transverse

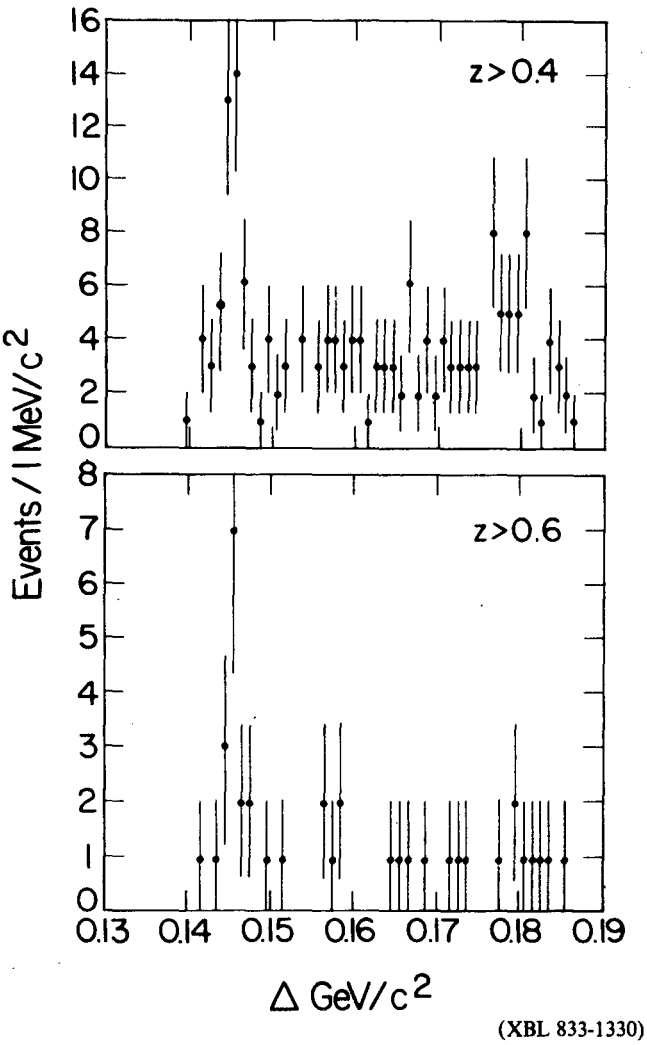


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Fig. 12. Δ is the mass difference between D* and D°. Plotted for $K^-\pi^+$ masses in this D° mass band and for two cuts on Z.

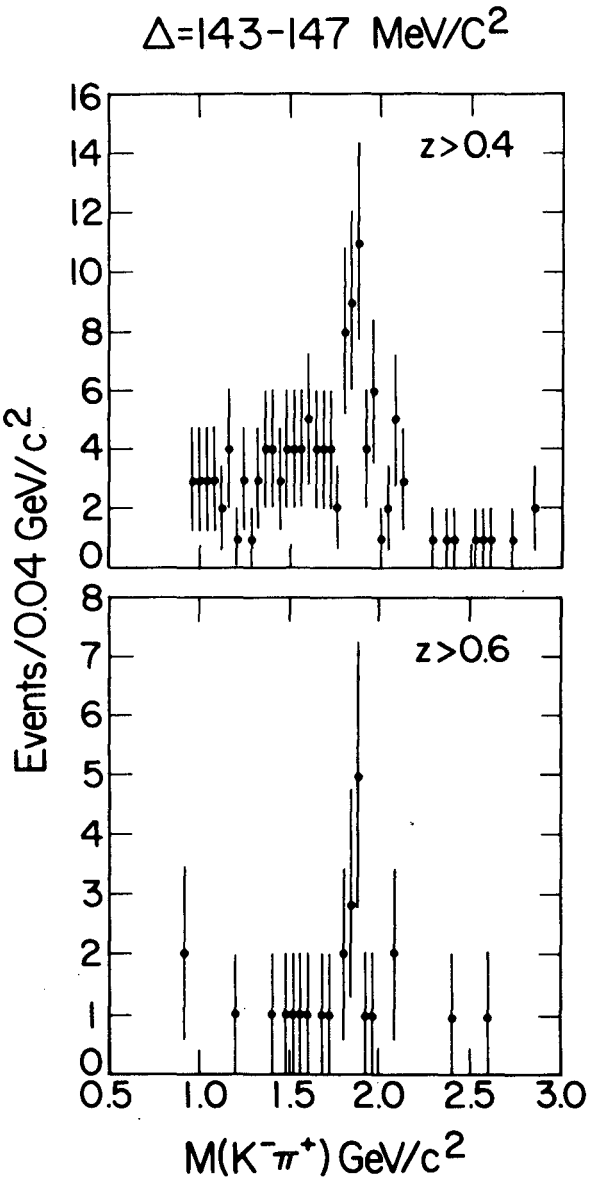


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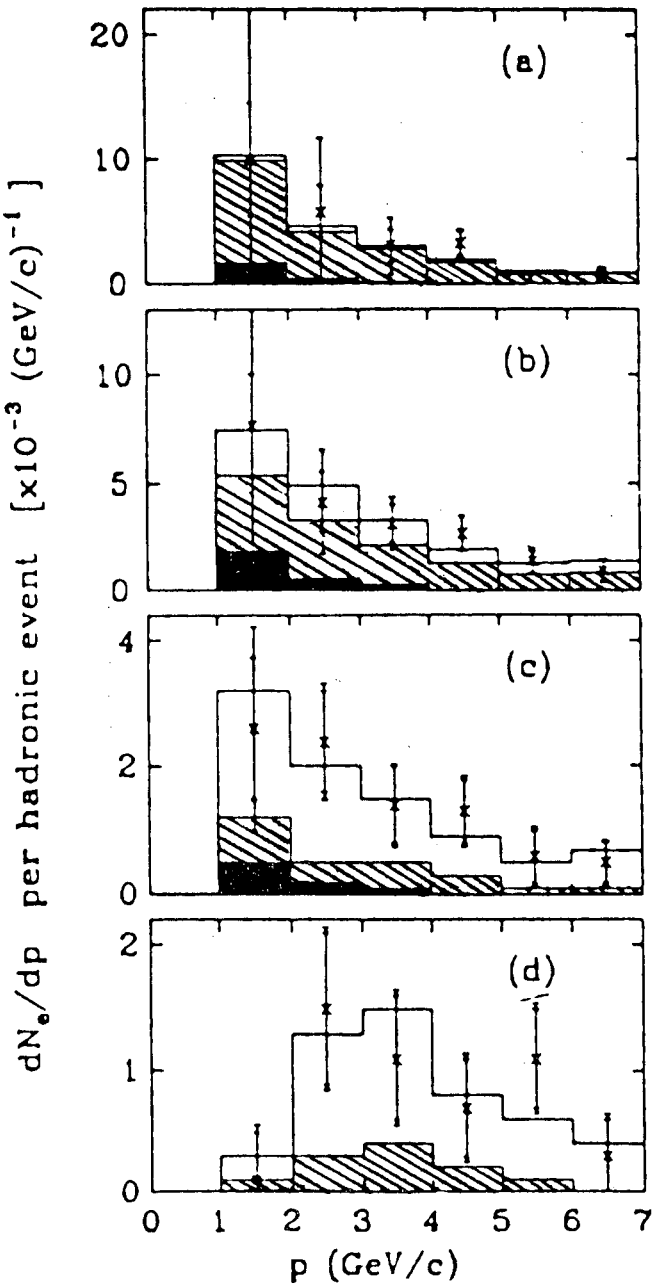
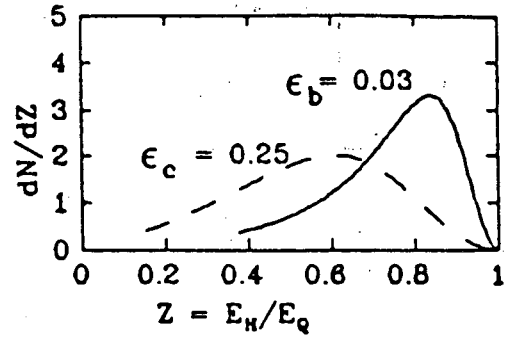
Fig. 13. The $K^-\pi^+$ mass plotted for Δ values in the signal region for two cuts on Z.

momentum distributions for electrons from charm and bottom decays, we have been able to extract information on c and b quark semi-electronic branching ratios and the b quark fragmentation function. We accomplished this by performing a maximum likelihood fit to the observed electron populations in the various p and $p_T$ bins, accounting for the signal above background in terms of the following contributions: a) charm decays in $c\bar{c}$ events, b) charm decays in $b\bar{b}$ events, and c) Bottom decays in $b\bar{b}$ events. The data points in Fig. 14 show the corrected electron spectrum and the histograms show the results of the fit and the relative contributions of (a)-(c) to the prompt electron signal in each p, $p_T$ bin. Figure 15 shows the shapes of the c and b quark fragmentation functions. The average semi-electronic branching ratios are measured to be $B_e(c) = (6.3 \pm 1.2 \pm 2.1)\%$ and $B_e(b) = (11.6 \pm 2.1 \pm 1.7)\%$. The average value of $z = E_Q/E_H$ for b quark fragmentation function is $\langle z \rangle = 0.75 \pm 0.05 \pm 0.04$.




(XBL 837-2837)

Fig. 14. Number of prompt electrons per hadronic event in four regions of transverse momentum $p_T$ (GeV/c): (a) $p_T < 0.5$, (b) $0.5 < p_T < 1.0$, (c) $1.0 < p_T < 1.5$, and (d) $p_T > 1.5$. Two sets of error bars are shown for each data point. The smaller ones are statistical only. The larger ones are the statistical and systematic errors added in quadrature. The highest momentum bin includes all momenta $\geq 6$ GeV/c. The histograms show the results of the fit. The three contributions shown are (i) c primary (diagonally hatched), (ii) c secondary (solid), and (iii) b primary (unshaded).




(XBL 837-2838)

Fig. 15. Heavy quark fragmentation functions. The dashed line is for charm and was an input to the fit. The solid curve is for bottom and is a result of the fit. $\epsilon$ is a parameter which determines the shape of the curves shown.

## Results from SPEAR: Baryonic Decays of the $\psi$

A high statistics study of $\psi$ decays into baryon final states based on $1.3\times10^6$ events has been done with the Mark II detector at SPEAR. New information on the baryon-antibaryon decays of the $\psi$ is found, allowing a detailed comparison of these two body decay modes. Substantial resonance formation is observed in multibody decays of the $\psi$ involving baryons. Table 2 shows a number of the branching ratios measured in this experiment. The flavor SU(3) violating decays $\psi \rightarrow \Sigma^{\pm}(1385)\bar{\Sigma}^{\pm}$ + c.c. are observed with substantial branching ratios.

## Mark II Upgrade for PEP and SLC

A total of nine proposals were submitted in December 1982 for installation of the first detector to be used at the SLAC Linear Collider (SLC). The Mark II was successful in being chosen by the SLAC program committee (EPAC) for this first experiment, which should begin after the SLC turn-on, expected near the end of 1986. To prepare for the new regime of physics at higher energies, several improvements and modifications of the Mark II detector are planned. These changes are to be implemented at PEP in 1984, in time to prove the new devices at PEP before the move to the SLC.

### Drift Chamber

A new 3-m diameter drift chamber has been designed to replace the present one. The new tracking chamber is designed with 12 superlayers of 8 sense wires each, or six times the number of measuring wires

Table 2. Summary of psi decay modes (units of $10^{-3}$).

| Decay mode | Events | $\epsilon$ | BR for this experiment |
|---|---|---|---|
| $\psi \to \bar{p}p$ | 1420 ± 37 | .497 | 2.16 ± .07 ± .15 |
| $\psi \to \Lambda\bar{\Lambda}$ | 365 ± 19 | .176 | 1.58 ± .08 ± .19 |
| $\psi \to \Sigma^0\bar{\Sigma}^0$ | 90 ± 9 | .043 | 1.58 ± .16 ± .25 |
| $\psi \to \Xi^-\bar{\Xi}^+$ | 194 ± 14 | .129 | 1.14 ± .08 ± .20 |
| $\psi \to \Delta^{++}\bar{\Delta}^{--}$ | 233 ± 19 | .160 | 1.10 ± .09 ± .28 |
| $\psi \to \Sigma^-(1385)\bar{\Sigma}^+(1385)$ | 56 ± 14 | .050 | .86 ± .18 ± .22 |
| $\psi \to \Sigma^+(1385)\bar{\Sigma}^-(1385)$ | 68 ± 16 | .050 | 1.03 ± .24 ± .25 |
| $\psi \to \Sigma^-(1385)\bar{\Sigma}^+$ | 36 ± 10 | .067 | .41 ± .11 ± .10 |
| $\psi \to \Sigma^+(1385)\bar{\Sigma}^-$ | 34 ± 10 | .068 | .38 ± .11 ± .10 |
| $\psi \to \bar{p}p\gamma$ | 49 ± 9 | .195 | .38 ± .07 ± .07 |
| $\psi \to \bar{p}p\pi^+\pi^-\gamma$ | < 12 | .023 | < .79 |
| $\psi \to \bar{p}p\pi^0$ | 685 ± 56 | .458 | 1.13 ± .09 ± .09 |
| $\psi \to p\pi^-\bar{n}$ | 1288 ± 47 | .482 | 2.02 ± .07 ± .16 |
| $\psi \to \bar{p}\pi^+n$ | 1191 ± 47 | .467 | 1.93 ± .07 ± .16 |
| $\psi \to \bar{p}N^+(1470\text{-}1535)$ | 209 ± 31 | .153 | 1.03 ± .15 ± .26 |
| $\psi \to \bar{p}N^+(1650\text{-}1690)$ | 85 ± 24 | .129 | .50 ± .15 ± .13 |
| $\psi \to \Delta^{++}\bar{p}\pi^-$ | 332 ± 49 | .159 | 1.58 ± .23 ± .40 |
| $\psi \to \Lambda\pi^-\bar{\Sigma}^+$ | 135 ± 15 | .067 | 1.53 ± .17 ± .38 |
| $\psi \to \Lambda\pi^+\bar{\Sigma}^-$ | 118 ± 18 | .065 | 1.38 ± .21 ± .35 |
| $\psi \to \bar{p}p\eta$ | 826 ± 52 | .309 | 2.03 ± .13 ± .15 |
| $\psi \to \bar{p}p\rho^0$ | 38 ± 16 | .158 | < .31 |
| $\psi \to \bar{p}p\omega$ | 486 ± 73 | .323 | 1.10 ± .17 ± .18 |
| $\psi \to \bar{p}p\eta'$ | 19 ± 6 | .021 | .68 ± .23 ± .17 |
| $\psi \to pK^-\bar{\Lambda}$ | 307 ± 25 | .262 | .89 ± .07 ± .14 |
| $\psi \to pK^-\bar{\Sigma}^0$ | 90 ± 19 | .236 | .29 ± .06 ± .05 |
| $\psi \to pK^-\bar{\Sigma}^0(1385)$ | 115 ± 46 | .132 | .66 ± .26 ± .11 |
| $\psi \to \bar{p}p\pi^+\pi^-$ | 1435 ± 38 | .168 | 6.46 ± .17 ± .43 |
| $\psi \to \bar{p}p\pi^+\pi^-\pi^0$ | 364 ± 70 | .082 | 3.36 ± .65 ± .28 |

in the present Mark II chamber, and it will measure tracks over about 90% of the total solid angle. The sets of 8 wires in each superlayer lie along radial directions and are staggered somewhat (~400 $\mu$m) azimuthally to help resolve track position and charge (dE/dX) for track ionization. The longitudinal coordinate is derived from the ±3.50 ° stereo angle of wires in 6 of the 12 superlayers, the other 6 layers having axial wires. The maximum drift distance is about 3.3 cm azimuthally, and multihit capability in the electronics system will allow several tracks to be measured in the 3.3 cm gap. Detailed Monte Carlo studies of the chamber performance predict the position resolution to be ~150 $\mu$m and the dE/dX resolution as ~7% for a minimum ionizing track. This latter capability will be very important in helping to identify particles, particularly $e^{\pm}$.

End Cap Shower Counters

A design was begun for a set of two electron shower counters to be installed on the movable end doors of the Mark II detector where only very primitive (2-layer) counters now exist. Each shower counter is nearly 3 m in diameter and about 0.6 m deep, consisting of 36 layers of 2.8 mm ($0.5X_0$) lead sheet and gas tube sampling counters ($1.8 \times 0.9$ cm). An energy resolution of about $17\%/\sqrt{E(GeV)}$ and an angular resolution of ~10 mrad are expected. These calorimeters will cover from about 18° to to 45° in the end regions, or about 25% of the total solid angle. These new shower counters essentially close the gap in solid angle not presently covered by the liquid argon shower counters, providing nearly complete and continuous

shower calorimetry and electron identification over the entire solid angle. LBL is assuming primary responsibility for the design and construction of the endcap calorimeters.

### Time of Flight System

The time-of-flight system will be replaced and improved. New scintillator of smaller width (4 inches instead of 8) will avoid the difficulties of pile-up that otherwise would be expected to occur in the SLC environment. Some improvement in time resolution may be possible by doubling the counter thickness (to 2 inches).

### End Door Retraction Mechanism

The end doors (~20 tons) of the detector now are retractible only with the aid of a crane, and require a considerable time to move in and out. A drive mechanism for support and movement of the doors will be installed to facilitate access to the interior of the detector at PEP and SLC.

All of these improvements are planned for installation in the summer-fall period of 1984. This leaves an additional year at PEP to test, debug, and assimilate these new devices into a working system before the anticipated move to SLC. There are, in addition, proposed devices in an earlier developmental stage, that will only be installed after the move to SLC. These include a vertex detector and a small angle monitor for tracking and luminosity measurement.

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## Free Quark Search

Analysis continued on the search for inclusive, exclusive, and highly interactive production of free quarks in $e^+e^-$ interactions. To date no quark candidates have been found and upper limits near 2% R have been published. These measurements have improved the limits on free quark production in electromagnetic interactions by up to 7 orders of magnitude and have extended the limits on possible quark mass up to 14 GeV.

### Research Staff

D.M. Chew, R.P. Ely, T.P. Pun, V. Vuillemin.

### Publications

Experimental Limits on Quarks, Tachyons, and Massive Particles in Cosmic Rays. J. Napolitano, D. Besset, D. Chew, R.P. Ely, S.J. Freedman, R. Fries, B. Gobbi, W. Guryn, F.A. Harris, I. Karliner, A.M. Litke, A. Marini, D.H. Miller, S.I. Parker, I. Peruzzi, M. Piccolo, T.P. Pun, F. Ronga, M.T. Ross, V. Vuillemin, T.C. Wang, and D.E. Yount. Phys. Rev. D26, 1777 (1982).

Search for Exclusive Free Quark Production in $e^+e^-$ Annihilation at PEP. A. Marini, I. Peruzzi, M. Piccolo, F. Ronga, D.M. Chew, R.P. Ely, T.P. Pun, V. Vuillemin, R. Fries, B. Gobbi, W. Guryn, D.H. Miller, M.C. Ross, D. Besset, S.J. Freedman, A.M. Litke, J. Napolitano, T.C. Wang, F.A. Harris, I. Karliner, S. Parker, and D.E. Yount. Phys. Rev. Lett. 48, 1649 (1982).

An Inclusive Search for Free Quarks at PEP. M.C. Ross, F. Ronga, D. Besset, D.M. Chew, R.P. Ely, S.J. Freedman, R. Fries, B. Gobbi, W. Guryn, F. Harris, I. Karliner, A. Litke, A. Marini, D. Miller, J. Napolitano, S.I. Parker, I. Peruzzi, M. Piccolo, T.P. Pun, V. Vuillemin, T. Wang, and D. Yount. Phys. Lett. 118B, 199 (1982).

Search for Fractionally Charged Particles at Large Zenith Angles. M.C. Ross, F. Ronga, D. Besset, D.M. Chew, R.P. Ely, S.J. Freedman, R. Fries, B. Gobbi, W. Guryn, F. Harris, I. Karliner, A. Litke, A. Marini, D. Miller, J. Napolitano, S.I. Parker, I. Peruzzi, M. Piccolo, T.P. Pun, V. Vuillemin, T. Wang, and D. Yount. Phys. Rev. D25, 2837 (1982).

## PEP Experimental Facilities Coordination

The installation of all detectors and facilities approved for the initial PEP program was completed during 1982. All detectors, Mark II, TPC, $2\gamma$, MAC, HRS, Delco and the Monopole Search, operated smoothly with no major breakdowns during the year. The experimental areas and support systems for experiments, including cryogenic and computer systems, were stable and provided efficient support for the program.

### Research Staff

Pier Oddone, Peter Nemethy.

# Research at Fermilab

During 1982 work on Fermilab experiments consisted of either research and development toward the future or analysis and publication of data taken in earlier years. In the latter category are the inelastic muon scattering experiment of LBL, Fermilab, and Princeton, in its final stage of analysis, the inclusive $\pi^\circ$ production experiment, and the study of neutrino interactions in the 15-ft. bubble chamber. Design, development, and prototype testing occurred for the highly segmented end-plug hadron calorimeter for the CDF at Fermilab. Conceptual studies were continued on the second-generation inelastic muon spectrometer experiment approved for the new muon beam at TeV II. A collaborative effort with Yale and Fermilab was directed toward study of short-lived particles (lifetimes less than $10^{-12}$ s), using a high-pressure, high-resolution streamer chamber. Data analysis is under way.

