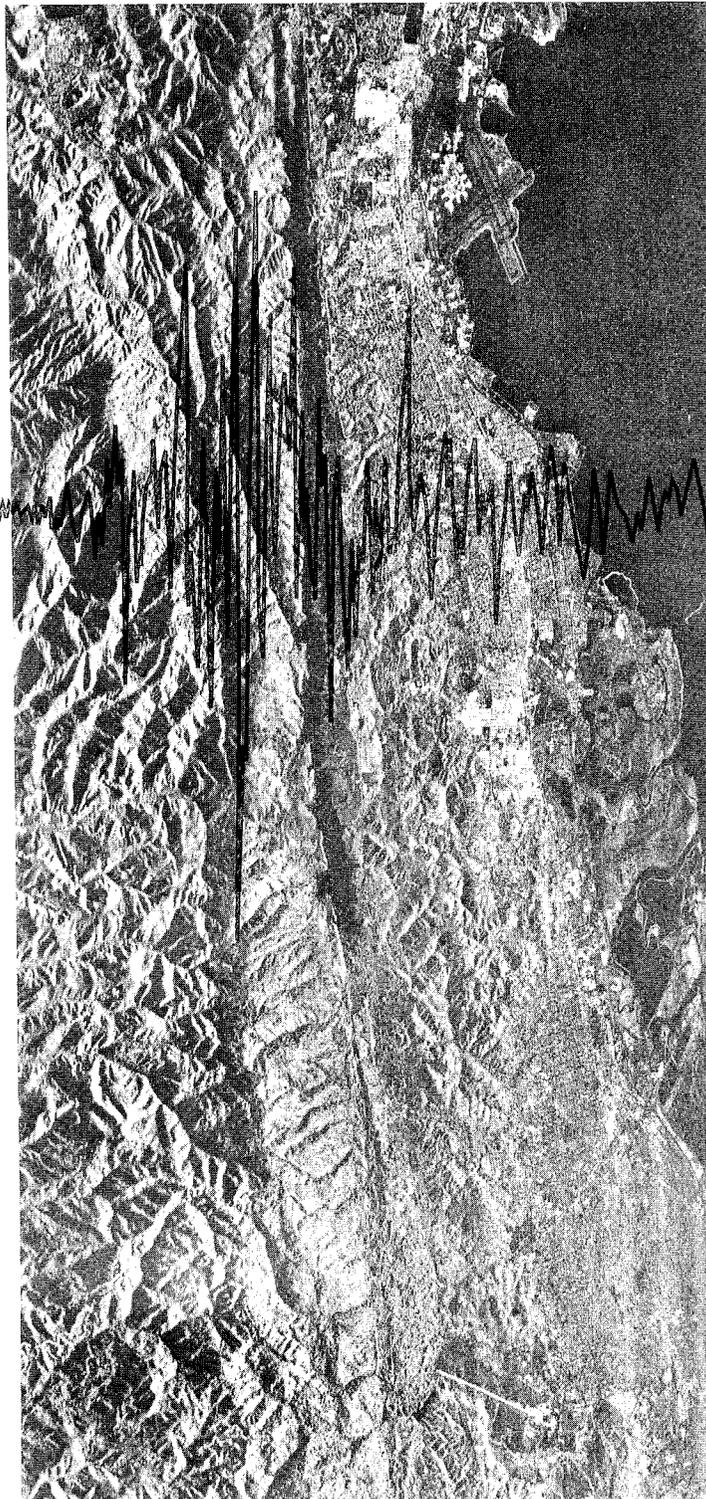


# SLAC BEAM LINE

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**SLAC BEAM LINE**

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**FROM THE EDITOR'S DESK:**

This issue marks the entry of a new and major addition to the *Beam Line* editorial staff. Rene Donaldson, who recently came to SLAC after twenty years at Fermilab and the SSC Central Design Group, is now our new Associate Editor. Her impact on the design of the *Beam Line* can be seen throughout this issue.

Of equally earthshaking importance is our lead article on SLAC's recovery from the Loma Prieta Earthquake of 1989. In a great effort, involving hundreds of staff members, the lab got back on its feet extremely quickly, losing only about a month in the SLC schedule. This article recounts these efforts.

Beginning on page 6 is a summary of SLAC achievements in high-energy physics and accelerator development during the past fiscal year, ending September 30. Written by several different contributors, it has been woven into a single, coherent article by the *Beam Line* editors. FY89 has been a good year for SLAC, with significant advances being made on many fronts, and this article recounts the major achievements.

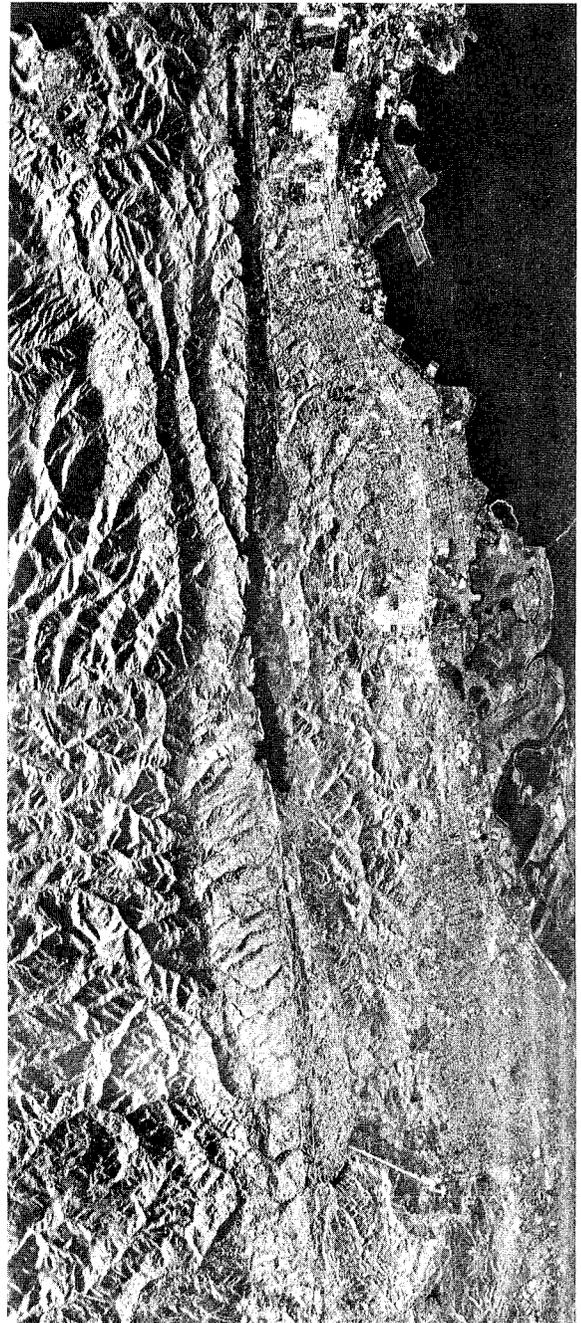
Starting with next year's first issue, the *Beam Line* will undergo a major facelift. A completely new design, both inside and out, will help to present the scientific output of SLAC in a more appealing fashion. Watch for our next debut!

**Cover Photo:** A satellite photograph of the San Francisco Peninsula showing major fault lines. The San Andreas Fault is the large gash in the earth running vertically through the center of the photo. The San Francisco Airport can be seen jutting into the Bay at upper right, and SLAC is visible at lower right. Superimposed on the cover photo is one of the seismograph traces of the Loma Prieta Earthquake, as recorded on the Stanford University campus.

(Maps courtesy of USGS)

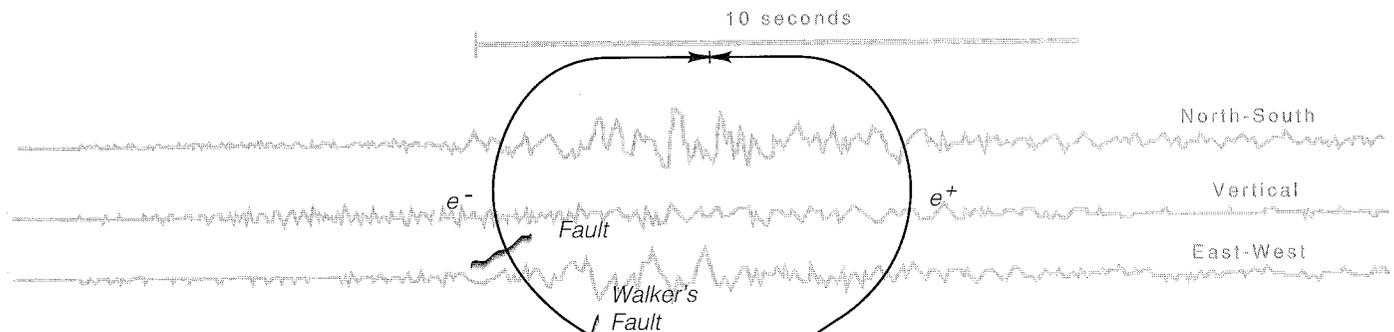
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# SLAC SURVIVES A PRETTY BIG ONE

by Michael Riordan



After a successful six-month run for high-energy physics research, the Stanford Linear Collider was shut down on Monday morning, October 16, for scheduled upgrades and installation of two vertex detectors in the big Mark II detector. At 5:04 p.m. the very next day, however, the Earth put a halt to these ambitions. A tremendous earthquake measuring 7.1 on the Richter scale rocked the entire Bay Area from its epicenter along the San Andreas Fault in the Southern Santa Cruz Mountains bringing everyday life to a jarring halt.

