# SLAC BEAM LINE

*In science there's nothing more tragic than the slaying of a beautiful theory by an ugly fact.*
*— Thomas Huxley*

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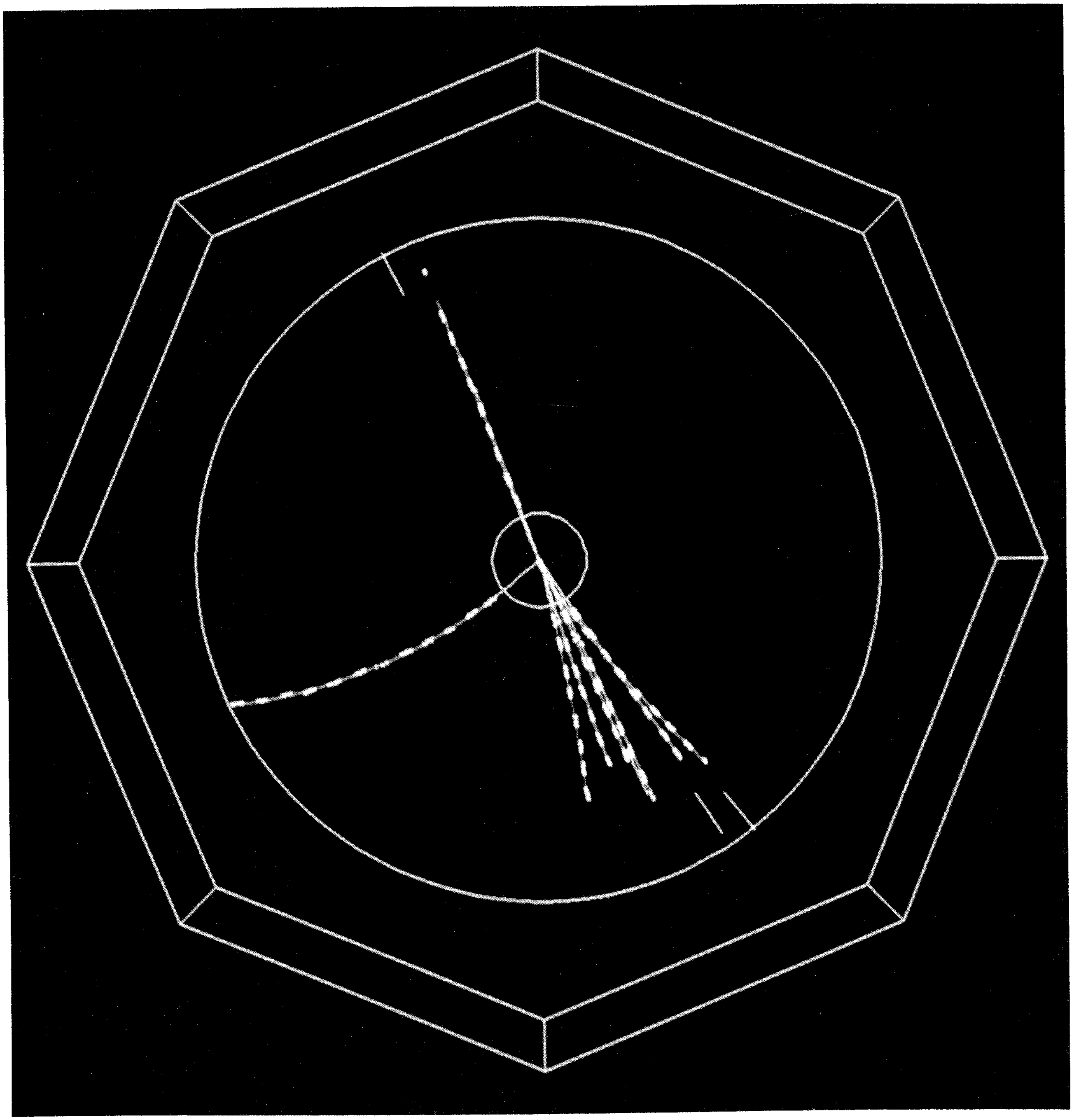

The First $Z^\circ$ Particle Appears at the SLC

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*Stanford University operates SLAC under contract with the U.S. Department of Energy.*

With this issue the *Beam Line* grows to a full 20 pages, due mainly to a new feature that will appear regularly — a compendium of the scientific publications issued by SLAC during the previous quarter. These comprise one of the principal end products of the lab's efforts, and the Directors have asked that they be listed herein.

They have also instituted an Editorial Advisory Board for the *Beam Line*, whose purpose is to oversee its editorial direction and help suggest authors and topics to be covered in these pages. The first Board includes John Matthews of Johns Hopkins, Associate Director John Rees and Marvin Weinstein of the SLAC Theory Group. They are interested in hearing your opinions and suggestions.

Once again, our sincerest thanks to the hard-working individuals in the Publications Department who helped us put this issue together. In particular, Terry Anderson provided excellent drawings, Shirley Boozer gave invaluable aid with the typesetting, and Sylvia MacBride did precision paste-up of the camera-ready copy from which it was printed. Bette Reed and Crystal Tilghman handled relations with photo services and printers. We could not have done it without their efforts.

— *the Editors*

# FROM THE DIRECTOR'S OFFICE

As you all know, we celebrated the production and detection of the first $Z^{\circ}$ particle at the Stanford Linear Collider (SLC) with an all-hands get-together on Friday afternoon, April 14. As I write this brief note on the following Monday, the count of $Z^{\circ}$'s recorded by the Mark II collaboration is up to *four*, with three more having been produced over the past weekend. The SLC ran well thoughout the weekend, and there is a pretty good chance that we already have another one or two more in the bag, waiting to be uncovered by computer analysis of the data tapes.

All of this is of course very good news, but it is important to remember that the SLC is still a long way from reaching the performance levels for which it was designed. Its ultimate success depends not only on our ability to keep it operating efficiently and with good beam characteristics in the days, weeks and months ahead, but also on our ability to make major improvements in its reliability and in the rate at which $Z^{\circ}$'s are produced.

We have already learned a great deal about this novel collider, and the prospects for better operation in the future are bright. As a small token of our appreciation for all the hard work of the SLAC staff, which was crucial to the success of the SLC, the Directors are enclosing with this issue of the *Beam Line* a color print of the first $Z^{\circ}$ to be produced at this collider. Thank you all for your untiring efforts this past year.

—*Burton Richter*

*Note added in proof:* As this issue of the *Beam Line* went to press (May 10), the count of $Z^{\circ}$'s produced by the SLC and observed by members of the Mark II collaboration is over ten. During the day shift on Monday, May 8, the SLC energy was lowered slightly in order to begin mapping out the shape of the $Z^{\circ}$-production curve. Thus we are now well into the process of getting important research information from the data on $Z^{\circ}$ production and decay.

The linear collider continues to work well, often operating in a colliding-beam mode for better than 50 percent of the time. We will soon begin taking some steps that will increase the rate at which $Z^{\circ}$'s are being produced. Let's keep up the good work.

— *BR*

*COVER PHOTO: Computer-generated image of the first $Z^{\circ}$ particle created at the SLC. It was produced at the center and decayed immediately to a pair of quarks, which converted into two back-to-back "jets" of hadrons that left the tracks reconstructed here. (Photo by Joe Faust)*

# THE SLC MAKES ITS FIRST Z° PARTICLES
## by Michael Riordan

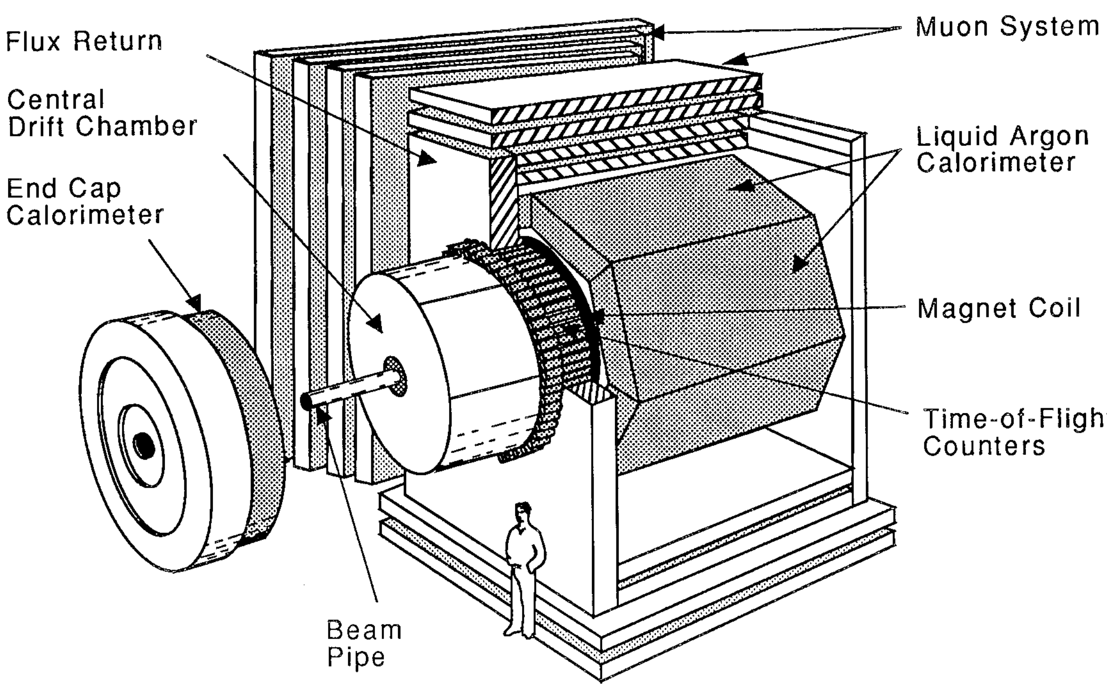
The long wait is over. On April 11 the Stanford Linear Collider created its first $Z^\circ$ particle. The arduous commissioning of this novel collider, which began little more than two frustrating years ago, is finally complete. SLAC again has a machine to do forefront research at the energy frontier. High-energy physics has begun on the SLC.

Like the machine itself, the first $Z^\circ$ to be recorded at the SLC did not come without a struggle. It was created when an electron and positron annihilated each other at 7:32 a.m. on Tuesday, April 11. This first $Z^\circ$ disintegrated in a fraction of an eyeblink into a pair of heavy quarks, which in turn converted almost immediately into two back-to-back jets of subatomic particles that left telltale traces in the surrounding Mark II detector. One jet tore into the north endcap of the Mark II and the other slammed into the south.

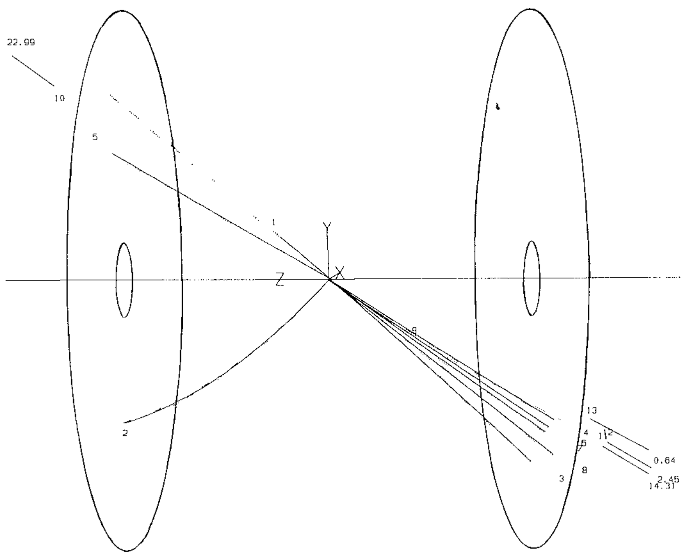
Fortunately the detector triggered on this event, which however slipped past the on-line computer analysis. Its only remains, an innocuous string of ones and zeroes, was unceremoniously deposited on magnetic tape for later off-line analysis. But the wrong tape number was entered into the Mark II runlog by weary physicists just ending the owl shift that morning, so the tape went unanalyzed — and the event unrecognized — for almost another day.

