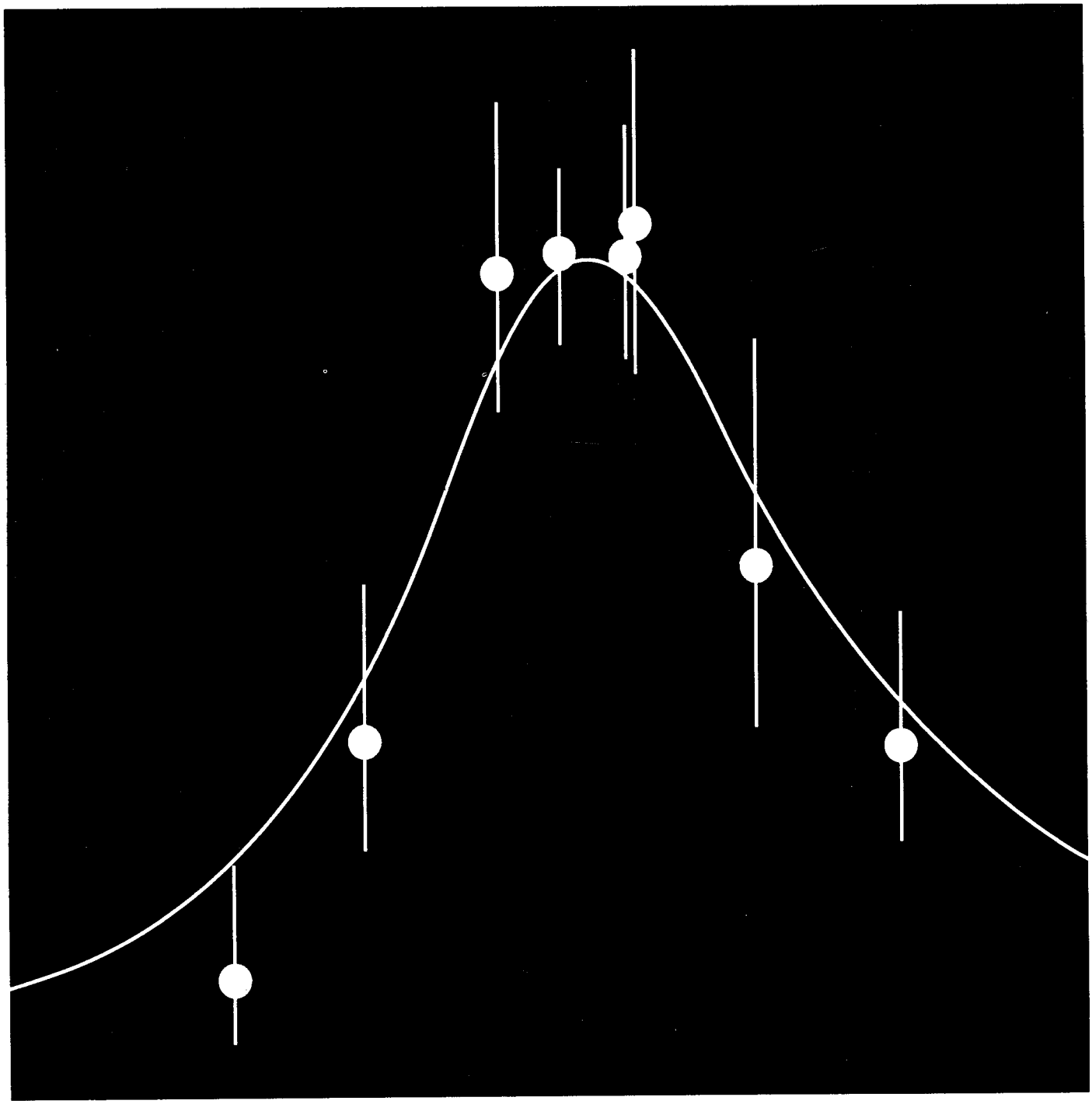
SLAC BEAM LINE

The thing that doesn't fit
is the thing that's most interesting.
— Richard Feynman