Advancing north along the San Francisco peninsula at speeds up to five kilometers per second, the mighty shock waves radiating outward from the epicenter ripped through the bedrock of 25 million year-old Miocene sandstone on which SLAC rests, subjecting the laboratory to ground accelerations that were as much as 30 percent of the acceleration due to gravity. The lab shuddered violently for nearly 15 seconds as the waves rumbled through.

People still working at that hour dashed for doors or dove under desks to avoid the hail of books, ceiling tiles and other objects falling all about. In the Collider Experimental Hall at SLC, physicists standing on the teetering endcaps of the SLD clung to the railings or dropped to all fours, hoping these upright slabs of iron would not topple onto the concrete floor forty feet below. A technician suspended in a bucket from the massive overhead crane swung precariously to and fro above the gaping pit as the crane jostled back and forth in its tracks.

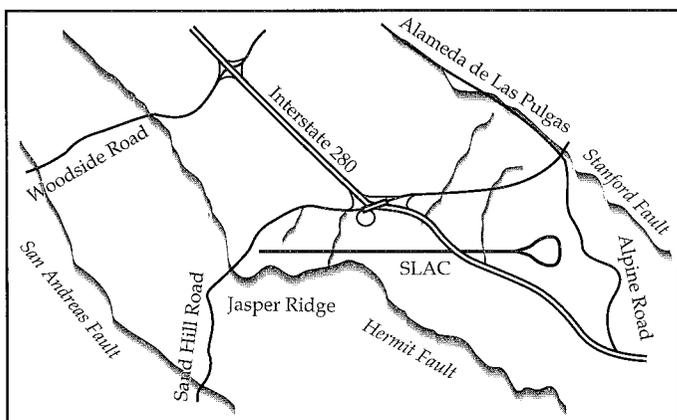
Minutes later, after the main jolt had passed and the lab still quivered under the effects of aftershocks, staff members began assessing the level of injury to the laboratory and its staff. Miraculously, nobody at SLAC had been hurt in the temblor even though many were still present at the moment it struck.

The primary damage to buildings and equipment seemed at first to be relatively minor: a few small cracks in walls, some nasty leaks, two broken transformers in the SLAC substation, ground faults in magnets and power supplies. End Station A, designed and built in the 1960s, took some of the hardest hits; two magnets in the old 8-GeV Spectrometer jostled back and forth in their mounts, ripping open a hole in the vacuum chamber inside them. The lack of serious damage was testament to the foresight in building SLAC according to stringent standards that exceeded the requirements of the local building codes and to the watchdog work of the Earthquake Safety Committee. For years its members had made themselves unpopular around SLAC by badgering everybody to bolt cabinets to walls and to secure anything heavy that might topple in a major quake.

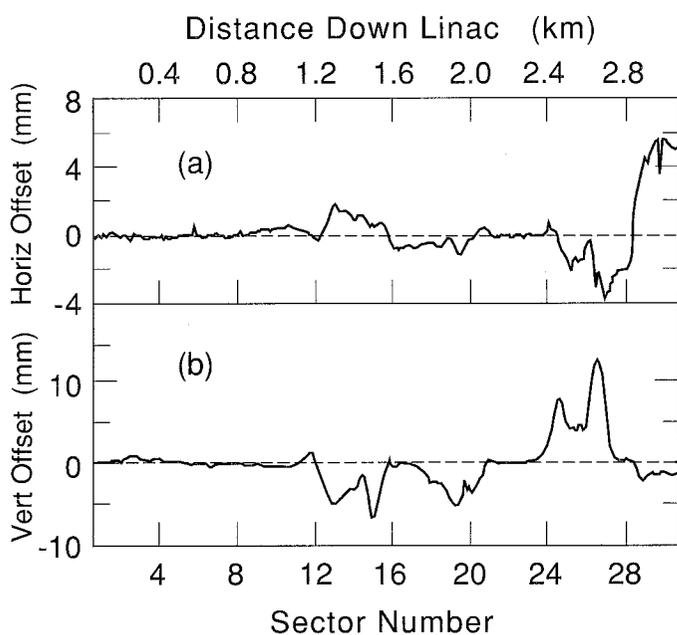
Overnight they became heroes. Damage to the Collider Hall was relatively light. Even with its endcaps open to install the vertex detectors, the Mark II survived the shock with only minor damages. It developed a water leak in a heat shield, and some bearings were damaged in the structure supporting the endcaps, but otherwise it seemed to be in good shape.

Most impressive was how well the SLD had survived, even though only partially assembled at the time. Its 600

*SLAC seismograph traces superimposed on a schematic diagram of the SLC. The three curves correspond to ground accelerations in the North-South, Vertical and East-West directions. Faults extending across the SLC indicate places where there were sizable shifts in the positions of magnets or accelerator sections.*



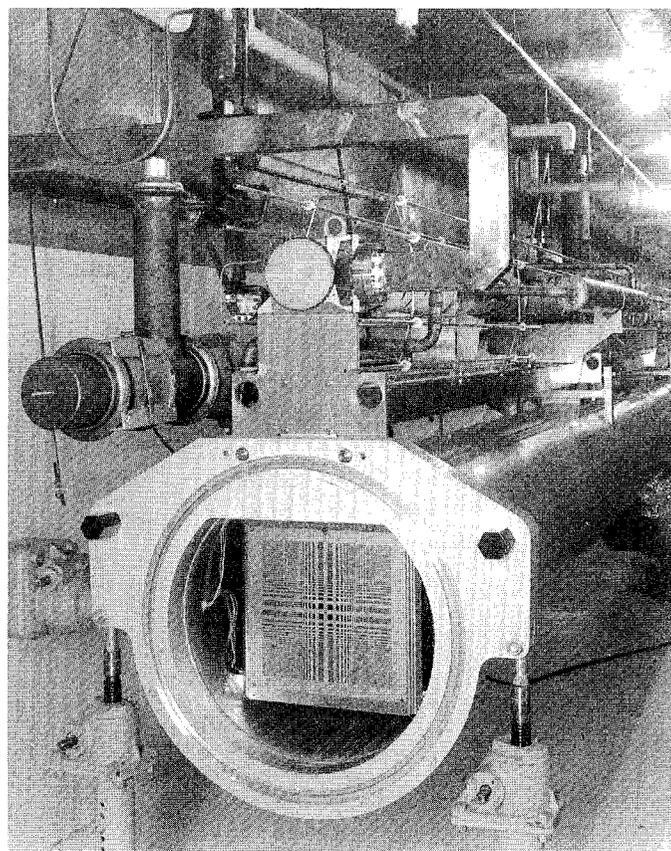
Fault map of SLAC vicinity.



Quake-induced offsets in the linac, as measured in late October by laser surveying techniques.

ton liquid argon calorimeter (LAC) rocked back and forth within the enormous vacuum chamber surrounding it but caused no apparent damage. This ponderous cylinder is supported at each end by stainless steel slings as thick as a man's leg. Under the accelerations of a major quake, the LAC could swing freely along its axis like a huge clanger in a bell, and bash into the end plates of the surrounding chamber. To prevent such a calamity, eight oil-filled shock absorbers were being installed at each end, but only four (out of a total of sixteen) were fully activated at the time the quake struck. Fortunately, the shock absorbers damped out any swaying motions, in the process spilling some oil out onto the pit floor.

But the serious work of assessing all the effects of the jolt had only just begun. By late that week and early the



One of the targets used in the laser survey positioned inside a section of the accelerator support tube.

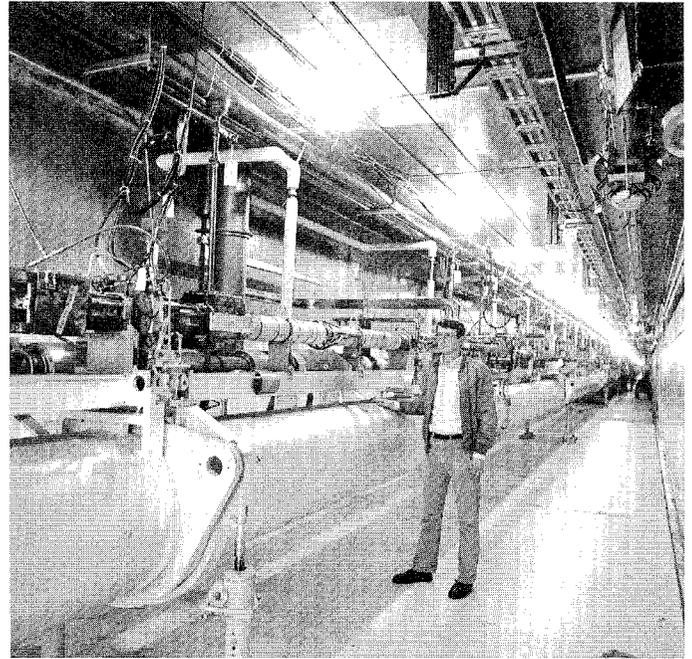
next, many instances of secondary damage had been uncovered as people looked around more carefully. Most worrisome for SLAC's immediate future were the small misalignments of the linear accelerator waveguide and of the magnets in the SLC arcs. As Associate Director Kaye Lathrop put it, "All of the accelerator systems are now somewhere else from where they were before the quake."

First on the agenda was to get the linac functioning again so its precision electron beam could be used to survey the rest of the SLC. Using a laser beam aimed down the large aluminum tube supporting the two-mile copper waveguide, surveyors found small dips and offsets at two points where the linac had been built on fill rather than sandstone bedrock. Settling had occurred there in the past, however, and these accelerator sections were easily jacked back into alignment.