At about 7:30 the next morning, April 12, Caltech postdoc Barrett Milliken noticed that this tape had just been analyzed only a few hours earlier. He is one of a group of Mark II physicists calling themselves the "fire-eaters" who had been poring through the data in search of the first $Z^\circ$. Eagerly he began running a program on the SLAC IBM 3090 computer that enabled him to scan this recent data remotely from his Caltech office.

His program identified two potential $Z^\circ$ candidates on tape number SC8725, but that was nothing out of the ordinary. "There were usually two or three such candidates on every tape," he said later, but a closer look had always shown them to be "junk." This was true of the first candidate, too, but when Milliken brought up the computer-reconstructed image of the second, he knew almost immediately that it was different. The backgrounds in the detector were low, there was lots of momentum in charged particles, and




*Cut-away view of the Mark II detector, with the endcap removed and central drift chamber shifted left along the beam axis.*




*Side view of the first $Z^\circ$ created at the SLC.*

plenty of energy in the endcap calorimeters. "Once I saw there was at least 25 GeV in the endcaps," Milliken admitted later that day, "I knew it had to be a real event."

But was it in fact a $Z^\circ$? There are other kinds of events that can mimic it. Milliken began bringing up more images that showed the same event from different perspectives. He could discern one clear jet of four hadrons emerging toward the bottom and a high-energy track headed in the opposite direction, hitting the south endcap near a big energy deposit. There seemed to be *two back-to-back jets* of hadrons!

Just then Chris Hawkes, another Caltech fire-eater, strolled into the office and Milliken, excited, showed him the computer images of the event. "Yeah," Chris agreed. "That's a $Z^\circ$!"

Milliken put in a call to Jonathan Dorfan, head of SLAC Group C and a spokesman of the Mark II collaboration. Finding him at the Main Control Center (MCC) just before eight, he told Dorfan that he thought they had a $Z^\circ$ and wanted him to take a look at it. Jonathan asked him to print off the images on the MCC laser printer as soon as possible. Then he went into the MCC Conference Room to attend the daily 8 o'clock meeting of physicists, engineers and technicians who for more than two years have been struggling to bring the SLC to life.

At this meeting there was plenty of head-scratching and hand-wringing going on. The previous week outdoor air temperatures had hit a record 95°F, and daytime brownouts had shut down the SLC, bringing back haunting memories of the previous summer. But on Sunday evening, cool Pacific fogs once again began creeping over the Santa Cruz Mountains, carrying with them ocean-like temperatures and ideal conditions for running the collider. The past few days the Mark II physicists had been able to log data better than 25 percent of the time. They were witnessing plenty of Bhabha scattering — glancing collisions between an electron and a positron. But no $Z^\circ$'s had appeared yet. Not a single one.

It was beginning to be a major quandary. Where were the $Z^\circ$'s? Was 92 GeV the wrong energy at which to be searching for them? Already the Mark II had recorded 2.2 "Z-equivalents" worth of data, or enough total luminosity to have produced 2.2 $Z^\circ$'s, had they been sitting right on the center of the $Z^\circ$ peak. And still none had appeared.

"When the number gets up to three Z-equivalents, the argument will begin among the Mark II collaboration that it's time to change energy," observed Burt Richter at meeting's end. "When it gets to five, the rebels will win out!"

"Yeah," added Dick Taylor sitting next to him, "And then there'll be an argument about whether to go up or down!"

Dorfan had kept silent the entire meeting. He wanted to see those images before saying anything to anybody. They arrived about 8:15, shortly after the meeting ended. He picked them up and looked at them intently. The view along the beamline was not entirely convincing, Dorfan recalled, but when he saw the side view, he was pretty sure they had the first $Z^\circ$ at last.

He called over Gary Feldman, head of SLAC Group H and another Mark II spokesman, to show him the pictures. Then they both took Richter, who had been standing nearby, into their confidence. All three agreed it was a strong $Z^\circ$ candidate, but decided not to broadcast the news until the collaboration could meet later that day to decide the matter collectively.

But this was the kind of news that simply could not be suppressed. After more than a year of unanticipated technical problems that had delayed the SLC startup, the long $Z^\circ$-drought was finally over. By mid-morning the SLAC corridors were humming with rumors of the great event.

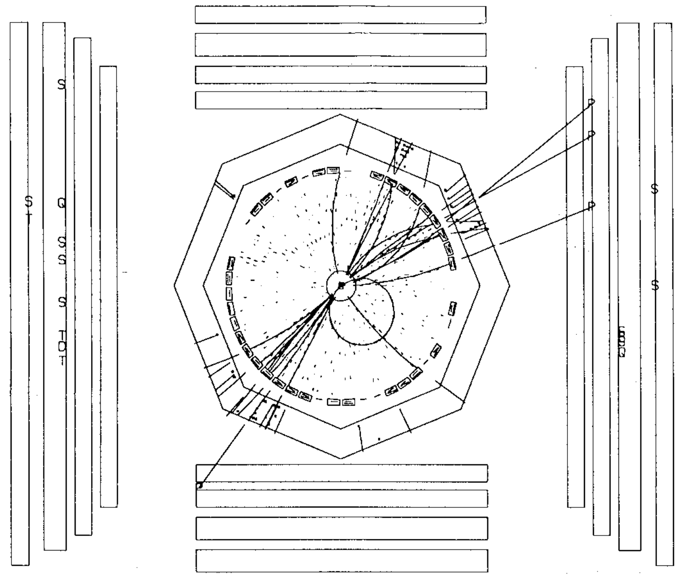
Computer messages were flashing across oceans and continents, spreading the word far and wide to the rest of the high-energy physics community. At 10 o'clock, Richter received a BITNET message from Mario Greco in Rome, congratulating him on his success. Another came in just before noon from CERN Director Carlo Rubbia, who had shared the 1984 Nobel Prize for discovering the $Z^\circ$ in 1983. "Congratulations," it read. "And welcome to the club."

By the time the Mark II collaboration met early that afternoon in the SLAC Auditorium, the identity of the event was a foregone conclusion. "I don't think there's anybody here who's seen this event and doesn't think it's a $Z^\circ$," said Dorfan, opening the meeting. Having flown up from Pasadena that morning, Milliken presented his images next and explained why it had to be a $Z^\circ$. John Bartelt, a postdoc in Group H, showed results of further analysis in which he relaxed certain cuts on the data. Two or three more tracks became visible, reinforcing the interpretation of two back-to-back jets. "I haven't seen this many smiling faces in a long time," observed Dorfan as the meeting ended with little doubt remaining in anybody's mind.

Corks popped and champagne flowed among the redwoods of the Panofsky Grove beginning at 4:00 that afternoon, just as a press release went out from Stanford News Service letting all the world know what had happened at SLAC. Richter took the opportunity to clamber up onto a picnic table and address the couple hundred people who had gathered to celebrate. "The significance of the event is not that it represents a revolution in science," he cautioned. "It's that the machine we struggled so hard to make work is starting to perform as it's supposed to."

By 6 o'clock TV crews were converging on SLAC to cover the day's events for the evening news. Andrew Hutton, an accelerator physicist who heads the Beam Delivery group, had rushed home to change into coat and tie. (An hour earlier he was wearing sneakers and a T-shirt with a big green and yellow blob on it labeled "SUMO" in large red letters.) He handled the interviews with graciousness and aplomb, even though Channel 4's Sylvia Chase introduced him as "Dr. Burton Richter, Director of SLAC."

*Burton Richter congratulating SLAC staff in the Panofsky Grove (Photo by Edward Souza).*



*Computer-reconstructed image of the fifth $Z^\circ$ produced at the SLC, showing three hadron jets.*

"A Triumph for Stanford's Huge Collider," crowed the page-one headline on Thursday morning's *San Francisco Chronicle.* "Stanford's 2–Year Struggle Yields an Elusive Z Particle," read the *San Jose Mercury News.* SLAC could finally bask in favorable press coverage again.

At the 8 o'clock meeting that morning, Richter congratulated everybody who had labored so long and hard to make the SLC work, but urged them not to let up. "One leaf," he quipped, "does not make a laurel wreath." He became increasingly fond of this sound bite as the day wore on and other TV crews visited SLAC to cover the previous day's excitement — the most we've had in a decade.

It felt as if a great weight had been lifted from our shoulders and we could begin to breathe freely again. Only six months earlier, the SLC had been shut down for repairs after a disappointing summer in which only 30 hours worth of data had been logged and not a single $Z^\circ$ produced.

The fall and winter SLC upgrades have certainly made a big difference, however, because the Mark II has been able to collect data about 30 percent of the time lately — a vast improvement over last summer's discouraging performance. That, and a doubling of the current in both electron and positron beams, are the primary reasons the SLC can now produce $Z^\circ$s at the rate of about one or two per day, as it proved the weekend after making its first. Four more $Z^\circ$s were recorded in less than three days' running.

While still not a wreath, there were five leaves in the headband by week's end, an encouraging start for the first linear collider ever built.