Volume 19, Number 3 *September 1989*



First Results from the SLC

SLAC BEAM LINE
Mail Bin 80, (415) 926–2282
Bitnet Address: BEAMLINE @ SLACVM

Editor: Michael Riordan
Assistant Editors: Nina Adelman Stolar, Bill Kirk
Editorial Advisory Board:
John Matthews, John Rees, Marvin Weinstein
Photography: Joe Faust
Illustrations: Terry Anderson
Production: Publications Department

IN THIS ISSUE:

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

This issue celebrates the return of SLAC to center stage in the field of elementary particle physics. With the successful summer run of the Mark II Collaboration on the SLC, we are once again involved in experimentation at the energy frontier. And this August SLAC hosted an international symposium on high-energy physics that was the principal gathering of the year in this field. The story of the summer run is recounted beginning on page 3; an overview of the symposium starts on page 8.

Special thanks on this issue are due to Shirley Boozer and Vani Bustamante, who coaxed our unruly TEX manuscript into the crisp type now before your eyes. Kevin Johnston and Sylvia MacBride whipped the text and graphics into a coherent package, and Crystal Tilghman looked after it during anxious moments at the printer. Without their efforts, given eagerly and with little advance notice, this publication would be extremely difficult to produce.

— the Editors

COVER ART: Data points representing the yield of Z^0 particles versus combined electron-plus-positron energy, as recorded from April through August at the SLC. (Graph drawn by Jim Wahl based on data of the Mark II collaboration)

FROM THE DIRECTOR'S OFFICE

Now that the SLC has begun to work well and produce important new results in high-energy physics (see article beginning on p. 3) it is a good time to look ahead at the work that SLAC plans to be doing in the coming years. As before, the laboratory's future will depend upon the productivity of its major research facilities. As I see it, our future program can be divided into the following three areas:

1. *Stanford Linear Collider.* The mainstay of our experimental research program during the next few years will continue to be the SLC. A planned series of modifications and upgrades to this unique facility will allow it to produce Z^0 particles at a rate much higher than achieved so far. Next year we expect to replace the present Mark II detector with a more powerful detector, the SLD — and to begin a new series of experiments using polarized beams. These improvements will permit an experimental program on the SLC that is competitive with those of our colleagues who are working at the new LEP storage ring at the CERN laboratory in Europe.

2. *The Next Linear Collider.* The SLC has also provided a proof-of-principle demonstration that the basic linear collider idea is indeed sound. If electron-positron machines are to continue to play as important a role in high-energy physics as they have in the past, it is clear that only linear colliders can carry this role forward to energies beyond those attainable at LEP. SLAC has been the world leader in this work; we are the standard-bearers for linear collider research, and much of our future is tied into its continuation.

We have an active and growing program of accelerator R&D (new power sources, accelerator structures, a final-focus test beam, and more) aimed at the development, design and eventual construction of a next-generation linear collider. Such a machine would have a collision energy some three to five times that of the SLC (that is, 300 to 500 GeV), perhaps upgradable in energy to as much as 1,000 GeV, or 1 TeV. Depending on the context, we call this larger machine the NLC (Next Linear Collider), the ILC (Intermediate Linear Collider) or the TLC (TeV Linear Collider). No matter what you call it, however, a Big Collider is the laboratory's principal long-term goal because it would be an extremely powerful machine with a rich program of high-energy physics research. A detailed proposal to build such a collider might be ready for submission by 1993 or 1994.

3. *Storage Rings.* Our present storage rings, SPEAR and PEP, have served us well for many years.

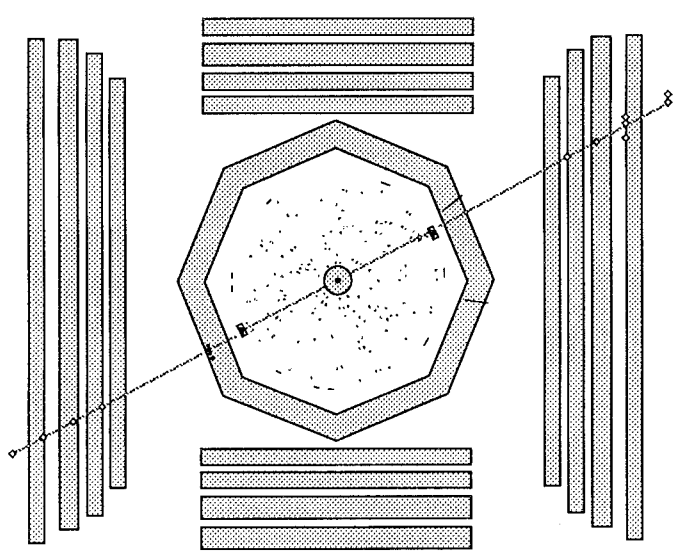
(continued on page 11)