At the end of the linac, however, this laser survey uncovered an abrupt vertical shift of more than a centimeter and a horizontal offset almost half as large. Fresh cracks in the concrete walls of the tunnel testified to the existence of a fault cutting across the linac; it had obviously slipped a bit during the quake. The last two sectors and the entire SLC arcs had shifted more than a centimeter relative to the rest of the linac!



*Workmen installing one of the combined-function dipole magnets inside the SLC arc tunnel.*



*John Seeman, who coordinated efforts to realign the linac, stands beside it.*

No amount of jacking would ever get these two segments of the SLC back in perfect alignment. Instead the affected accelerator sections were repositioned in a smooth curve through which the electron and positron beams could be steered on slightly altered trajectories from one segment to the other.

The linac alignment work was completed in early November, just as the SLC was returning to life further upstream. By Monday, November 12, both electron and positron beams were once again surging routinely down the entire linac and into the arcs. Later that week measurements of the electron beam emittance (which is the product of the beam size and its angular spread) showed the beam quality to be as good as it ever had been beforehand. "The fact that the linac has come back so well, and for both beams," said physicist John Seeman, who led this effort, "is yet another triumph for strong-focusing machines."

More problematical were small displacements of the thousand or so magnets used to bend and guide electrons and positrons through the SLC arcs. Getting these magnets properly positioned in the first place had been an arduous job, and realigning them could easily be a major task. Spot checks of these finicky magnets made within the first week after the quake revealed that several were indeed out of alignment, and bellows between some of them had been compressed as these magnets jostled back and forth during the jolt.

When the electron beam from the linac first entered the north arc, it made it to the reverse bend, almost a third of the way through, before disappearing. Visual

checks of the magnets in that vicinity revealed that there were offsets of up to a centimeter from their nominal positions. Yet another crack in the sandstone had thus been discovered, and it was promptly dubbed "Walker's Fault" after Nick Walker, the man in charge of the arcs.

Repositioning these magnets in a smooth curve, the crews finally worked the electron beam all the way through the north arc to the SLC final focus on Thursday, November 17. Meanwhile the positron beam had been successfully guided through the south arc earlier that week, indicating no gross misalignments there. The beams were once again knocking on the door of the Collider Hall, exactly one month after one of the worst disasters ever to occur in the United States. Although there was plenty of work remaining to be done in bringing these beams back to pre-quake performance levels, it was a very encouraging recovery.

By late November alignment crews had returned to the Mark II detector for the critical installation of its two vertex detectors, work that had been halted abruptly after the October 17 jolt. Plans were to complete these installations and restart physics research by mid-December. If successful, it would mean that the quake had caused a delay of just over a month in the SLC program.

Including the costs of realignment, SLAC had suffered almost \$2 million in losses due to the Pretty Big One. In the final analysis, the lab was extremely lucky to have gotten back on its feet so quickly and avoided much of the devastation that had hit the rest of the Bay Area. But our good fortune came largely through years of foresight and planning for just such a possibility.

## SLAC ACHIEVEMENTS IN FY1989

During the 1989 fiscal year SLAC continued commissioning the Stanford Linear Collider (SLC), and the Mark II collaboration began high-energy physics research with the world's very first sample of  $Z$  particles produced by an electron-positron collider. This work established the  $Z$  mass to a high level of precision and restricted the Standard Model to three conventional families of quarks and leptons. Additional progress was made in the construction and commissioning of the SLD, a state-of-the-art particle detector to be installed at the SLC in 1990, and in commissioning the accelerator components needed to produce a beam of polarized electrons.

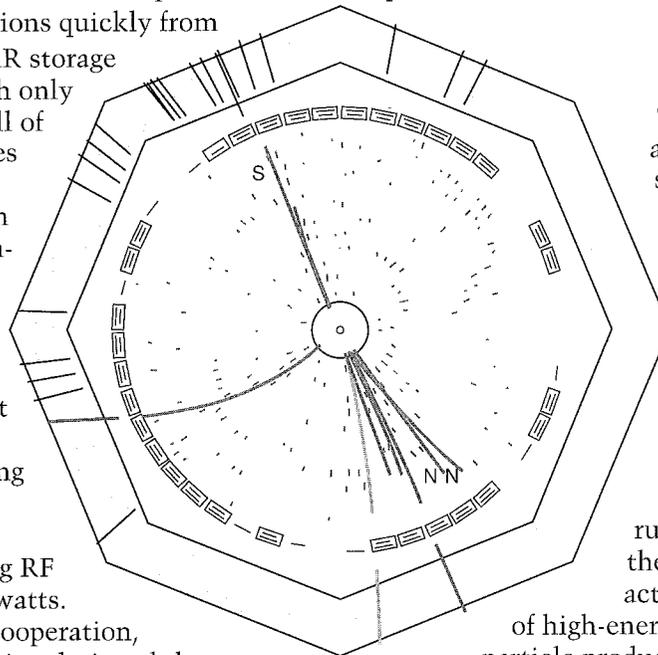
Attempts to switch operations quickly from the SLC to the PEP and SPEAR storage rings and back again met with only mixed success. During the fall of 1988, record high luminosities were achieved on PEP while operating the TPC detector in a special configuration. Meanwhile the Mark III collaboration logged a sample of more than 200,000  $\psi'$  particles at SPEAR.

Research and development aimed at a next-generation linear collider progressed along several fronts, including the development of a relativistic klystron capable of generating RF power levels up to 330 megawatts. With growing international cooperation, a Final Focus Test Beam is being designed that will help accelerator physicists understand how to produce and control electron and positron beams having submicron dimensions.

A global analysis of all SLAC experiments in deep inelastic electron scattering yielded the world's most accurate values of the proton and deuteron structure functions. These results helped to resolve apparent discrepancies between the two major high-energy muon scattering experiments performed at CERN, and an elastic electron-nucleon scattering experiment in End Station A led to the most precise determinations yet made of the neutron form factors.

Several proposals for future experimental facilities were made or initiated during FY89, including a high-luminosity tau-charm factory, an asymmetric  $B$  factory, and a gas-jet internal-target facility to be installed at PEP. And SLAC hosted the 14th International Symposium on Lepton and Photon Interactions—as well as several other major conferences and workshops.

These achievements and other significant advances, made during FY1989, are discussed here in greater detail.

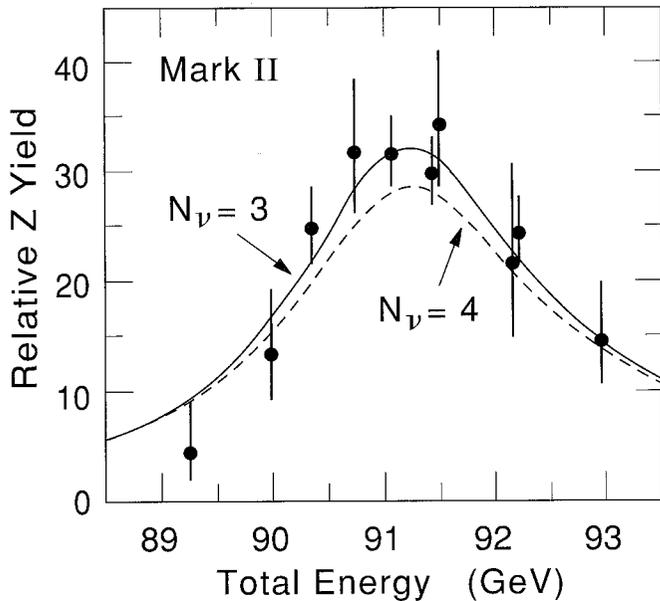


### First $Z$ Particle

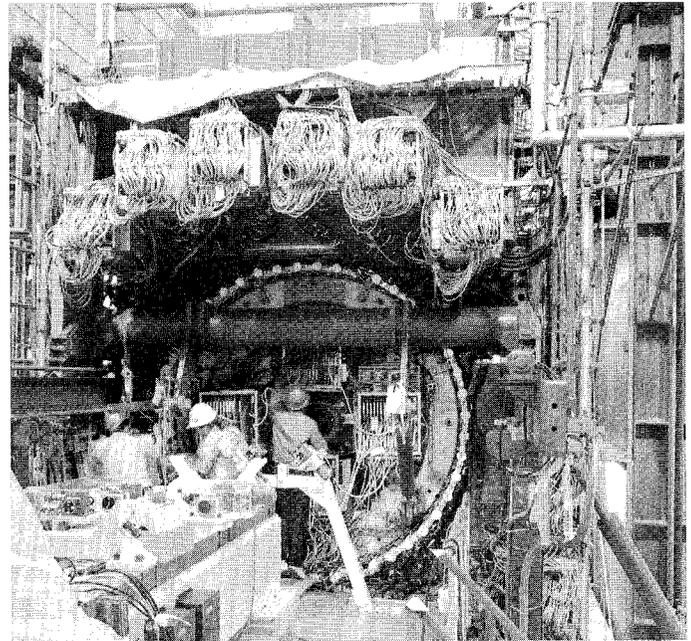
The major activity taking place at SLAC during FY1989 was the successful commissioning of the SLC and the production of its first sample of  $Z$  particles. Machine development studies were interleaved with PEP and SPEAR filling during the period lasting from October through December 1988. The SLC was then shut down for installation of hardware during January and February 1989, followed in March by the resumption of commissioning activities and the commencement

of high-energy physics research. The first  $Z$  particle produced by the SLC was recorded by the Mark II detector on April 11 (see April 1989 *Beam Line*, p. 3). Installation of new collimators at the end of the linear accelerator (linac), a doubling of the machine repetition frequency to 60 pulses per second, and the achievement of small beam sizes less than 4 microns in radius at the SLC clashpoint combined to boost the peak  $Z$  production rate beyond 1 per hour by June. In late August, after realignment of masks in the Mark II detector had helped to lower beam-induced backgrounds, the peak luminosity rose to an equivalent rate of 2  $Z$ 's per hour. By early October almost 500  $Z$  particles had been recorded in the Mark II detector.