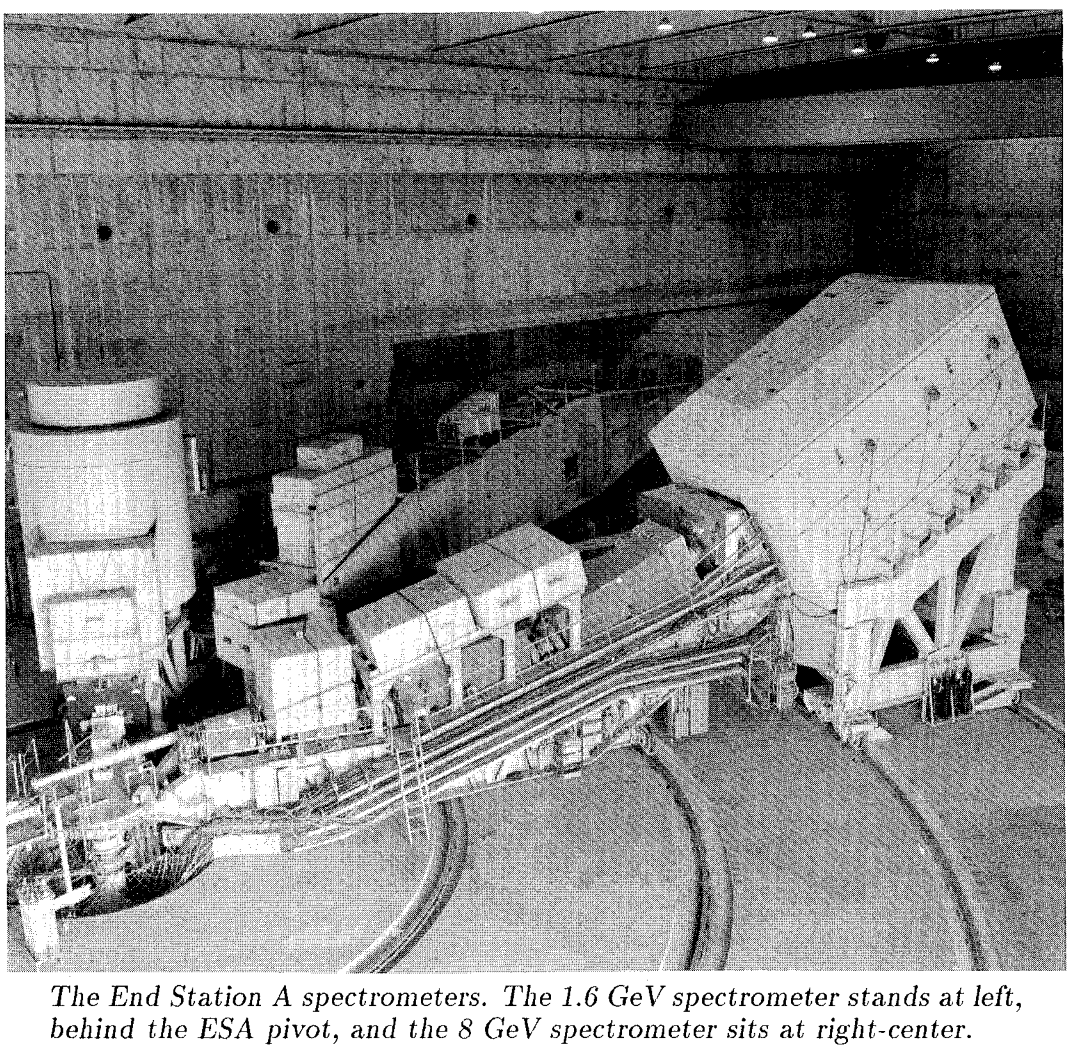
# STILL AT IT AFTER 25 YEARS

One of the original reasons for building SLAC and the spectrometers in End Station A (ESA) was to measure the fundamental properties of what were then considered elementary particles — the proton and the neutron. Among these properties are their charge and magnetization currents, or how the sources of electric and magnetic fields are distributed within these particles. Never quite completed, these important studies were taken up again early this year in yet another ESA experiment, labelled NE–11.

One way to determine these two currents is to measure the chances that an electron will scatter elastically (i.e., bounce off the proton or neutron, leaving it intact) as a function of a single kinematic variable, generally chosen to be the momentum transferred from the incident electron to the target particle, or $Q^2$. If the electron scatters at large or backward angles, the cross section or scattering probability is proportional to the magnetic form factor $G_M$ of the particle. At forward angles the cross section depends on both $G_M$ and its electric form factor $G_E$, which is related to its charge distribution. By making measurements at forward *and* backward angles, both form factors can be determined simultaneously (in what is called a Rosenbluth separation). To make an accurate determination of $G_E$, however, requires very precise measurements of the elastic cross section over a wide range of scattering angles.

The task of measuring the proton and neutron form factors with high precision was recently taken up by a collaboration of nuclear and particle physicists using the ESA spectrometers. Led by American University, the NE–11 collaboration includes physicists from Lawrence Livermore Laboratory, the National Bureau of Standards, Stanford University, SLAC, and the Universities of Maryland, Massachusetts, Pennsylvania and Rochester.

Over the years, many improvements have been made to the detectors in the 8 and 1.6 GeV spectrometers in ESA to increase their reliability and reproducibility. A recent floating-wire measurement of the 8 GeV spectrometer led to a much better understanding of its optical properties. These and other



*The End Station A spectrometers. The 1.6 GeV spectrometer stands at left, behind the ESA pivot, and the 8 GeV spectrometer sits at right-center.*

improvements now allow cross sections to be measured with relative systematic errors at or below the 1 percent level.

For the NE–11 experiment, electron beams with energies of 1.5 to 10 GeV were produced using the Nuclear Physics Injector (NPI) and directed onto liquid hydrogen and deuterium targets in ESA. Electrons scattering at forward angles were detected in the 8 GeV spectrometer, while those rebounding at large angles (greater than 60 degrees) were simultaneously collected in the 1.6 GeV spectrometer. The latter device had been modified to increase its solid angle (and hence data collection rate) by a factor of five.

Beam was delivered a remarkable 50 percent of the time during a six-week running period in January and February. A record for the peak current intensity ($6.5 \times 10^{11}$ electrons per beam pulse) was set, principally because the new 6045 klystrons produced for the SLC had finally been installed throughout linac sectors 25 through 30 (those used to accelerate NPI beams). The highest energy used, 10 GeV (running in the SLED mode), was also an NPI record. And beam stability was much enhanced due to the many improvements made for the SLC.

From the measured elastic $e-p$ cross sections, the proton form factors were separately determined up to $Q^2 = 7$ (GeV/c)$^2$. Neutron cross sections were measured up to 4 (GeV/c)$^2$ by scattering electrons from a deuterium target and subtracting contributions from elastic $e-p$ scattering. In both cases, NE–11 has effectively doubled the $Q^2$ range over which Rosenbluth separations of the nucleon form factors have been performed. The full results of this experiment should be published within a year.

— *Peter Bosted*

### Segré Dead at 84

We regret to hear about the passing of Emilio Segré Emeritus Professor of Physics at the University of California, Berkeley. He died of a heart attack while walking near his home in Lafayette, California, on Saturday, April 22.

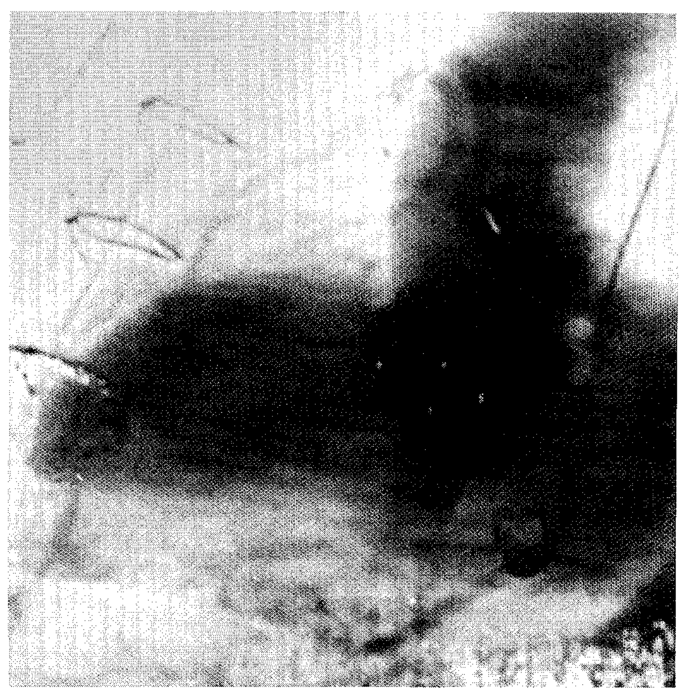
Segré earned his Ph.D. in physics at the University of Rome, working on nuclear physics under the tutelage of Enrico Fermi. While a professor of physics at Berkeley, he teamed with Owen Chamberlain to discover the antiproton on the Bevatron particle accelerator, for which the two men were awarded the 1959 Nobel Prize in physics.

Segré authored many books, among them *Nuclei and Particles*, a textbook, and *From X-rays to Quarks*, a history of nuclear and particle physics. His broad-ranging talents will indeed be missed.

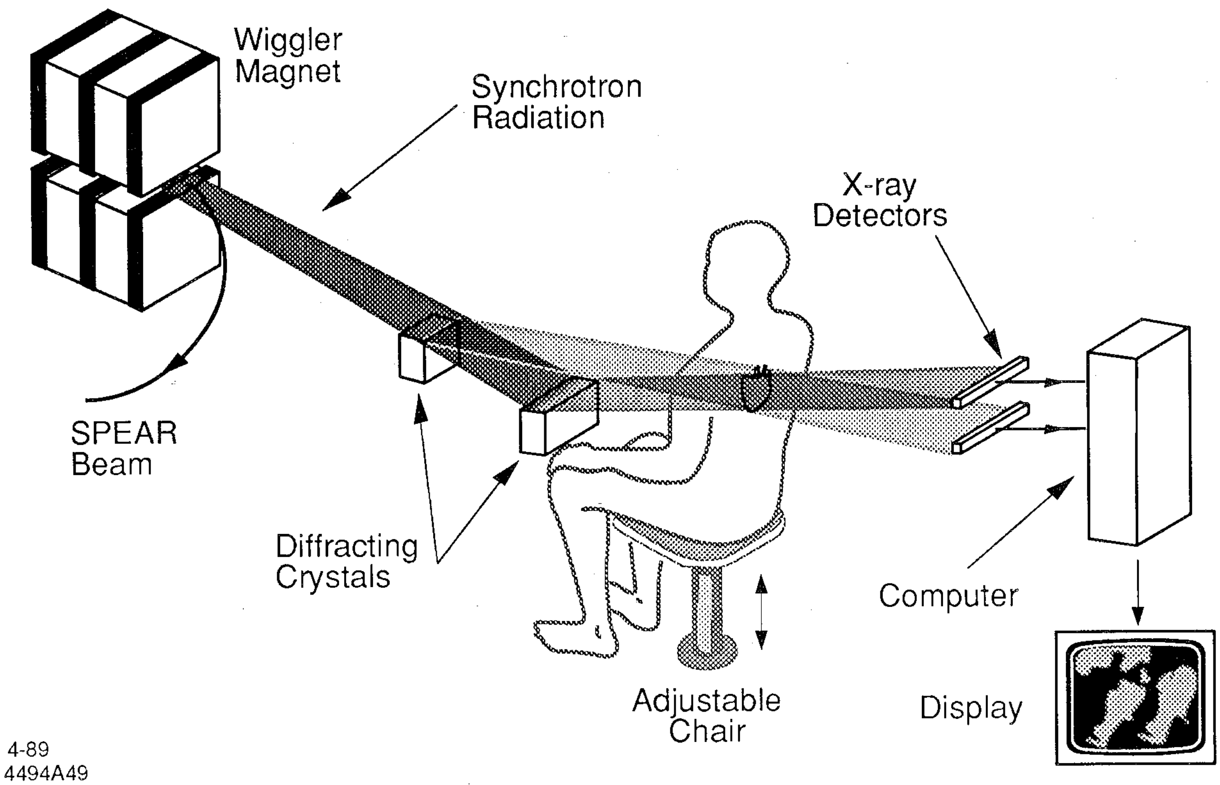
## SSRL MAKES MAJOR ADVANCE IN ANGIOGRAPHY

On March 15 a team of physicians and scientists from Stanford University, Lawrence Berkeley Laboratory and Brookhaven National Laboratory made a major advance in the imaging of human coronary arteries. Led by Edward Rubenstein of Stanford Medical School, they employed dual beams of synchrotron radiation produced in a dedicated run on the SPEAR storage ring. Sharp, high-quality images were obtained by a noninvasive process imposing much less risk on patients than methods commonly use in hospitals today.