FIRST RESULTS FROM THE SLC
by Michael Riordan

During July and August physicists in the Mark II Collaboration released their initial results on the Z° particles produced by the Stanford Linear Collider (SLC). These presentations came first at the Topical Conference of the SLAC Summer Institute, on July 21, and three weeks later at the 14th International Symposium on Lepton and Photon Interactions, held August 7–12 at Stanford University (see article on page 8). Further results were announced in early September at the European Physical Society meeting in Madrid.

Prior to this year, the high-energy physics community's understanding of the Z° had been based on a supply of about a hundred events witnessed at the CERN and Fermilab $p\bar{p}$ colliders. The more than three hundred Z°'s produced by the SLC from April through August have improved this understanding substantially.

The Mark II Collaboration is a group of about 130 physicists from Cal Tech, Johns Hopkins, the Lawrence Berkeley Laboratory (LBL), SLAC, and the Universities of California (Santa Cruz), Colorado, Hawaii, Indiana and Michigan. They have upgraded the 1800-ton Mark II detector for Z° research (see September 1988 *Beam Line*, p. 3) and installed it surrounding the SLC clashpoint in the Collider Experimental Hall. The SLC began producing Z°'s on April 11 (see April 1989 *Beam Line*, p. 3); by September 1 almost 350 had been observed.



First muon-pair decay of a Z° observed at SLC.

Z° particles are created at the SLC when a high-energy electron in one beam crashes into a positron from another beam and they annihilate. The probability of this occurrence, known as the cross section for Z° production (and written σ_Z), depends on the combined electron-plus-positron energy E. As the total energy of the two beams increases toward 90 GeV, the yield of Z°'s was expected to rise, reaching a maximum at about 92 GeV, then to fall off at higher energies. So the Mark II physicists began their research in April at $E = 92.2$ GeV — about the average of the two earlier measurements of the Z° mass by the CERN collaborations UA1 and UA2.

By early May it was obvious that the SLC energy had *not* been set right on the top of the peak. The total number of Z°'s observed was only half what had been anticipated based on the Standard Model; they had to be sitting on the shoulder of the peak. The only question was whether they were on the low-energy or high-energy side. Led by Jonathan Dorfan and Gary Feldman of SLAC, and Gerson Goldhaber of LBL, the Mark II physicists decided they were probably on the high side. Thus they elected to drop the energy to 90.5 GeV and see what happened to the counting rate. Within days it became obvious they had guessed correctly, because the rate of Z° particle production increased substantially.

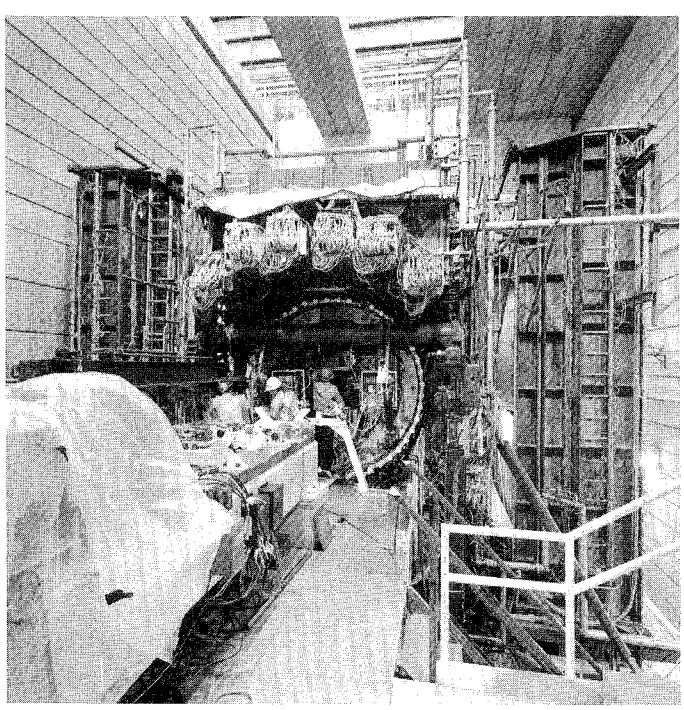
The first fifteen Z° events to be observed at the SLC were all sprays of hadrons, indicating that the Z° itself strongly preferred to decay into a quark-antiquark pair, as expected. In mid-May, however, pairs of leptons also began to appear among the final debris. The first was an electron-positron pair that deposited large quantities of energy in the Mark II liquid argon calorimeter. Two days later came the first muon pair, making two straight, back-to-back tracks that penetrated all the way through the calorimeter and the thick iron walls of the muon detector behind it. And late that month the first tau pair surfaced, too. Such leptonic decays are the *only* kinds of Z° decays that have been detected thus far at proton colliders.