## Hadron Calorimeter for CDF Collaboration

A full scale prototype of the end plug hadron calorimeter for the Collider Detector at Fermilab (CDF) was constructed early in 1982. The prototype calorimeter consisted of 20 proportional tube chambers as detectors and 5-cm steel plates as converters. The chambers were constructed with resistive plastic tubes and cathode pad readout.

The prototype calorimeter was shipped to Fermilab in May 1982. It was installed in the M4 beam and tested with pions and electrons from 25 to 150 GeV. The hadron calorimeter was then augmented with a prototype of the end plug shower counter, just as the final CDF detector will be configured. The tandem combination was then tested with electron and pion beams.

The data were analyzed in a preliminary form over the summer. The energy resolution was somewhat better than the design specification at low energies, but saturated at about 10% for energies above 100 GeV. This saturation can be improved by operating at lower voltage. The position resolution matched the design specification.

Following the successful prototype tests, we began the design of the final production version of the chambers. This design was completed and approved in a critical design review held at Fermilab in December 1982.

Production of the final chambers will begin in spring 1983 and is scheduled for completion by fall 1984. We expect the full end plug hadron calorimeter to be installed for the initial $\bar{p}p$ tests at the FNAL B0 collision area in 1985.

Research Staff

F. Butler, W. Carithers, W. Chinowsky, R. Ely, M. Franklin, M. Gold, P. Rowson, K. Shinsky.

## Muon Reactions

The Fermilab Muon Experiment is a collaborative effort by LBL, Fermilab, and Princeton University. The analysis of multimuon final states was completed during 1982.

Work continued on the measurement of nucleon structure functions in inelastic muon scattering. A detailed study of the acceptance and resolution of the apparatus has been completed. Final analysis of the data will be finished in early 1983.

Research Staff

Alan R. Clark, Frederick R. Goozen, Leroy T. Kerth, Stewart C. Loken, Peter D. Meyers, Timothy E. Nuzum, Wesley H. Smith, Mark W. Strovink, Thomas F. Weber, William A. Wenzel.

Publications

Study of Rare Processes Induced by 209-GeV Muons. W.H. Smith, A.R. Clark, K.J. Johnson, L.T. Kerth, S.C. Loken, T.W. Markiewicz, P.D. Meyers, 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. D 25, 2762 (1982).

## Tevatron Muon Experiment

A new muon beam will be constructed at Fermilab for use with the Tevatron. The Berkeley-Fermilab-Princeton collaboration has been approved to move the Multimuon Spectrometer to this new beam.

The experiment will study single and multimuon final states at incident muon energies up to 700 GeV. The initial physics goals of the experiment are the following:

1. Measurement of nucleon structure functions in inelastic muon scattering.

2. Study of heavy vector-meson production by muons.
3. Investigation of charm and bottom meson production in inelastic muon interactions.
4. Study of rare multimuon final states.

During 1982, work continued on the planning for this experiment. It is expected that installation of the apparatus in the new beam will begin in mid-1984.

Research Staff

Alan V. Barnes, Alan R. Clark, Frederick R. Goozen, Leroy T. Kerth, Stewart C. Loken, Lisa G. Mathis, Timothy E. Nuzum, Thomas F. Weber, William A. Wenzel.

## Strong Interaction Experiments at FNAL

The latest experiment in our FNAL series on Reggeism, E-350, investigated the forward going portion of the reaction $\pi^- p \rightarrow \pi^0 X$ in the kinematic region $0.8 \leq x \leq 1.0$. This inclusive reaction provides a definitive test of the relatively simple predictions of triple Regge theory for this case. The trajectory is determined to values of $|t| \leq 6 \left( \frac{GeV}{c} \right)^2$ whereas it was formerly known from the reaction (at 200 GeV) $\pi^- p \rightarrow \pi^0 n$ only to values of $|t| \leq 1.5 \left( \frac{GeV}{c} \right)^2$. The data have prompted a reexamination of Regge theory at small values of $|t|$.

Our latest publication concerns an SU(3) based comparison between inclusive kaon and pion scattering in the triple Regge region. It shows that the SU(3) relation $\sigma(K^- p \rightarrow \bar{K}^0 X) = 0.5\sigma(\pi^- P \rightarrow \pi^0 X) + 2.2\sigma(\pi^- P \rightarrow \eta X)$ is approximately valid throughout the kinematic range of $x \geq 0.2$ and $-t \leq 1(Gev/c)^2$ for the final state particle. The data are consistent with SU(3) mixing of $\eta$ and $\eta'$. SU(3) breaking observed in this work corresponds in the Regge formalism to the ratio of $K\bar{K}$ and $\pi\pi(\eta)$ couplings of the $\rho$ and $A_2$ trajectories being 14% larger than the SU(3) predicted value.

Research Staff

O. Dahl, R. W. Kenney, A. Ogawa, M. Pripstein.

Publications

An SU(3)-Based Comparison between Inclusive Kaon and Pion Charge Exchange Scattering in the Triple Regge Region. A.V. Barnes, et al., Nucl. Phys. B206 173 (1982).

## Experiments Using Polarized Proton and Antiproton Beams

Lambda and anti-lambda production at Tevatron energies is so abundant that enriched polarized proton, and polarized antiproton beams from lambda and antilambda decays are being built for counter physics as part of the Tevatron II development at FNAL. A first round of experiments has been approved to make the first use of the polarized beam. We will measure total cross-section differences with polarized beam and target, high-x low-$p_T$ inclusive pion production with polarized beam, lambda production with polarized beam on unpolarized hydrogen target, and inclusive $\pi^0$-production under the same conditions.

This is a collaborative effort, involving physicists from Argonne National Laboratory, Rice and Northwestern Universities; LAPP, Annecy, France; INFN, Sezione di Trieste, Italy; Serpukhov and Kyoto, as well as LBL.

Research Staff

G. Shapiro.

## Charm Search with a High Resolution Streamer Chamber

The direct observation of short-lived particles (charm, bottom, etc., $\tau < 10^{-12}$ sec) requires high resolution vertex detectors. Experiments utilizing a high pressure, high resolution streamer chamber as an active target for hadronic charm production (FNAL E490/E630) continued in 1982. The streamer chamber reduces the physical size of electron avalanches by increasing the pressure and scaling all other variables correspondingly. Streamer sizes of 50 $\mu$m in a 40-atmosphere chamber were achieved. A new experiment using a neutron beam was run in the Proton Area at Fermilab. The scanning, measuring, and analysis of the pictures from this run is in progress. Studies on further development of the high resolution streamer chambers are under way.

This work is a collaborative effort with Yale University and Fermilab.

Research Staff

Peter Nemethy.

Publications

Design and Performance of a High Resolution Streamer Chamber. R. Majka, T. Cardello, S. Dhawan, A. Disco, R. Kellog, T. Ludlam, P. Nemethy, J. Sandweiss, A.J. Slaughter, L. Tzeng and I. Winters. Nucl. Inst. and Methods, 192, 241 (1982).

## Neutrino Interactions at Fermilab

The high purity of the dichromatic antineutrino beam was exploited by the Berkeley, Hawaii, FNAL group (E388) to place limits on the neutrino oscillations $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ and $\bar{\nu}_\mu \rightarrow \bar{\nu}_\tau$. The 90% confidence level upper limits obtained for the average oscillation probabilities are $P(\bar{\nu}_\mu \rightarrow \bar{\nu}_e) < 5.7 \times 10^{-3}$ and $P(\bar{\nu}_\mu \rightarrow \bar{\tau}_\tau) < 4.4 \times 10^{-2}$.

Research Staff

G.R. Lynch, J. Lys, M.L. Stevenson.

Publications

Limits on the neutrino oscillations $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ and $\bar{\nu}_\mu \rightarrow \bar{\nu}_\tau$ using a narrow band beam. G.N. Taylor, R.J. Cence, F.A. Harris, M.D. Jones, S.I. Parker, M.W. Peters, V.J. Stenger, H.C. Ballagh, H.H. Bingham, T. Lawry, J. Lys, M.L. Stevenson, G.P. Yost, D. Gee, F.R. Huson, E. Schmidt, W. Smart, E. Treadwell, submitted to Phys. Rev. D.

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# Search for Effects of a Right-Handed Gauge Boson

Experiment 185, a search for right-handed currents in $\mu^+$ decay, has accumulated data during two very productive runs at TRIUMF during April-May and November-December, 1982. Already it appears that much of what is now known about the phenomenology of a possible right-handed partner to the left-handed $W^\pm$ boson is contained in these data.

The experiment is sensitive to a small admixture of (V+A) current in muon decay at rest, as might occur in left-right-symmetric electroweak models. Nearly completely polarized $\mu^+$ obtained from the TRIUMF "surface" beam are stopped in essentially non-depolarizing pure metal foils. Within 200 mrad of the beam direction, decay $e^+$ near the spectrum endpoint are momentum-analyzed to 0.2%. Data are collected in two alternating modes: (i) with the stopped $\mu^+$ spin precessed in a ~70 gauss transverse magnetic field, and (ii) with the $\mu^+$ spin held in a ~12 kilogauss longitudinal field. In the former mode, departure of the muon-spin-rotation signal amplitude from the nearly full modulation expected at the spectrum endpoint would signify the presence of a non V-A component. In the latter mode, the muon decay rate via V-A currents is required to approach zero as the $e^+$ momentum component opposite to the muon spin approaches its max-

imum value. This "null" method affords a precise search for any residual non V-A component of the decay. In both modes, a quantity similar to the muon decay parameter $\xi$ is determined.

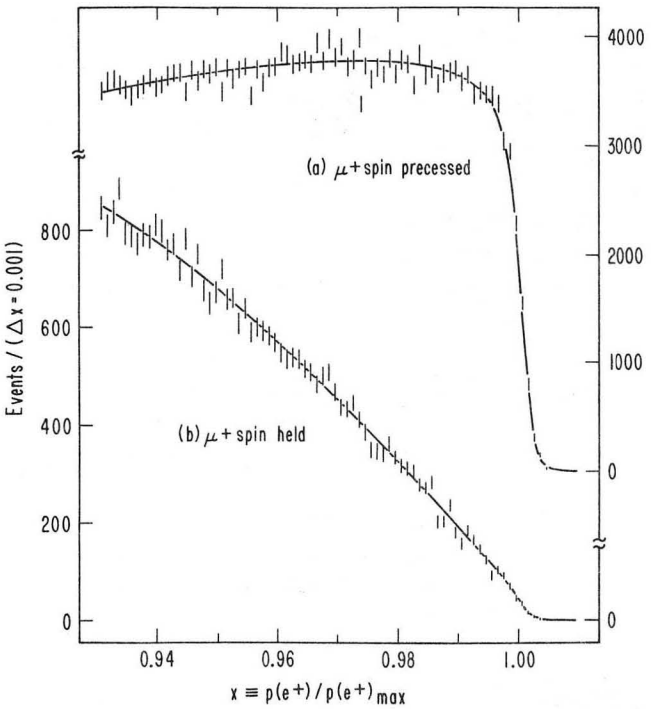
The reliability and performance of the Muon Polarimeter have exceeded our expectations. After extensive calibration, the 120-wire-plane drift chamber system has exhibited a spatial resolution approaching 200$\mu$m, even with the low specific ionization associated with the use of a methane-methylal gas mixture. This high spatial precision and the concentration of material at the foci of the 'Sagane' spectrometer magnet has produced a momentum resolution at 50 MeV that is better than our design goal of 0.5% by a factor of 3. Figure 16 exhibits the sharp edge at the endpoint of the spin-precessed data.

The shakedown run in April-May 1982 was more than adequate to commission the detector and to facilitate the development of analysis software. In fact these earliest data provide the basis for a search for right-handed W's up to ~400 GeV in mass, which we expect to submit for publication within the first half of 1983. In the November-December 1982 run, at least twice as much useful data were collected. A dedicated VAX-11/750 performed the preliminary analysis of half of the events nearly in real time.

Detailed analysis of all the data is continuing. A terminal run at TRIUMF is planned for late 1983.

Research Staff

John Carr, George Gidal, Bruno Gobbi (Northwestern Univ.), Alexander Jodidio, Christopher Oram (TRIUMF), Kirk Shinsky, Herbert Steiner, David Stoker, Mark Strovink, Robert Tripp.




(XBL 834-146)

Fig. 16. Distribution in the ratio of the positron momentum to its maximum value: (a) with the $\mu^+$ spin $\vec{s}$ precessed about an axis transverse to the direction of $\hat{p}_e$ of positron emission; (b) with $\vec{s}$ held so that $2\langle\vec{s}\cdot\hat{p}_e\rangle = 0.9850$. The horizontal scale is calibrated by the edge position in (a). Distributions are uncorrected for acceptance; errors are statistical. The solid line in (a) is a fit with parameters that are empirical except at the shoulder; the Gaussian part of the resolution is $< 0.2\%$ rms. The fit in (b) is to a linear combination of the shape of (a) with that expected from pure (V-A) and 100% $\mu^+$ polarization opposite to $\hat{p}_e$.

# 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. Some members of the group are also active in research projects at LBL and elsewhere. The Particle Data Center is the major U.S. center for data compilation in high energy physics. The center works in collaboration with a large number of institutions, among which are CERN, Durham, Helsinki, Serpukhov, and SLAC. It is responsible, with the help of its many collaborators, for the production of the "Review of Particle Properties" and for a number of other projects aimed at providing easy access to experimental data and information.

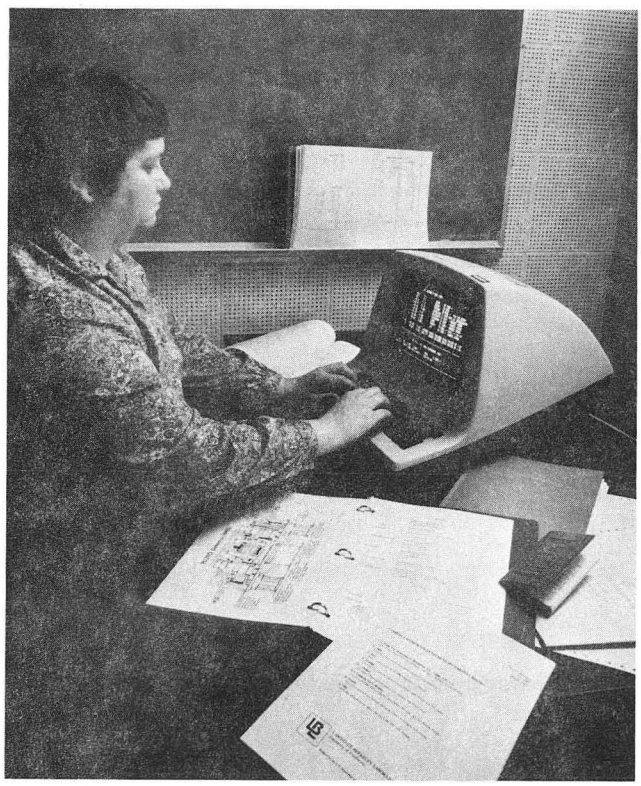
The year 1982 marked the 25th anniversary of the "Review of Particle Properties." It also marked the beginning of a major modernization of the review and other activities of the center.

## Activities

There are six major activities:

1. Compilation of particle properties, and the biennial publication of the "Review of Particle Properties," with the associated Data Booklet and Pocket Diary.

2. Compilation of information on experiments, including physics information such as beam and target particles, momentum, reaction or particle studied, and type of data. Annual publication of a comprehensive index to these experiments with a list of available beams (LBL-91), and two-page loose-leaf detector descriptions for major detectors (LBL-91 Supplement).
3. Compilation of physics information on published articles and preprints containing new data. Publication of indices that permit location of these data (LBL-90).
4. Interactive distribution of our compiled information on experiments, preprints, published articles, and particle properties via the SLAC-SPIRES system.
5. Maintenance and continued development of the Berkeley Database Management System and its associated processors to store, maintain, update, retrieve, display, and distribute the compiled information referred to above.



(XBB 834-3794)

Fig. 17. Betty Armstrong accesses the SLAC-SPIRES database, RPP, to obtain the latest updates to the "Stable Particle" section of the "Review of Particle Properties." Interactive access is a key word in the Particle Data Group modernization program. PDG's 1982-1983 publications, including the new "Major Detectors in Elementary Particle Physics," are shown.

6. Participation in various research projects at LBL and elsewhere.

## Accomplishments

Understaffing problems were overcome by strong Physics Division support through the addition of two new part-time members, Cahn and Gidal. Together with the new group leader Trippe, they form the PDG Steering Committee and bring significant new theoretical and experimental expertise to the group. In addition, a new physicist and a new programmer will be restored to the program in late FY83. This strong support allowed the following accomplishments:

1. The 1982 edition of the "Review of Particle Properties" was completed. The usual high standards of accuracy and completeness were maintained. Increased recruitment of consultants and outside authors permitted significant additions and improvements in areas of high current interest such as neutrino-mass and lepton-mixing limits, monopole searches, etc. The UNIX/TROFF phototypesetting system was used to produce the Tables of Particle Properties and other tables as a first step in modernizing production of the review and improving its readability. The companion Data Booklet, Diary, and Address-Phone list were also published.
2. Work began on a fifth edition of LBL-91, "Current Experiments in Elementary Particle Physics." To reflect current trends in high energy physics, this project's database was expanded to include information from four new laboratories: CESR, LAMPF, SIN, and TRIUMF. A new product, an LBL-91 Supplement, "Major Detectors in Elementary Particle Physics," was initiated. Publication of both documents is scheduled for spring 1983.
3. The LBL-90 project was reactivated and indexing of the backlog of high energy physics documents according to their data content commenced. With help from PDG's Russian collaborators, a return to steady state operation is expected by 1984 with publication beginning soon thereafter.
4. Some highly active sections of the "Review of Particle Properties" have been converted to a SLAC-SPIRES database called RPP, and are now accessible interactively. This database will be updated every six months, whereas updating used to be done only every two years for publication of the review. For those physicists not having access to the SLAC-SPIRES system, the newly updated database will also be distributed on microfiche, computer printout, and magnetic tape. Work began on the first update in preparation for spring

1983 distribution. Updating of the SPIRES PROPOSALS database also began in conjunction with the LBL-91 project described above. The LBL-90 document indexing will be added to the SLAC-SPIRES HEP database by 1984.

5. The Berkeley Database Management System continues to be used to maintain our various databases at LBL. Because of its hardware-independent design, BDMS now runs on CDC, VAX, IBM, and Russian ICL computers. It is an effective tool in our LBL-90 collaboration with Serpukhov. In addition, BDMS is used for the Reaction Data database, a project designed and implemented by LBL, CIT, and Durham, and now maintained by the U.K. Particle Data Group and Serpukhov.

6. Physicist members of the group continued their involvement in research, participating in the following individual and collaborative efforts:

   a. Valuable information on charmed particle production and decay was obtained from the SLAC laser-produced photoproduction experiment, which used the 40-inch bubble chamber with a high resolution camera. Lifetimes were published.

   b. A study of the charge-dependent behavior of final state particles in $\pi^-$p interactions from a Fermilab 205 GeV/c experiment was published.

   c. A simple method was published for determining isospin relations in the strong interaction without need of Clebsch-Gordan tables.

   d. Some useful calculator programs for particle physics were developed and documented.

   e. A review of baryon spectroscopy including both theoretical and experimental aspects was completed.

   f. Studies of gluon bremsstrahlung effects in hadron-hadron scattering were completed.

   g. A recently reported violation of Bell's inequality by a local model of the quantum behavior of two electrons in a spin zero state was studied and found to be incorrect.

   h. Work continued on the study of $e^+e^-$ interactions at PEP using the Mark II detector, and on the search for right-handed currents via measurement of the $\xi$ parameter in $\mu^+$ decay at TRIUMF.

   i. Work continued on theoretical topics including supersymmetry as well as high energy pp and $p\bar{p}$ collisions.

## Research Staff

Betty Armstrong, Robert N. Cahn, George Gidal, Robert Kelly, Alan Rittenberg, Thomas G. Trippe, Charles G. Wohl, George P. Yost.

## Publications


Review of Particle Properties. M. Roos, F. C. Porter, M. Aguilar-Benitez, L. Montanet, Ch. Walck, R. L. Crawford, R. L. Kelly, A. Rittenberg, T. G. Trippe, C. G. Wohl, G. P. Yost, T. Shimada, M. J. Losty, G. P. Gopal, R. E. Hendrick, R. E. Shrock, R. Frosch, L. D. Roper, B. Armstrong. Phys. Lett. 111B, 1 (1982).

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Study of Charge-Dependent Behavior of Final-State Particles in $\pi^-$p Interactions at 205 GeV/c. G. P. Yost, H. H. Bingham, D. M. Chew, B. Y. Daugeras, W. B. Fretter, W. R. Graves, J.-F. Grivaz, A. D. Johnson, J. A. Kadyk, L. Stutte, and F. C. Winkelmann. Phys. Rev. D25, 1181 (1982).