At the present time, the diagnosis of coronary arterial diseases requires a risky angiographic procedure in which a peripheral artery is punctured and a catheter is carefully threaded back to the heart itself. The tip of the catheter is then guided into the artery to be examined. Injection of a contrast agent containing iodine through the catheter permits the suspect artery to be imaged using conventional X-ray techniques. Diagnostic-quality images result, but at considerable risk to the patient. The catheter can cause a heart attack or stroke, or it can trigger cardiac arrhythmias. About five patients in a thousand suffer some ill effects from the exam, and about one in a thousand dies as a result of it.



*Human angiogram made by the new method developed at SSRL. The dark areas are the aorta and ventricles; the rings at upper left are sutures remaining in the patient from previous heart surgery (SSRL photo).*




*Artist's conception of angiography procedure developed at SSRL. Two beams of X-rays are passed through the patient's heart simultaneously and their images recorded by two separate detectors. By subtracting one image from the other, the effects of soft tissues and bone can be eliminated, enhancing the contrast.*

A safer procedure called intravenous angiography entails placing the catheter into a major vein rather than an artery. In this approach there is no risk of heart attack, stroke or arrhythmia. But the contrast agent is diluted by the blood before reaching the coronary arteries, which consequently cannot be imaged using conventional X-ray techniques.

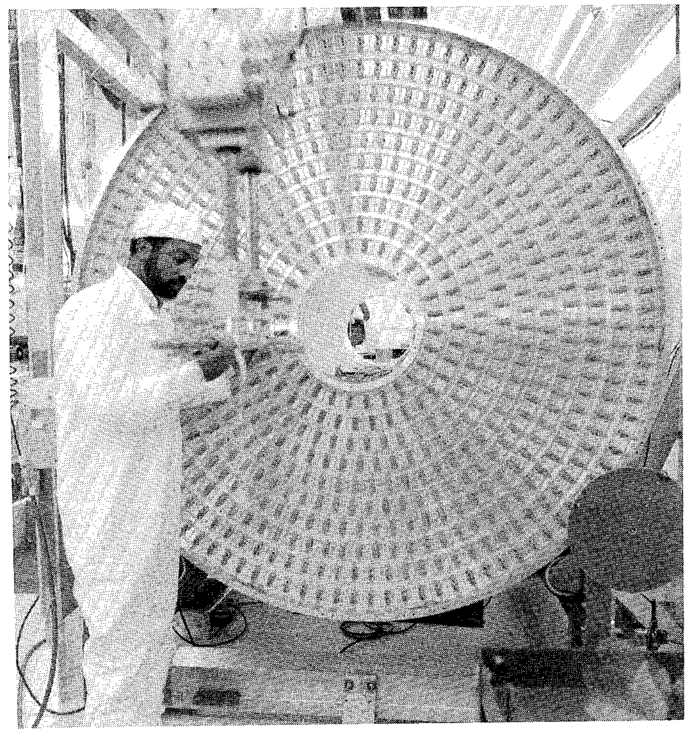
The high-intensity, monochromatic X-ray beams available at the Stanford Synchrotron Radiation Laboratory (SSRL) have allowed researchers to enhance the image contrast markedly, thereby permitting use of the intravenous approach. By using two beams simultaneously, one with an energy just below the K-edge of iodine (33.16 keV) and the other just above it, they can make the coronary arteries stand out distinctly. Because the absorption of one beam by iodine is *six times* greater than the other while there is little change for soft tissue and bone, the difference between the images made with each beam will reveal contrast only from the iodine and not the surrounding tissues.

The imaging apparatus used in the March run was much improved over that used in previous (1986-87) SSRL tests on human patients. The recent experiments were performed on beamline 4-2, which is illuminated by an 8-pole, 18 kG wiggler magnet (see January 1989 *Beamline*, p. 3, for a discussion of wigglers). The 3 mm high by 12 cm wide beam of 33 keV synchrotron radiation strikes two separate diffracting crystals, which produce the two X-ray beams (of slightly different energy) simultaneously. The two beams converge into a single horizontal line at the patient's heart and then diverge toward two arrays of position-sensitive detectors. As the patient is moved vertically through the beams in a specially designed chair, two separate images are recorded electronically, and a full two-dimensional image of the blood circulation is obtained by logarithmic subtraction. The total X-ray dosage absorbed by the patient is far less than the typical dosage in hospital-based angiograms today.

The image quality obtained in the 1989 experiment was significantly better than that obtained in previous tests. Although preliminary results are very encouraging, however, final judgment must await a detailed analysis of the twenty-odd images obtained. The angiography group owes a debt of gratitude to the many people at SSRL and SLAC who contributed to the success of this experiment.

— *George Brown*

*Connie Reeve prepares a bundle of sense wires and guard wires for testing and installation.*



*After a rigorous series of tests, the bundles of wires are individually inserted through the end plates of the cylindrical drift chamber.*

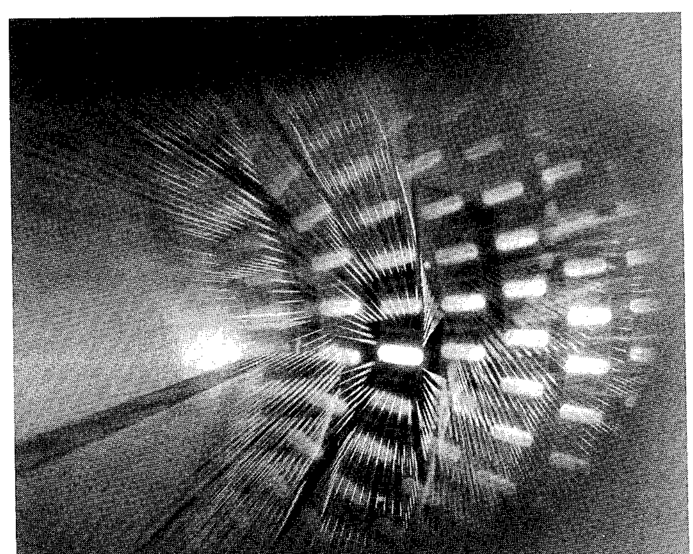
# SLD DRIFT CHAMBER STRINGING IS FINISHED

The stringing of the SLD central drift chamber (CDC) was completed early in April, a little more than six months after it had begun. Filled with gas (mostly argon and carbon dioxide), this cylindrical chamber will eventually sit at the core of the SLD, detecting the passage of charged particles, which ionize the gas molecules. The ions drift to "sense wires" under the influence of electric fields set up by "field wires" running parallel to the chamber axis. The pattern of particle tracks thus deposited on the sense wires is reconstructed by computer, providing a visual image of an $e^+e^-$ collision.

There are ten layers of wires in the CDC, grouped into 640 cells. Each cell contains 25 field wires plus 8 sense wires surrounded by an array of 20 "guard wires." Every one of this total of more than 30,000 wires had to be painstakingly strung and then put through a series of rigorous tests before being inserted into the chamber through precision-drilled holes in the aluminum end plates. In an average week 30 cells were strung, tested, and installed in the chamber.

There is still plenty of work remaining to be done, however, before the CDC becomes a useful, functioning particle detector. Gas manifolds and cooling loops must be installed; high-voltage distribution and signal-processing circuitry will be added. Once these tasks are finished this fall, the detector will be moved from its clean room in the Light Fabrication Building and installed inside the SLD magnet yoke (see January 1989 *Beam Line*). Commissioning should begin by the end of 1989.

— *Michael Riordan*



*Interior view of the SLD drift chamber.*

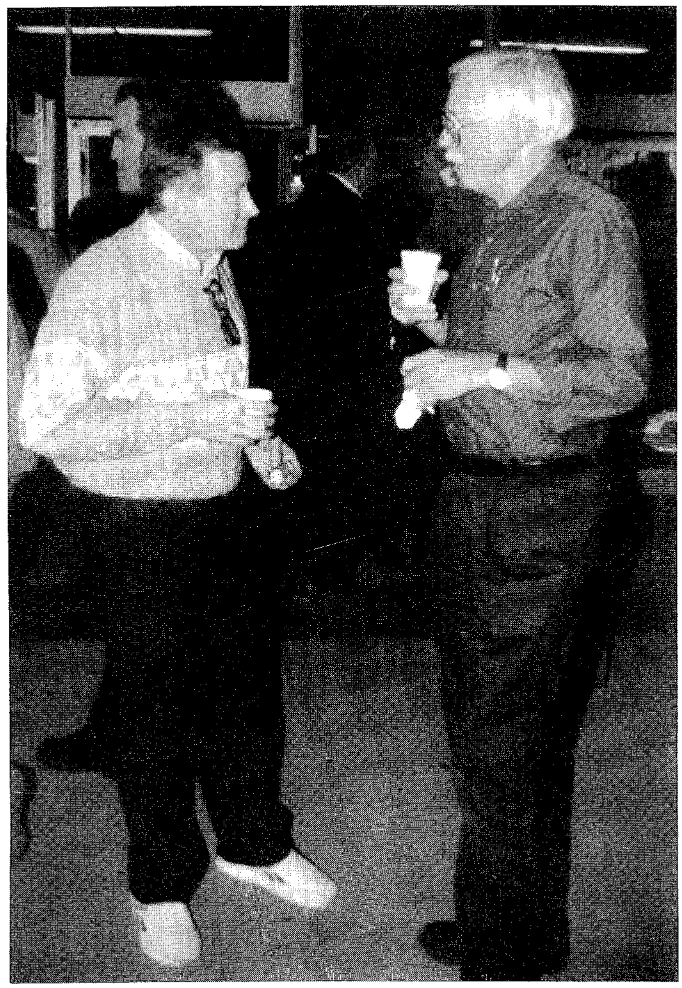
# LINEAR COLLIDER WORKSHOP

The International Workshop on Next-Generation Linear Colliders was held at SLAC between November 28 and December 9, 1988. There were 113 participants including 28 from outside the United States representing Novosibirsk in the USSR; CERN, DESY, Frascati and Orsay in Europe; and KEK in Japan. Such broad participation indicates the worldwide interest in linear colliders. The purpose of the workshop was to discuss the research programs on linear colliders around the world, to identify areas that are common or complementary in their goals and to advance these programs by collaboration.

Plenary sessions were held the first two and one half days in the auditorium, where representatives from various laboratories and institutions presented their latest linear collider designs and research programs. For most of the next week, the participants formed seven working groups to discuss in more detail specific programs on individual subsystems. During this period, there was a lively exchange of ideas within and between the groups. Their results were summarized and presented in two days of plenary sessions at the end of the meeting.