As June began the Mark II Collaboration had logged almost fifty Z° particles at three different energy settings. An intrepid physicist could start trying to fit these data, skimpy as they were, to determine where the peak center was located. Certain Mark II physicists began to do just that. In the daily

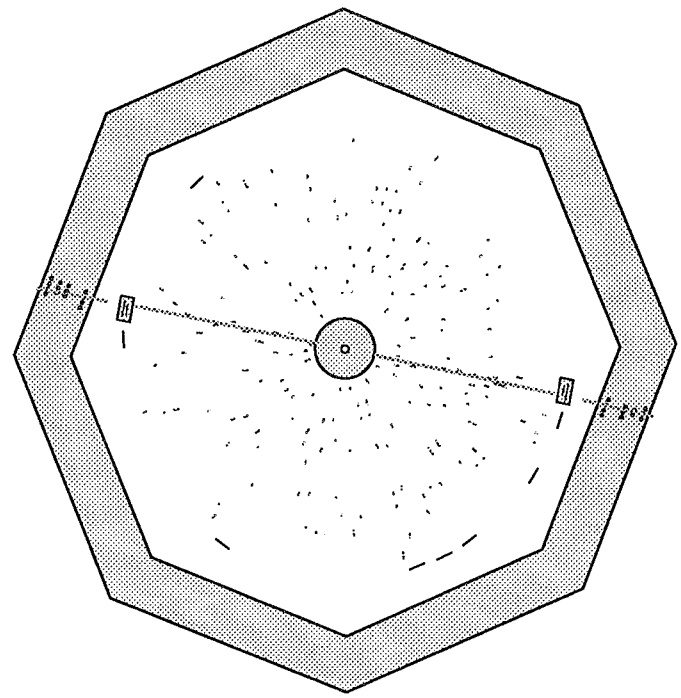
8 o'clock meetings where the previous day's events on the SLC were reviewed, Feldman began showing his plots of the data points, with a curve drawn through them peaking at about 90.7 GeV. Except for slight adjustments to correct for the fact that electrons and positrons are prone to radiate energy before colliding, this central value should correspond to the Z° mass — the first important parameter of the Standard Model expected to be measured precisely at the SLC.

Even with so few events at that early stage, the accuracy of the Mark II data was already good enough to give them the world's best measurement of the Z° mass. In previous determinations, there had been a considerable range of different values quoted for this mass. The published results of the UA1 and UA2 collaborations were 93.0 and 91.5 GeV, for example, and only a month earlier the CDF collaboration working on Fermilab's Tevatron collider had reported a value of 90.4 GeV at the American Physical Society annual meeting in Baltimore. A Z° mass as low as 89 GeV was even being suggested by physicists working on the TRISTAN e^+e^- collider at KEK in Japan. All these measurements carried uncertainties of about 2 GeV, so there was no contradiction between them, just lots of spread. The Mark II error, by contrast, was already down to 0.4 GeV, about a factor of 5 better than any previously reported measurement.

The Mark II physicists could probably have published this result at that stage, and SLAC Director Burton Richter began to suggest they do so. But they stuck doggedly to their original plan — which



The Mark II detector at the SLC clashpoint.