The improved performance of the SLC over the 1988 run was due to many advances made in the areas of background reduction, machine reliability and beam tuning. New toroidal magnets in the final focus and collimators in the linac reduced backgrounds of muons and other extraneous debris in the Mark II detector by better than a factor of 10, thereby permitting substantial increases in beam currents and hence in machine luminosity. Improvements to the damping-ring kicker systems, which



Graph illustrating the apparent yield of Z particles observed by the Mark II Collaboration on the SLC. The two curves represent the yields predicted by the Standard Model assuming the number of neutrinos  $N_\nu$  is 3 or 4. The vertical bars drawn through the data points give the uncertainty in each measurement.



The Mark II detector in position at the interaction point of the SLC. The circular feature in the center is the north endcap; at extreme left is one of the muon detectors.

were the principal cause of SLC outages during the 1988 run, have essentially removed them from the equipment-failure list. Temperature-related problems were brought under control by better ventilation of the linac equipment gallery, and by insulation and air-conditioning of critical components.

Better optical matching of the beams into the linac from the damping rings, plus reduction of dispersive effects at the start the linac, have helped limit the spread of the beams during acceleration. When combined with a better understanding of the final focus optics and the use of beam-beam deflections as a powerful tuning aid, these advances have permitted operators to achieve rms beam radii of 3 microns routinely in colliding-beam mode. The smallest radius yet attained is about 2 microns, close to the original design value.

In its present configuration, the SLC is estimated to be limited to a peak Z production rate of about 2.5 per hour. Near-term upgrades, which include a new generation of kicker magnets and a high-power positron-production target scheduled for installation early next year, should increase this figure by about a factor of 10 in 1990.

### Mark II Z Physics

By taking advantage of a well-understood detector fully ready for research, the Mark II collaboration was able to produce very rapidly a series of important results

that have significantly advanced our understanding of elementary particle physics (see September 1989 *Beam Line*, p. 3). Based on a sample of almost 500 Z particles observed at the SLC through early October, these physicists mapped out the shape of the Z peak between energies of 89 and 93 billion electron volts (GeV). Their measurements yielded a precise value of the Z mass,  $91.14 \pm 0.12$  GeV, which was reported in a scientific paper sent to the *Physical Review Letters* on October 11.

Of even more fundamental importance was the Mark II limit on the number of conventional quark-lepton families that can be accommodated within the Standard Model. Additional families beyond the three definitely known to exist should each include a light neutrino as one of their four members, giving the Z additional ways to decay without leaving a trace in the detector. Thus an extra family would cause a small drop in the apparent Z particle yield, but the data recorded by the Mark II collaboration showed no such deficit. In the same paper, these physicists concluded that the number of light neutrinos was  $2.8 \pm 0.6$ , which ruled out 4 neutrinos at better than 95 percent confidence. This result (which was immediately confirmed by the four LEP detectors at CERN) settled one of the principal open questions of particle physics. There can be only three conventional quark-lepton families in the Standard Model.

Using these data the Mark II physicists also studied how Z particles disintegrate into leptons and hadrons. As expected in the Standard Model, the Z decays into a pair

of electrons, muons or tau leptons about 10 percent of the time—with each of these three leptonic decay modes having roughly the same likelihood. The decays of the  $Z$  into hadrons, which occur about 70 percent of the time, were the first to be observed unambiguously at any particle accelerator. The kinematic distributions of these hadronic decays were found to agree completely with the predictions of the Standard Model, providing important information about the underlying dynamics of quarks and gluons—the fundamental constituents of hadrons.

Finally, the initial sample of  $Z$  particles produced by the SLC was used to search for direct evidence of new and hitherto unobserved particles like the long-sought top quark, or a charge- $1/3$  quark of a (previously possible) fourth family, or a neutral heavy lepton. No convincing evidence could be found for any of these objects, and the Mark II collaboration was able to place lower limits ranging from 40 to 45 GeV on the masses of any such particles.

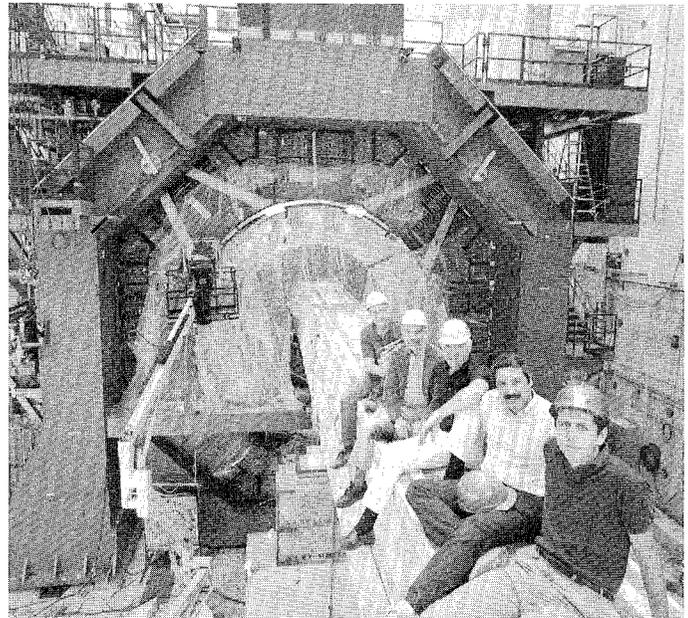
With this impressive array of results, presented only six months after it began operations this year, the SLC has begun to achieve the second major goal stated for this novel collider: to serve as a source of  $Z$  particles for high-energy physics research.

### SLD Construction

The SLD, a state-of-the-art particle detector designed for a second generation of research on the  $Z$  particle (see January 1989 *Beam Line*, p. 10), is now in its final stages of assembly. Commissioning of the full detector will begin early next year using cosmic rays; installation on the SLC beam line is slated for late 1990.

During FY1989 all major subsystems of the SLD were completed. Tracking chambers for the warm-iron calorimeter were fully installed, and nearly all of them have already been commissioned on cosmic rays. The barrel and endcap liquid-argon calorimeters were installed and pumped down in preparation for full-scale cryogenic testing. Stringing of the central drift chamber was completed in April, and it will soon be installed; the endcap drift chambers are already in place. The annulus of the Cerenkov ring-imaging detector (CRID) was installed this summer inside the liquid-argon calorimeter, complete with all its mirrors; its drift boxes are nearly finished and their installation is beginning. The SLD beampipe, complete with masks and luminosity monitor, is ready for production. Cryostats for the superconducting final focus magnets are being assembled, and a facility to supply them with liquid helium is now operational; transfer lines were installed in October.

All the electronics for the calorimeters and CRID are either finished or in production, and manufacture of the drift chamber electronics has almost begun. The vertex



*Some of the key people involved in the construction of the SLD, which sits in the background. Back to front, Knut Skarpaas, Senior Engineer; Martin Breidenbach, spokesman of the SLC collaboration; Bob Bell, Chief Engineer; Mike Shaevitz (Columbia University), Commissioning Coordinator; Dan Alzofon, Engineering Physicist. The massive steel I-beam on which they are sitting was used to support the 600-ton liquid argon calorimeter as it was rolled into place in the SLD magnet yoke behind them.*

detector chips, mountings and readout electronics are in full production. Online software for monitoring the detector is already in use, and event reconstruction programs are well developed. The SLD should be ready to begin logging data in late 1990.

### Polarized Electrons

A unique feature of the SLC that will be central to the physics research done by the SLD collaboration is its ability to collide a beam of partially polarized electrons with an unpolarized positron beam. Polarized electrons are produced by shining an intense beam of circularly polarized laser light on a crystal of gallium arsenide (GaAs); nearly 50 percent polarization has been achieved for wavelengths above 750 nm. In addition, 43 percent polarization has been obtained using GaAlAs cathodes at a wavelength of 700 nm, where long dye lifetimes have been achieved with the dye laser. After commissioning, the laser was installed at the SLC injector, together with the necessary control and monitoring electronics. Optical transport elements designed to direct the laser light onto the cathode have been prepared, and their installation is occurring this fall.

Preservation of the electron polarization through the SLC requires three superconducting solenoid magnets to rotate the spin vectors as the electrons enter and exit the damping rings. During FY1989 these solenoids and their associated cryogenic systems were commissioned; installation is scheduled to begin in January 1990.

Three polarimeters—two based on Möller scattering and one on Compton scattering—will be used to monitor the polarization of the electron beam. The Möller polarimeters have already been installed on the SLC, and studies of backgrounds are in progress. A prototype detector for the Compton polarimeter has been commissioned and is now serving as an SLC luminosity monitor.