The Parameters working group examined the existing designs for high-energy linear colliders, which sport the acronyms CLIC, ILC, JLC, TLC and VLEPP, and tabulated their design parameters in a consistent form to aid comparisons. Another group

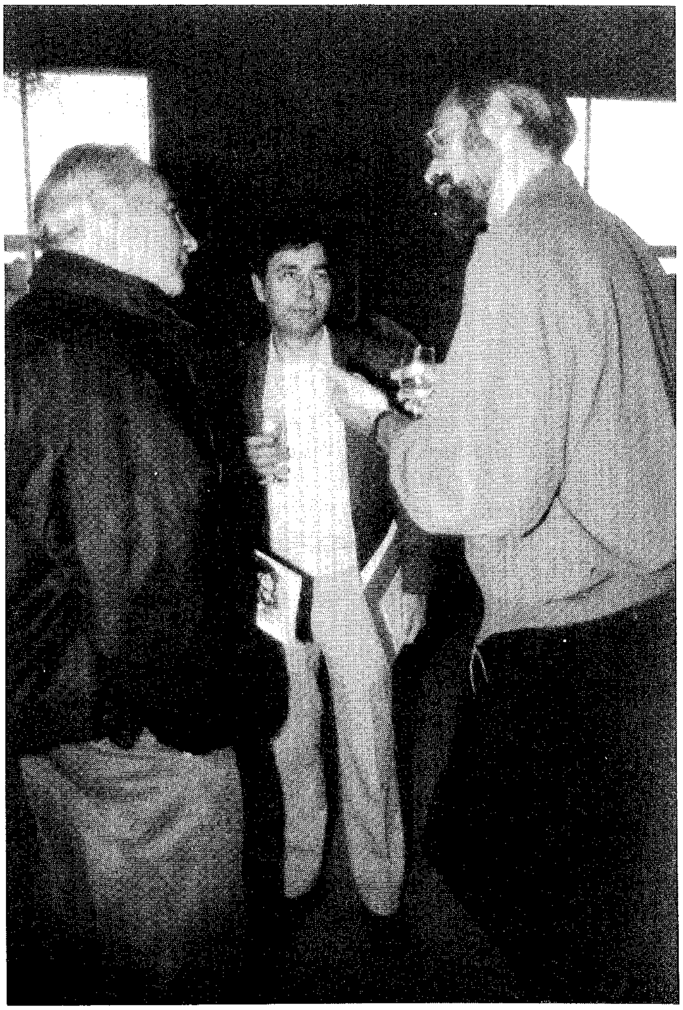
*Workshop Chairman Ewan Paterson (left) talks with Witold Kozanecki and John Seeman during one of the coffee breaks between sessions.*



*John Rees and Perry Wilson, Co-Chairmen of the Parameters working group.*

working on Beam Dynamics and Wakefields studied emittance preservation (i.e., keeping the electron bunches compact and focused) from damping rings through to the final focus and the problems associated with the use of multibunch trains of particles. The group of specialists studying Damping Rings and Sources concluded that the desired emittances could be achieved in several different designs, all of which require wiggler magnets in the rings.

One of the largest working groups concentrated on the topic of RF sources. This key problem requires a continuing worldwide effort to explore alternate and complementary solutions. The research programs discussed included many "small" sources of "modest" power, sources with peak power outputs of more than a gigawatt, and two-beam accelerators where energy of the drive beam ranged from tens of MeV to several GeV. This RF power is needed to energize novel Accelerator Structures, a topic which had its own working group that discussed new construction techniques, experiments on RF breakdown



*SLAC's Andrew Hutton (right) sampling wines with noted French oenophiles Joel LeDuff (left) and Michel Davier of LAL–Orsay.*

limits, and designs that damp out wakefields to allow multibunch operation.

The working group on Instrumentation explored the precision and tolerances needed in various designs of damping rings and accelerators. Many techniques for component alignment and beam diagnostic measurements were explored, but considerable research is clearly required to achieve the desired performance level. One problem identified is the extreme difficulty in collimating high-power, low-emittance beams.

A large working group studied problems associated with the design of the Final Focus. Participants discussed the geometry around the collision point using different crossing angles and "crab" crossing to provide head-on collisions. The biggest surprise of the workshop appeared in the general subject area of beam-beam interaction effects. In the very strong beam-beam interaction typical of linear colliders, of the opposing bunch. Under conditions with high the particles radiate in the electromagnetic fields bunch populations, these "beamstrahlung" photons can generate electron-positron pairs by interactions with the opposing beam. Subsequently deflected to large angles, these pairs can cause severe background problems for the detector surrounding the interaction point. The whole subject of beamstrahlung pair production and deflection will need much more study before collider and final focus parameters can ever be optimized.

A proposed Final Focus Test Beam at SLAC, using the SLC beam as input, was well received and much discussed. Many groups expressed interest in collaboration on both construction and use of this beamline. Its unique capabilities will make it an important part of a linear collider R&D program where optics ideas, hardware and beam instrumentation can be developed and tested. After the workshop there will be continuing discussions on the organization of an international collaboration to construct and use this facility.

Overall, the workshop was a great success and contributed much to advancing our knowledge of future linear colliders. The excellent technical and social interactions which took place augur well for our continuing collaboration.

— *Ewan Paterson*

*(Editor's note: The Workshop Proceedings, consisting of the working-group summaries and copies of the transparencies of the final plenary-session talks, is available as SLAC Report No. 335.)*

*Sergei Kazakov, Nilolay Solyak and Vasilli Parkhomchuk (left to right) of Novosibirsk enjoying California wines with Samuel Heifets of CEBAF. (All photos these pages by Elsi Stucki)*

# INTERNAL TARGET CONFERENCE

For the past few years an assortment of nuclear and particle physicists from institutions such as American University, Lawrence Livermore Laboratory and the University of Massachusetts have been considering a novel idea. They want to use the PEP storage ring for fixed-target experiments. What makes this sleight of hand feasible is the use of a gas-jet target, which shoots a narrow stream of atoms (hydrogen, helium, argon, xenon, for example) through the circulating electron beam. Pioneered at CERN and Novosibirsk, such "internal target" facilities will allow physicists to study electron-nucleon and electron-nucleus collisions in far more detail than has been previously possible.

From January 9 through 12, about a hundred physicists from around the world met in the SLAC Auditorium to discuss the prospects for and problems of experiments in this growing field. The Topical Conference on Electronuclear Physics with Internal Targets drew large contingents from CERN and MIT; Caltech, Fermilab, Frascati, Livermore and Novosibirsk were also well represented. The Conference was organized and chaired by Ray Arnold of American University, Coordinator of the Nuclear Physics at SLAC (NPAS) program; he was ably assisted by Lynn Hanlon and Elsi Stucki.

The opening session was devoted to a discussion of the physics accessible at electron storage rings with internal targets. Stan Brodsky noted that electroproduction experiments continue to be the definitive way to resolve the structure of nucleons in terms of their constituent quarks and gluons. Recent surprising revelations by the EMC collaboration at CERN, reviewed by Frank Close of Tennessee, suggest that the proton spin might not be due merely to the spin of the quarks, as previously supposed. Some theorists have proposed that the gluons are responsible, while others point to orbital motion of the quarks. Whatever the case, electron scattering from polarized targets should help provide some answers. The entire question of how quarks are organized within nucleons is still remarkably unresolved; it will benefit from the detailed studies that can be performed at internal target facilities.

Hadronization of the struck quark in deep inelastic scattering was another subject of strong interest. By studying the hadrons produced when leptons strike different nuclei, noted Andreas Bialas of Cracow, physicists can gain added insight into this poorly understood process. So far most such experiments have been accomplished with beams of muons and neutrinos at CERN and Fermilab. The excellent duty cycle and high luminosities available at electron storage rings, however, make them the ideal place to examine the hadronization process in great detail.

The circulating electron bunches in a storage ring provide high average currents that appear almost continuous to a particle detector. Such a beam is far

**The PEGASYS Proposal**

*PEGASYS (for PEp GAs-jet Spectrometer sYStem) is a joint nuclear/high-energy physics facility being proposed for the PEP storage ring. It consists of a multi-gas cold-cluster jet target, a forward dipole spectrometer (of approximately one steradian solid angle) with full particle-identification capability, and nuclear physics detectors surrounding the target to measure decays of spectator fragments.*

*Operation of PEGASYS will be fully compatible with both colliding-beam physics and synchrotron radiation research, which can occur on PEP simultaneously. Luminosities of* $10^{33} cm^{-2} s^{-1}$ *will be possible with hydrogen and deuterium targets and* $10^{30}$ *is achievable with xenon. The thin, pointlike target, the time structure of the PEP beam, and the large-aperture spectrometer should open up a whole new realm of multiparticle coincidence measurements of deep-inelastic electron scattering that are impossible to carry out in End Station A.*

*The research anticipated for PEGASYS includes experiments where nuclei are used as a "laboratory" to study the space-time evolution of struck quarks in deep-inelastic scattering (quark propagation and hadronization) and studies of fundamental QCD processes for nucleons (virtual Compton scattering and "higher-twist" effects). Measurements of structure functions tagged on specific nuclear decays should help to understand the origin of the EMC effect. Also planned are measurements of the high-momentum quark contributions to the deuteron wavefunction and searches for neutral bosons decaying into leptons.*

*Formed in 1986, the PEGASYS collaboration has now grown to include groups from twenty universities and research laboratories. The NPAS Program Advisory Committee approved the proposal at its January meeting and called for a formal Technical Review to be held early this fall. The Nuclear Science Advisory Committee (the parallel body to HEPAP) warmly received a presentation of the project in February. If it passes further review and receives appropriate funding, now estimated at about $10 million, PEGASYS could begin experimentation by late 1992 or early 1993.*

— *Karl Van Bibber*

better suited for detecting several secondary particles in coincidence than are the beams with short pulse durations extracted from electron accelerators like SLAC. With a large-acceptance detector, it becomes feasible to analyze most of the spray of particles and nuclear fragments produced in electron-nucleus collisions. Karl Van Bibber of Livermore described the PEGASYS internal target facility (see box) proposed for the PEP storage ring. The PEGASYS collaboration aims to study both the fate of the struck quark as it hadronizes and the response of a nucleus to the sudden removal of one of its quarks.

Another advantage of gas-jet targets is the fact that they are so thin that slow particles and heavy nuclear fragments are not absorbed in the target and can thus reach detectors. A whole new class of nuclear structure measurements therefore becomes possible in which heavy-fragment "tags" are used at low-energy storage rings. Stan Kowalski outlined the 1 GeV electron stretcher ring and internal target facility under construction at the MIT-Bates linear accelerator, and Kees de Jager revealed similar plans for NIKHEF in Amsterdam.

A major potential bonus of gas-jet targets is the possibility of producing targets of polarized nuclei. The recent EMC surprises in muon scattering from polarized protons have whetted theorists' appetites for similar measurements on the neutron, which will require targets of polarized deuterium or helium-3. The polarized targets of solid materials used previously in external beams have often proved unwieldly, but beams of polarized atoms are beginning to show promise. Richard Milner of MIT discussed recent work on a novel polarized target with optically pumped helium-3 atoms and described plans for an experiment being proposed for HERA to measure the spin structure functions of the nucleons.

Several other speakers described the wide range of groups planning to use internal targets in circulating proton or anti-proton beams. Louis Dick reviewed the UA6 experiment, which used a "cluster-jet" target of hydrogen atoms in the CERN $p\bar{p}$ collider to study $pp$ collisions. And Martin Perl indicated how the PEGASYS facility might even be used to perform bona fide searches for new particles — such as neutral spin-0 and spin-1 bosons weakly coupled to electrons.

At week's end, conference participants departed with a new appreciation of the great variety of experiments that will soon be possible with internal targets. They also had a much better idea of the work remaining to be done before such facilities become commonplace features at storage rings around the globe.

— *Michael Riordan*

# MARCH SLUO MEETING

After an extended period of relative inactivity, the SLAC-LBL Users Organization (SLUO) met on March 4. About 40 representatives of SLAC and the various universities engaged in research here gathered in the Orange Room for day-long discussions of how SLUO might take a stronger role in meeting the future needs of the users and SLAC itself.

Serving as acting chairman, Uriel Nauenberg of Colorado opened the meeting by reviewing the history of SLUO. He indicated his willingness to serve as the official Chairman of the organization, replacing Richard Prepost of Wisconsin whose term ended recently, but felt that an election more in accord with the SLUO charter should be held for all the offices.