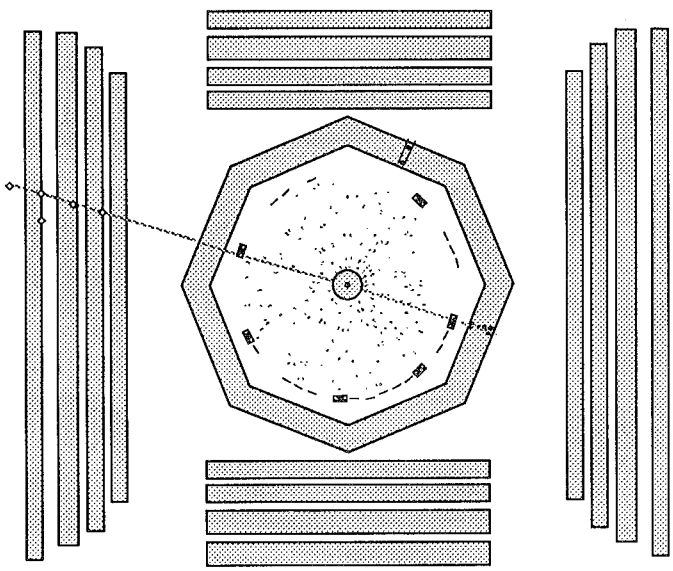


First e^+e^- decay of a Z° witnessed at the SLC.

was to collect about a hundred events in all at five or six different energy settings, and then publish their first paper on the Z°. Given that there were a few possible oddities in these early data, this was certainly the prudent course to take. As more events rolled in during June, however, Feldman began a draft of a paper, titled "Initial Measurements of the Z Boson Resonance Parameters in e^+e^- Annihilation," leaving blanks where he planned to insert the key numbers later on.

Finally, on July 7, the collaboration had enough data — about 115 events at six different energies — and decided to publish. The center of the peak had crept slightly higher during June, so the Z° mass was then about 91.1 GeV. Setting the total SLC energy at this peak value, where the counting rate is nearly maximal, the Mark II physicists continued to log events during July while hashing out the details of their first few publications. Now that their result for the Z° mass was about ten times more accurate than any published value, they wanted to log as many Z°'s as possible before the approaching Lepton-Photon Symposium, scheduled for the second week in August.

An important reason for this urgency was the fact that there were apparent anomalies in this first batch of Z°'s. The width of the peak had come in substantially lower than expected, for example, and there were more muon-pair and tau-pair decays than anticipated based on the Standard Model. The statistical significance of these observations was marginal,



Remnants of a Z° that decayed into two tau leptons. One tau decayed into a penetrating muon (left track) plus invisible neutrinos, the other into an electron (right track) plus neutrinos.

however, and more events were needed to tell whether these were real or spurious effects.

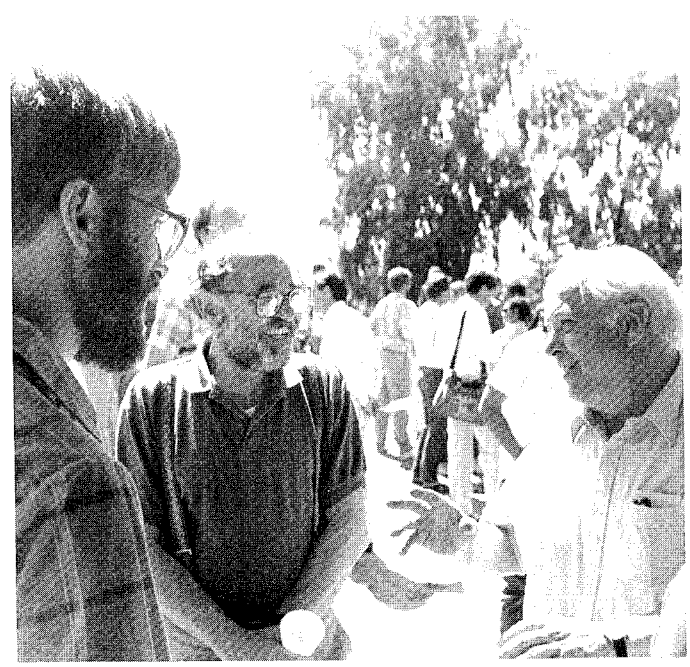
But the most important reason to measure the cross section right at the top of the Z° peak was to determine how many kinds of light neutrinos exist. Normally this would have been done by scanning across the peak in small energy steps and measuring its width precisely. In the Standard Model with three different kinds of light neutrinos, this width is expected to be about 2.5 GeV — with another 0.17 GeV added for each additional species. Given the available luminosity of the SLC (which has reached only $2\times10^{28}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ as this issue goes to press), however, such a detailed energy scan would have taken far too long. A quicker method was to measure the *height* of the peak accurately and compare it with predictions of the Standard Model; additional neutrino types deplete the peak at its center. By measuring its height, therefore, one could determine the possible number of species.