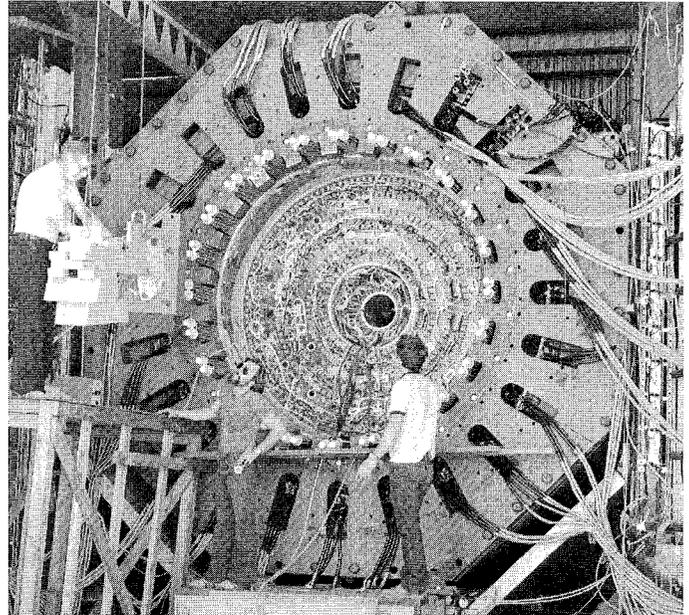
### PEP Operations

In order to run the PEP storage ring in parallel with the SLC, it is necessary to switch from SLC operations, fill PEP quickly with electrons and positrons, and then return to full colliding beams with small spot sizes in a complete cycle time on the order of one hour or less. During the fall of 1988, the first attempts to achieve such a "quick switchover" included simultaneous attempts to fill the SPEAR ring, and no efforts were made to return to colliding SLC beams. Severe difficulties were encountered in trying to fill SPEAR because of the gross mismatch between its low injection energy and the high SLC energy. Subsequent tests of the switching process, which occurred from August through mid-October 1989 concentrated on filling PEP and then returning quickly to colliding SLC beams. The average cycle time for a full switchover, PEP fill, and return to SLC exceeded two hours, but this interval should come down with further instrumentation and practice.

In the 1988 tests, the PEP luminosity reached  $6 \times 10^{31}$   $\text{cm}^{-2}\text{s}^{-1}$ , which is higher than has been attained by any other electron-positron collider except the Cornell storage ring CESR (see January 1989 *Beam Line*, p. 9). With additional modifications to correct for beam-induced heating inside the TPC vertex detector, which limited the achievable luminosity, it seems possible to attain  $10^{32}$   $\text{cm}^{-2}\text{s}^{-1}$  on PEP.

### Mark III Physics

Owing to problems injecting beams into SPEAR and consequently low luminosity in the fall of 1988, the Mark III collaboration elected to log data at a center-of-mass energy equal to 3.68 GeV, the peak position of the  $\psi'$  resonance. During this three-month run, more than 200,000  $\psi'$  particles were recorded in the detector. Analysis of these data is underway; preliminary results were presented at the 1989 SLAC Summer Institute and at the Hadron89 Conference.

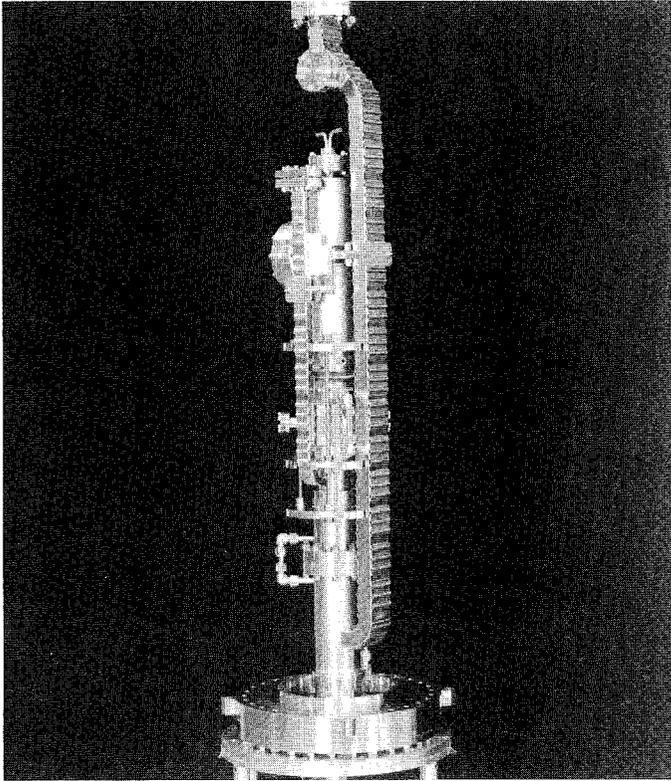


*View of the Mark III detector at SPEAR with its endcap removed, revealing the central drift chamber within. Bob Eisele, chief engineer on the project stands at left.*

In the past data has been taken by the Mark III collaboration at three principal energies: *i*) at the peak of the  $J/\psi$  resonance, whose decays can be examined for possible glueballs (bound states of gluons); *ii*) at the  $\psi''(3770)$  resonance, which decays primarily to pairs of charmed  $D$  mesons; and *iii*) at 4.14 GeV, where the charmed-strange  $D_s$  meson is produced together with its vector partner, the  $D_s^*$ . Analyses of these data sets are continuing, and several important papers have been published in journals during the past year: *i*) a determination of the mixing of quark families from semileptonic  $D$  decays; *ii*) observation of hadronic  $D_s$  decays to final states containing kaons, and *iii*) an upper limit on rare  $D$  decays. The search continues for glueballs in decays of the  $J/\psi$ .

### Accelerator R&D

A vigorous R&D program to develop an RF power source suitable for the next generation of linear colliders is underway. In collaboration with Lawrence Livermore Laboratory, SLAC has developed a relativistic klystron that has produced up to 330 MW at a frequency of 11.4 GHz, with a pulse width of 30 nanoseconds. This power has been fed to a small experimental accelerator section, and electron beams have been accelerated at gradients up to 84 MV per meter. Much higher accelerating fields are expected to be demonstrated soon; over 140 MV/m has been obtained without any electron beam in the cavity.



*Relativistic klystron SHARK built at SLAC and now undergoing tests at Livermore.*

Also being studied is an alternate approach, using a conventional klystron that develops 100 MW together with RF pulse compression techniques. Low-power RF pulses have been successfully compressed by a factor of 3.2 using these methods. A crossed-field amplifier is also under development as an alternative to the klystron.

To study the beam optics and final focus system needed for a next-generation collider, a Final Focus Test Beam will be constructed at SLAC, with international collaboration coming from Novosibirsk, KEK, Orsay and possibly CERN. Its goal will be to produce and control beams with a size of 1.0 by 0.1 microns. A detailed design of this facility, which will replace the SLAC C-beams and extend into the Research Yard from the Beam Switchyard, is presently underway.

### Fixed-Target Physics

In the realm of fixed-target physics, the results of all deep inelastic electron-nucleon scattering experiments that were done at SLAC between 1970 and 1985 were recently combined in a single global analysis. The aim of this effort was to extract the most accurate possible values for the proton and deuteron structure functions and for the ratio  $R = \sigma_L/\sigma_T$  over the entire SLAC kinematic range. Systematic differences between the various experiments were minimized by normalizing them to the

recent precision SLAC experiment 140. Comparisons of these structure functions (in overlapping kinematic regions) with those measured at higher energies by the CERN muon-scattering experiments BCDMS and EMC have helped to resolve a troubling discrepancy between them. These results were presented at the Lepton-Photon Symposium in August.

In January and February of 1989, a group of nuclear and high-energy physicists used the End Station A spectrometer facility to measure cross sections for elastic electron-proton and quasi-elastic electron-deuteron scattering. A major goal of this experiment was to determine the neutron form factor to an unprecedented level of accuracy (see April 1989 *Beam Line*, p. 6).

The community of physicists interested in doing fixed-target work at SLAC has proposed a novel facility dubbed PEGASYS for the PEP storage ring. Combining a gas-jet target with a large-acceptance forward spectrometer, it would allow them to study electron scattering in far greater detail than previously possible. This proposal has received conceptual approval from the EPAC and NPAC at SLAC, and now awaits a detailed Technical Review scheduled for January 1990.

### High Luminosity Colliders

SLAC has been examining the possibility of constructing a new high-luminosity electron-positron colliding-beam facility operating in the center-of-mass energy range from 3.0 to 4.2 GeV. Called the Tau-Charm Factory, it would open up new possibilities in the study of the tau lepton and charmed  $D$  mesons, plus the  $\psi$  particles and their decay products, by generating far more copious quantities of these particles than is possible at existing or planned machines (see September 1989 *Beam Line*, p. 12). The design luminosity of  $10^{33} \text{ cm}^{-2}\text{s}^{-1}$  would be attained by circulating many bunches of electrons and positrons in two separate rings crossing over at one interaction region, and by having a dedicated injector. Detailed designs for such a collider, and its associated particle detector, were discussed at a Tau-Charm Factory Workshop held in May 1989 at SLAC.

Another possible future collider under intensive study is an asymmetric  $B$ -meson factory that would be built inside the existing PEP tunnel (see p. 11, this issue). Beams of electrons and positrons would circulate in two separate rings, one at 9 GeV and the other at 3 GeV. Because of this asymmetric energy configuration,  $B\bar{B}$  pairs would be produced with a measurable separation between their decay vertices. Such a feature offers distinct advantages over other sources of  $B$  mesons; it would be crucial to the measurement of CP violation in the  $B$  meson system, which might be possible with such a facility. The anticipated luminosity of the Asymmetric  $B$  Factory would fall in the range from  $10^{33}$  to  $10^{34} \text{ cm}^{-2}\text{s}^{-1}$ .

## THE ASYMMETRIC B FACTORY

After a November endorsement by the Experimental Program Advisory Committee, work has begun in earnest on the design of a high-luminosity  $B$  factory, which promises to be a major new project for SLAC in the 1990s. This novel  $e^+e^-$  collider, which could be built in the PEP tunnel using some existing components, would be devoted to studies of the physics of  $B$  mesons, tau leptons and charmed particles.