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# High Energy Astrophysics and Interdisciplinary Experiments

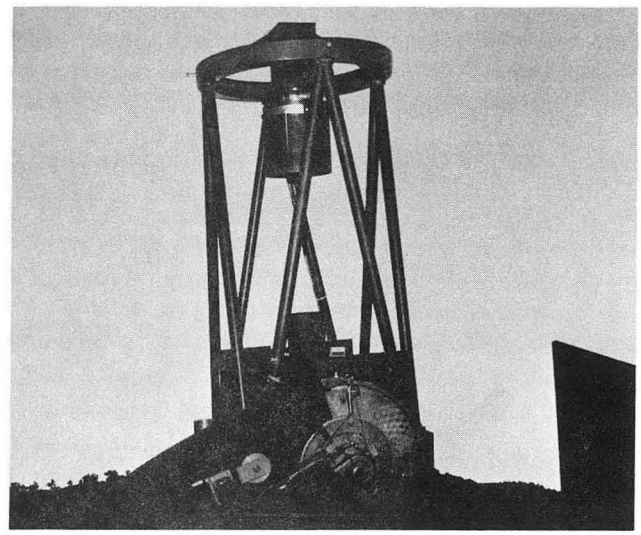
Particle physics research often leads to applications and research projects that appear on the surface to have little in common with high energy physics itself. Some of these projects are outgrowths of the fact that some of the new theories of particle physics are best tested in the astrophysical environment (supernovae or the Big Bang), and others simply use techniques developed in particle physics experiments to solve problems in other areas of science (e.g., radioisotope dating with accelerators). A description of several of these projects is given below.

## Supernovae Detection

The most extreme conditions of energy and density that are currently attained in our universe are probably in the explosion of stars called "supernovae." We are developing a system capable of recording the images of 7500 galaxies on a three night cycle, with real time analysis that will enable us to detect new supernovae. Supernovae play a fundamental role in many areas of astrophysics . They are the progenitors of black holes, neutron stars, and pulsars; they are probably responsible for nucleosynthesis of 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, 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- and gamma-ray radiation.

The most interesting and least understood period of the supernova explosion is the first few days. There have been very few supernovae reported in this period, and there has never been a spectrum obtained this early. 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 practically no data. Our search should detect one supernova every three to six days at 10 to 40 percent of maximum light before the peak. For supernova explosions in the nearby Virgo cluster of galaxies, we should see supernovae at a few percent of maximum light.

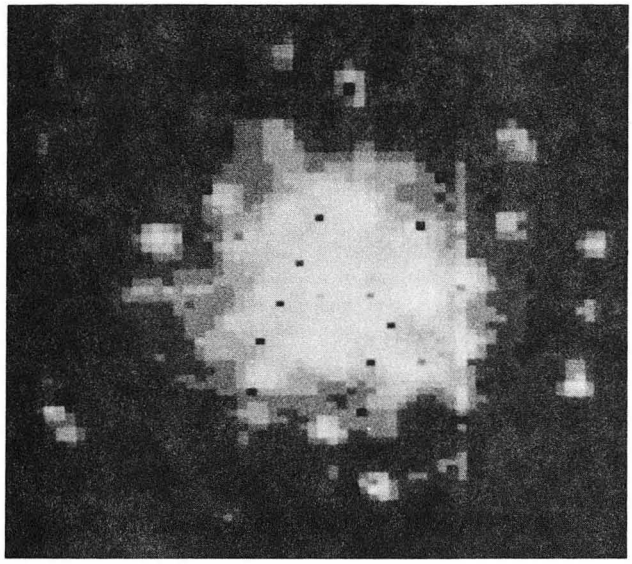
We will use an RCA charge-coupled imaging device (CCD) with a 36-inch automated optical telescope and repeatedly scan about 7500 galaxies, cycling through this sample every three days. The image of the galaxy will be compared to the standard (no supernova present) image of the galaxy, and checked for a brightness increase in any one image element. We are using a dedicated PDP 11/44 mini-computer for controlling the CCD and telescope 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, uv, and gamma-ray spectra.



(XBC 8210-10486)

Fig. 18. Berkeley Supernova Search. The 36-inch MIRA telescope (Monterey Institute for Research in Astronomy) has been computer-automated and fit with a CCD imaging device. It will look at a new galaxy every eight seconds. A PDP 11/44 computer will analyze the image and look for supernovae in real time.

During calendar year 1982, the group began tests of the CCD camera on the Monterey Institute for Research in Astronomy's (MIRA) 36-inch optical telescope. The performance of the CCD, electronics, and optics were good, and no major changes are anticipated in the hardware. The group made regular trips to the telescope, collecting images of galaxies and stars for system optimization and testing. Last year saw the completion of many of the important routines for the detection of supernovae. Routines have been written for subtracting one image from another, storing reference images, finding centroids and widths of stellar images, and managing arrays of images in memory and



(XBC 820-9604)

Fig. 19. An image of the star cluster M-3 taken with the Berkeley CCD camera on the MIRA 36-inch telescope.

disk. These routines will be integrated during the first few months of 1983, and we hope to detect our first supernova in late spring or early summer of 1983.

### Research Staff

M. Shane Burns, Frank Crawford, George Gibson, Jordin Kare, Rich Muller, Carl Pennypacker, Robbie Smits, Roger Williams, John Yamada.

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## Cosmic Background Radiation Primordial Blackbody Radiation

### Angular Distribution/Anisotropy

Experimental observation of the angular anisotropy of the cosmic background radiation is continuing. In April 1982 our liquid-helium-cooled balloon-borne radiometer completed observations of the CBR anisotropy at 3-mm wavelength in the northern sky. The first order, or dipole, anisotropy measured previously at lower frequencies by our group and others is clearly evident in our data; higher order anisotropies that had been reported in lower frequency observations by other groups were not seen at 3 mm. Our results, published in Phys. Rev. Lett. (in press), show no significant higher order anisotropy.

The radiometer was taken to Brazil in November and flown to make measurements of the southern sky. The equipment, including the onboard data recorder, was unfortunately lost when the flight termination equipment failed. Some data may be recoverable from telemetry.

Work continues on experiments to measure the CBR anisotropy from the Cosmic Background Explorer (COBE) Satellite. The COBE project received its official "start" from NASA in October 1982; development of hardware and data analysis techniques is proceeding at LBL and other locations.

### Polarization

We have made 9 mm measurements of the polarization of the CBR and begun measurements at 30 mm. At 9 mm and 30 mm we see no polarization greater than $10^{-4}$. We are continuing measurements of the CBR polarization at 30 and 9 mm and expect to begin measuring at 3 mm. For 3 and 0.9 cm wavelengths the system noise seems to be the limiting factor, so that continued observation improves the measurement and sky survey.

### Spectrum

The group made measurements of the low frequency spectrum of the CBR on July 4 and 5, 1982 from the White Mountain High Altitude Research Station in California. The experiment is a collaboration of groups led by Giorgio Sironi (Milano, Italy), Reno Mandolesi (Bologna, Italy), Bruce Partridge (Haverford College, Pennsylvania), and George Smoot (Astrophysics Group, LBL).

The spectrum was measured at five wavelengths (12, 6.3, 3, 0.9, and 0.3 cm) in the Rayleigh-Jeans region, where, according to many theories, any distortion will be most readily observed. The three short wavelength radiometers were built at LBL; the other two were provided by the Italian groups. A sixth radiometer, used to measure the atmospheric emission at 3.2 cm, was built by the Haverford group.

Previous measurements in this wavelength region were made more than 12 years ago by several groups using different techniques. This experiment used new technology not available at that time, including wavelength-scaled, low-sidelobe corrugated antennas. This experiment suffered from fewer systematic errors

because it used a single liquid-helium-cooled calibrator for all five radiometers, and the calibration was referred to the front end of each radiometer.

No evidence for a distortion was seen. Furthermore, the temperature of the CBR was found to be consistent with the recent results in the infrared region by Woody and Richards.

The group plans to repeat the measurements with improved versions of the same radiometers during the summer of 1983. A new radiometer that can be continuously tuned in the region 2-15 cm, now under construction at LBL, will be added to provide better spectral coverage.

Research Staff

Giovanni De Amici, Jerry Epstein, Scott Friedman, John Gibson, Steve Levin, Phil Lubin, Philip Melese-d'Hospital, George Smoot, Chris Witebsky.

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## Ten Meter Telescope

The group working on the University of California's Ten Meter Telescope project (TMT) has been concentrating most of its efforts during 1982 on a technical demonstration prototype. The goals are to design, build, and test prototype components critical to the feasibility of the TMT. We will test the sensors, actuators, and the active segment control algorithm, as well as the passive support system for each segment. The full-size segment and reference mirror will be installed in a special telescope for this testing. The methods for the optical fabrication and testing of the segments are also being tested.

The fabrication of the control prototype is well underway. In mid-1982 a 1.9 meter diameter mirror blank was acquired. This blank is being ground and polished to a 10 meter radius of curvature sphere in collaboration with Tinsley Laboratories in Berkeley. Establishing and refining the optical testing procedures for this mirror occupied much of the second half of the year. The mirror will be cut into a hexagonal segment. Design and fabrication of the steel support structure is being carried out at LBL, the Space Sciences Laboratory of UC Berkeley, and Lick Observatory at UC Santa Cruz; it will be completed early in 1983. The mirror will be placed in the structure and most tests of the support and control systems completed by fall 1983.

Along with this effort, more general development of the design of the TMT itself and scientific instruments to be used with the telescope is proceeding. Funding for the project comes entirely from the University of California.

Project scientists are collaborating with Kitt Peak National Observatory to fabricate a large (2 meter) off-axis section of a parabolic mirror. This project is part of the National New Technology Telescope development, the results of which are directly applicable to the TMT.

A campaign to raise funds for the final design and construction of the TMT observatory is underway. Assuming the success of the campaign, the detailed design of the entire observatory will begin. This includes the telescope, the building and dome, the optical fabrication facilities, scientific instrumentation, etc.

Construction of the observatory is expected to begin in 1985 with the completion scheduled for 1989.

Research Staff

Michael Breen, Michael Budiansky, Dave Cudaback, Terry Mast, Jerry Nelson, Susan Ottke, Barbara Schaefer, Marc Temple-Raston, Richard Yang.

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## Determination of the Atmospheric $CO_2$ Budget

The rise in the atmospheric $CO_2$ 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 $CO_2$ is seriously impaired by the fact that the present $CO_2$ budget does not seem to be in balance. Very precise measurements of changes in the global atmospheric $O_2/N_2$ ratio in the course of a few years could provide the key to the solution of the "missing $CO_2$" problem.

An apparatus has been built that utilizes Raman scattering from a laser beam to make precise comparative measurements of the $O_2/N_2$ ratio in a sample and a standard. The scattering targets (air) are located inside the laser cavity. Interference filters match the spectral signatures of $O_2/N_2$. Coupled choppers rotating at about 50 Hz interchange the signal from sample and

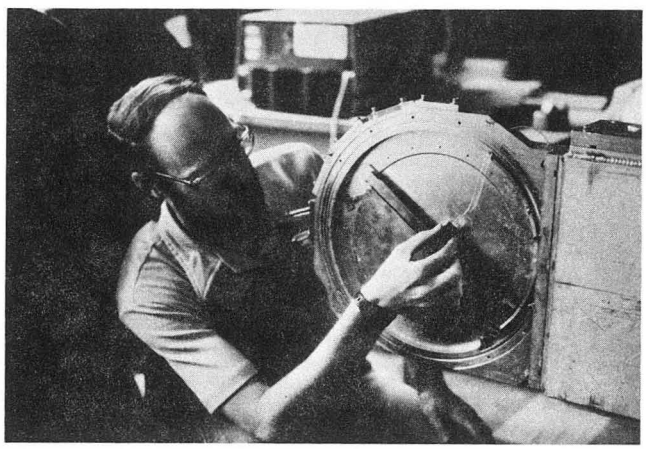
standard. We are presently working to obtain the required stability in the comparison of intensities to about one part in a million.

Research Staff

Dan Lashof, Pieter Tans.

## The Cyclotrino

A small low energy cyclotron, of 30 cm diameter and 50 keV energy, is being developed for the purpose of ultrasensitive detection of long-lived radioisotopes. Mass spectrometry using cyclotrons and tandem Van de Graaf accelerators has proven to be a far more sensitive means of detection of many long-lived radioisotopes than decay counting. Minimum sample sizes are in most cases more than two or three orders of magnitude smaller. $^{14}C$ ($t_{1/2}$ = 5770 years) has been measured by a high energy cyclotron in rain water, ice cores, and various sediments. $^{26}Al$ ($t_{1/2} = 0.72 \times 10^6$ years), $^{36}Cl$ ($t_{1/2} = 0.30 \times 10^6$ years), and $^{129}I$ ($t_{1/2} = 16 \times 10^6$ years) are other radioisotopes of interest. They have been measured to provide information about the cosmic ray bombardment history and terrestrial age of meteorites. $^{10}Be$ once deposited on the ocean floor and carried down into a subduction zone by the movement of continental plates has been detected in nearby volcanic deposits.



(CBB 837-6071)

Fig. 20. Graduate student Jim Welch inserting a filament ion source on the 12-inch cyclotrino. The cyclotrino has one "dee" visible behind Jim's hand. The gap is vertical, and the entire instrument slides between the pole tips of the NMR magnet visible behind Jim.

The unique advantage a cyclotron has over a conventional mass spectrometer is that the suppression of nearby masses is essentially total. Therefore, one can obtain a very low count rate of radioisotopes without significant background provided the mass resolution excludes the nearest masses. The cyclotrino will use this feature to perform particle identification. Unlike high energy accelerators, this low energy machine does not require massive radiation shielding, high magnetic fields, or a large magnet; and it will be dedicated solely to radioisotope measurements.

At the present time a beam of $^{14}N$ positive ions has been accelerated to the extraction radius with reasonably good transmission. After the deflector is built, the mass resolution and suppression of non-resonant masses can be measured.

Research Staff

Peter Friedman, Don Morris, Richard Muller, Jim Welch

# Detector and Other Research and Development

## R&D Using TPC Concept

The technique of drifting ionization over long distances used in the PEP-4 TPC finds natural extension in attempting several new experiments. A group of physicists who collaborate on the PEP-4 TPC is also carrying on an active program of research and development extending TPC concepts to new regimes.

### Gated Time Projection Chambers

Because of their long drift distance, TPCs are susceptible to the buildup of positive ion clouds in the drift volume, where the charge clouds can lead to serious track distortions.

The group has continued its previous work on the suppression of positive ions by gating the TPC. By

pulsing a gating grid with hundred-volt pulses, the TPC is turned on only for interesting events. The generation and collection of positive ions in inhibited at all other times. An additional shielding grid protects the electronics during the switching of the gate.

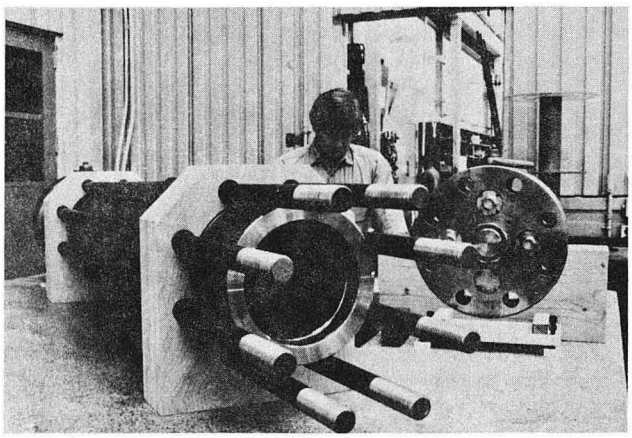
The practicality of such a "tetrode" gating scheme was demonstrated by successfully operating a fully instrumented spare sector of the PEP-4 TPC in the gated mode.

The gating system will be installed on the PEP-4 TPC in the summer of 1983. It should reduce track distortions from positive ions by several orders of magnitude. Besides improving the performance of TPC at $e^+e^-$ machines, gated operation opens up the application of TPC to high rate hadronic experiments.

## Muon Neutrino Mass: The Tracking Imaging Cerenkov Counter

There is a great deal of interest, theoretical, experimental, and astrophysical, in the possibility of nonzero neutrino masses. An experiment to improve significantly the muon neutrino mass limit, now equal to the electron mass, has been developed by the group.

The experiment requires a new kind of differential Cerenkov counter, combining several technologies, to do a very precise measurement of the pion and muon velocity in forward $\pi^+ \rightarrow \mu^+ \nu$ decay in a 2 GeV/c pion beam. Such a device, the multisegment Tracking Imaging Cerenkov Counter (TRICC), has been designed. The essential new ingredient is a Time Projection Chamber inside the Cerenkov Counter, for measuring particle trajectories without obscuring the Cerenkov light. Position sensitive image intensifiers detect the Cerenkov photons, and chromatically correcting optics cancel the optical dispersion of the Cerenkov medium.



(CBB 820-9351)

Fig. 21. Garth Smith working with the 500 atmosphere pressure vessel for the high density TPC test stand.

The construction of a single segment prototype TRICC has been started. The pressure vessel for the 20-atmosphere $H_2$ Cerenkov counter has been nearly completed. The first of the TPC stations for the prototype is undergoing testing, the TPC electronics are being constructed. An image intensifier has been procured and the optical design of the prototype lens-mirror system has been completed. The optical elements remain to be built.

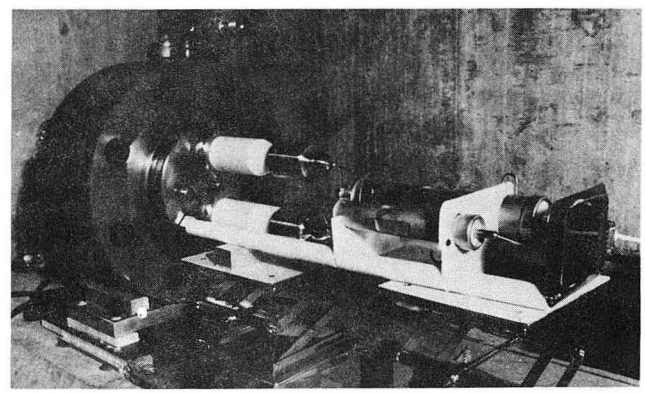
Completion of the prototype TRICC and velocity resolution measurements in a BNL test beam are planned for 1983. A letter of intent to do the experiment has been written to Brookhaven National Laboratory.

## New Proton Decay Detector: Higher Density TPC

The group is attempting to develop an ultra high pressure TPC as a way to obtain a dense and massive nucleon decay detector capable of identifying and measuring the energies of all possible nucleon decay products except neutrinos. The detector would operate in hydrostatic equilibrium deep in the ocean, or in a pressurized deep underground cavern.

A high pressure test stand (Fig. 21) with a volume of 60 liters and a pressure rating of 500 atmospheres has been built and is being utilized to study proportional multiplication vs. pressure for several test cells. The gas purification necessary to achieve long drifts at such pressures is being investigated.

If proportional multiplication at densities higher than 0.5 g/cm$^3$ can be achieved, and if meter-long drift distances are possible with tolerable electron capture, then this development work should lead to a proposal for a detector of 10 kilotons capable of setting lifetime



(CBB 832-1625)

Fig. 22. Pressure vessel endcap with high voltage feedthrough and proportional tubes for the first high density experiment.

limits greater than $10^{33}$ years for all decay modes, or studying all the nucleon decay modes, should the lifetime be shorter than $10^{33}$ years.

Research Staff

Lazlo Baksay, Peter Nemethy, Piermaria J. Oddone, William Wenzel.

Publications

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## TOPAZ TPC R&D

We have been engaged in a program of R&D for the TOPAZ detector to be operated at KEK in Japan. This work is part of a collaborative effort involving the Physics Division, KEK, and the University of Tokyo. The purpose of the R&D effort is to focus on several potential problem areas in the design of a TPC for the TOPAZ detector. We have modified an early prototype of a PEP-4 endplane sector so that it approximates the TOPAZ geometry by having, as its last wire, a wire of 1-meter length. Tests of electrostatic stability with this prototype showed it to be stable at wire gain far in excess of its design operating point. We have also been investigating the problems associated with the use of a pulsed grid on the modified sector. This grid is supposed to decrease the positive ion current which reaches the main body of the TPC from the endplane sectors. The idea is known to work in principle. However, a practical design tailored to a real endplane sector has yet to be demonstrated. The problem is to deliver the required pulses to the grid wires by means of a distribution network that can fit within physical constraints imposed by a desire to minimize dead space in the detector. This network must not couple so strongly to the sense-wire electronics as to saturate them. We have been systematically investigating a prototype of such a distribution network. In addition, we have had fabricated a drift region of 30 cm drift length with field cages of the PEP-4 design to investigate electrostatic distortions of the drift field. This drift region is tailored to the modified PEP-4 sector prototype. In order to test this whole system, we have also modified the test tank originally used for PEP-4 sector tests to accommodate the new source, which will allow us to do the time resolved measurements needed in distortion studies.

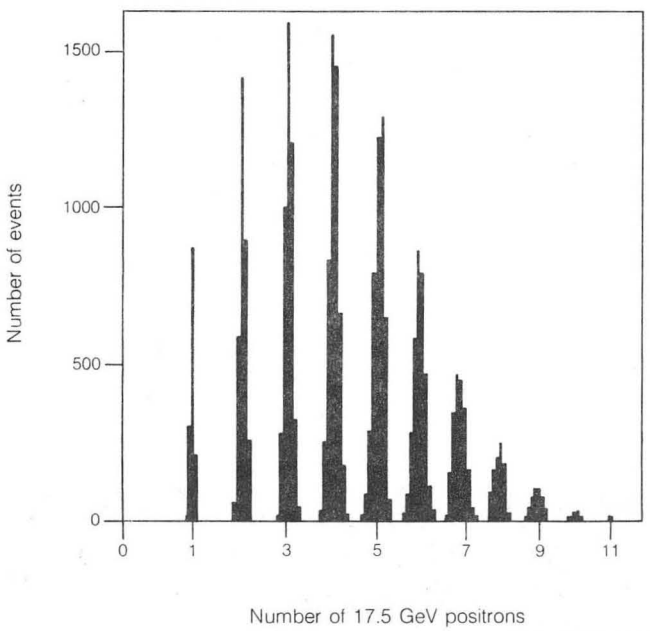
Research Staff

F. Fuzesy, P. Robrish, F. Rouse, H. Spieler.

# Electron-Photon Calorimetry

## Saturated Avalanche Calorimeters

During FY 1982 a paper was completed (see Publication below) describing a new mode of operation of wire calorimeters: the saturated avalanche mode. In this mode the sampling tubes are operated at a gas gain very much higher than in the conventional proportional mode, so high that space charge saturation suppresses




(XBL 837-2833)

Fig. 23. This figure shows the detector response to multiple positrons of 17.5 GeV. It shows that for as many as 11 simultaneous positrons the energy resolution of the detector is sufficiently good to resolve them with clear minima between the peaks of the pulse height distributions for the corresponding numbers of positrons.