For at least a month, the Mark II Collaboration had been planning to divulge its first results — on the Z° mass, width and decays — on Friday, July 21, in talks given on the final day of the Topical Conference of the SLAC Summer Institute. It was caught completely off guard on Wednesday of that week, however, when Ken Ragan of the CDF collaboration announced its updated value of the Z° mass, 90.9 GeV. What was particularly disconcerting was the small size of their quoted uncertainty, 0.35 GeV, or about a factor of *six* better than what had been reported at the Baltimore APS meeting hardly two months earlier. While the Mark II physicists had been glancing nervously over their shoulders at the inevitable startup of LEP at CERN, these Fermilab upstarts had almost pulled even with them in the global Z° race!

Not to be outdone, Chris Hearty of LBL presented the first SLC results on Friday morning, quoting the Z° mass as 91.11 ± 0.23 GeV. This was an obviously superior measurement, but the CDF announcement two days earlier had clearly stolen a lot of the Mark II thunder. Hearty also gave listeners packing the SLAC auditorium a first look at the width of the Z° peak and the number of different neutrinos. The width was less than 3.1 GeV, at the 90 percent confidence level, and there were fewer than 5.5 kinds of neutrinos.

Meanwhile, the Collaboration was hurriedly putting the finishing touches on its first Z° paper, which went off to the *Physical Review Letters* the very next day. By computer mail and telefax, the paper was refereed, altered, and accepted for publication within a single day. It was published just after the CDF paper in the August 14 issue.

During late July and early August, the SLC finally began performing up to snuff, crunching out a steady stream of Z° particles. Sometimes more than ten were observed in a single day, and more than a hundred were produced in the month the SLC ran at 91.1 GeV — bringing the cumulative number of Z°'s

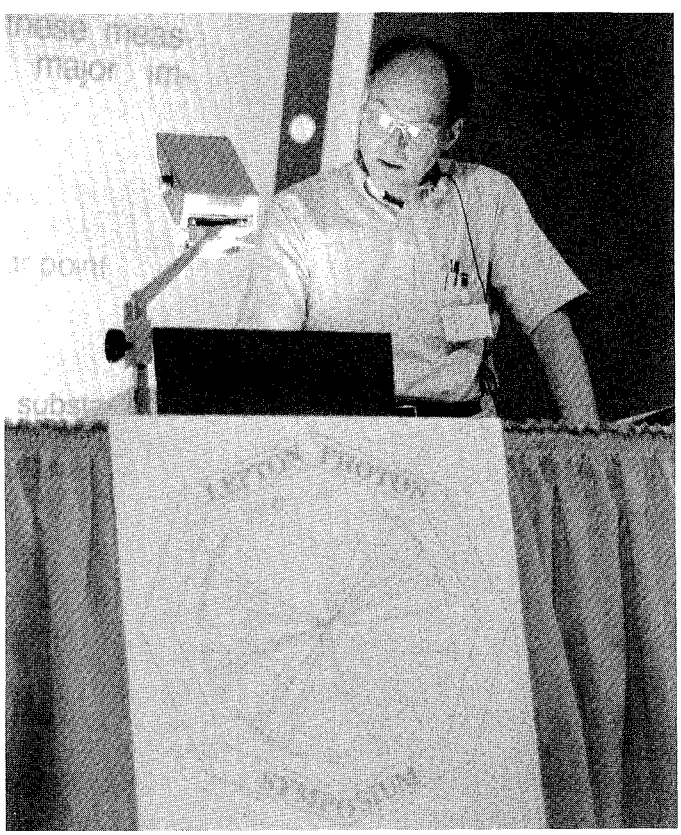


Chris Hearty (left), Gerson Goldhaber and Burton Richter discussing the day's events during a coffee break at the SLAC Summer Institute.