The primary motivation for the project, led by Jonathan Dorfan of SLAC, David Hitlin of Caltech and Pier Oddone of LBL, is the measurement of  $CP$  violation in  $B$  meson decay. The phenomenon of  $CP$  violation, so far observed only in decays of  $K_L^0$  mesons, is a key to detailed tests of the Standard Model, which has thus far withstood all experimental assaults. It should produce a host of effects in the decay of  $B$  mesons, but they are difficult to measure without a copious supply. SLAC is the first laboratory to endorse a project specifically aimed at measuring  $CP$  violation in the  $B$  meson system.

All experimental approaches require the production of millions of  $B$  mesons in a configuration that allows one to distinguish them from their antiparticles unambiguously. The optimal method is to produce them as  $B\bar{B}$  pairs in  $e^+e^-$  collisions at the  $Y(4S)$  resonance, which occurs at a center-of-mass energy of 10.58 GeV. Hundreds of thousands of  $B$ s have been generated this way using the DORIS II storage ring at DESY and CESR in

Cornell. The collider anticipated for the PEP tunnel would have a much higher luminosity than these machines; its goal is at least  $3 \times 10^{33} \text{ cm}^{-2} \text{ sec}^{-1}$ , a factor of 30 higher than CESR, the most prolific existing  $B$  factory.

A unique feature of our proposed collider is the fact that the electron and positron energies will not be the same—as has been true in all previous  $e^+e^-$  colliders. Such an "asymmetric" design is necessary because experimenters need to search for differences between  $B$  and  $\bar{B}$  decays to specific final states. The  $Y(4S)$  is an ideal source of  $B\bar{B}$  pairs, which are produced in 25 percent of all  $e^+e^-$  collisions at this energy, and the mesons that emerge are easy to identify and reconstruct. But because the  $Y(4S)$  resonance is a spin-1 object (like the famous  $J/\psi$ ), no measurement that treats the  $B$  and  $\bar{B}$  mesons in the same fashion can yield a non-zero result for any observable quantity that might indicate  $CP$  violation.

The solution to this quandry is to produce the  $Y(4S)$  in motion. By clashing beams of unequal energy, say 9 GeV for electrons and 3.1 GeV for positrons, it becomes possible to create the  $Y(4S)$  resonances moving in the laboratory (along the electron beam direction). When the  $Y(4S)$  subsequently decays to  $B\bar{B}$  pairs, these are "Lorentz-boosted" in a manner that permits physicists to examine the  $B$  and  $\bar{B}$  decays separately. Such a measurement asymmetry allows one to detect the presence of  $CP$  violation.

—David Hitlin

## RECENT SLAC PUBLICATIONS

The following is a list of SLAC publications issued during the period from July 1 through October 31, 1989. This list was prepared by the staff of the SLAC Library. It is organized according to four categories: Experimental High Energy Physics, Theoretical Physics, Accelerator Physics, and Instrumentation and Techniques.

To obtain copies of these publications, write to the Publications Department, SLAC Bin 68, P. O. Box 4349, Stanford, CA 94309. Please be sure to specify author and publication number in your request.

### Experimental High-Energy Physics

G.S. Abrams *et al.*, "Initial Measurements of  $Z$  Boson Resonance Parameters in  $e^+e^-$  Annihilation" (SLAC-PUB-5037, Aug 1989; Published in *Phys. Rev. Lett.* **63**: 724, 1989).

G.S. Abrams *et al.*, "Measurements of  $Z$  Boson Resonance Parameters in  $e^+e^-$  Annihilation" (SLAC-PUB-5113, Oct 1989; Published in *Phys. Rev. Lett.* **63**: 2173, 1989).

MARK II Collaboration: G.S. Abrams, " $Z^0$  Physics from the MARK II at the SLC" (SLAC-PUB-5079, Jun 1989; Presented at Int. Conf. on Physics in Collision, Jerusalem, Israel, Jun 19-21, 1989).

MARK III Collaboration: J. Adler *et al.*, "Recent Results on Hadronic  $D_s$  and  $D$  Meson Decays from the MARK III" (SLAC-PUB-5052, Jul 1989; Submitted to 14th Int. Symp. on Lepton & Photon Interactions, Stanford, CA, Aug 7-12, 1989).

MARK III Collaboration: J. Adler *et al.*, "Upper Limit on the Absolute Branching Fraction for  $D_s \rightarrow \phi\pi^+$ " (SLAC-PUB-5044, Jul 1989; Submitted to *Phys. Rev. Lett.*).

TPC/ $2\gamma$  Collaboration: H. Aihara *et al.*, "A Measurement of the Total Cross Section in Tagged  $\gamma\gamma$  Reactions" (SLAC-PUB-5101, Sep 1989; Submitted to *Phys. Rev. D*).

R.G. Arnold *et al.*, "Transverse Electrodisintegration of the Deuteron in the Threshold Region at High  $Q^2$ " (SLAC-PUB-4918, Aug 1989; Submitted to *Phys. Rev. Lett.*).

W.B. Atwood *et al.*, "CP Violation with Polarized  $Z^0$ " (SLAC-PUB-5006, Oct 1989; Submitted to Phys. Lett. B).

W.B. Atwood and Benoit Mours, "B Physics at the  $Z^0$  Pole" (SLAC-PUB-5048, Oct 1989; Invited talk at Workshop on B Physics, Blois, France, Jun 26-Jul 1, 1989).

T. Browder, "Unsolved Problems in Hadronic Charm Decay" (SLAC-PUB-5083, Aug 1989; Presented at Tau-Charm Factory Workshop, Stanford, CA, May 23-27, 1989).

MARK III Collaboration: T. Browder, "Recent Results on Weak Decays of Charmed Mesons from the MARK III Experiment" (SLAC-PUB-5118, Oct 1989; Invited talk at 17th SLAC Summer Inst.: Physics at the 100-GeV Mass Scale, Stanford, CA, Jul 10-21, 1989).

MARK III Collaboration: D. Coffman *et al.*, "Study of the Doubly Radiative Decay  $J/\psi \rightarrow \gamma\gamma\rho^0$ " (SLAC-PUB-5104, Oct 1989; Submitted to Phys. Rev. D).

K.K. Gan, "Physics with Low-Energy  $e^+e^-$  and  $e^-e^-$  Collisions at Tau-Charm Factory" (SLAC-PUB-5005, Jul 1989; Invited talk presented at Tau-Charm Factory Workshop, Stanford, CA, May 23-27, 1989).

J.J. Gomez-Cadenas *et al.*, "Future Limits on the Tau-Neutrino Mass" (SLAC-PUB-5019, Aug 1989; Submitted to Phys. Rev. D).

C.A. Hawkins and Martin L. Perl, "Search for a Charged Lepton Specific Force in Electron-Positron Collisions" (SLAC-PUB-4949, Mar 1989; Submitted to Phys. Rev. Lett.).

K.G. Hayes, "Status of the Tau 1-Prong Problem" (SLAC-PUB-5061, Aug 1989; Presented at Tau-Charm Factory Workshop, Stanford, CA, May 23-27, 1989).

U. Karshon, "Monte Carlo Study of CP Asymmetry Measurement at a Tau-Charm Factory" (SLAC-PUB-5046, Jul 1989; Presented at Tau-Charm Factory Workshop, Stanford, CA, May 23-27, 1989).

A. Petradza, "Study of Four Lepton Final States in Electron-Positron Interactions at 29 GeV" (SLAC-347, Aug 1989; Ph.D. thesis).

B. Ratcliff, "Strangeonium Spectroscopy at the  $J/\psi$ : A Comparison with Kaon Hadroproduction" (SLAC-PUB-5081, Aug 1989; Presented at Tau-Charm Factory Workshop, Stanford, CA, May 23-27, 1989).

K. Riles *et al.*, "Search for a Nearly Degenerate Lepton Doublet ( $L^-, L^0$ )" (SLAC-PUB-5043, Aug 1989; Submitted to Phys. Rev. D).

R.H. Schindler, "Charmed Meson Physics Accessible to an  $L = 10^{33} \text{ cm}^2\text{s}^{-1} e^+e^-$  Collider Operating Near Charm Threshold"

(SLAC-PUB-4995, Jun 1989; Invited talk at Les Rencontres de Physique de la Vallée d'Aoste: Results and Perspectives in Particle Physics, La Thuile, Italy, Feb 26-Mar 4, 1989).

R.H. Schindler, "An Experimental Review of the Decays of the  $D_s$  Meson" (SLAC-PUB-4997, Jun 1989; Invited talk at 12th Int. Workshop on Weak Interactions and Neutrinos, Ginosar, Israel, Apr 9-14, 1989).

T.R. Steele, "A Search for Single Electron Production in Electron-Positron Annihilation at  $E = 29 \text{ GeV}$ " (SLAC-350, Sep 1989; Ph.D. thesis).

W. Toki, "Tau-Charm Factory Physics" (SLAC-PUB-5094, Sep 1989; Invited talk at 1989 Int. Symp. on Heavy Quark Physics, Ithaca, NY, Jun 13-17, 1989).

MARK III Collaboration: W. Toki, "Study of  $D_s$  Decays" (SLAC-PUB-5087, Sep 1989; Invited talk at KEK Topical Conf. on  $e^+e^-$  Collision Physics, Tsukuba, Japan, May 17-19, 1989).

MARK III Collaboration: W. Toki, "Study of  $\gamma'$  Decays" (SLAC-PUB-5093, Sep 1989; Invited talk at 1989 Int. Symp. on Heavy Quark Physics, Ithaca, NY, Jun 13-17, 1989).