Immediately following Nauenberg, Burton Richter presided over a lengthy and broad-ranging discussion concerning the future of SLAC and the national high-energy physics program over the next five to ten years. One of the central concerns voiced was how to maintain an active and vital research program during a period in which national resources are being diverted toward building the SSC. Since research there is at least ten years away, it is of utmost importance that SLAC chart a course that will continue to offer forefront research facilities in the interim — the next five to eight years. There is growing interest at SLAC in a number of possible new projects at SLAC; B factories, tau/charm factories, and SSC detector development were mentioned.

Richter expressed the need for a strong and active SLUO organization to help in addressing these future needs, and offered secretarial and financial support to achieve this goal. He encouraged SLUO input and suggested that the organization become involved in offering workshops to discuss possible future projects at SLAC.

There was discussion about the membership of SLUO, now that SLAC facilities are also being used by nuclear physicists and scientists working with synchrotron radiation. The general consensus was that the former be included in SLUO because their needs closely resemble those of the high-energy physics community. SSRL users, a very large community with relatively short-term experiments, had different needs and their own organization to meet them.

In response to a question about the SLC, Richter reviewed the recent upgrades and discussed the performance of the collider through early March. He saw a marked improvement over last summer's performance and suggested that high-energy physics research would soon begin.

After considerable discussion about election procedures, nominations were made and the following SLUO officers elected:

*Chairman:* Uriel Nauenberg

*Secretary/Treasurer:* Richard Kofler

*Coordinator of Committees:* Bruce Barnett

These officers will serve until the fall of 1989, a term consistent with the charter, unless new officers are required earlier by a possible reorganization.

There was a wide-ranging discussion about such a reorganization of SLUO, whose charter was formulated in 1975 and needs to be reexamined. Among other things, the relationship between SLAC and LBL has changed, and the charter should be updated accordingly. The discussion culminated with the nomination of members to serve on a SLUO Reorganization Committee.

From this list of nominees the chairman selected Ray Arnold of American University, Alberto Benvenuti of INFN Bologna, Elliott Bloom of SLAC, Donald Coyne of UC Santa Cruz, Gail Hansen of Indiana University, Michael Ronan of LBL, Alan Weinstein of Caltech and Richard Yamamoto of MIT to serve on the committee.

It was a good start, but much remains to be done before SLUO becomes a truly effective organization. The next general meeting is scheduled for Friday morning, June 2, in the SLAC Auditorium.

*—Dick Kofler*

## Dates to Remember

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| Scientific Policy Committee Meeting | May 4–6 |
| Tau-Charm Factory Workshop | May 23–27 |
| Experimental Program Advisory Committee Meeting | May 30–31 |
| SLAC-LBL Users Organization Meeting | June 2 |
| SLAC Summer Institute | July 10–21 |
| SLD Collaboration Meeting (Kirkwood) | July 31–August 5 |
| International Symposium on Lepton-Photon Interactions | August 7–12 |
| SSRL Users Conference | October 19–20 |

# RECENT SLAC PUBLICATIONS

The following is a list of SLAC publications issued during the first quarter of 1989, from January 1 through March 31. They are organized according to five categories: Experimental High-Energy Physics, Theoretical Physics, Accelerator Physics, Instrumentation and Techniques, and Other Topics. To obtain copies of these publications, write to the Publications Department, SLAC Bin 68, P. O. Box 4349, Stanford, CA 94309, U.S.A. Please be sure to specify author and publication number in your request.

### Experimental High-Energy Physics

MARK-III Collaboration: J. Adler, et al., "Measurement of the Branching Fractions for $D^\circ \longrightarrow \pi^- e^+ \nu_e$ and $D^\circ \longrightarrow K^- e^+ \nu_e$ and Determination of $(V_{cd}/V_{cs})^2$," (SLAC-PUB-4745, Jan 1989; Submitted to Phys. Rev. Lett.).

J. Alexander, et al., "Search Strategies for Higgs Bosons at High-Energy $e^+e^-$ Colliders," (SLAC-PUB-4775, Jan 1989; Contributed to DPF Summer Study: Snowmass '88, High Energy Physics in the 1990's, Snowmass, Colo., Jun 27 - Jul 15, 1988).

D. Aston, et al., "Recent Results in Strangeonium Spectroscopy," (SLAC-PUB-4773-Rev., Feb 1989; Revised version. Invited talk given at 1988 Annual Mtg. of the Div. of Particles and Fields of the APS, Storrs, Conn., Aug 15-18, 1988).

D. Aston, et al., "Recent Results from S = –3 Baryon Spectroscopy from the LASS Spectrometer," (SLAC-PUB-4821, Feb 1989; Invited talk given at Summer Inst. on Elementary Particle Physics, Stanford, Cal., Jul 17-28, 1988).

W.B. Atwood, "B Meson Physics with Polarized Electron Beams at Linear Colliders Running at the $Z^\circ$," (SLAC-PUB-4827, Dec 1988; Presented at DPF Summer Study Snowmass '88, High Energy Physics in the 1990's, Snowmass, Colo., Jun 27 - Jul 15, 1988).

C. Baltay, et al., "New Particle Searches in $e^+e^-$ Collisions," (SLAC-PUB-4844, Jan 1989; Presented at DPF Summer Study: Snowmass '88, High Energy Physics in the 1990's, Snowmass, Colo., Jun 27 - Jul 15, 1988).

MAC Collaboration: H.R. Band, et al., "A Measurement of the $e^+e^- \longrightarrow B\bar{B}$ Forward - Backward Charge Asymmetry at $\sqrt{s} = 29$ GeV," (SLAC-PUB-4871, Feb 1989; Submitted to Phys. Lett. B).

J. Dorfan, "$Z^\circ$ Physics at the SLC," (SLAC-PUB-4816B, Feb 1989; Lectures at Banff Summer Inst.,

Aug 1988 and NATO ASI on Techniques and Concepts of High Energy Physics, St. Croix, V.I., Jul 14-25, 1988).

G.J. Feldman, et al., "Report of the B Factory Group. 1. Physics and Techniques," (SLAC-PUB-4838, Jan 1989; Contributed to DPF Summer Study: Snowmass '88, High Energy Physics in the 1990's, Snowmass, Colo., Jun 27 - Jul 15, 1988).

W.T. Ford, et al., "Measurement of $\alpha_s$ from Hadron Jets in $e^+e^-$ Annihilation at $\sqrt{s}$ of 29 GeV," (SLAC-PUB-4348, Jan 1989; Submitted to Phys. Rev. D).

K.K. Gan, "Searching for an Exotic Lepton and Gauge Boson at High-Energy $e^+e^-$ Colliders," (SLAC-PUB-4748, Jan 1989; Contributed to DPF Summer Study Snowmass '88: High Energy Physics in the 1990's, Snowmass, Colo., Jun 27 - Jul 15, 1988, Submitted to Phys. Rev. D).

P. Grosse-Wiesmann, "$H^\circ$ at a 300 GeV $e^+e^-$ Collider," (SLAC-PUB-4616, Dec 1988; Presented at Workshop on Intermediate Mass and Nonminimal Higgs Bosons at the SSC, Davis, Cal., Jan 4-6, 1988).

C.A. Hawkins and Martin L. Perl, "An Exploration of the Limits on Charged Lepton Specific Forces," (SLAC-PUB-4721, Nov 1988; Submitted to Phys. Rev.).

C.A. Hawkins, "Tests of QED to Fourth Order in $\alpha$ in $e^+e^-$ Collisions at 29 GeV," (SLAC-0337, Feb 1989; Ph.D. Thesis).

C. Hearty, et al., "Search for the Anomalous Production of Single Photons in $e^+e^-$ Annihilation at $\sqrt{s} = 29$ GeV," (SLAC-PUB-4684-Rev., Mar 1989; Submitted to Phys. Rev. D).

D. Hitlin and W. Toki, "Hadronic and Radiative Decays of the $J/\psi$," (SLAC-PUB-4853, 1988; Published in Ann.Rev.Nucl.Part.Sci. vol.38, pp.497-532, 1988).

S. Klein, et al., "$\Lambda_c^+$ Production and Semileptonic Decay in 29 GeV $e^+e^-$ Annihilation," (SLAC-PUB-4696, Feb 1989; Submitted to Phys. Rev. Lett.).

Sachio Komamiya, et al., "Searches for Nonliminal Higgs Bosons from a Virtual Z Decaying Into a Muon Pair at PEP," (SLAC-PUB-4771, Jan 1989; Submitted to Phys. Rev. D).

MARK-III Collaboration: U. Mallik, "Results from MARK-III on the $J/\psi$ Decays," (SLAC-PUB-4828, Jan 1989; Invited talk given at Mtg. of BNL Workshop on Glueballs, Hybrids and Exotic Hadrons, Upton, N.Y., Aug 29 - Sep 1, 1988).

Martin L. Perl, "Tutorial Guide to the Tau Lepton and Close Mass Lepton Pairs," (SLAC-PUB-4739, Oct 1988; Invited talk given at Int. School of Subnuclear Physics, The Super World III, Erice, Italy, Aug 7-15, 1988).

Martin L. Perl, "The Tau and Beyond: Future Research on Heavy Leptons," (SLAC-PUB-4819, Jan 1988; Presented at 8th Int. Conf. on Physics in Collision, Capri, Italy, Oct 19-21, 1988).

Martin L. Perl, "Tau Physics and Tau Factories," (SLAC-PUB-4855, Jan 1989; Presented at Rare Decay Symposium, Vancouver, Canada, Nov 30 - Dec 3, 1988).

MARK-III Collaboration: D. Pitman, "Evidence for $D_s^+ \longrightarrow e^+X$," (SLAC-PUB-4826, Jan 1989; Invited talk given at 16th SLAC Summer Inst. on Elementary Particle Physics, Stanford, Cal., Jul 18-29, 1988).

N.A. Roe, "Resonance Production in Two Photon Interactions," (SLAC-0338, Feb 1989; Ph.D. Thesis).

MARK-III Collaboration: R.H. Schindler, "Results on Semileptonic $D^\circ$ and $D_s$ Decays and Evidence for Non $D\bar{D}$ Decays of the $\psi(3770)$," (SLAC-PUB-4694, Dec 1988; Invited talk given at 24th Int. Conf. on High Energy Physics, Munich, West Germany, Aug 4-10, 1988).

MARK-III Collaboration: W. Toki, "Review of $J/\psi$ Decays," (SLAC-PUB-4784, Nov 1988; Invited talk given at Mtg. of Div. of Particles and Fields of the APS, Storrs, Conn., Aug 15-18, 1988).

W. Toki, "BNL Glueball Review," (SLAC-PUB-4824, Dec 1988; Invited talk given at Mtg. on BNL Workshop on Glueballs, Hybrids and Exotic Hadrons, Upton, N.Y., Aug 29 - Sep 1, 1988).

E.M. Wang, et al., "Higgs $\longrightarrow$ Four Leptons at the SSC," (SLAC-PUB-4876, Feb 1989; Contributed to DPF Summer Study: Snowmass '88, High Energy Physics in the 1990's, Snowmass, Colo., Jun 27 - Jul 15, 1988).

### Theoretical Physics

Changrim Ahn and Mark A. Walton, "Spectra of Strings on Nonsimply Connected Group Manifolds," (SLAC-PUB-4870, Feb 1989).