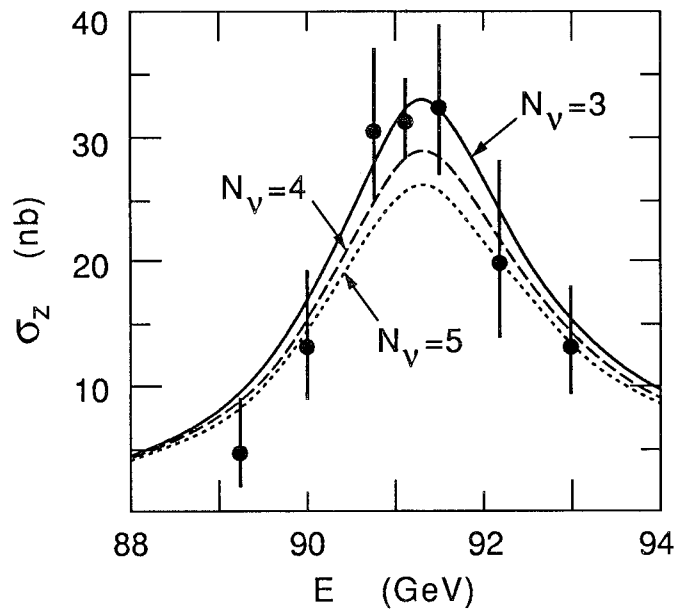
close to 250. Data-taking came to an abrupt halt shortly after midnight on Monday, August 7 (the first day of the Lepton-Photon Symposium), when a lightning bolt from a freak summer thunderstorm caused a site-wide power dip that crashed power supplies all along the machine. As a maintenance shutdown had been planned to begin at the end of that shift, no immediate attempt was made to restart the SLC. It had been a good month for the collider.

From the full sample of Z°'s collected at the SLC, Feldman and colleagues culled 233 events that passed a set of preliminary cuts. Working night and day on the analysis of these events, they were finally ready for the scheduled presentations in the Thursday morning session of the Symposium. As the appointed hour approached, the remaining empty seats in Kresge Auditorium became filled with expectant listeners, while the windowsills along both sides of the hall provided impromptu seating for latecomers.

Speaking to an audience of over 600 scientists who had come to Stanford from more than 50 countries, Feldman began by describing the Mark II detector and outlining their event analysis. From the full set of data, he could extract a somewhat more precise value for the Z° mass, 91.17 ± 0.18 GeV. The width of the Z° peak came in at 1.95 GeV — a little low,



Gary Feldman delivering Mark II results on the Z° particle at the Lepton-Photon Symposium.

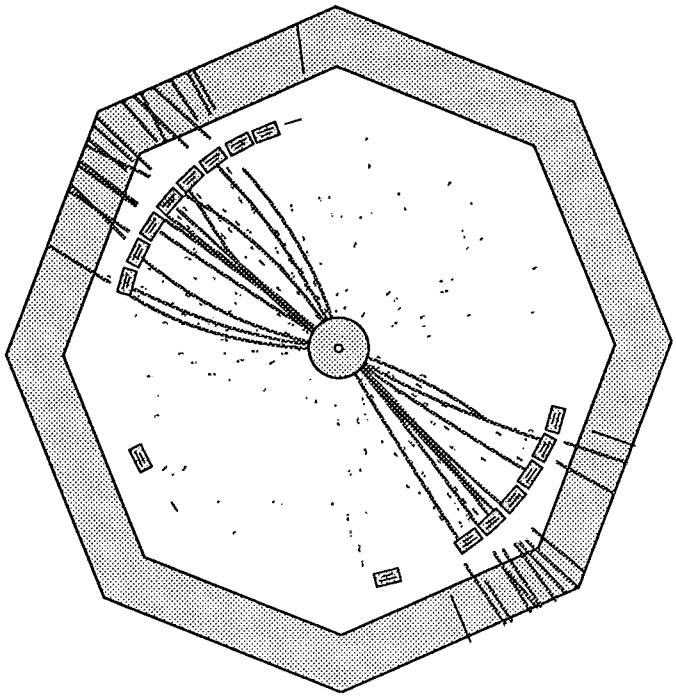


Data on the cross section for production of Z° particles in e^+e^- collisions, as presented by the Mark II Collaboration at the Lepton-Photon Symposium. Curves drawn through the data points represent Standard Model expectations for the cases of three, four and five different kinds of light neutrinos.

but still consistent with expectations based on the Standard Model.