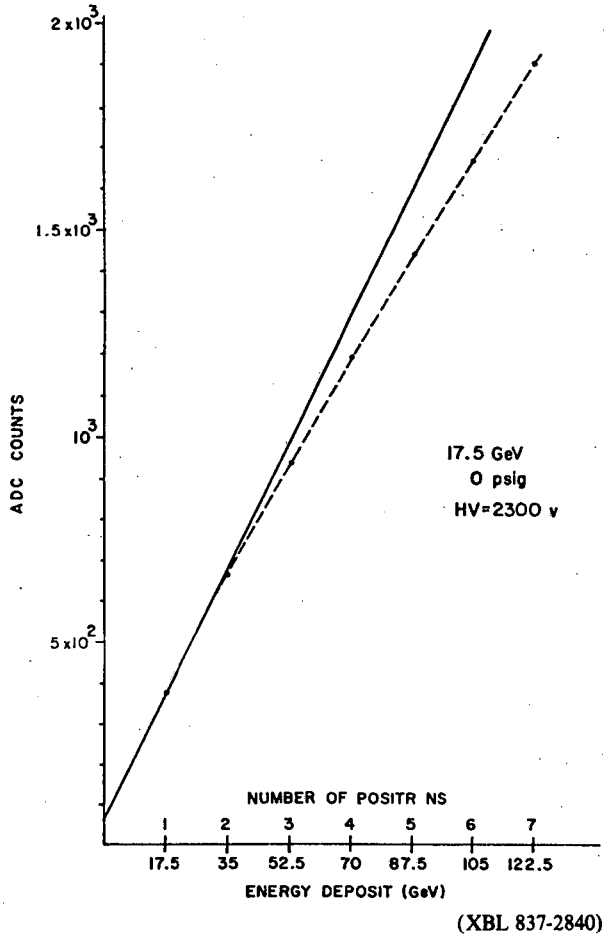



Fig. 24. The pulse heights for the multiple positrons deviate in a smooth way from linear behavior for more than a two-positron (35-GeV) shower, as seen in this figure.

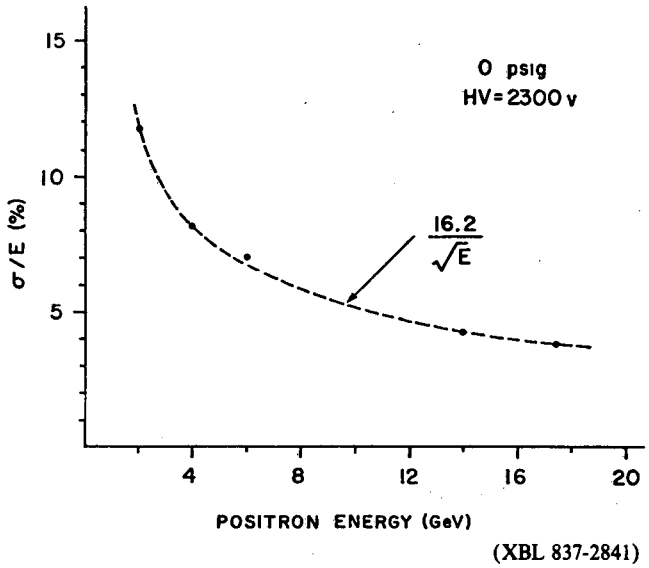



Fig. 25. The energy resolution as a function of energy for single incident protons.

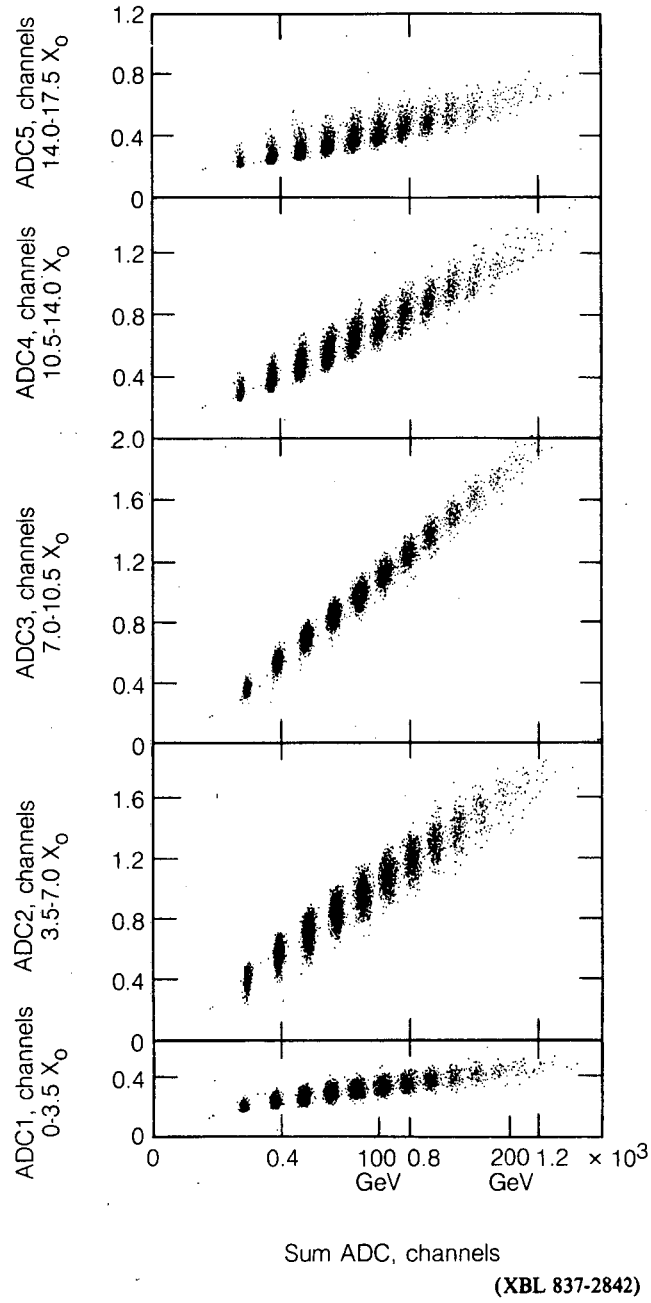



Fig. 26. Scatter plots of each of the five distributions vs the sum of the outputs of the five ADCs. Distinct clusters of data points are clearly seen in each plot, showing the response to as many as 13 positrons simultaneously incident on the calorimeter segments.

the deleterious fluctuations of energy deposit due to delta rays (the Landau effect). This improves the energy resolution somewhat. A perhaps more significant advantage is that the signal level is much higher, so that in many applications there should be no need for preamplifiers on each channel.

### Drift Calorimeter Studies

Considerable progress was achieved in the study of a single plane of an electrodeless drift calorimeter. In this scheme, each plane, perhaps as long as 1 meter, can be read out with a single wire, and the shower location accurately determined by the measured drift time. In fact, the complete drift time history is available for possible signal processing, which may improve both position and energy resolution. The planar chamber was tested with a beta source ($^{106}$Ru) and a scintillation counter telescope to achieve very stable track drifting with ~100% efficiency up to 50 cm. Drifting over longer distances was clearly possible. Conceptual solutions have been developed to solve the problem of "overcharging" of the insulating planar surfaces by positive ions which seems to occur after a certain operating time. These ideas can be tested in future studies, as well as other solutions developed to allow correct drifting in the presence of an arbitrary magnetic field and with arbitrary (nonplanar) geometries.

#### Publication

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#### Research Staff

John Kadyk, Paul Sheldon.

## High Resolution Vertex Detector Development

Work has continued on device studies for high-resolution sampling solid-state detectors. Two separate approaches have been studied. One involves the use of monolithic CCD area imagers as particle detectors. The other uses a hybrid CCD technology.

Detailed studies of Texas Instruments virtual phase charge coupled devices have proceeded. Two devices have been studied, one in a 200×200 element format and one in an 800×800 element format. Both devices have been shown to be sensitive to minimum ionizing radiation, giving a signal level of approximately 900 electrons for a single track. A high speed/low noise amplifier, coupled with a correlated sample-and-hold system has been completed that will allow for clocking rates in excess of 10 megapixels/sec. Noise floor measurements with the 800×800 element device indicate a floor of approximately 70 electrons. This number is quite high (30 electrons should be attainable) and is directly attributable to a device fabrication problem. Texas Instruments is aware of this and is working on a solution. We have also made measurements indicating that larger signals for minimum ionizing tracks can be obtained (5× increase) by building the CCDs on thicker epitaxial layers (50 $\mu$m instead of 10 $\mu$m).

In a collaborative effort with a group from SLAC, a CCD particle tracking telescope system is now near completion. Beam studies using this system will be carried out at SLAC. The first tests will involve the TI 800×800 element device. The system can accommodate up to five detectors.

Studies of hybrid CCD detectors (Rockwell International 32×32 element array) have also continued. In this case, a CCD multiplexer is coupled to a high resolution silicon detector via microscopic metallic contacts. Charge is injected into the CCD, and the CCD is then used as a readout structure. We have studied the charge injection operation of the Rockwell device and made noise floor measurements. The present device has been optimized for large signal operation (up to $10^7$ electrons) and does not appear to be adequate for single particle detection. However, the general hybrid approach shows much promise for particle detectors and work will continue with existing devices and on the possible development of a new device optimized for HEP applications.

#### Research Staff

A. Bross.

## Monopole Search

The Physics Division project to look for monopoles has progressed. A detector using cylindrical modules has been sketched. It would have the properties of a hodoscope that could reconstruct a monopole trajectory within one millimeter. The redundancy of such apparatus would be much higher than any existing detector of monopoles so far.

To justify the usefulness of such a search, some published astrophysical limits to the monopole flux in our galaxy have been re-examined and found not valid.

#### Research Staff

P.H. Eberhard.

#### Publications

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Comments at the Monopole Workshop, Wingspread, October 1982, P.H. Eberhard. Physics Note 952 (1982).

## NMR Imaging

A new technique of point sensitive NMR imaging has been suggested. A patent application has been filed in Washington.

Research Staff

P. Eberhard, R. Smits.

## Gas-Filled Detectors

Development work was done on various types of radiation detectors. Emphasis was on gas-filled multi-electrode devices, but some work was also done on new types of solid detectors. While the primary application of these detectors was in high energy and nuclear physics, they also found application in medical physics and in x-ray diffractometry.

### Self Quenched Streamers

Investigations of this high gain mode of wire chamber operation were carried out to determine the effects of gas composition, pressure, and chamber geometry. The high avalanche gain in the streamer mode makes it possible for wire chambers to be read out without the use of expensive amplifiers, while the saturated nature of the signals makes their employment for digital sampling in calorimetry attractive.

### Gas Sampling Calorimetry

Design studies of a drift collection calorimeter, in which the radiator and drift field shaping structure are combined in the form of lead glass tubing, were done using Monte Carlo shower simulation in cooperation with W. R. Nelson (SLAC). A highly resistive metallic layer is formed inside the tubing by surface reduction of the lead oxide in the glass. This process, originally developed for our medical work on positron emission tomography, results in a very uniform field shaping structure, allowing the efficient drifting of electrons to the detection wire chamber.

### Non-Crystalline Solid State Detectors

A program was initiated to investigate the possible use of non-crystalline materials as solid state radiation detectors. Such detectors would not suffer from the size limitations imposed by the necessity of using single crystals of material as in conventional devices. Literature searches and preliminary calculations were made in preparation for experimental work on such substances as chalcogenide glasses and metal oxide films.

### Application Other than High Energy and Nuclear Physics

Work on the application of gas filled detectors to biomedical problems was continued. Improvements were made in the fused lead glass tube converters incorporated in wire chambers used for positron emission tomography. Work also continued on the development of computer codes to reconstruct the distribution of the radioisotope within the sample being scanned.

Improvements were made on gas filled linear chambers to be used in x-ray scattering measurements. In cooperation with the materials science group of C. N. Wagner (UCLA) a linear chamber having a curved anode, to eliminate parallax error was developed. The curved anode geometry is achieved by orbiting the anode wire in a magnetic field. Delay line readout provides spatial resolution in the 100 $\mu$m range.

Research Staff

A. Del Guerra, D. Feinberg, S. N. Kaplan, T. Mulera, V. Perez-Mendez, G. Schwartz, B. Sleaford, P. Wiedenbeck

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Quantitative Computer Graphics Displays of Cardiac CT Scans, D. Feinberg, R. Palmer, P. Wiedenbeck, V. Perez-Mendez, E. Carlson, IEEE Trans. Computers, to be published.

# Publications and Reports of Other Research

## X Rays from Pionic Deuterium

In an on-going experiment at TRIUMF in collaboration with the George Beer group at the University of Victoria, we have observed and made preliminary measurements of the $\pi$–d $K_\alpha$ x rays. The object of the experiment is to measure the critical absorption of the x rays in a foil of Bi in order to make a precise determination of the x-ray energy.

Research Staff

C. Wiegand.

Publications

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# Computation and Communication

To provide computation facilities for the high energy physics program, the Division has installed computer systems at LBL and has developed a high speed microwave system between LBL and SLAC.

A VAX 11/780 computer system is used for off-line analysis of data from the TPC and from other experiments. In addition, the facilities are used for program development, general computation and for the development and testing of detectors. During 1982, additional disk capacity was added to provide a total of 1.3 gigabytes of mass storage. Three high-density tape drives are used for the processing of experimental data.

As part of its collaboration on the TPC project, the University of Tokyo has installed a VAX 11/780 at LBL. The system has been integrated into the LBL local-area-network and LBL staff provides system programming support.

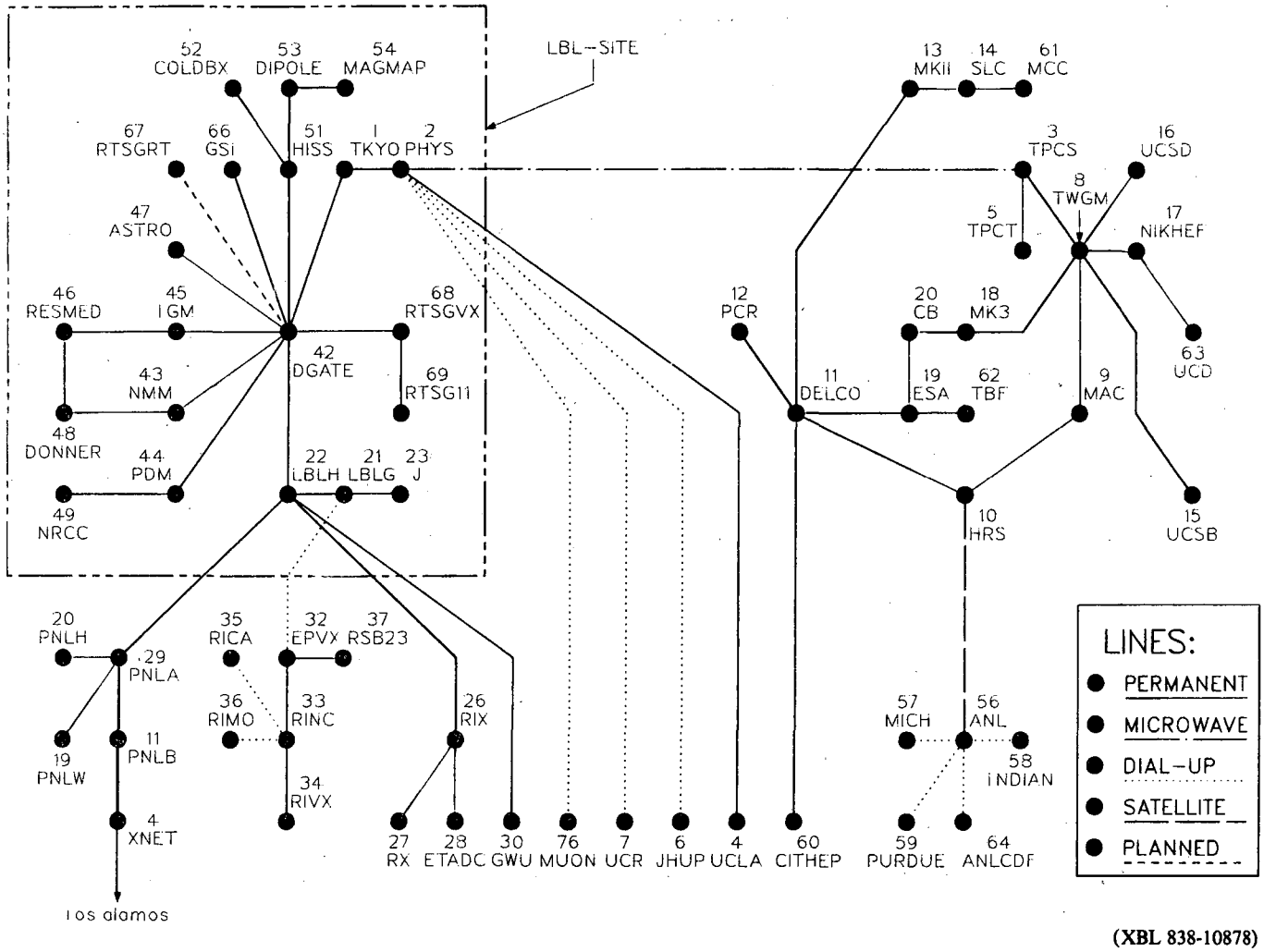
The physics computing is closely coordinated with the LBL Computer Department. Physicists use VAX systems within the Computer Center and the Center has added high-density tape drives to these systems to meet the requirements of the Physics Division. Interactive computing is provided through the Center's Develcon switch. Computer network hardware and Decnet software are used to link computers at LBL, at PEP, and at a number of universities where groups are collaborating on PEP experiments.

A new VAX 11/750 computer was purchased during 1982. This system is installed at TRIUMF as part of the muon decay experiment. The smaller VAX system runs programs developed on the Division's VAX 11/780 and provides extremely valuable feedback on the performance of the experiment. After its service at TRIUMF, the computer will be moved to Fermilab as part of the Tevatron muon program.

The microwave communication system links LBL and SLAC to provide high-speed computer-to-computer networking, terminal-to-computer communication, and voice lines. In addition, a TV conferencing facility is provided, with two rooms at SLAC and three at LBL.

Research Staff

S. C. Loken, E. Whipple.




(XBL 838-10878)

Fig. 27. Schematic diagram of LBL computer network showing microwave link to SLAC and connections to computers throughout the U.S.

# Engineering, Evaluation and Support Operations

Instruments, detectors and instrumentation systems that meet specific as well as general applications are continually being designed and developed. Commercially available devices and instruments are continually evaluated. Operating manuals are supplied, and maintenance and support of instruments and instrumentation systems are provided by our support operations. 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 has been a continuing activity since 1976. A new system was configured using parts from previous experiments and fabricating new time digitizer boards. This system will digitize signals from several hundred signal channels in both the charge and time mode.

## Multiwire Proportional Chambers

Several new multiwire proportional chamber (MWPC) systems have been constructed and installed this past year. Costs for some of these systems are kept low by using boards from previous experiments. Ongoing technical support of the MWPC systems in the field is provided.

## Hybrid CCD Solid State Detector

The second phase for the CCD detector is completed. The hybrid CCD solid state detector will be used as a high-resolution, position-sensitive target for neutral-beam, high energy experiments. Sample-and-hold boards and their control boards have been designed.

## Mark II Drift Chamber Electronics

Electronics for a new drift chamber to be used with Mark II is being developed. LBL is responsible for the dE/dx electronics and its associated trigger and calibration systems. Much of the prototype electronics have been designed. Continued development will extend into FY 1984.

## Technical Support and Pool Operations

Services are provided in connection with all electronic instruments used in Physics Division programs, both on site and off site, on a continuing basis. Repair and maintenance of electronic equipment and systems, maintaining inventory records, arranging temporary loans among research groups, procurement of new equipment, and providing operating manuals and consulting on all aspects of instruments and detectors are the types of devices rendered. The base of the equipment pool is enhanced by coordinating it with those serving other LBL divisions.

Research Staff

G. A. Constantian, E. J. Lampo, A. E. Larsh, K. L. Lee, B. Leskovar, C. C. Lo, M. Nakamura, C. Nunnally, S. R. Olson.

Publications

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# THEORETICAL PHYSICS

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# THEORETICAL PHYSICS RESEARCH

## Particle Physics

The research of the Theoretical Particle Physics Group ranges from supergravity to proton-proton elastic scattering. Most of the work in 1982 fell into one of four categories: supersymmetry, nonperturbative field theory, electroweak interactions, and general phenomenology. Much of this work, even that in supersymmetry, had a connection to the Laboratory's experimental program. In addition, members of the Theoretical Group participated in workshops both at LBL and elsewhere, dedicated to consideration of future machines and detectors in high energy physics. The research effort of the group involves collaborations of staff, faculty, postdoctoral associates, students, and visitors.