A.J. Weir *et al.*, "Upper Limits on  $D^\pm$  and  $B^\pm$  Decays to Two Leptons Plus  $\pi^\pm$  or  $K^\pm$ " (SLAC-PUB-4999, Jun 1989; Submitted to Phys. Rev. D).

L.W. Whitlow *et al.*, "A Combined Analysis of SLAC Experiments on Deep Inelastic  $ep$  and  $ed$  Scattering" (SLAC-PUB-5100, Aug 1989; Contributed to Europhysics Conf. on High Energy Physics, Madrid, Spain, Sep 6-13, 1989).

### Theoretical Physics

C. Ahn, "Two Aspects of One Loop Structure: Unitarity Delay in the Standard Model and Modular Invariance in String Theory" (SLAC-349, Aug 1989; Ph.D. thesis).

C. Ahn and M.A. Walton, "Field Identifications in Coset Conformal Theories from Projection Matrices" (SLAC-PUB-5067, Aug 1989; Submitted to Phys. Lett. B).

A. Aurilia *et al.*, "Evolution of Bubbles in a Vacuum" (SLAC-PUB-4697-Rev., Jul 1989; Revised version; Submitted to Phys. Rev. D).

L. Bento, "Electroweak Theory with Spontaneous Breaking of Parity and CP" (SLAC-PUB-5099, Sep 1989; Submitted to Phys. Rev. Lett.).

S.J. Brodsky, "Color Transparency and the Structure of the Proton in Quantum Chromodynamics" (SLAC-PUB-5082, Jun 1989; Presented at Distinguished Speaker Colloq. Series, Minneapolis, MN, Feb 2, 1989, To be publ. by Addison-

- Wesley in the book *Trends in Theoretical Physics*, Vol.1., ed by P.J. Ellis & Y.C. Tang].
- S.J. Brodsky, "Tests of Quantum Chromodynamics in Exclusive and Inclusive Electroproduction" (SLAC-PUB-5013, Jun 1989; Presented at Topical Conf. on Electronuclear Physics with Internal Targets, Stanford, CA, Jan 9-12, 1989).
- S.J. Brodsky, "Tests of Quantum Chromodynamics in Exclusive  $e^+e^-$  and  $\gamma\gamma$  Processes" (SLAC-PUB-5088, Sep 1989; Presented at Tau-Charm Factory Workshop, Stanford, CA, May 23-27, 1989).
- S.J. Brodsky *et al.*, "Nuclear Bound Quarkonium" (SLAC-PUB-5102, Sep 1989; Submitted to Phys. Rev. Lett.).
- S.J. Brodsky and H.J. Lu, "Shadowing and Antishadowing of Nuclear Structure Functions" (SLAC-PUB-5098, Sep 1989; Submitted to Phys. Rev. Lett.).
- S.J. Brodsky and I. Schmidt, "Polarized and Unpolarized Intrinsic Gluon Distributions" (SLAC-PUB-5036, Sep 1989; Submitted to Phys. Lett.).
- R. Brooks, "Conformal Field Theories for the Green-Schwarz Superstring" (SLAC-PUB-5074, Aug 1989; Submitted to Phys. Rev. Lett.).
- C. Dib *et al.*, "Standard Model Predictions for CP Violation in  $B^0$  Meson Decay" (SLAC-PUB-5109, Oct 1989; Submitted to Phys. Rev. D).
- F.J. Gilman, "CP Violation in Rare  $K$  Decays" (SLAC-PUB-5000, Aug 1989; Invited talk at Conf. on CP Violation in Particle Physics and Astro-physics, Blois, France, May 22-26, 1989).
- F.J. Gilman, "Predictions for CP Violation" (SLAC-PUB-5018, Aug 1989; Invited talk at Int. Symp. on Heavy Quark Physics, Ithaca, NY, Jun 13-17, 1989).
- F.J. Gilman, "Prospects in  $K$  Physics" (SLAC-PUB-4992, Jun 1989; Invited talk at Workshop on Physics at the Main Injector, Batavia, IL, May 16-18, 1989).
- F.J. Gilman, "Rare Decays" (SLAC-PUB-4984, Sep 1989; Invited talk at 12th Int. Workshop on Weak Interactions and Neutrinos, Ginosar, Israel, Apr 9-14, 1989).
- F.J. Gilman and R.L. Singleton, "Analysis of Semileptonic Decays of Mesons Containing Heavy Quarks" (SLAC-PUB-5065, Aug 1989; Submitted to Phys. Rev.).
- M.C. Gonzalez-Garcia and Y. Nir, "Implications of a Precise Measurement of the Z Width on the Spontaneous Breaking of Global Symmetries" (SLAC-PUB-5090, Sep 1989; Submitted to Phys. Lett. B).
- M.C. Gonzalez-Garcia and J.W.F. Valle, "Constraints on Additional  $Z'$  Gauge Bosons From a Precise Measurement of the Z Mass" (SLAC-PUB-5076, Aug 1989; Submitted to Phys. Rev. Lett.).
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- D.C. Lewellen, "Embedding Higher-Level KAC-Moody Algebras in Heterotic String Models" (SLAC-PUB-5023, Jul 1989; Submitted to Nucl. Phys. B).
- D.C. Lewellen, "Tree-Level Constraints on Conformal Field Theories and String Models" (SLAC-PUB-5022, May 1989; Contributed to Superstring Workshop, College Station, TX, Mar 12-18, 1989).
- B.A. Li, "Production of  $Q^2$  Anti- $Q^2$  States" (SLAC-PUB-5007, Jun 1989; Invited talk at Tau-Charm Factory Workshop, Stanford, CA, May 23-27, 1989).
- B.W. Lynn, "Running Couplings in  $SU(2)-L \times U(1)$ " (SLAC-PUB-5077, Aug 1989; Submitted to Phys. Lett. B).
- A.M. Mourao *et al.*, "Effects of the Mass and Magnetic Moment of the Neutrinos in  $ve \rightarrow ve\gamma$ " (SLAC-PUB-5117, Oct 1989; Submitted to Phys. Lett. B).
- Y. Nir, "Phenomenology of the CKM Matrix" (SLAC-PUB-5051, Jul 1989; Invited talk at 1989 Int. Symp. on Heavy Quark Physics, Ithaca, NY, Jun 13-17, 1989).
- H.P. Noyes, "What is to be Done" (SLAC-PUB-4837, Jan 1989; Submitted to ANPA West Meeting, Stanford, CA, Jan 28-29, 1989).
- J. Sonnenschein, "Moduli Spaces and Topological Quantum Field Theories" (SLAC-PUB-5031, Jul 1989; Presented at 18th Int. Conf. on Differential Geometric Methods in Theoretical Physics: Physics and Geometry, Tahoe City, CA, Jul 2-8, 1989).
- V.L. Telegdi and S.J. Brodsky, "General QED/QCD Aspects of Simple Systems" (SLAC-PUB-5095, Sep 1989; Presented at Symp. on the Hydrogen Atom, Pisa, Italy, Jun 30-Jul 2, 1988).
- Y.S. Tsai, "Effects of Charged Higgs in Tau Decay" (SLAC-PUB-5003, Jul 1989; Contributed to Tau-Charm Factory Workshop, Stanford, CA, May 23-27, 1989; Submitted to Phys. Rev. D).
- Y.S. Tsai, "Effects of WR and Charged Higgs in the Leptonic Decay of Tau" (SLAC-PUB-5029, Jul 1989; Contributed to Tau-Charm Factory Workshop, Stanford, CA, May 23-27, 1989; Submitted to Phys. Rev. D).
- J.W.F. Valle, "Neutrinos Beyond the Standard Model" (SLAC-PUB-5057, Aug 1989; Invited talk at Int. Symp. on Weak and Electromagnetic Interactions in Nuclei, WIEN '89, Montreal, Canada, May 15-19, 1989).

B.F.L. Ward, "Renormalization Schemes: Where Do We Stand?" (SLAC-PUB-5025, Jul 1989; Invited talk at NATO Advanced Workshop on Radiative Corrections: Results and Perspectives, Brighton, England, Jul 9-14, 1989).

B.F.L. Ward, " $V_{ed}$  and  $V_{es}$  from Current Models" (SLAC-PUB-5030, Jul 1989; Invited talk at Tau-Charm Factory Workshop, Stanford, CA, May 23-27, 1989).

### Accelerator Physics

*Proceedings of the International Workshop on Next-Generation Linear Colliders*, Stanford, CA, Nov 28-Dec 9, 1988 (SLAC-335, Dec 1988).

G.S. Abrams *et al.*, "Experimental Beam Dynamics and Stability in the SLC Linac," (SLAC-PUB-5068, Sep 1989; Presented at 14th Int. Conf. on High Energy Accelerators, Tsukuba, Japan, Aug 22-26, 1989).

M.A. Allen *et al.*, "High-Gradient Electron Accelerator Powered by a Relativistic Klystron" (SLAC-PUB-5039, Aug 1989; Submitted to Phys. Rev. Lett.).

M.A. Allen *et al.*, "Recent Progress in Relativistic Klystron Research" (SLAC-PUB-5070, Aug 1989; Invited talk at 14th Int. Conf. on High Energy Accelerators, Tsukuba, Japan, Aug 22-26, 1989).

K.L. Bane, "Optimizing the Average Longitudinal Phase of the Beam in the SLC Linac" (SLAC-AP-76, Sep 1989).

T. Barklow *et al.*, "Commissioning Experience with the SLC Arcs" (SLAC-PUB-5056, Aug 1989).

K.L. Brown and R. Servranckx, "Cross-Plane Coupling and Its Effect on Projected Emittance" (SLAC-PUB-4679, Aug 1989; Submitted to Part. Accel.).