Varouzhan Baluni, "Embedding and Breaking of Gauge Symmetries," (SLAC-PUB-4825, Jan 1989; Submitted to Phys. Lett.).

Geoffrey T. Bodwin, et al., "Effects of Initial State QCD Interactions in the Drell-Yan Process," (SLAC-PUB-4813, Dec 1988; Submitted to Phys. Rev. D).

Roger Brooks, "Topological Invariants and a Gauge Theory of the Superpoincare Algebra in Three Dimensions," (SLAC-PUB-4799, Nov 1988; Submitted to Nucl. Phys. B).

Roger Brooks, "The Spectrum of Topological Quantum Field Theories on N Manifolds," (SLAC-PUB-4901, Feb 1989; Submitted to Nucl. Phys. B).

C.G. Callan and L. Thorlacius, "Using Reparametrization Invariance to Define Vacuum Infinities in String Path Integrals," (SLAC-PUB-4765, Oct 1988; Submitted to Nucl. Phys. B).

Jong Bum Choi, "Annihilation Contributions in a Wilson Loop Formalism," (SLAC-PUB-4842, Jan 1989; Submitted to Phys. Rev. D).

Jong Bum Choi, "Linear Plus Coulomb Potential or $\Upsilon(6s)$?" (SLAC-PUB-4854, Feb 1989; Submitted to Phys. Rev. D).

Savas Dimopoulos, et al., "Cross-Sections for Lepton and Baryon Number Violating Processes from Supersymmetry at $p\bar{p}$ Colliders," (SLAC-PUB-4797, Sep 1988; Submitted to Phys. Rev. D).

Frederick J. Gilman, "Prospects in B Physics," (SLAC-PUB-4829, Dec 1988; Invited talk given at Rare Decay Symposium, Vancouver, Canada, Nov 30 - Dec 3, 1988).

David Horn, et al., "Heisenberg Antiferromagnet on a Triangular Lattice," (SLAC-PUB-4880, Feb 1989; Submitted to Phys. Rev. D).

Kent Hornbostel, "The Application of Light Cone Quantization to Quantum Chromodynamics in (1+1) Dimensions," (SLAC-0333, Dec 1988; Ph.D. Thesis).

Yosef Nir, "The Mass Ratio $m_c/m_b$ in Semileptonic B Decays," (SLAC-PUB-4847, Jan 1989; Submitted to Phys. Lett. B).

Yung Su Tsai, "Production of Neutral Bosons by an Electron Beam," (SLAC-PUB-4877, Mar 1989; Submitted to Phys. Rev. D).

P. Voruganti, "Stable Static Solitons in the Nonlinear Sigma Model with a Topological Term," (SLAC-PUB-4807, Jan 1989).

**Accelerator Physics**

P. Bambade, et al., "Rollfix: an Adiabatic Roll Transition for the SLC Arcs," (SLAC-PUB-4835, Jan 1989; Contributed to IEEE Particle Accelerator Conf., Chicago, Ill., Mar 20-23, 1989).

P. Bambade, et al., "Operational Experience with Optical Matching in the SLC Final Focus System," (SLAC-PUB-4776, Jan 1989).

P. Bambade, et al., "Observation of Beam-Beam Deflections at the Interaction Point of the SLAC Linear Collider," (SLAC-PUB-4767, Jan 1989; Submitted to Phys. Rev. Lett.).

P. Bambade and A. Hutton, "Specification of Harmonic Corrections (Wirefix) for the SLC Arcs," (SLAC-CN-370, February 1989).

Giovanni Bonvicini, et al., "First Observation of Beamstrahlung," (SLAC-PUB-4856, Mar 1989; Submitted to Phys. Rev. Lett.).

Pisin Chen, et al., "A Bootstrap Disruption Scheme Using a Final Focus Under a Dense Plasma Lens," (SLAC-PUB-4746, Oct 1988; Submitted to Phys. Rev. Lett.).

Pisin Chen, "Review of Linear Collider Beam-Beam Interaction," (SLAC-PUB-4823, Jan 1989; Contributed to U.S. Particle Accelerator School, Batavia, Ill., Jul 20 - Aug 14, 1987).

Pisin Chen, "Disruption, Beamstrahlung and Beamstrahlung Pair Creation," (SLAC-PUB-4822, Dec 1988; Contributed to DPF Summer Study Snowmass '88, High Energy Physics in the 1990's, Snowmass, Colo., Jun 27 - Jul 15, 1988).

P. Emma, et al., "Online Monitoring of Dispersion Functions and Transfer Matrices at the SLC," (SLAC-PUB-4907, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, Ill., Mar 20-23, 1989).

W.T. Ford, et al., "Interactive Beam Tuning Simulator for the SLC Final Focus," (SLAC-PUB-4915, Mar 1989; Contributed to IEEE Particle Accelerator Conf., Chicago, Ill., Mar 20-23, 1989).

H. Hanerfeld, et al., "Higher Order Correlations in Computed Particle Distributions," (SLAC-PUB-4916, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, Ill., Mar 20-23, 1989).

T. Himel, "Calculation of Detector Backgrounds at TeV Linear Colliders," (SLAC-PUB-4804, Nov 1988; Contributed paper to DPF Summer Study Snowmass '88, High Energy Physics in the 1990's, Snowmass, Colo., Jun 27 - Jul 15, 1988).

T. Himel and K. Thompson, "Energy Measurements from Betatron Oscillations," (SLAC-PUB-4917, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, Ill., Mar 20-23, 1989).

Robert Jacobsen and T. Mattison, "Beam Loss Monitors in the SLC Final Focus," (SLAC-PUB-4909, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, Ill., Mar 20-23, 1989).

Ralph G. Johnson, "Stanford Linear Collider History Data Facility," (SLAC-PUB-4885, Mar 1989; Contributed to IEEE Particle Accelerator Conf., Chicago, Ill., Mar 20-23, 1989).

S. Kheifets, et al., "Bunch Compression for the TLC: Preliminary Design," (SLAC-PUB-4802, Dec 1988; Contributed paper at DPF Summer Study: Snowmass '88, High Energy Physics in the 1990's, Snowmass, Colo., Jun 27 - Jul 15, 1988).

W. Kozanecki, "Where Do We Stand on the SLC?" (SLAC-PUB-4859, Feb 1989; Presented at Int. Conf. on Physics in Collision, Capri, Italy, Oct 19-21, 1988).

G.A. Loew and J.W. Wang, "RF Breakdown and Field Emission," (SLAC-PUB-4845, Jan 1989; Contributed to DPF Summer Study Snowmass '88, High Energy Physics in the 1990's, Snowmass, Colo., Jun 27 - Jul 15, 1988).

T. Lohse and P. Emma, "Linear Fitting of BPM Orbits and Lattice Parameters," (SLAC-CN-371, February 1989)

K.C. Moffeit, "Polarization at the SLC," (SLAC-PUB-4764, Oct 1988; Invited talk at Int. Symp. on High Energy Spin Physics, Minneapolis, Minn., Sep 12-17, 1988).

Katsunobu Oide, "Final Focus System for TLC," (SLAC-PUB-4806, Nov 1988; Contributed to DPF Summer Study on High Energy Physics in the 1990's, Snowmass, Colo., Jun 27 - Jul 15, 1988).

Katsunobu Oide and Kaoru Yokoya, "The Crab Crossing Scheme for Storage Ring Colliders," (SLAC-PUB-4832, Jan 1989).

R.B. Palmer, "Energy Scaling, Crab Crossing and the Pair Problem," (SLAC-PUB-4707, Dec 1988; Invited talk given at DPF Summer Study Snowmass '88: High Energy Physics in the 1990's, Snowmass, Colo., Jun 27 - Jul 15, 1988).

J.M. Paterson, "PEP as a Synchrotron Radiation Source: Status and Review," (SLAC-PUB-4899, Mar 1989; Invited talk given at IEEE Particle Accelerator Conf., Chicago, Ill., Mar 20-23, 1989).

T. Raubenheimer, et al., "Damping Ring Designs for a TeV Linear Collider," (SLAC-PUB-4808, Dec 1988; Contributed to DPF Summer Study: Snowmass '88, High Energy Physics in the 1990's, Snowmass, Colo., Jun 27 - Jul 15, 1988).

T. Raubenheimer, et al., "A Damping Ring Design for Future Linear Colliders," (SLAC-PUB-4912, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, Ill., Mar 20-23, 1989).

R.D. Ruth, "Progress on Next Generation Linear Colliders," (SLAC-PUB-4848, Jan 1989; Contributed to Proceedings of U.S. Particle Accelerator School., Batavia, Ill., Jul 20 - Aug 14, 1987).

R.D. Ruth, "Multibunch Energy Compensation," (SLAC-PUB-4541, Feb 1989; Invited talk given at ICFA/INFN Workshop on Physics of Linear Colliders, Capri, Italy, Jun 13-17, 1988).

J. Seeman, "Beam Dynamics Verification in Linacs of Linear Colliders," (SLAC-PUB-4752, Jan 1989; Invited talk given at 1988 Linear Accelerator Conf., Linac '88, Williamsburg, Va., Oct 3-7, 1988).

R. Siemann, et al., "Report of the B Factory Group. 2. Accelerator Technology," (SLAC-PUB-4839, Jan 1989; Contributed DPF Summer Study: Snowmass '88, High Energy Physics in the 1990's, Snowmass, CO, Jun 27 - Jul 15, 1988).

K. Thompson and R.D. Ruth, "Multibunch Instabilities in Subsystems of 0.5-TeV and 1-TeV Linear Colliders," (SLAC-PUB-4800, Nov 1988; Presented at DPF Summer Study, Snowmass '88, High Energy Physics in the 1990's, Snowmass, Colo, Jun 27 - Jul 15, 1988).

K. Thompson and R.D. Ruth, "Controlling Multibunch Beam Breakup in TeV Linear Colliders," (SLAC-PUB-4537, Jan 1989; Presented at Workshop on the Physics of Linear Colliders, Capri, Italy, Jun 13-17, 1988).

K. Thompson and R.D. Ruth, "Multibunch Beam Breakup in High-Energy Linear Colliders," (SLAC-PUB-4873, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, Ill., Mar 20-23, 1989).

K. Thompson, et al., "Operational Experience with Model Based Steering in the SLC Linac," (SLAC-PUB-4874, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, Ill., Mar 20-23, 1989).

J.W. Wang and G.A. Loew, "RF Breakdown Studies in Copper Electron Linac Structures," (SLAC-PUB-4866, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, Ill., Mar 20-23, 1989).

J. Weaver, et al., "Design, Analysis and Measurement of Very Fast Kicker Magnets at SLAC," (SLAC-PUB-4897, Mar 1989; Contributed to IEEE Particle Accelerator Conf., Chicago, Ill., Mar 20-23, 1989).

P.B. Wilson, "RF Pulse Compression and Alternative RF Sources for Linear Colliders," (SLAC-PUB-4803, Dec 1988; Contributed to DPF Summer Study: Snowmass '88, High Energy Physics in the 1990's, Snowmass, Colo., Jun 27 - Jul 15, 1988).

P.B. Wilson, "Introduction to Wake Fields and Wake Potentials," (SLAC-PUB-4547, Jan 1989; Contributed to U.S. Particle Accelerator School, Batavia, Ill., Jul 20 - Aug 14, 1987).