### Supersymmetry

Should supersymmetry turn out to be applicable to particle physics at energies below 100 GeV, there should be found bosonic partners of the known fermions. Tests for these and other manifestations of supersymmetry at available energies have been investigated for $e^+e^-$ collisions, for neutral current phenomena, and for the decay $K^+ \to \pi^+ \tilde{\gamma}\tilde{\gamma}$. It had been difficult to construct phenomenologically viable models. It has been shown, however, that this is possible in an $SU(2) \times U(1) \times \tilde{U}(1)$ which is anomaly free. Other constraints on supersymmetric models have been derived from cosmology and from experimental limits on parity violation in nuclear transitions. Constraints on models that attempt to generate large hierarchies by radiative corrections have also been found.

If supersymmetry is a symmetry of nature, it might be a global symmetry, like isospin, or a local symmetry like gauge invariance in electromagnetism. Local supersymmetry is interesting both because it provides a means of unifying gravity with the other forces and because it may help us understand the especially difficult problem of supersymmetry breaking. Much of the most recent work in the group focuses on this latter aspect.

Superspace in light-cone coordinates takes a simple form, and generalization to extended supersymmetries is straightforward. By applying the method to the $N = 4$ model, it was shown that there are no divergences in gauge-invariant quantities in any order of perturbation theory.

### Nonperturbative Field Theory

While quantum chromodynamics is presently accepted as the theory of strong interactions, it remains to find an effective means of computing its predictions for the fundamental quantities of interest such as hadron masses. It is possible to treat the problem with Monte Carlo methods. The primary investigations during the past year have been instead focused on SU(N) theories for large N, rather than on SU(3)-color. These theories have a simplicity that is absent in the SU(3) theory. The relevant expectation values can be computed from a master field and the fluctuations in the results decrease as $1/N$.

Nonperturbative methods have been used to study Polyakov's new string model as a model for the confining potential of QCD. This work is motivated by the SU(N) Yang-Mills theories at large distances.

### Electroweak Theory

Conventional electroweak interaction theory is based on the $SU(2) \times U(1)$ gauge group. While this orthodoxy is so well established that the physics of the yet-to-be-discovered intermediate vector bosons can already be the subject of a review article, the properties of the Higgs boson associated with spontaneous symmetry breaking are subject to greater uncertainties. Indeed, the Higgs boson, in certain circumstances might decay predominantly into undetectable modes. A theory of electroweak interactions similar to, but not identical with the conventional one emerges from the topological approach. It differs in that there are eight vector bosons instead of four, and $\sin^2\theta$ is predicted to be 0.25 rather than 0.21. Such specific predictions may provide a means for distinguishing between the two approaches.

### General Phenomenology

The Theoretical Group continues to direct much of its research towards problems of direct interest to experimenters, especially those at LBL. With the glueball perhaps nearing canonization by the Particle Data Group, it became interesting to consider the possibility that there may be hadrons whose fundamental constituents include both gluons and quarks. These hadrons are called meiktons. The physics of high energy $p\bar{p}$

colliders has also been reviewed at some length. Efforts have been directed, as well, at the physics of machines further in the future, including TeV linear colliders.

## Miscellaneous

Additional research was conducted on fundamental aspects of quantum theory, especially the Einstein-Podolsky-Rosen paradox and the infrared problem.

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# Heavy Ion Fusion

The LBL program in Heavy Ion Fusion is administered through the AFRD Division; general descriptions of this activity are given in the annual reports of that division. The major activities of the PCSM Division's research staff person working in this program were in three areas in 1982.

1. It is currently agreed that the first major step in the U.S. HIF program should be an investment of over 50 million dollars in an accelerator capable of delivering enough energy and power to a small amount of material to create a plasma with electron temperature between 50 and 100 eV. The purpose is to learn about the associated accelerator problems, to provide a facility for study of the energy deposition mechanism, and to verify or modify the complex calculations that predict plasma behavior under such conditions. Calculations made at LLNL provide requirements for accelerator performance. The work reported here, done partly in collaboration with LLNL, has contributed to this activity in several ways. Advice has been provided to LLNL on parameter selection compatible with feasible accelerator design. For example, Liouville's theorem requires that the six-dimensional phase space volume containing the accelerator beam must be less than that required by target and focusing demands. Work performed in 1978 for rf linac systems, and extended in 1981-1982 to include induction linac systems, led to formulas for phase space ratios; these have been used in sorting through a number of engineering cost optimization calculations to find the most promising induction linac properties for the high-temperature facility mentioned above. The problems of geometrical and physical design of arranging a largish number of beam lines to converge on the target have been studied. A start has been made on applying the phase constraint, and others, to design of rf linac systems using storage rings for the proposed facility.

2. About a year ago a claim was made that a type of coaxial-cylinder electrostatic alternating-gradient transport system for annular (hollow) beams could provide a much greater current-carrying capacity than a conventional quadrupole system. A detailed analysis of such systems was made; they appear to offer no significant advantage.

3. A proposal was made and studied in Europe, and also examined at LBL, to use for the high-temperature spot-heating facility mentioned above a system for employing an isochronous cyclotron-like storage ring, fed by an rf linac, in which the voltage gain per turn decreases with increasing radius. It was hoped to achieve the needed current amplification by having the successive injected turns pile up at the outer radius of the ring. Some detailed work was done on two aspects of such systems. First, a possible magnet design for the ring, with certain desirable properties, was developed. Then the impact of Liouville's theorem on the hoped-for pile-up was developed. This phase space constraint appears to be a serious one for the range of parameters proposed.

Research Staff

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# COMPUTER SCIENCE AND MATHEMATICS

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# COMPUTER SCIENCE AND MATHEMATICS

The Computer Science and Mathematics (CSAM) Department conducts basic and applied research in mathematics, computer science and statistics. Research in mathematics concentrates on applied analysis, computational mathematics, and numerical methods for partial differential equations. Statistics research focuses on the the analysis of ecologic data: data that exists in summary form. The problems addressed are the development of statistically valid data extrapolation and projection techniques. The computer science research addresses four areas: data management, database machines, distributed systems and networks, and graphics.

Funding for basic research is provided by the Applied Mathematical Sciences (AMS) research program and the Office of Health and Environmental Research (OHER) in the Office of Energy Research, DOE. Funding is also provided for research, development and demonstration projects by other federal agencies, including the U. S. Department of Labor Employment and Training Administration, the Army Corps of Engineers, the Defense Nuclear Agency, and the Defense Advanced Research Projects Agency. The combination of basic research with practical prototype projects and applications provides a base for innovative solutions to research problems in information systems development, computer networking, epidemiological studies, and the application of numerical methods to energy technology. During 1982 the projects undertaken included continued demonstration and development of a distributed information system containing extensive socio-economic, environmental, and demographic data (SEEDIS/DCN); design issues for a seismic data center (DARPA Center for Seismic Studies, CSS); and upgrade of research computing facilities supporting the department's basic research.

The CSAM staff is comprised of over 50 computer scientists, mathematicians, engineers, computer technicians, and administrative personnel. UC Berkeley and UC San Francisco faculty, postdoctoral research associates, and graduate students are an integral part of the research staff.

CSAM sponsors workshops, colloquia and seminars and provides supervision of graduate students in the master's and doctoral programs in mathematics, statistics, and computer science at UC Berkeley.

During 1982 the Department hosted the Sixth Berkeley Workshop on Distributed Data Management and Computer Networks and began planning for the Second International Workshop on Statistical Database Management, to be held in September, 1983. Other meetings hosted during 1982 included the ANSI Committee on Computer Graphics Programming Languages, and several local user group meetings of DECUS (the Digital Equipment Corporation Computer Users Group.)

## Mathematics

Research in mathematics includes the areas of applied analysis, computational mathematics, and numerical methods for partial differential equations. The staff also provides limited consulting services and supervises the LBL Computer Center mathematical software library.

### Applied Analysis

#### Capillarity Phenomena

The work in capillarity phenomena is concerned with questions of the existence, stability, and qualitative behavior of solutions of the governing nonlinear elliptic partial differential equations. New analytical results were obtained for the discontinuous behavior of capillary free surfaces. A subsidiary variational problem was developed that reduces the question of existence of a capillary free surface in a cylinder to a lower dimensional one of whether curves having certain properties can be found in a section of the cylinder. These curves forming the minimizing set of the subsidiary variational problem are circular arcs that intersect the cylinder boundary with the prescribed contact angle. With them

a promising technique arises for developing new and sharper theorems on the transition from existence to nonexistence for solutions of the capillary problem in the absence of gravity. These mathematical results continue to interact with the design in progress of a NASA Spacelab experiment for testing the theoretical predictions.

A nondifferentiable penalty-function method was developed for the mathematical analysis of variational problems, such as the capillary free surface problem, with a volume constraint. The method permits the volume constraint to be neglected over a range of the Lagrange multiplier parameter, thereby putting the problem into the range of analytical methods applicable to variational problems that are unrestricted. Numerical computations for the meniscus in a circular cylindrical container and for rotating liquid drops indicate that the method holds promise as a technique for yielding useful mathematical results.

### Inverse Problems

#### Reconstruction of the Density of the Earth from Free Oscillation Data

This work uses the frequencies of the fundamentals and overtones of the earth's free oscillations to determine the velocity of the waves and the density in the upper mantle. The last year has seen the development of a stable algorithm for solving the inverse problem for the mantle of the earth. By using the eigenfrequencies from two torsional spectra, one can determine the density and the velocity of the S-waves in the upper mantle provided the density and the velocity in the lower mantle are known. Numerical experiments indicate that the overtones with the lowest angular order lead to the most accurate results. In addition, a mathematical theory for inverse problems with one discontinuity has been developed and applied to the inverse problem for the torsional modes of the mantle.

#### Image Reconstruction from Projections

This work is directed toward developing optimal numerical schemes and understanding the mathematical constraints on different forms of tomography, with special emphasis on the effects of limiting the number or range of the directions defining the projections. The goal is a quantitative prediction of the quality of a reconstructed image as a function of the projection data (the quality as a function of radiation dose in the case of x-ray tomography).

The problem of optimal choice of the directions on the sphere for the purpose of reconstruction of a function from plane integrals has been investigated. It has been verified experimentally that choosing the directions to be the equilibrium configuration of an array of M electrons attached to the surface of the sphere gives close to an optimal choice for M directions. The problem of computing the spectral decomposition of an integral operator has been studied for geometries more complicated than those previously reported. This problem is made numerically manageable by producing analytically a second-order differential operator that commutes with the integral one. The classical results cover the Euclidean case but the tomographic application deals with functions on the sphere. A connection has been found between geometries for which such operators exist and special solutions of the Korteweg-de Vries equation.

## Computational Mathematics

### Elliptic Partial Differential Equations

Work continued on developing block preconditionings for the conjugate gradient method. For the case of linear systems arising from discretization of elliptic equations in two dimensions, extensive comparisons were made between different types of incomplete block Cholesky factorization preconditionings and commonly used point preconditionings. It was found for a typical class of test problems that the block preconditionings consistently gave faster convergence, in terms of number of iterations and computer time, than the point ones for the same amount of storage. A new block preconditioning INV based on a special property of inverses of tridiagonal matrices was found to be approximately twice as efficient on test problems as the frequently used incomplete Cholesky point preconditioning. Extensions to three dimensions are being initiated.

### Dynamical Theory of Tridiagonal Matrices

To find the eigenvalues of a symmetric matrix the standard technique is to transform the matrix to a tridiagonal form and then use the QR method with shifts to calculate the eigenvalues. A new approach has been developed recently in connection with the dynamical theory of tridiagonal matrices. One constructs a system of ordinary differential equations whose solution corresponds to the evolution over time of a tridiagonal matrix. The flow defined by this system has the properties that the eigenvalues of the matrix are independent of time, i.e., the flow is isospectral, and the off-diagonal elements of the matrix go to zero as the time approaches infinity. Consequently, the matrix converges to a diagonal matrix consisting of the eigenvalues of the initial matrix. This system of equations was introduced by Flaschka to study the Toda lattice of statistical mechanics and was further analyzed by Moser.

A general framework for the eigenvalue problem has been developed for real symmetric band matrices. There exists an isospectral flow corresponding to each real function defined on the spectrum of the matrix. Under this flow the matrix converges exponentially to a diagonal matrix as time approaches infinity. Toda flow and the QR method without shifts are special cases of this framework; the evaluations of the matrix at integer times are identical to the successive iterations of the QR method.

The system of equations of the generalized framework can be solved explicitly for the matrix at any time by means of a QR factorization. This explicit integrability was shown to be a consequence of a generalized Liouville's theorem. It was shown that a change of variables can be made such that the flow is linear in terms of the new variables. The existence of these variables involves the solution of an inverse spectral problem for band matrices. The algorithm for this inverse problem has been used also to solve a submatrix problem for Jacobi matrices.

# Numerical Methods for Partial Differential Equations

## Vortex Dynamics and Turbulence

Research in vortex dynamics and turbulence concerns numerical methods for low Mach number, high Reynolds number flow in two and three dimensions. Of central interest is the vortex method, which represents vorticity as discrete elements that are transported within the fluid. The coalescing and stretching of the vortex elements in a computation simulate in a natural manner physically observed fluid motion.

Work in vortex dynamics in 1982 encompassed four different areas: 1) development of computer codes to model numerically high Reynolds number turbulent flow in a variety of physical situations, 2) creation of more efficient algorithms to model vortex dynamics, 3) numerical investigations into questions of accuracy and consistency for higher order vortex methods, and 4) theoretical studies of vortex instability and blowup.

A series of numerical models for high Reynolds number flow were developed utilizing a combination of the techniques of random vortex blobs and vortex sheets developed at LBL. Applied to the problem of a swirling viscous flow inside a closed rectangle, the results of numerical simulations clearly show the growth and development of counterrotating eddies in the corners, and the mechanism by which small eddies grow, coalesce, and diffuse downstream. In another experiment, the development of flow in a planar turbulent jet was modeled with highly successful results, detailing the formation and structure of the flow around the inlet. A technique for extending vortex methods through the Boussinesq approximation to include bouyantly driven flows was developed, and applied to the problem of the convection of a thermal.

An efficient and accurate algorithm for computing the velocity field produced by vortex elements was developed using fast Poisson solvers and local correction methods; this technique removes a restriction on the speed of the calculation that handicapped earlier formulations. In addition, fast Poisson solvers were used to devise a direct method for performing the Hodge decomposition of a vector field. Together, these two techniques substantially decrease the amount of labor required for vortex calculations.

Extensive numerical calculations were performed to test higher order spatial schemes for modeling vortex dynamics. These tests numerically verified the theoretical conclusions, which showed that by altering the form of the cutoff associated with the vortex core, higher order accuracy could be achieved with little extra cost. In addition, careful numerical studies of the advantages of higher order time integration techniques were made, with the conclusion that while more accurate methods are highly desirable for solving the ordinary differential equations associated with the motion of vortex blobs, they prove unnecessary for the vortex sheet calculation.

The question of instability in incompressible flow and the transition to turbulence continues to receive a great amount of attention. Three dimensional vortex methods were used to look at the evolution of a vortex filament, with the goal of analyzing the finite time breakdown of Euler's equations; one possible outcome of this work is the discovery of the self-similar energy cascades and vortex stretching that are believed to characterize three-dimensional incompressible turbulence. To study the transition to turbulence of parallel shear flow, a combination of asymptotic analysis and numerical methods was used to model the nonlinear evolution of vortex sheets. In addition, work continued in the study of higher order accurate vortex methods in two and three dimensions.

Reduction of numerical noise in the vortex-blobs and vortex-sheets method through better random number generators and better ODE solvers was achieved. These improvements should permit calculation closer to the values of the critical Reynolds number for boundary layer instability.

## High Resolution Methods for Hyperbolic Equations

Research in high resolution methods for hyperbolic equations concerns the development of accurate and robust numerical methods for problems whose solu-

tions have discontinuities. These methods are based on the incorporation of analytical solution elements into the numerical algorithms. Practical applications are to gas dynamics, flow through porous media, and combustion.

Work continued on the higher order Godunov methods. A second order Godunov method was developed for nonideal gases. The treatment of the equation of state has been substantially improved over previous algorithms. It is no longer necessary to require that the internal energy be locally a function of temperature; in the current algorithm, any convex equation of state can be modeled. In addition, a mixed implicit/explicit algorithm for gas dynamics in one space variable has been implemented. This algorithm has the property that it treats at each mesh point each characteristic field implicitly or explicitly, depending on whether the CFL condition for that characteristic is violated or not. For those characteristics that are explicit, the method reduces locally to one of the higher order Godunov methods discussed above.

In all the work done to date on higher order Godunov methods, the multidimensional calculations were performed using operator splitting. While this gives quite satisfactory results for unsteady flows, there are situations - for example, calculations of steady states, or on distorted grids - for which unsplit schemes are more appropriate. Such a method has been derived to obtain left and right states for Riemann problems; it is based on solving multidimensional characteristic equations in conjunction with a modal synthesis procedure. It is believed that these methods will prove particularly useful in applications for which the wave propagation properties of the system are anisotropic, e.g., in magneto-hydrodynamics, or for petroleum reservoir simulation.

Work was begun to couple higher order Godunov methods to front tracking methods for general discontinuities in one dimension, and for linear discontinuities in two dimensions. The approach being taken is that of using a fully conservative coupling of the tracking algorithm to the difference scheme, i.e., one that would make it possible to track some distinguished discontinuity, such as a shock, contact discontinuity, or a combustion wave, while capturing any other discontinuities, even if they intersect the tracked discontinuity. This approach is distinguished from previous such algorithms in that it requires neither differencing across the tracked discontinuity nor a complicated regridding scheme to avoid problems with CFL constraints as the tracked wave approaches a zone boundary.

A continued topic of interest is shock reflection in gases. Numerical calculations obtained are in excellent quantitative and qualitative agreement with shock tube experiments, and illustrate new qualitative phenomena that the experiments have been unable to resolve. Adaptive mesh techniques have been implemented that move mesh points with the complicated structures arising in multiple Mach reflection problems. This improves the resolution of two dimensional calculations, and enables study of a wider range of problems. In addition, work has begun on implementing these methods for transonic flow problems, particularly those arising in flows in cascades and turbines. Preliminary calculations have been performed of flows in two-dimensional ducts obstructed by a circular arc and past the Sanz cascade.

Higher order Godunov methods have also been used to model flow in porous media. Due to the presence of an underlying incompressible velocity field, it is necessary to use the unsplit formulation of these methods. Calculations of solutions of the Buckeley-Leverett equation in one and two dimensions were made. Results were better than those obtained with conventional finite difference and finite element methods.

During the past year work continued on adaptive mesh refinement for hyperbolic systems including computation of the Riemann shock tube problem. An extension to problems with hyperbolic behavior such as the Korteweg de Vries equation is underway. The strategy is to use time-splitting and apply an explicit method to the convective term and an implicit method to the dispersive term.

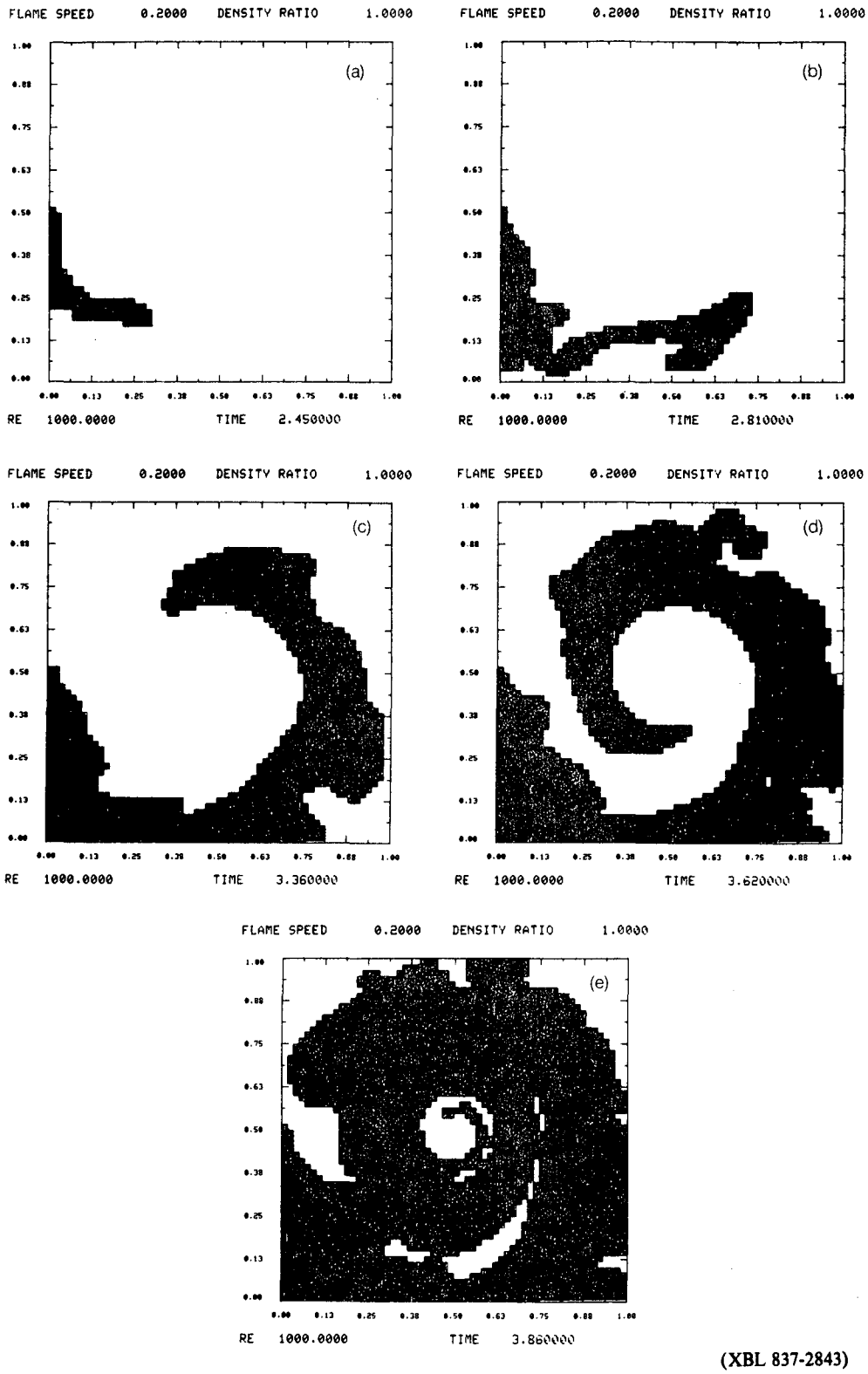
The technique of pseudo global pressure, found to be effective for numerical solution of two-phase flow through a porous medium, was extended to the three-phase case. This permits a simplification of the pressure equation when capillary pressure and gravity effects are included, allowing efficient numerical solution and mathematical analysis of petroleum reservoir simulations.