P. Chen *et al.*, "An Adiabatic Focuser" (SLAC-PUB-5060, Aug 1989; Presented at 14th Int. Conf. on High Energy Accelerators, Tsukuba, Japan, Aug 22-26, 1989).

P. Chen, "Coherent Pair Creation from Beam-Beam Interaction" (SLAC-PUB-5086, Sep 1989; Presented at 14th Int. Conf. on High Energy Accelerators, Tsukuba, Japan, Aug 22-26, 1989).

J.E. Clendenin *et al.*, "Energy Matching of 1.2 GeV Positron Beam to the SLC Damping Ring" (SLAC-PUB-5050, Aug 1989; Presented at 14th Int. Conf. on High Energy Particle Accelerators, Tsukuba, Japan, Aug 22-26, 1989).

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M. Cornacchia, "Requirements and Limitations on Beam Quality in Synchrotron Radiation Sources" (SLAC-PUB-5021, Jul 1989; Presented at CERN/Daresbury Course on Synchrotron Radiation and Free Electron Lasers, Chester, England, Apr 6-13, 1989).

D. Coupal, "Status of the SLC" (SLAC-PUB-5010, Jul 1989; Presented at Rencontres de Moriond: Electroweak Interactions and Unified Theories, Les Arcs, France, Mar 5-12, 1989).

P. Emma *et al.*, "Online Monitoring of Dispersion Functions and Transfer Matrices at the SLC" (SLAC-PUB-4907-Rev., Jul 1989; Submitted to Nucl. Instrum. Meth.).

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E. Forest and R.D. Ruth, "Fourth-Order Symplectic Integration" (SLAC-PUB-5071, Aug 1989; Submitted to Physica D).

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S. Kheifets and J.M. Voss, "A Kick Experienced by a Particle Obliquely Traversing a Bunch" (SLAC-PUB-4994, Jun 1989; Submitted to Particle Accelerators).

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K. Oide, "Design of a High-Luminosity Collider for the Tau-Charm Factory" (SLAC-PUB-5038, Aug 1989; Presented at Tau-Charm Factory Workshop, Stanford, CA, May 23-27, 1989).

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J. Seeman *et al.*, "Observation and Control of Emittance Growth in the SLC Linac" (SLAC-PUB-4889, Sep 1989; Presented at 14th Int. Conf. on High Energy Accelerators, Tsukuba, Japan, Aug 22-26, 1989).

J. Seeman, "Effects of RF Deflections on Beam Dynamics in Linear Colliders" (SLAC-PUB-5069, Sep 1989; Contributed to 14th Int. Conf. on High Energy Accelerators, Tsukuba, Japan, Aug 22-26, 1989).

E. Tanabe *et al.*, "A 2-MeV Microwave Thermionic Gun" (SLAC-PUB-5054, Aug 1989; Presented at 14th Mtg. on Linear Accelerators, Nara, Japan, Sep 7-9, 1989).

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P.B. Wilson, "Advances in Linear Collider Technologies" (SLAC-AAS-48, Sep 1989; Invited talk at 14th Int. Conf. on High Energy Accelerators, Tsukuba, Japan, Aug 22-26, 1989).

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D. Aston *et al.*, "Development and Construction of the SLD Cherenkov Ring Imaging Detector" (SLAC-PUB-4795, Jun 1989; Presented at Int. Wire Chamber Conf., Vienna, Austria, Feb 13-17, 1989).

W.B. Atwood, "B Identification by Topology with the SLD Detector" (SLAC-PUB-5047, Aug 1989; Contributed to Workshop on B Factories and Related Issues, Blois, France, Jun 26-Jul 1, 1989).

A.C. Benvenuti *et al.*, "The Digital Data Acquisition Chain and the Cosmic Ray Trigger System for the SLD Warm Iron Calorimeter" (SLAC-PUB-5066, Aug 1989; Invited talk at

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A. Breakstone *et al.*, "Radiation Hardness and Annealing Tests of a Custom VLSI Device" (SLAC-PUB-4104, Oct 1986; Presented at Nucl. Sci. Symp., Wash., DC, Oct 29-31, 1986).

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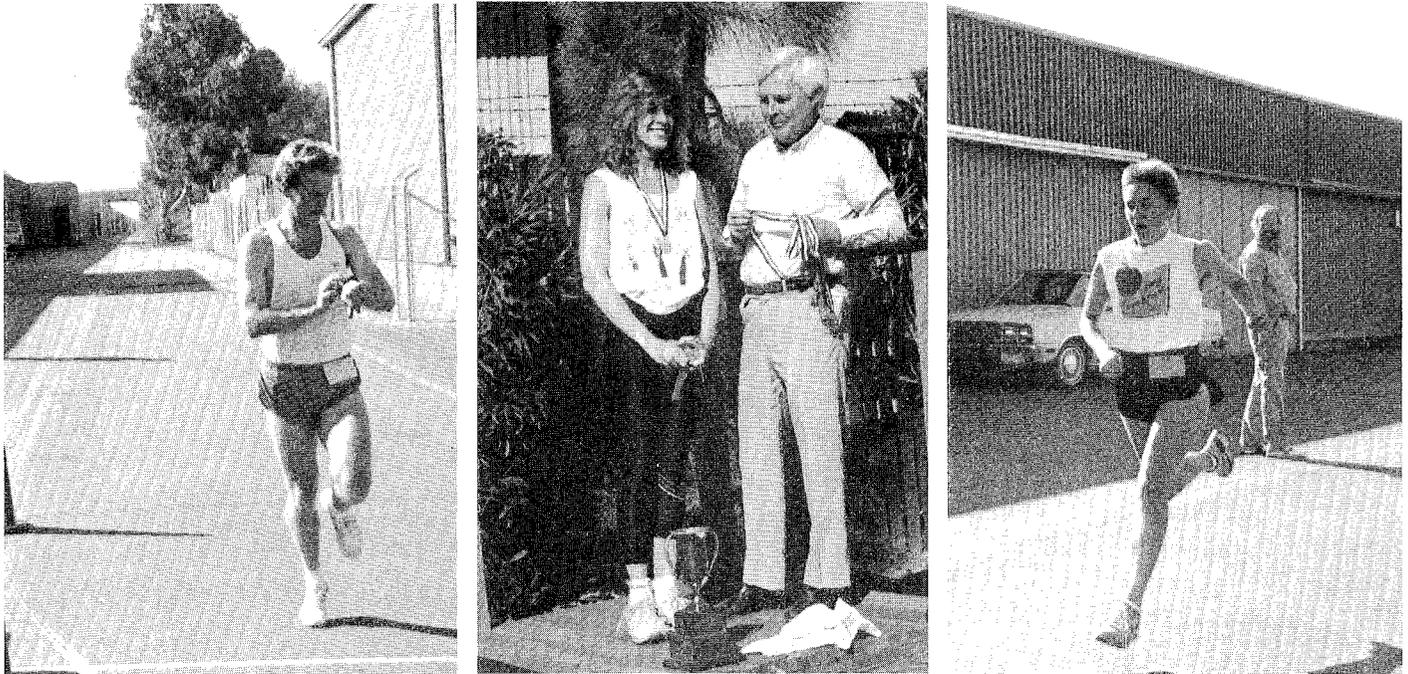
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D.W.G.S. Leith, "A Review of  $4\pi$  Cherenkov Ring Imaging Detectors" (SLAC-PUB-5002, Jun 1989; Invited talk at Symp. on Particle Identification at High Luminosity Hadron Colliders, Batavia, IL, Apr 5-7, 1989).

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B. Ratcliff, "Design Considerations for a Cherenkov Ring Imaging Detector at the Tau-Charm Factory" (SLAC-PUB-5040, Aug 1989; Presented at Tau-Charm Factory Workshop, Stanford, CA, May 23-27, 1989).

## THE 18TH SLAC RACE



*Left to right: Mike Fero checks his time as he crosses the finish line—first for the second consecutive year. Chris Charbonneau with Bernie Lighthouse who presented the awards. Dale Pitman, first female finisher for the fifth consecutive year, shows her winning form.*

By noon on the ninth of November, an eager crowd had gathered for the yearly show-down and a chance to share in the coveted prizes. It was the 18th running of the Annual SLAC Race, for which 88 runners showed up, among them 10 former first-place winners and a total of 9 women.

Pre-race activities went smoothly on this warm and sunny day, thanks to careful planning and preparation and the efforts of a large group of volunteers. At the gun, the thundering horde swept along the linac from the Sector 30 starting line, gradually spreading out as the race progressed.

Last year's overall winner Mike Fero took the gold again with a time of 20:36, a bit slower than his 1988 time. Paul Weber came in second at 21:22. The 1982 winner Jasper Kirkby, visiting SLAC from CERN this fall, finished fourth overall in 22:10, taking first place in the 40–49 age bracket. Lawrence Pan, coming in eighth with a time of 23:31, won the under-30 age group.

The first woman to cross the finish line was Dale Pitman in 16th place, her fifth successive triumph in the women's division. Her time of 24:48 was a bit off her best, but plenty good for the victory. With a time of 28:38, Chris Charbonneau was the first woman in the under 30 group to cross the finish line.

Jim Clendenin, who has just attended a meeting in his running clothes so as not to be late for the start, finished in 24:39 to take first in the men's 50–59 age bracket. Herb Weidner won the men's over-60 group with a time of 30:45.

Nancy Witthaus finished first in the women's 50–59 age group with a time of 37:22. Not far behind was Rene Donaldson winner of the women's 40–49 age group with a time of 39:41.

We wish to thank the people who helped with the registration, the shirt sales, and the running and timing of the race for making this a pleasant and smooth-running event.

—SLAC Race Committee