### Instrumentation and Techniques

J.V. Allaby, et al., "The MAC Detector," (SLAC-PUB-4833, Feb 1989; Submitted to Nucl. Instrum. Methods).

W. Ash, "Final Focus Supports for a TeV Linear Collider," (SLAC-PUB-4782, Nov 1988; Contributed paper at DPF Summer Study Snowmass '88, High Energy Physics in the 1990's, Snowmass, Colo., Jun 27 - Jul 15, 1988).

D. Aston, et al., "Development of CRID Single Electron Wire Detector," (SLAC-PUB-4875, Feb 1989; Presented at Int. Wire Chamber Conf., Vienna, Austria, Feb 13-17, 1989).

A.C. Benvenuti, et al., "A Nonflammable Gas Mixture for Plastic Limited Streamer Tubes," (SLAC-PUB-4687, Mar 1989; Submitted to Nucl. Instrum. Methods).

G.B. Bowden, et al., "Retractable Carbon Fiber Targets for Measuring Beam Profiles at the SLC Collision Point," (SLAC-PUB-4744, Jan 1989; Submitted to Nucl. Instrum. Methods).

R. Cassell and F. Villa, "High Speed Switching in Gases," (SLAC-PUB-4858, Feb 1989; Invited talk given at 4th Workshop: Pulse Power Techniques for Future Accelerators, Erice, Italy, Mar 4-9, 1989).

K.R. Eppley, "Design of a 100-Mw X-Band Klystron," (SLAC-PUB-4900, Feb 1989; Contributed to IEEE Particle Accelerator Conf., Chicago, Ill., Mar 20-23, 1989).

Z.D. Farkas, "Radiofrequency Pulse Compression," (SLAC-PUB-4820, Dec 1988; Invited paper given at Workshop on Physics of Linear Colliders, Capri, Italy, Jun 13-17, 1988).

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# *SLAC* PEOPLE IN THE NEWS

The 1989 Wolfgang K. H. Panofsky Prize has been awarded to Richard Taylor of SLAC Experimental Group A and Jerome Friedman and Henry Kendall of MIT for their leadership in the first deep-inelastic electron scattering experiments. Sponsored by the Division of Particles and Fields of the American Physical Society (APS), this prize is given annually to recognize outstanding achievements in experimental particle physics. The award was presented to Friedman, Kendall and Taylor at the Baltimore APS meeting held the first week of May.

According to the citation recognizing their achievements, "These electron-nucleon scattering experiments, which were a vehicle for the discovery of the 'scaling' phenomenon, gave the first direct evidence for a charged, pointlike substructure inside the nucleon." Further experiments with electron, muon and neutrino probes established that these pointlike constituents were in fact the quarks predicted in 1964 by Murray Gell-Mann and George Zweig. They also supplied the first evidence for the existence of gluons and provided experimental foundations for the development of QCD.

The leaders of the famous SLAC-MIT collaboration, Friedman, Kendall and Taylor were instrumental in the conception and development of the End Station A facilities during the 1960s. This powerful complex of magnetic spectrometers (see photo on page 6), detectors and computers — state-of-the-art equipment at the time — became the standard for later fixed-target facilities at CERN and Fermilab. As testament to their far-sighted design, two of the three spectrometers remain in productive use today, almost a quarter of a century after they were originally built.

Led by Burton Richter and David Ritson, Experimental Groups C and F used the same spectrometers for studies of high-energy photon-nucleon collisions, while Friedman, Kendall and Taylor chose to concentrate on elastic and inelastic electron-nucleon scattering. It proved to be a fortunate choice indeed. The SLAC-MIT experiments were what initially put SLAC on the map of high-energy physics.

Jack Steinberger of CERN, who shared the 1988 Nobel Prize in physics, had the highest praise for the SLAC-MIT experiment. Reviewing the field of lepton-nucleon scattering during Panofsky's 1984 retirement ceremonies, he observed that "No experiment in our time has had a greater impact on our way of doing physics today."

* * *

In late December 1988, Professor Wolfgang Panofsky, Director Emeritus of SLAC, was elected a foreign member of the USSR Academy of Sciences. He was informed of his election in a telegram from Academy President G. I. Marchuk, who cited Panofsky's scientific accomplishments in nuclear physics and expressed his hope that this choice would "further strengthen the relations between USSR and USA scientists."

Panofksy was one of only two U.S. scientists elected to the Soviet Academy in nuclear physics. The other was Professor Samuel Ting of M.I.T., who shared the 1976 Nobel prize in physics with SLAC Director Burton Richter.

Panofksy came to Stanford from Berkeley in 1951 and soon took the helm at the High-Energy Physics Laboratory down on campus. In 1961 he became the first Director of SLAC, remaining in that position until 1984.

Since stepping down from that post, Panofsky has been devoting most of his time to work on arms control and future particle accelerators, including the Superconducting Super Collider. He was a key advisor to Chinese physicists who designed and built the Beijing Electron-Positron Collider, now in the final states of its commissioning process.

When not away on one of his frequent trips, Pief can be found almost daily at SLAC, working away in his offices (dubbed Pief-à-Terre) on the first floor of the Central Laboratory.

* * *

Perry Baker Wilson was recently elected a Fellow of the American Physical Society. In honoring him the APS cited his "significant theoretical and experimental contributions to accelerator science and technology in the theory of particle beams and in the development of linear accelerators, RF superconductivity, and high-power microwave techniques."

A Professor at SLAC (Applied Research), Wilson is the leader of the Advanced Accelerator Studies Group. He devotes much of his time to research on RF pulse compression techniques and various other methods of generating the intense microwave power that will be necessary for the next-generation of linear colliders.

Wilson earned his Ph.D. in physics at Stanford in 1958. He joined the SLAC Accelerator Department in 1969, and has worked here ever since.

— *Michael Riordan*

# DOUG DUPEN HEADS BACK TO CAMPUS

After spending over a quarter of a century at the laboratory, Doug Dupen has accepted the position of Deputy Manager of Employee Relations at Stanford University. He will continue at SLAC on a part-time basis, however, providing an important link between the laboratory and campus. A multi-faceted person, Dupen plans to shoulder these new responsibilities while remaining involved in community relations and serving as a knowledgeable member of the SLAC staff.

Though many have worked closely with Doug over the years, few know the personal side of this quiet man whose sense of humor is reflected in his extensive collection of cartoons. Born in Sacramento, he holds BA degrees in both Physics and Speech/English. After starting work at the laboratory in 1962, he earned his MS degree in Physical Sciences from Stanford University in 1966. He and his wife Joanne have two sons, a daughter, and four grandchildren.

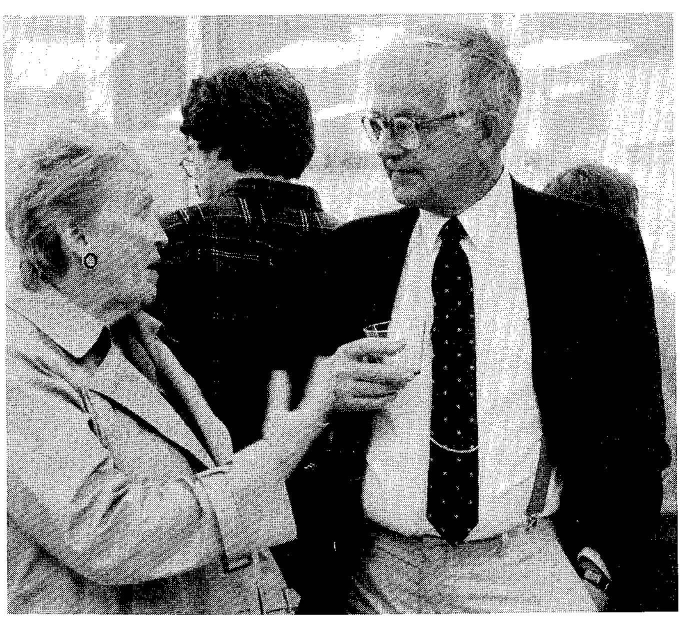
Doug's early interests included broadcasting. He has been an FCC licensed radio operator, an FAA licensed pilot, and a DMV licensed bus driver. A conscientious member of the community, he contributed time and effort to local homeowners associations, worked with business, and even served as Mayor of Menlo Park.

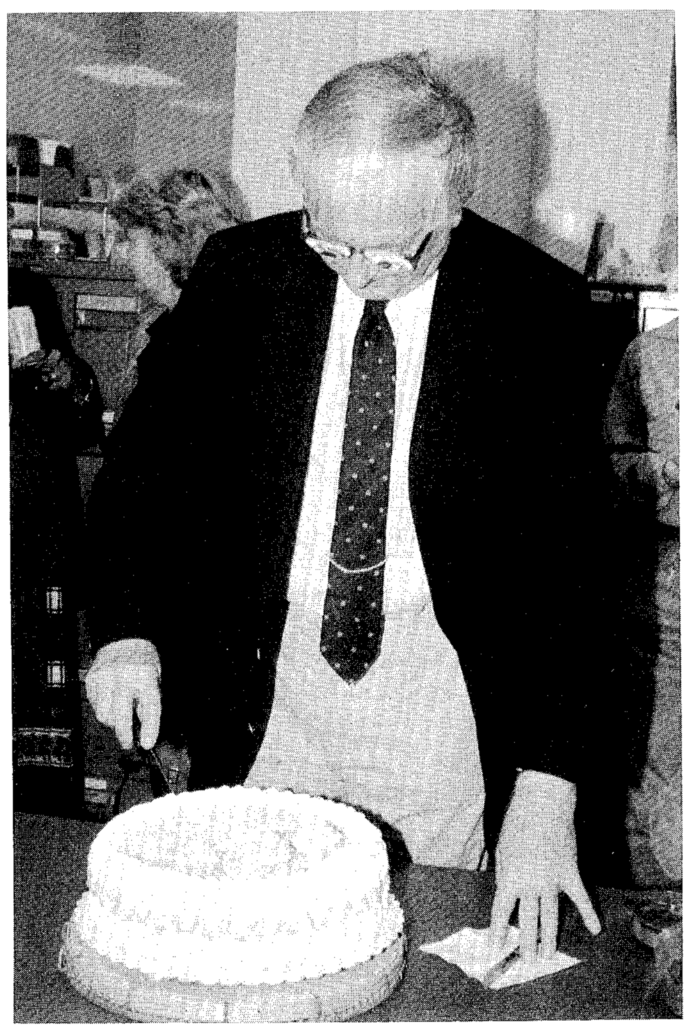
As the laboratory grew from Project M to the sprawling complex it is today, Doug grew with it. From Technical Information Officer to Director of Personnel/Laboratory Relations he has worn many hats — speaker, writer, supervisor, labor negotiator and tour guide. Public speaking, handling the media, and writing brochures describing the laboratory are just a few of the activities that have involved his energies throughout his SLAC career.

Hosting conferences and tours with guests ranging from heads of state to the laboratory's neighbors, Doug has been able to convey enthusiasm for SLAC's work to people from all walks of life. He has been — and will continue to be — actively involved with the Consortium, a program that supports minorities and women working towards graduate degrees in engineering.

Those who work with Doug will still find him in his A&E office, occasionally burning the midnight oil as he makes progress on his infinite list of special projects.

— *Nina Adelman Stolar*





*Dupen chats with Marie Arnold of the SLAC Benefits Office and cuts his cake during an April 24 party given in his honor. (Photos by Tom Nakashima)*