## Reacting Flows

### Combustion

The research in combustion is concerned with the accurate calculation of possibly turbulent fluid flows in the presence of large energy sources due to chemical reactions. This work utilizes the vortex and high resolution numerical methods coupled with numerical techniques for the exothermic reactions. Research included 1) computer simulations of turbulent combustion in open and closed vessels, 2) the study of compressibility effects in combustion, and 3) development of new theoretical models of combustion and flame propagation, as well as algorithms for their solution.

Improvements were made in the numerical model of turbulent combustion developed last year, which utilized the techniques of vortex blobs, vortex sheets, and flame propagation algorithms developed at LBL. Some of the improvements were 1) a bias towards propagation

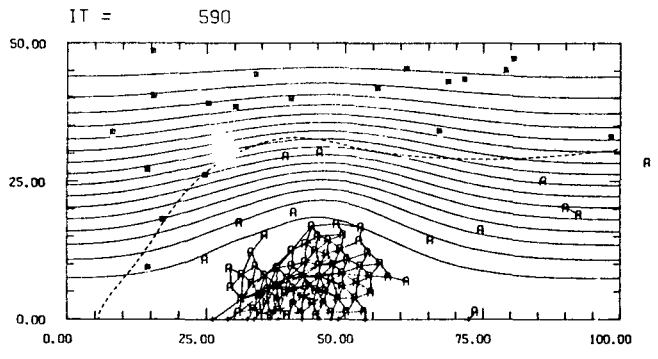



(XBL 837-2843)

Fig. 28. Flame propagating in a viscous swirling incompressible turbulent flow. The swirling fluid is ignited halfway up the left side (a). The flame burns in a direction normal to itself and is advected by the flow (b-e). The development of turbulent eddies in the flow wrinkles the flame front, increasing its surface area and thus accelerating the rate of combustion in the vessel.

in certain directions was discovered and corrected, 2) a technique to determine the exact position of the front as seen by the flame algorithm was developed, 3) that this technique was used together with fast Poisson solvers to create a fast direct method to compute inexpensively the velocity field produced by volumetric expansion along the flame front. Applied to the problem of a flame propagating in a swirling viscous flow inside a closed square, the results of a numerical simulation showed the interaction of the flame with turbulent structures and the wrinkling of the front due to viscosity. See Fig. 28. Other applications of the method included the aerodynamics of turbulent flames and turbulent combustion in a long channel.

Work was begun on applying some of the higher-order Godunov methods for gas dynamics to study combustion in regimes in which the effects of compressibility may be important. Compressible Navier-Stokes calculations in one space dimension have been made to test the limits of validity of the low Mach number combustion model. Numerically "stable weak detonation" traveling wave solutions have been computed for both a reacting Burgers' equation model and for the compressible Navier-Stokes equations in one space dimension. These solutions were proved to exist as traveling wave solutions in the case of a model equation. The numerical calculations indicate that they can arise from the process of a jump satisfying the Chapman-Jouguet detonation conditions splitting into a weak detonation, followed by a shock. Numerical experiments have also demonstrated that such waves can form in inviscid calculations using schemes that introduce large amounts of numerical diffusion, in parameter regimes where they would not be expected to form physically.




(XBL 837-10694)

Fig. 29. A numerical study of the growth of a platelet aggregation in response to an exogenous supply of the platelet-activating agent adenosine diphosphate (ADP). Platelets crossing the ADP threshold-concentration contour (dotted line) become activated and able to adhere to the aggregate of platelets forming along the bottom wall.

A theoretical model of combustion was developed for flame propagation inside closed vessels. This model details the effect in closed regions of volumetric expansion along the flame front, opening the way for the application of vortex element calculations to closed vessel and piston problems. Using results obtained earlier, work was continued on the evolution of Mach stems in reacting shock fronts. In addition, a grid-free numerical algorithm, using the random element method, was developed for a one-dimensional reaction-diffusion model of laminar flame propagation in premixed gases.

### Transport Modeling

The research on transport modeling centered around a study of platelet adhesion and aggregation. A mathematical model of blood clotting was investigated, and numerical schemes were used to produce computer simulations of the formation of blood clots within small vessels. See Fig. 29.

Improvements were made in a numerical method developed to study a mathematical model of platelet adhesion and aggregation in the early stages of blood clotting. Blood is represented as an incompressible viscous fluid containing discrete massless platelets which can secrete a clot-enhancing chemical. The platelets and the secreted chemical both move by fluid convection and diffusion. The numerical scheme includes finite difference methods to solve the transport and hydrodynamic equations, non-linear optimization techniques to calculate interplatelet forces and a linked-list data structure to keep track of the development of the growing aggregate. Results to date show substantial qualitative agreement with biological observations. Work has begun using random walk techniques to solve the chemical convection-diffusion equation. Such techniques will remove constraints on chemical diffusivity imposed by previous methods.

In the mathematical model of platelet aggregation described above, a more sophisticated formulation of the chemistry of clotting was added. The effect of chemical inhibitors on platelet aggregation was included, as well as a mechanism for shear-induced breakup (embolization) of clots. Work has begun to incorporate these ideas into the existing numerical method.

## Mathematical Software and Consulting Services

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

During the past year improvements to the numerical program libraries at LBL were continued. A new library, MINPACK-1, for nonlinear least squares and nonlinear systems of equations was added. New versions of the IMSL, NAG, and NPL optimization libraries were installed. Four libraries previously existing on the CDC computers were installed on the VAXes: IMSL, NAG, LINPACK, and MINPACK. The CORE library on the CDC machines was updated to reflect more recent algorithms by replacing the routines DCADRE, GB, GEARIB, and ZSYSTM by the routines D01AJF, D01BCF, LSODI, and HYBRD1 respectively. The catalog of software, WRITEUPS subset LIBRARY, was updated and revised to reflect these changes.

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# Computer Science

## Data Management Research

The data management research program deals with the topic of scientific and statistical data bases. Data bases created and collected for scientific, socio-economic, demographic, and similar applications, have requirements that cannot be easily supported by existing commercial data management systems. Such data are prevalent in government (e.g., energy, census, pollution) and in scientific environments (e.g., seismic data, experimental data), but they also exist in industry (e.g., effects of drugs, economic forecasts). Often, the major use of such data bases is statistical analysis.

The next section describes aspects of the research effort that are of a general nature, such as survey papers, and organization of panels. The following four sections describe progress in 1982 in the areas of user interfaces, modeling, physical organization, and specialized machines for data management.

### General Aspects of SSDBs

In 1982 a tutorial and survey paper was presented by invitation at the International Conference on Very Large Data Bases (VLDB), 1982. Research staff were also invited to present this paper and a summary of this work at a Statistical Database Workshop organized in Tokyo, Japan. The main purpose of the workshop was to present the work in SSDBs currently in progress in Japan, and this presentation was the only one invited from outside Japan. Involvement with this workshop established ties with Japanese researchers, which should lead to further exchange of ideas.

Two panel sessions on the subject of Statistical Database Management were organized. The first was at the International Conference on Management of Data (SIGMOD), 1982 and the second panel was organized as a session in the conference on Computer Science and Statistics: Fifteenth Symposium on the Interface, 1983.

### User Interfaces

The following sections represent two different approaches to user interfaces. Both approaches eliminate the need for the user to remember names, acronyms, formats, and complex syntax rules. The first section discusses our work on a graphical user interface for data exploration (GUIDE). The second section describes a system (SUBJECT) which is based on the representation of statistical data bases as logical graphs.

#### User Interfaces for Data Exploration

The purpose of this research is the organization of information associated with data bases that are very large or have complex semantic relationships for presentation to users. It is based on the premise that guided exploration of this information using rich and flexible graphics tools will lead to an effective, easy-to-use user interface for finding and displaying data.

The research is motivated by technological developments with respect to networks and workstations. Large data bases are often centralized resources with non-expert users attempting to access them via workstations. In addition, recent developments in the data base modeling area lend themselves to the use of graphics for representation of the semantics of data.

The graphical user interface under development is called GUIDE (Graphical User Interface for Database Exploration). There are three major differences between existing work in the area and the GUIDE approach: the GUIDE approach uses a rich underlying model that can be displayed graphically; it supports partial queries, thus enabling the user to issue progressively more complex queries rather than specifying a long complex query in a single step; and it explicitly represents metadata.

The major effort in 1982 focused on the design and development of two major packages: a graphics edi-

tor and a graphical menu manager. In addition, a graphical data presentation system and tabulation facility have been implemented. These facilities are described in a paper to be presented at the 15th Annual Interface Conference of Computer Science and Statistics. A general paper describing the GUIDE system and approach was published in the Eighth International Conference on Very Large Data Bases.

### The SUBJECT System

SUBJECT is a continuing project whose purpose is to provide users with simple but effective means of accessing statistical data bases. This is achieved by using a specially designed graph structure to represent the logical content of statistical data bases. A novice user can browse through the graph for descriptive information about data bases, select a data base to explore, and continue on to express queries. The user interface represents data in a menu format, thus eliminating the need to remember names, values and formats of data elements.

An alternative to the browsing capability is provided for experienced users, where they can search for a data file by keys. They may quickly locate a desired data file, and proceed to express query conditions in the usual fashion (i.e. by moving around the directed graph). The system also provides access to documentation associated with nodes in the graph.

An important concept of the graph representation is that of "node sharing," which permits more than one arc to point to the same node, thus forming directed acyclic graphs. Node sharing allows for attribute domains to be shared between different files, providing several advantages: eliminating duplicate data values; consistency of naming (where items that are the same, but reside in different files, are forced to have the same name); and allowing the specification of join domains between files, permitting multiple physical files or fractions of these files to be viewed jointly as a single logical entity.

The main facility added this year to the SUBJECT system is node sharing and the software to support it. An additional construct was incorporated in the graph structure to allow for "back pointers" between nodes, i.e., it is possible to find the ancestor nodes of a given node. In the past, it was only possible to traverse the graph from the root node forward. A user can now traverse the graph backwards, which makes it possible to find the existence of join conditions. For example, given a certain year and oil type, it is possible to find all the files that have information (i.e. production, consumption, etc.) about the year and oil type, by traversing backwards.

The "graph builder" is an interactive facility used to specify the structure of a SUBJECT graph, including the specification of shared nodes. This facility was integrated with the previous browsing facility making it possible to browse existing portions of the graph. In addition to supporting the construction of multiple levels, it is possible to connect to a substructure of an existing graph. This provides a convenient way to join files.

Another facility implemented this year is the "data editor," which allows interactive data entry and modification of data values. The editor prompts the user with the combination of parameters (category values) for which a data value has to be entered.

## Data Base Modeling

Two areas of data base modeling are discussed below. The first area is described in the section entitled "Semantic Core Model" which is concerned with the representation of conceptual entities and their relationships. The second area is described in the section entitled "physical modeling," which is concerned with the representation of physical data base structures and their characterization.

### Semantic Core Model

Scientific and statistical data base (SSDB) applications present formidable modeling requirements that tax the power of conventional record-oriented data base models (such as the relational or CODASYL models). Since data are viewed in terms of the structures in which they are defined and the operations performed on them, the available model exerts a powerful influence on the ability of applications to deal naturally with the data. At issue is the size of the gap between a naturalistic model and the data base system-imposed model.

Based on observations of SSDBs in practice and as reported, it was concluded that conventional data models and data base systems provide inadequate representational tools for these applications.

These and other considerations have led to development of a new model for representing SSDBs, the *Semantic Core Model* (SCM). This model is based largely on the semantic data abstraction models found in the literature. However, none of the extant models address all of the issues raised earlier regarding SSDBs. A detailed rationale and specification of the Semantic Core Model was elaborated and summarized in a technical report.

During 1982 a data definition syntax for most of the constructs proposed in the SCM was developed and went through several iterations. These constructs were used to experimentally model several applications of SSDBs. These included portions of the U.S. Census Database, Bureau of Labor Statistics Labor Area Unemployment Statistics, and seismological data from the

DARPA Center for Seismic Studies (CSS). These experimental models have proven to be a valuable specification tool which is serving as the basis for user interface and physical data base design and development for the CSS.

### Physical Organization

The following sections describe work in compression and file migration. The first section discusses the continuing work on compression for statistical data bases. It is concerned with achieving a high level of compression while providing fast access to the compressed data. The second section deals with algorithms to rearrange data base attributes in order to maximize the compression factor. The third section describes automatic file migration replacement policies for moving files from secondary to tertiary storage devices.

### Compression for Statistical Databases

The header compression scheme, developed by CSAM, has the capability of both eliminating multiple types of constants from the data base and compressing each stored value to its minimal byte length. The scheme is a variation of run-length encoding, in which modified run-lengths are extracted from the data stream and stored in a header. The header is used to form the base level of a B-tree index into the data base. The run-lengths are cumulative, and therefore a logarithmic search algorithm can be used to obtain an access time that is logarithmic in the size of the header. The main effort in 1982 was in the design and implementation of two versions of the header compression scheme, called the basic and general versions. The basic version compresses only a single type of constant (e.g., zero), while the general version compresses both multiple types of constants and stored data to their minimum byte length. These particular versions of header compression were chosen for two reasons. First, they represent the extreme cases in the tradeoff between functional capability and degree of compression and access time. Second, they have the widest applicability.

The benchmarking of the compression scheme will be done against a run length encoding scheme. Therefore the remainder of the implementation concentrated on the version of run-length encoding chosen. Both the loader and the access method for this scheme were completed.

### Rearranging Data to Enhance Data Compression Efficiency

Vertical partitioning of the data (i.e., storing each domain (or column) in a separate file) markedly increases the effectiveness of run-length type data compression schemes such as header compression. Other rearrangements of the data also may increase the efficiency of data compression. For example, storing population counts in an array indexed by race, sex, age, and county it would be reasonable to assign adjacent codes to the least populous races and counties, because this tends to maximize the probability of consecutive zero counts. The header compression scheme mentioned above, can then be used to compress the consecutive zero counts more efficiently. Furthermore, race or county would be plausible variables for the least rapidly varying index and sex for the most rapidly varying array index.

There are two subproblems involved. One is the assignment of ordering to category values, (i.e., reordering rows or columns of the matrix). The second is the ordering of the category attributes within the indexing function (i.e., transposing the matrix). Thus far only the first problem has been addressed.

For the sake of tractability probabilistic models of the data rather than exact deterministic models are used. Two analytical results for the value ordering problem were obtained. Both results, which are achieved under different assumptions, show that the value ordering should be according to the familiar "pipe organ" assignment, or a variation of it. Simulation techniques will be used to explore the attribute ordering problem.

### File Migration

This work is concerned with modeling and managing the automatic movement of files between secondary (disk) and tertiary (tape) storage. The emphasis was on the development of replacement policies for deciding when to remove a file from the secondary storage device and send it to the tertiary storage device. Results show that the optimal holding time could be simply characterized in terms of a scaled hazard rate (i.e., the hazard rate divided by file size).

A paper describing this work was completed and submitted to the 1983 SIGMETRICS conference.

## Specialized Machines for Data Management

The Microprocessor Assist System (MAS) is a set of back-end microprocessors to be used to implement an experiment in data management research. The area of research is database machines, which are computing systems designed especially for data management. The use of multiple microprocessors in a database machine to handle two I/O related functions: compression/decompression and attribute assembly/dis- assembly is being explored.

The experiment has two purposes: the first is to determine if the parallelism obtained by associating one

microprocessor per disk on a database machine, and dedicating that microprocessor to a single I/O related function, is a cost-effective solution to interesting performance bottlenecks in database systems. The second purpose is to define a general methodology for the modeling and construction of multiple-microprocessor systems.

It is important to this particular project and to LBL as a whole to have access to systems that can accurately forecast the performance of multiple processor systems. Several systems were considered and the Performance Analyst's Workbench System (PAWS) was chosen to model the performance of the system. PAWS is an outgrowth of performance evaluation research at the University of Texas and is a combination computational queueing/simulation system. PAWS is currently being used to model the performance of more general multiple processor computers as well as the MAS. The next step is to validate those models by measuring the general multiple processor system, and by building and measuring the MAS.

Software for the MAS has been designed. It is a relational data management system, where the functions performed at the disk-level microprocessors are simple restrictions, attribute assembly and decompression (for retrieval); disassembly and compression (for storage). Two possible prototype applications are being explored: time-series, instrumental data from the TPC, and mixed textual and numeric data from the Particle Data Group. It is expected that one, or both applications will be brought up in prototype form on the MAS.

Hardware for the MAS has been partially defined. The microprocessors will be M68000s; the decision of which 68000 systems to use depends on results of modeling the system and on the potential vendors actually delivering promised systems to customers. Since the purpose is to develop generally useful methodologies for building and using multimicroprocessor systems, there is no interest in one-of-a-kind systems; hence, commercial well functioning systems will be used.

Research Staff

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# Distributed Systems

Members of the Distributed Systems Research Group are active in the areas of computer network performance evaluation, design methodologies for distributed applications, and participation in LBL-wide networking activities.

## Network Performance Evaluation

The activities in this area consist of performance measurements of local-area network interconnection hardware, performance measurements of communication protocol implementations utilizing this hardware, and subsequent analyses of the measurements using simulation and other modeling techniques. The work in this area is motivated by the following realities of the DOE computation community:

1. Interconnection of computational resources via local-area networks is popular as a cost-effective means to further utilize the hardware and software base at many sites.
2. Very few quantitative comparisons of competing interconnection technologies have been performed.
3. Measurements comparing implementations of competing protocol sets are similarly unavailable.

In 1982 the activities in these areas were primarily of a start-up nature. The appropriate hardware for both ring and broadcast technologies were obtained because comparative measurements will provide insight into issues concerning network access arbitration. The ring technology was successfully integrated into one of the operating systems in use in CSAM (UNIX 4.2BSD). Integration into the other operating systems (VMS, RSX-11M, UNIX 2.8BSD) was initiated, with completion expected in early 1983.

In parallel with the integration efforts, the design of an architecture for the hardware measurement testbed was initiated in 1982. The purpose of such an architecture is to provide a framework that permits future interconnection technology offerings to be measured on an equal footing with previously measured hardware, thus facilitating quantitative comparisons of competing technologies. A formal description of this architecture is in preparation.

With the successful integration of the ring hardware into the 4.2BSD UNIX system, initial measurements of the performance of the TCP/IP protocol implementation for that system were begun. Besides providing absolute performance indications for this particular protocol implementation, the results of these first simple measurements are an aid in the design of a test suite for measuring the characteristics of an arbitrary protocol set.

The effort in the simulation and modeling areas was strictly preparatory. Several simulation systems were obtained and appropriately tailored to reflect the anticipated needs for analysis of the performance data.

## Distributed Application Design

The activities in this area are concerned with communication protocol design, with special emphasis on

methods to simplify such designs for application programmers. Important issues in this work are 1) ease of use of the resulting protocol, 2) reliance of the protocol on generic services provided by lower-level protocols, rather than exploiting the features of one specific support protocol, and 3) providing location transparency of network objects. Such studies are especially important, since they are crucial to the effective utilization of the heterogeneous network configurations that dominate the DOE computational community.

In 1982, CSAM researchers were active in several areas:

1. A joint European project to provide a general file transfer service between high energy physics laboratories. The resulting file transfer protocol, while being specific to the protocols in use in Europe, should have general applicability for DOE laboratories. A draft document describing the gateway is available.
2. The design and development of new ARPAnet mail protocols. This development was of importance to other departmental projects, of special importance was the ability to use the protocols in non-ARPA environments. A modification of the mail transport protocol was designed for use in batch environments, and has been adopted by BITNET.
3. The development of a portable electronic mail system was completed. Besides providing state-of-the-art mail system capabilities, the design of the software permits it to be ported to a new operating system environment by simply providing a few primitive functions. This software is currently in use on many systems at LBL and other DOE national laboratories, as well as at university and industry sites throughout the world.
4. The design of an application programmer's interface to a distributed name server facility. Besides permitting an application programmer to access remote objects transparently (independent of location on the network), such an interface is essential in the implementation of real-time distributed applications which must be able to dynamically reconfigure in the event of a failure of a participating host.

## LBL-wide Activities

In 1982 the Computer Policy Board commissioned several working groups to evaluate the computational capabilities and needs of LBL; the reports of these groups were then integrated into a final recommendation for computer policy at LBL. Distributed system staff members were quite active in several of the working groups, especially the Committee on Word Processors and Electronic Mail. With the establishment of the Advanced Development Project, activities continue in informal review and as sources of information for the network working group.

The portable mail system described above is in place on several LBL computers, and is currently a fundamental link in facilitating LBL-wide electronic mail. In cooperation with ADP personnel, the system is being adapted such that it can form the long-term basis for LBL-wide electronic mail communications.

### Research Staff

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# Graphics

## Device Independent Graphics Systems

Work was begun on a new device-independent graphics system (NGS).[1] Most of the design, and the start of a prototype implementation were completed in 1982. This graphics system incorporates the advanced concepts of 3D hierarchical structured picture definition, flexible styles of user interaction, and distribution across a local area network. This work is being carried out in the context of work with several other groups. In particular, SIGGRAPH,[2] a workshop sponsored by ACM, and with an ongoing component, was convened to determine ways to improve the quality of graphical human-computer interaction. The graphics group has also participated in ANSI, X3H3[3] since its inception. This committee made substantial progress in 1982 toward a first draft of the Programmer's Hierarchical Interactive Graphics System. The development of this system has had a major impact on research within CSAM on high-level graphics interfaces, in particular in the design of NGS.

### NGS Summary

NGS is a device-independent graphics system for a heterogeneous network environment. It is intended to provide a uniform, high-level, interface to dissimilar devices while allowing an applications program, if required, to sacrifice device-independence for close control of a specific device.

Among NGS capabilities are:

- Hierarchical object definition
  A graphical object can be defined in terms of smaller sub-objects.

[1] See "Network Graphics System Design Document", LBID-644

[2] Special Interest Group in Graphics of the Association for Computing Machinery

[3] American National Standards Institute, Technical Committee for Computer Graphics Programming Languages

- Two-tier attribute specification
  A graphical attribute, such as color, can be specified either directly by giving its value, or indirectly by giving an index into a table of values.
- Dynamic picture changes
  The definitions of graphical objects can be changed at any time, even when the objects are being displayed.
- Screen window management
  A single graphics device can simultaneously host several independent applications, each controlling its own screen window.
- Complex styles of interaction
  Simple graphics input devices can be combined into complex "virtual interaction devices".

## Publication Graphics

During 1982 research effort addressed the problem of producing computer graphic generated, "camera ready" images. The problem is that of producing images that may be taken directly from the graphics output device to produce an offset printing plate, without intermediate steps such as halftone screening.

The work in this area included the integration of text and graphics and the use of several graphics technologies.

### Formatted Text and Images for the Xerox 9700

Software was acquired and refined to produce line drawing images directly on the Xerox 9700. The Xerox 9700 is a high speed, digitally driven laser, xerographic printing device which accepts its input from computer generated tapes and produces moderate to high quality toner on paper output.

Concurrently, software was written to process formatted page images of census reports[4] into Grafpac[5] calls in order to deal with mixed text and rulings. Page layouts are designed and debugged on a local graphics device for preliminary review, test and debugging, due to the very long turnaround on the Xerox 9700.

The focus of this effort has been on formatting, layout, and composition, contributing to effective design of a report and on production of a finished report on the Xerox 9700. Major elements of the design are:

- proportional fonts, for a typeset appearance;
- bold typefaces and several type sizes, to convey relative importance, such as titles vs. footnotes and legal notices;
- rulings, to partition and organize a page;
- shading patterns, to identify universes;
- consistency in margins, indentation, justification, and typefaces, so that similar elements have the same location and appearance from one page to another.

A Helvetica typefont for software characters was adapted from a Hershey character set data file, developed in outline and solid fill format, and interfaced to Grafpac. It has been used to achieve high quality typography on maps, graphs, charts, prototype census reports, and slides for presentation. In the process of doing this a Grafpac interface to a device-independent polygon fill routine was written. This enables the use of a software solid fill character font on devices that do not have hardware area fill capability.

### Direct Reproduction of Grey Level Images by Ink on Paper

The quality of computer generated images is degraded when they are screened for offset ink printing, such as publication in reports or journals. Poor quality is especially noticeable for images that have mixed gray levels and text or lines, such as shaded thematic maps, graphs, and charts. A technique has been developed where hardware-generated dot patterns are used to "pre-screen" gray level areas, while solid lines are used for typography and other detail. This technique produces a camera ready image that can be used directly to make an offset printing plate, and eliminates the need for photo prints, screening, and manual processing on the part of the printer. A report on this technique is in preparation.

## Interactive Thematic Mapping

Accomplishments in 1982 included enhancements to CARTE, a program for the interactive design of thematic maps. CARTE was used to display patterns of flow, population migration in particular, using arrows whose width was proportional to the amount of flow.

### Research Staff

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[4]Census reports contain tabulations from the 1980 decennial census, computed indicators relevant to planning requirements of the Department of Labor Employment and Training Administration, and integrated computer graphics (maps and charts). This material is supplemented by textual pages of explanation, and prepared for a wide variety of geographic entities, such as states, counties, SMSAs, Federal Regions, Prime Sponsors, and cities.

[5]A locally developed, 2D, nonsegmented, device independent graphics system. See "Grafpac," UCID-8094 for more details.

## Research Computing Facility (RCF)

The Research Computing Facility is a major component of the Applied Mathematical Sciences Research Program within CSAM. The general mission of the RCF is to provide state-of-the-art computing in support of the ongoing research efforts in all three AMS research categories at LBL: analytical and numerical methods, information analysis techniques, and advanced computing concepts. Pursuant to this goal, the RCF functions as a testbed for the evaluation and deployment of new computing technologies.

In addition to providing facilities for LBL researchers, the RCF is a focal point for collaborative interactions with other DOE and federal research sites, and academic and industrial research communities. The LBL RCF is also the hub of the AMS electronic mail system; the combination of mail and research collaboration interaction makes it one of the most heavily used UNIX-ARPANET nodes.

During 1982 a major focus of effort for the RCF was the establishment of local area network interconnections, maintenance of network gateways for collaborative interaction, and maintenance of ARPANET facilities in support of research collaboration and electronic mail. CSAM is working closely with researchers at UC Berkeley in network technology development and evaluation and serves as a primary test site for releases of Berkeley UNIX. Additionally, major changes in ARPANET protocols and implementation as of January 1, 1983, required systems development and debugging effort. The LBL RCF has been at the forefront of this development and has provided both support and software to other DOE-AMS sites in maintaining ARPANET interconnection and network gateways.

Research Staff

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## PAREP

The Populations at Risk to Environmental Pollution (PAREP) project continues to expand and utilize the existing health and environmental pollution data base at LBL. The PAREP data base, primarily at the county and tract level, contains detailed information on mortality and cancer incidence, air quality, population (age-, sex- and race-specific), geographic location, and a number of socio-economic indicators. PAREP is intimately linked to SEEDIS, the LBL Socio-Economic Environmental Demographic Information System, which provides sophisticated data retrieval, analysis and display capabilities in a nationwide minicomputer network. The PAREP data and associated facilities comprise a powerful integrated information system, useful for epidemiologic investigations into the relationships of disease and environmental pollution.

The typical epidemiologic study focuses on the individual as the unit of investigation. The PAREP project has collected and analyzed data (called ecologic data) where the basic unit is a group of individuals. The methodology for analyzing this type of data is not well-developed, and consists of only a few techniques. The PAREP project has evolved specialized statistical techniques to deal with ecologic data. Without statistical tools, the utility of ecologic data for epidemiologic study is much reduced.

The PAREP data base was further developed during 1982 in terms of both data and techniques to efficiently access, analyze, and display selected subsets of information. These new resources are being increasingly used in epidemiologic studies at LBL, at the UC Berkeley School of Public Health, at the University of California in San Francisco, at the California State Department of Public Health, at the Northern California Resource for Cancer Epidemiology, and elsewhere.

### Additions to the PAREP Data Base

Important new data files were added in 1982 to SEEDIS. Epidemiologic conclusions, especially in ecologic studies, are generally obtained through comparison of normalized rates. Age-, race-, and sex-specific rates can be calculated as the ratio of the number of observed cases (e.g., incidences or deaths) to the corresponding age-, race-, sex-specific population at risk. The population at risk is normally derived from decennial census data. First, one needs accurate and detailed knowledge of the age-, race-, and sex-specific population in census years. This information must then be corrected for several important factors including:

- underenumeration biases in census data;
- unknown intercensal migration patterns;
- differences in geographic definitions or racial classifications between census and vital statistics data;
- intercensal changes in geographic definitions.

With this goal in mind, the PAREP project is expending considerable effort in obtaining the most complete and detailed information available from the 1980 Census.

LBL received 29 years (1950-1978) of mortality data—60 million death certificate records—from the Biometry Division of the EPA Health Effects Research Laboratory (HERL). Corresponding population data from the 1930, 1940, 1950, 1960, and 1970 Censuses were also obtained. These data are extremely important, because pre-1968 data are not publicly available from the National Center for Health Statistics, and

their existence is not widely known. A multiyear effort to incorporate these data into SEEDIS was begun.

Additional air quality data were received from the Environmental Protection Agency: sample annual summary data for a dozen pollutants and a complete SAROAD (Storage and Retrieval of Aerometric Data) Monitoring Station Site Directory file. These data will be used, beginning about FY1985, to extend the present SEEDIS air quality data base from 1974-1976 to the longer time period 1968-1982.

## Contact with the Epidemiologic Community

The time and effort required to adequately prepare raw data for statistical processing is generally not appreciated by the inexperienced epidemiologist or biostatistician. Conversely, serious errors in data can go long undetected until they are first used by a person with subject area expertise. The same is true for analysis and display tools: computer science expertise is essential for their design and development, but not all the "bugs" are ever found until the tools are actively used to solve real problems.

The success of the PAREP project is the result of continuing close cooperation between computer scientists, statisticians, and epidemiologists. For this reason, PAREP staff are actively encouraging use of the PAREP data base and associated computer facilities by statisticians and epidemiologists outside LBL. An important development during 1982 was a sudden growth of interest in the PAREP project, primarily due to the acquisition of SEER (Surveillance, Epidemiology and End Results) cancer incidence data, and presentations to epidemiology graduate students in the University of California, Berkeley, School of Public Health. Epidemiology research groups from UC Berkeley, the University of California in San Francisco, the Northern California Resource for Cancer Epidemiology, and the California State Department of Public Health have recently started to use SEEDIS and the PAREP data base in connection with their own projects.

## Estimation and Interpolation of Air Quality

Work on geographical and statistical analysis of air quality in the United States was continued and focuses on the development and application of analytic procedures for examining and exploring the air quality data collected by the Environmental Protection Agency. They are collected at monitoring stations most of which are in metropolitan areas. The data are irregularly distributed discrete point measurements and the techniques explored here may be useful in other disciplines with the same type of data.

The analyses are concentrated on two pollutants, suspended particulates and sulfur dioxide. There are two reasons for this restriction: 1. they are the most heavily monitored and 2. they are of interest to the health field. The state of Ohio is used as an example in most of the analysis, because Ohio is the most heavily monitored state in the United States.

Interpolation schemes were explored. A model was chosen that is similar to the moving average model in time series. The model is

$$e_i = \frac{\sum_{i=1}^{n} e^{(d_{ij}/d_0)^2} x_j}{\sum_{i=1}^{n} e^{(d_{ij}/d_0)^2}}$$

where
$e_i$ = the point of estimation,
$x_j$ = the data point,
$d_{ij}$ = the distance from the data point to the point of estimation,
$d_0$ = the smoothing parameter, and
$n$ = number of stations within $4d_0$ km of the point of estimation.

The choice of $d_0$ has been explored in great detail. Cross-validation was used and several measures for the "best" $d_0$ were examined. This led to the development of a much more efficient method for choosing a smoothing parameter. This involves measuring local variability as a function of disk radius. Each disk radius corresponds to a $d_0$, so by minimizing the local variability function the most appropriate $d_0$ can be chosen. Local variability functions were calculated for Ohio, New York, and Florida. This analysis, as opposed to cross-validation, makes the task of modeling the entire United States a much smaller one. The model combined with cross-validation has been useful in detecting outliers in these data.

The evaluation of the moving average model led to comparing it with another model that has been used, Akima's method of bivariate linear interpolation. A cross-validatory comparison for goodness of fit was done and contour maps were drawn using each method. The local variability function analysis allows for comparison by cross-validation to not be a two-deep cross-validatory choice. Different goals may prescribe different interpolation techniques.

### Research Staff

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# SEEDIS/DCN

SEEDIS (Socio-Economic Environmental Demographic Information System) is a research and development project studying the fundamental components of information management for planning, decision-making, and interdisciplinary analysis (epidemiology, demography, etc.). SEEDIS addresses the need to integrate and analyze large volumes of economic, environmental, and demographic data from various sources in addressing policy issues and the use and allocation of limited resources, both tangible and intangible. SEEDIS is installed on a network of Digital Equipment Corporation VAX-11/780 computers, and at other research sites working in collaboration with LBL in the development of analytic techniques. The network is an experimental network established as a framework for research in networking techniques, user interfaces, and distributed information technology. The DCN project is jointly funded by DOE and the Department of Labor Employment and Training Administration. An important component of the SEEDIS/DCN project during 1982 was addition of major portions of the 1980 Census of Population and Housing. Research and development activities for SEEDIS/DCN during 1982 included investigation of data management in a distributed environment, development of techniques for management of metadata—data about the databases contained in the information system, defining necessary tools and techniques for the interchange of data between heterogeneous computer systems, and enhancement of display and analysis techniques.

During 1982 the following activities were undertaken to enhance the functionality of SEEDIS/DCN.

## Systems Tuning and New Software Evaluation

As new system software (in particular, VMS 3.0) has brought new capabilities for resource management, new approaches to system tuning have been investigated. A CPU scheduler that operates in conjunction with the operating system scheduler was written to recognize jobs that are temporarily compute bound and reduce their priority in favor of interactive jobs. Main memory allocation schemes have been investigated that use a large number of free and modified pages to improve paging and swapping behavior. The VMS disk quota scheme has been modified to allow a more flexible overdraft policy.

## System and Network Security

The increasing use of computer networks has made systems more vulnerable to security problems. In the past, a user name and password combination was required to access a computing system. Today, however, network access to a computing system allows one to obtain a great deal of information about a system without ever logging in. Network access and configuration data bases must be set up very carefully in order to allow desired access and prevent unauthorized access.

## Screen Oriented Data Entry Systems for Data Base Management Applications

As data base management applications become more sophisticated, the components of 1) data storage, update, and retrieval, 2) data manipulation, and 3) user interface, need to be addressed as separate topics, each with their own set of tools and techniques. A screen oriented data entry system is an essential tool for modern user-interface designs. It addresses many ease of use and data validation problems (among others) that can most effectively be addressed outside the domain of the data management system *per se*. Methods are being sought for the coordination and integration of these three components that are modular and allow flexibility in each subsystem without impacting the other subsystems.

## High Quality Text Generation

Both hardware and software systems are needed to support the routine use of the computer in clerical operations. Software improvements are directed toward providing paradigms for user-friendly software for computer-naive users. Hardware investigations have centered on improving the quality of output text.

## Graphics

Computer generated graphics are increasingly used in the graphics art world as the most cost effective method of preparing many types of graphic materials. This has resulted in an increased emphasis on quality and flexibility in graphic images. To provide some of these capabilities for experimentation and development, CHART has been enhanced with 1) higher quality type fonts, 2) graphic input for positioning of components of the graphic image, and 3) high quality output to the DICOMED film recorder as well as less sophisticated graphics output devices for previewing.

CHART now includes high quality solid fill type fonts from the Hershey character set. In addition to a higher quality image, these fonts can be enlarged to any size without the "breakup" or "thinness" common to stick characters.

Graphic input allows the chart designer to work interactively with a graphic cursor to position each graphic component in exact relationship to the other graphic components in the image. This provides the

flexibility needed for the highest quality images.

To complement the higher quality graphic images, access to the highest quality output devices is required. CHART now provides automatic access to the DICOMED D-48 color film recorder, with the highest graphic resolution available at the Laboratory. This output can be composed and previewed on other faster turnaround devices using the device independent features of Grafpac until one is ready for a final production run.

## Metadata

Data description or *metadata* presents a significant database management challenge, particularly for scientific and statistical databases. Ideally, users should be able to access and manipulate data and metadata using the same DBMS tools, but there are few systems that even begin to provide such integrated capabilities. During 1982 CSAM staff continued research in this area and outlined a framework for more integrated metadata management by synthesizing ideas from statistical analysis, bibliographic retrieval, data dictionary, and database management systems. Drawing on experience and examples from a large statistical database project, this framework discusses and analyzes:

- General types and uses of data about data,
- Special types of metadata for statistical databases,
- Metadata structure and characteristics,
- Principles and requirements for metadata management.

Considerable work has gone into the development of data dictionary facilities that will facilitate use of census data files by non-programmer users. The data dictionary for Summary Tape File 1, as installed in SEEDIS, is a significant improvement over both the printed codebook and online CENSPAC dictionary provided by the Census Bureau.

During 1982 prototype computer programs were developed to translate CENSPAC data dictionaries for the 1980 Census Summary Tape Files and other census tape files (e.g., 1970 Census) into a standard, canonical form that will facilitate production of data definition files, data dictionaries, and related materials for SEEDIS and the 1980 Census Project. These programs have been successfully used to translate most of the CENSPAC metadata for several census data files.

## Archival Storage, Retrieval, and Caching

Archival storage is one component of distributed data management and is one of the most pressing problems in dealing with the massive amounts of data in SEEDIS data bases. In 1982 alone, approximately 10 billion bytes of census source data were added to the data base.

A three level hierarchical storage system was designed to maintain this archive and make it available to the SEEDIS user. The primary archive is the Automatic Tape Library in the LBL Computer Center. Some data sets form a duplicate secondary archive on magnetic disk on a particular DCN machine. The tertiary level is a local disk cache of requested subsets of data on each DCN node. Current research and development is directed towards local data installation on each node, with optional sharing to other machines, and appropriate updating of location information throughout the network. During 1982 the implementation of caching for SEEDIS data was nearly completed; the basic mechanisms were completed and some data are operationally available via caching. A cache of the most recently used files is maintained on the disk at each DCN computer. When the user requests data that is not available in the cache, a job is composed and submitted to the LBL Computer Center to retrieve the data from the Automatic Tape Library and send it to the DCN computer.

## Aggregation and Disaggregation

Users of geographic information systems frequently need to combine data from differently defined geographic entities, e.g., income data summarized at the state level of geography with population data available by county. In most data systems, either the problem is ignored, or the data are forced into consistency under arbitrary yet fixed assumptions. SEEDIS provides a unique solution to the data comparability problem in the Aggregation/Disaggregation module.

In this module an extensive data base of geographic correspondence files is utilized to supply the tools necessary to achieve ad-hoc proportionality assumptions entirely under the user's control. Thus the SEEDIS user can achieve data comparability by utilizing assumptions best suited for each particular application area—pollution data, health-effects data, economic data, etc.

## Comparison of Integrated Information Systems

Two papers were presented that describe and compare major integrated information systems (such as SEEDIS) in the United States and Canada.

The systems fall naturally into four major categories, bibliographic (B) systems containing primarily bibliographic citations or abstracts, with little or no numeric data; demographic (D) systems containing primarily census data that have strong mapping capabilities; econometric (E) systems containing primarily time series data with limited geographic detail; and integrated (I) systems that attempt to relate data from many different primary sources. The following systems are discussed:

| Category | System | Developer |
|---|---|---|
| B | DIALOG | Dialog Information Services Inc. |
| D | CACI | CACI, Inc. |
| D | DONNELLEY | Donnelley Marketing Information Services |
| D | MAX | National Planning Data Corporation |
| D | ONSITE | Urban Decision Systems, Inc. |
| E | CANSIM | Statistics Canada |
| E | DRI | Data Resources Inc. |
| E | IDC/CHASE | Interactive Data Corp/Chase Econometrics |
| E | MAGIC | I P Sharp Associates, Inc. |
| I | DADS | Data Resources Inc. and General Software Corporation |
| I | DATAGRAF | M/A-COM Sigma Data Inc. |
| I | DIDS | Executive Office of the President |
| I | GEMS | Environmental Protection Agency |
| I | GEOECOLOGY | Oak Ridge National Laboratory |
| I | SEEDIS | Lawrence Berkeley Laboratory |
| I | UPGRADE | M/A-COM Sigma Data Inc. |

Systems were compared on the following criteria:

- Usage and usage capacity;
- Amount of on-line data stored;
- Response in an on-line environment;
- Analytical capabilities;
- Graphic display capabilities.

From the comparisons presented, one sees an enormous diversity among the systems in terms of effort, size, capabilities, and applications. There is no one system that excels in all areas. Duplication of effort, at least in the public sector, is not a serious problem.

### Profile

As the volume of data installed within SEEDIS grows each year, users have a requirement for overview data for particular geographic entities to provide a quick summary of subject characteristics in a visually pleasing and informative format. The PROFILE module was developed within SEEDIS for 1980 Census data, using the generalized report generation tools implemented as part of the 1980 Census project. Current profiles include 1980 Census Report 1A, 1947-1977 Income and Housing, Business and Industry, and Report 2A, 1980 Income and Employment; the 1974 Census of Agriculture will be installed soon.

Research Staff

H. Holmes (Project Leader), Wayne Graves, J. McCarthy, L. Tabata, V. Sventek, W. Benson, A. Marcus, A. Yen, F. Gey, I. Kuo, C. Eades, R. Allen, I. Miranda.

## Labor Market Projections Model

The aim of the Labor Market Projections Model (LMPM) is to provide estimates of current requirements for employment and training services in local areas. To estimate current local needs, two models have been developed—the Population, Labor Force and Unemployment Projections model and the CPS-Census Updates.

Each year most of the effort is spent in maintaining and running these models. To maintain the models, it is necessary to update existing data where possible and insert new geographic areas as desired. The models are run for more than 1300 areas (all states, SMSAs, prime sponsors and other county groupings as requested by certain states) and the results are mailed to the State Employment Security Agencies (SESAs).

As time permits, work is done to improve the models and to fulfill special requests related to LMPM. The following highlights the major improvements made over the past year.

Most of the improvements made to the Projections Model over the past year involved the introduction of 1980 Census data into the population projections model. Although early 1980 Census data lacked important detail, they were an improvement over reliance on 1970 data. Also, the underlying methodology was enhanced.

### Obtaining 1980 Racial Control Total

The first data available from the 1980 Census were population counts by race for every geographic

level down to blocks (Census, 1981a). The racial categories are

- White,
- Black,
- American Indian, Eskimo and Aleut,
- Asian and Pacific Islander, and
- Other.

After making an adjustment for the military population, three population counts by race (White, Black, and Other) were used as population control totals for 1980, for all areas. This was done to bring the projections in line with current available data. However, since there are major differences in response, between the 1970 Census and 1980 Census, the racial breakdowns for the two years are *not* comparable in many cases.

The race concept used by the Bureau was based upon self-identification: the census questionnaire requested that persons identify themselves as of Spanish-origin or not; they were also asked to report the race with which they identified. In 1980, 40 percent of the Spanish-origin persons nationwide did not report a specific race, but reported in the "Other" category; about 56% reported "White." In 1970, the few Hispanic persons who marked "Other" and provided write-in entries such as "Puerto Rican" or "Mexican," were reclassified as "White." In 1970, only 1% of the Spanish-origin persons were classified as "Other" and 93% as "White."*

Thus, in many areas, it appears that there has been a huge increase in the racial category "Other". Although some of this increase may be true, a great deal of it is due to the way in which people have answered the race question in 1980. Many Hispanics, who were "White" in 1970, are "Other" in 1980.

In Texas the racial group "Other" increased over 5000% in some areas. The algorithms in the population projections model are unable to handle changes such as this. This growth is not due to births, deaths or migration, but due to a change in the way in which people classify themselves. By using data from the Survey of Income and Education (SIE), it was possible to obtain the distribution of male and female Hispanics in Texas in 1976. In each area in which the racial group "Others" grew by more than 500%, the cohort component model was no longer used; instead the racial control totals for "Others" were applied to the Texas distribution of Hispanics as derived from the SIE data.

*Data User News, Bureau of the Census, April 1981, Vol. 16, No. 4.

## Validations

A thorough testing of the Projections Model can not be done until STF4 of the 1980 Census becomes available. However some testing of the population results can be done using STF1. STF1 contains data on the population by sex and by age. By projecting to 1980, the population projections could be compared with the 1980 Census figures. The projections model was run twice for each area—once using the standard plus-minus technique for projecting migration and once using the migration model developed at LBL.

After looking at a comparison of many substate level projections with census data, it became apparent that there were problems with the fertility rates being used:

1. In the past, the fertility rates used in projecting from 1975 to 1980 were a weighted average of the state level rates for 1970-1975 and the national from 1975-1980. This is incorrect. The rates used to project from 1975 to 1980 should instead reflect the trend in the national rates from 1970-1975 to 1975-1980 as applied to the state level rates from 1970-1975.
2. For most rural counties, the projected number of persons aged 0-4 and 5-9 was much too low. For larger suburban areas, the projected figures were still low, but much closer to the census figures.

   Throughout, the model is using state level fertility rates. By definition, these rates represent the average level of fertility across each state. However, fertility is greater in rural areas than in the cities. For each area, the number of children aged 0-4 in 1970 is divided by the women of child-bearing age (15-39) in 1970. By comparing this percentage with the corresponding one of the state containing the area, a measure of past fertility is obtained. For most rural counties this number is well over one; for most large cities, the number is less than one. In each area, once the number of births in 1975 or 1980 is calculated, it is multiplied by the above number as a correction factor. Thus, the estimated number of births in rural areas is increased while in urban areas, it is usually decreased.

## Migration Model

These comparisons also pointed out weaknesses in the migration model. In particular, improvements were made to the migration rates of those 15 and under, and to the patterns of those areas with a sizable college population:

1. In the past, significant effort was spent modeling correctly the migration of those cohorts aged 15-

39. The migration of those under 15 was set and not particularly related to the migration of those 25-39. Better results would be obtained by relating the migration rates of the youngest age cohorts to the migration rates of those 25 years older. Thus areas with significant in-migration of people aged 25-39 would also have significant in-migration of the population aged 0-14.

    Since the migration of males is modeled separately from that of females, the above could lead to very different migration patterns for boys and girls. This is unlikely. Thus for males and females aged 14 and under, the migration rates of the two sexes were averaged.

2. For areas with a large student population, the college-type migration patterns were modified to allow for even more in-migration for those aged 15-24 and similarly greater out-migration for those aged 25-29.

Once these modifications were made to both the fertility rates and the migration model, many more comparisons were made. These comparisons were done at the state level and at the substate level in California, New York, and Washington. The modifications enhanced the results of both the plus-minus technique and the migration model. The migration model still outperforms the plus-minus technique however. As an example, for fourty areas in Washington (39 counties and the state), the migration model outperforms the plus-minus technique in 37 cases when projecting males and in 36 cases when projecting females.

Research Staff

E. Schroeder (Project Leader), L. Wong.

# 1980 Census Project

The 1980 Census Project is a technology-intensive application of the SEEDIS information tools to provide integrated data management for the 50 billion characters of data from the 1980 Decennial Census, and to produce 4 million pages of high quality typeset reports from census data for a wide variety of geographic entities, including states, counties, cities, and census tracts. Reports are produced for microfiche (COM), Xerox-9700 laser printers, as well as ordinary line printer devices. The reports include both numeric data, annotated textual headings and explanations, and graphic summary displays. The 1980 Census Project tests the state of the art in defining and creating high-speed, high-quality, computer-controlled typeset printing, as well as computer management of very large statistical databases. This project provides unique insights into the availability and useability of current metadata concepts for managing statistical databases, as well as mass storage facilities and local network transfer of large volumes of regularly structured numeric data. The project has developed a general purpose meta-table report generator that is currently being integrated into the SEEDIS environment.

## Typesetting Hardware and Software

Typesetting software was acquired and installed for the Xerox-9700 laser printer. This software was integrated into the regular census report preparation and production process by writing a GRAFPAC driver program to postprocess font descriptors from the report output. Similar software was prepared for the VARIAN plotter, and this device is utilized for prototyping reports before final test copy is sent off to Xerox-9700 printers operated by outside contractors.

## Data Installation

During 1982 the project acquired over 100 tapes of 1980 Census data (about 10 billion bytes of source data). The data consisted of about 700,000 summary census records from both Summary Tape File 1 (STF1), the first major tabulations from the 1980 Census, as well as Summary Tape File 3 (STF3), the first major sample data tabulations released by the Census Bureau. Much of this data has been compressed using the SEEDIS compression algorithms to eliminate wasted space, and the resultant data is being archived on the LBL Computer Center's Automatic Tape Library.

Software was developed to automatically translate metadata from the Census Bureau's CENSPAC data dictionary format into the newly-devised SEEDIS extended data definition language which provides for array data elements.

## Report Specification and Production

In order to improve quality control and reduce the human labor required to create and maintain input for our census report generating program, CSAM staff developed a number of facilities to automate the report input process. These facilities use existing text editing and formatting tools from the UNIX system, including the stream editor, the AWK pattern scanning and processing language, and the MAKE utility for running sequences of operations on files that have been updated.

Now specialized input files for different output devices (the Xerox 9700 laser printer, a standard computer lineprinter, and a computer output on microfilm (COM) device) are automatically created from a single master set of text and format specification files. Specification of format and content have been separated so that changes in one do not require laborious manual changes in the other.

During 1982 the project specified the first report (Report 1A) and produced the report over a two month period for all counties in the United States (bound in booklets by each state) and all cities and towns in the country (also bound by each state). In addition, complete report specifications have been prepared for Report 1B, which breaks out population by race for each of the 50,000 census tracts in the U.S., and Report 2A, which has income and employment data for all levels of geographic summary.

Research Staff

H. Holmes (Project Leader), F. Gey, J. McCarthy, R. Healey, A. Marcus, W. Benson, B. Burkhart.

# DARPA Center for Seismic Studies

The Center for Seismic Studies is a Defense Advanced Research Projects Agency facility located in Washington, D.C. Four areas addressed in the CSAM research program are particularly relevant to the development of resources at the Center to support geophysics research: data management, display techniques, user interfaces, and local networks.

## User Interface

As the Center develops, its effective use by researchers requires a good environment for accessing and manipulating data. This includes access through a programming language and an interactive interface that provides researchers with a cohesive set of data manipulation tools. These two distinct levels of requirements are addressed in the development of a Seismic Program Library and the Seismic User Environment.

Data access was initially provided through a set of Ingres "macros" available through the data base management system's interactive interface. The macros are predefined sets of Ingres commands, designed to optimize those types of inquiries that the system handles easily but that requires the user to have a reasonable understanding of the data structures involved. The macros were created to allow a quick implementation of a general purpose seismic data management environment. In 1982 design work was begun on a subroutine library that reflects the user's conception of the data. Once the program library proves satisfactory, a set of utilities could be developed to provide the researcher with an integrated environment for accessing and manipulating data, integrating "foreign" software and data, interfacing to graphics and networking systems, and performing other functions especially tailored for seismic researchers.

An effective user environment for seismic analysis and research should consist of a uniform and cohesive set of utilities and an interface tailored specifically for seismic researchers. It should include on-line help and learning facilities, general data installation and manipulation functions, "foreign" software installation techniques, interfaces to graphic and network functions, and some normal (seismic) system maintenance functions. The design and development of the analyst environment was begun as an application of the macro-design approach used in the Software Tools Virtual Operating System project.

## Data Management

In 1982, data management activities involved:

- supporting demonstrations of prototype CSS operations and processing;
- bringing a functioning CSS data base and data base management system into operation;
- validating and modifying requirements specifications by observing initial uses;
- laying groundwork for rational evolution of the CSS data management facility.

Design of a generalized logical database structure that is more flexible than the current system was begun in 1982. The design takes the initial database structure as a starting point, and includes standard representations of all relevant entities of interest in the domain of seismic detection, discrimination and yield estimation.

In 1982 several possible performance enhancing strategies were studied, ranging from writing seismic data management software from scratch, to re-writing or stripping out inefficient or superfluous portions of the Ingres data management system. The conclusion was that the most cost-effective approach was to pursue the development of the Rigel data base programming language compiler. This provides a general-purpose tool for data base application programming that also gives more flexible and efficient access to Ingres data bases than the interpretive Ingres query language. Work on the Rigel compiler builds upon an initial implementation done as a programming language research project at U.C. Berkeley. An initial version of the compiler was implemented in fall 1982.

In 1982 a set of utility programs and modules for handling waveform data were designed. Components of that set are utilities to read waveform data from the CIS network connection or from tape and fully de-multiplex, install and catalog the data in the waveform data base; initialize tape volumes for writing archived waveform

data; and to write out selected waveform data for a requested time interval onto an initialized tape.

### Graphics

The graphics component of the LBL/CSS project provides the CSS with a network distributed, device independent, basic graphics system which in turn provides uniform access to the graphics devices used by the CSS.

The design of a basic graphics system (NGS) that provides network distributed, device independent access to various graphics devices was completed.

### Local Networks

In 1982, local area network activities involved:

1. Definition of a Network Semantic Model. This work is concerned with the definition of the system call interface available to application programs, and the services provided by these system calls.

A document describing the interface was completed in 1982. In addition to describing the proposed system calls, a general discussion of a distributed application design methodology was included, as well as examples of one or more applications using the proposed system calls.

2. Fall-Back Planning for a New Local Network. This effort is to provide a workable local area network alternative for the Sytek network system.

Accomplishments in this area were that the Proteon 10Mbit ring hardware was successfully interfaced to the network architecture of the 4.2bsd kernel. And Ethernet interfaces have been obtained so the performance characteristics of these implementations of the Ethernet specification can be measured.

### Research Staff

P. Hawthorn (Project Leader), P. Kreps, R. Healey, D. Scherrer, J. Sventek, M. O'Dell, W. Greiman, W. Johnston, W. Laubenheimer.

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# APPENDIX

## APPENDIX

## RESEARCH PROGRESS MEETINGS

**January 1982 - June 1983**

| DATE | SPEAKER | SUBJECT |
|---|---|---|
| (1982) | | |
| January 14 | Don Miller, Northwestern | Precision Comparison of Proton-Proton and Proton-Antiproton Elastic Scattering at the ISR |
| January 19 | Robert Schrock, Stonybrook | Some New Implications of Dirac and Majorana Neutrinos in Weak Decays and Reactions |
| February 4 | Kay Kinoshita, UCB | Applications of Plastic Track Detectors to High Energy Physics |
| February 11 | W. Carithers, LBL | CDF-A Detector for 2-TeV Proton-Antiproton Collisions |
| February 23 | Bernard Sadoulet, CERN | The UA1 Detector at CERN |
| February 25 | Albrecht Wagner, Heidelberg | Recent Results from DESY |
| March 25 | David Herrup, Cornell | Upsilon Spectroscopy at CLEO |
| March 31 | Bob Blair, Columbia | Neutrino Cross Sections from 30 GeV to 230 GeV |
| April 8 | Herb Chen, UC Irvine | Liquid Time Projection Chambers |
| April 15 | Jim Napolitano, Stanford | Search for Free Fractional Charge |
| May 20 | Alan Bross, LBL | Use of Charge Coupled Devices as High Resolution Vertex Detectors |
| June 10 | Ian Hinchliffe, LBL | Supersymmetry: What's In It For You? |
| July 8 | Melissa E.B. Franklin, SLAC | Charmonium Studies at SPEAR |
| July 15 | Francois Vannucci, LPNHE - Paris, France | Neutrino Oscillations from Mountain Peaks to Ocean Depths |
| July 22 | G. Yost, UCB/LBL | Lifetimes of Charmed Particles |

| DATE | SPEAKER | SUBJECT |
|---|---|---|
| July 29 | Werner Hofmann<br>Univ. of Dortmund | Tests of QCD in Deep Inelastic Proton-Proton Scattering |
| August 5 | D.R. Nygren, I. Hinchliffe,<br>W.A. Wenzel, LBL | Report on the DPF Summer Study on Elementary Particle Physics and Future Facilities, Snowmass, Colorado, 28 June - 16 July 1982 |
| August 19 | Holger Lierl, DESY | Recent Results from CELLO |
| September 1 | Frank Close,<br>Rutherford Lab | Looking for Quark-Gluon Mixtures in Psi-Decays |
| September 23 | Larry McLerran,<br>U. of Wash. | Status of Our Understanding of High Energy Nucleus-Nucleus Collisions |
| September 30 | Larry Hall,<br>UCB/LBL | What You Always Wanted to Know About Proton Decay But Were Afraid to Ask |
| October 7 | L. Stevenson,<br>B. Wenzel, LBL | Report on the Los Alamos Meeting |
| October 12 | R. Tripp, LBL | Double Beta Decay |
| October 14 | T. Yamazaki,<br>U. of Tokyo | Heavy Neutrino Search Using K$\mu$2 Decay |
| October 21 | Mike Ronan, LBL | Performance of the TPC Detector at PEP |
| October 26 | Nick Hadley, LBL | A First Look at Physics from PEP-4 (TPC) |
| October 28 | Martin Block,<br>Northwestern University | pp and $p\bar{p}$ Elastic Scattering |
| November 2 | Roger Cashmore,<br>Oxford | Results on Weak Interaction and Quark Fragmentation from TASSO |
| November 3 | H. Montgomery,<br>CERN | Deep Inelastic Scattering Results from Muon Beams at CERN |
| November 9 | Philippe Eberhard and<br>Ron Ross, LBL | Report on the Monopole Conference at Racine, Wisconsin |
| November 11 | P. Nemethy and R. Madaras | Report on the IEEE Meeting in Washington (Oct. 20–22) |

| DATE | SPEAKER | SUBJECT |
|---|---|---|
| November 11 | J. Kadyk, LBL | Report on the Gas Calorimeter Workshop (Fermilab, Oct. 27–28) |
| November 16 | M. Chanowitz, LBL | Mesons: Ordinary and Extraordinary |
| November 18 | S. Lindenbaum, BNL | Evidence for Glueballs in $\pi p \rightarrow \phi\phi$ n |
| November 23 | M. Nelson, LBL | Recent Results from Mark II |
| December 7 | Bill Lockman, SLAC | Progress Report on the Crystal Ball at DESY |
| December 9 | Mark Eaton, Harvard | The Decay $\psi \rightarrow$ Baryon Antibaryon |
| December 14 | Angela Galtieri and Ian Hinchliffe, LBL | Review of the Irvine Meeting |
| (1983) | | |
| January 5 | Cathy Newman, Princeton | Recent Research on Radiative $J/\psi$ Decay |
| January 6 | Steve Holmes, Columbia | Production of Longitudinal Polarization in e-p Colliders |
| January 13 | Maury Tigner, Cornell | Future of $e^+e^-$ Machines |
| January 18 | R. Fabrizio, UC-Santa Cruz | Mark III Detector at SPEAR |
| January 20 | B. Gittelman, Cornell | Recent Results from CLEO |
| January 25 | Norbert Wermes, SLAC | Two Gamma Results from TASSO |
| January 27 | Geoffrey Chew, LBL | A Moderate Mass $Z_0'$ Beyond the Standard Model — Predicted by Topological Theory |
| February 3 | John Ellis, CERN-SLAC | Particle Physics and Cosmology |
| February 8 | Ann Kernan, UC - Riverside | Results from UA1 at CERN |
| February 10 | Orlando Alvarez, LBL/UCB | Criticality, Universality, the Renormalization Group and Ken Wilson |

| DATE | SPEAKER | SUBJECT |
|---|---|---|
| February 24 | Harry Sticker, Rockerfeller U. | Photon Scattering in a High Pressure Gas Chamber |
| March 3 | Gunter Wolf, DESY | News From DESY: PETRA and HERA |
| March 10 | Steve Parke, SLAC | Helium as a New Magnetic Monopole Detector |
| March 15 | Alan Guth, MIT | $10^{-35}$ Seconds After the Big Bang |
| March 17 | Takashi Maruyama, U. of Wisconsin/SLAC | $e^+e^-$ Annihilation With the MAC Detector |
| March 22 | Robert Shrock, SUNY, Stony Brook | Theoretical and Experimental Status of Neutron Anti-Neutron Oscillations |
| March 24 | Chris Sachrajda, U. of Southampton/SLAC | What Can Be Reliably Calculated About Drell-Yan in QCD? |
| March 31 | Gerson Goldhaber, LBL | Results from PEP |
| April 6 | Peter Weilhammer, CERN | Silicon Strip Detectors with 5 Micron Resolution to Study Hadronic Charm Production |
| April 7 | Orlando Alvarez, UCB/LBL | What You Should Know About Lattice Gauge Theory |
| April 19 | Jim Siegrist, CERN | Hadron Jets and Large Transverse Momentum Electrons at the SPS Collider |
| April 21 | John Carr, LBL | Search for Right Handed Currents in Muon Decay |
| April 26 | J.D. Bjorken, Fermilab | Fermilab Dedicated Collider |
| April 29 | Clyde Taylor, LBL | Summary of the Cornell Workshop on $20 \times 20$ TeV Collider |
| | Ian Hinchliffe, LBL | Physics at 40 TeV |
| May 3 | Nick Samios, BNL | The Colliding Beam Accelerator at Brookhaven National Lab |
| May 12 | Lucien Montanet, CERN | A Review of the Seventh Int'l Conference on Meson Spectroscopy |
| May 17 | James Sethian, LBL | Numerical Modeling of Turbulent Combustion |
| May 19 | Jerry Vavra, SLAC | Search for the Best Timing Strategy in High Precision Drift Chambers |

| DATE | SPEAKER | SUBJECT |
|---|---|---|
| May 24 | Helmut Koch,<br>U. of Karlsruhe | Search for Baryonium States in $pp \rightarrow \gamma x$:<br>Status and Future Developments |
| May 26 | Juliet Lee-Franzini, SUNY | Upsilon Studies with the CUSB Detector |
| May 31 | Craig Moody, BNL | Production of $\pi^{\circ}$'s, $\eta$'s, Single $\gamma$'s at<br>Small Angle at the ISR |
| June 1 | Peter McIntyre,<br>Texas A&M | Texatron: A New National Lab for HEP |
| June 2 | Phillip Guitierrez,<br>UC-Riverside | Small Angle Elastic Scattering and Total<br>Cross Section Measurements from UA1 |
| June 9 | Wesley Smith,<br>Columbia | Search for $\nu$ Oscillations with $\Delta m^2 < 20\ eV^2$ |
| June 23 | Al Clark, LBL | Report on the Pisa Meeting on Advanced<br>Detectors and the HERA Workshop |
| June 30 | David Coward, SLAC | Electron Scattering from Iron, Aluminum,<br>and Deuterium |

This report was done with support from the Department of Energy. Any conclusions or opinions expressed in this report represent solely those of the author(s) and not necessarily those of The Regents of the University of California, the Lawrence Berkeley Laboratory or the Department of Energy.

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