His key result — perhaps the most important result of the Symposium — was the number N_ν of light neutrino species that could be extracted from these data: $N_\nu = 3.0 \pm 0.9$. The most probable number of different light neutrinos (and with it the number of quark-lepton families in the Standard Model) is therefore the three presently known. One additional neutrino (or family) is still possible, but a total of *five* was ruled out by these data, at better than 95 percent confidence.

After Feldman finished telling the audience how Z°'s are produced, Alan Weinstein of Cal Tech presented important new information about how they disintegrate. Based on a slightly different event sample, he unveiled first-ever results comparing its leptonic versus hadronic decays. In the Standard Model, the Z° is expected to break up into charged leptons only about 10 percent of the time (see June 1988 *Beam Line*, p. 4) — and into quarks (or hadrons) about seven times as often. Expressed as a ratio of leptonic/hadronic decays, this comes out as a ratio of 0.048 for each charged lepton. The muon decays were falling in line with this expectation, while there were twice as many tau decays (15 had been observed) and only half as many e^+e^- decays as anticipated. Although the probability was only a few



A hadronic Z° decay. The Z° breaks up first into a quark-antiquark pair, which subsequently generates two back-to-back hadron jets.

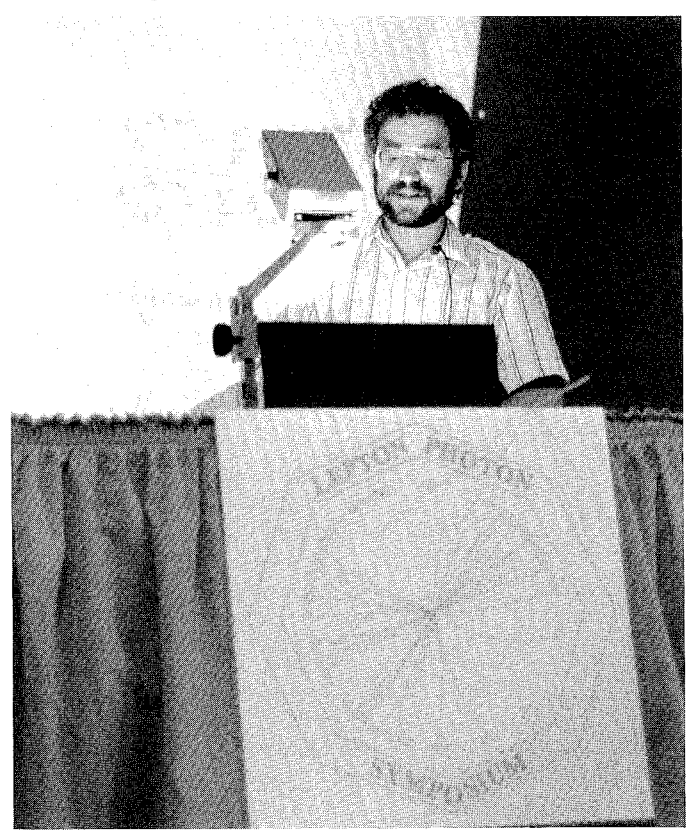
percent that such discrepancies were due to chance fluctuations in the data, Weinstein cautioned listeners that more events were needed before they could make any firm conclusions.

Considered by themselves, the hadronic decays of the Z° are bearing out expectations based on quantum chromodynamics (QCD), a subset of the Standard Model. And there was no evidence among the decay products of this first sample of Z° events for any production of the top quark, nor for a charge $-1/3$ quark of a fourth quark-lepton family nor for a neutral heavy lepton. Depending a bit on what was assumed for their decay modes, the Mark II Collaboration concluded that the masses of any such particles were above 40 GeV.

At the European Physical Society meeting in Madrid, Jonathan Dorfan and Jordan Nash of SLAC Experimental Group C presented an update on the Mark II data. (These data are displayed on the front cover of this issue.) With another hundred Z°'s logged through the end of August, they were able to report that the number of different neutrinos is $N_\nu = 2.7 \pm 0.7$ — and that there are less than 4, with better than 95 percent confidence. The chance that there might be a fourth quark-lepton family in the Standard Model is now less than 5 percent.

Arguments based on the cosmology of the early Universe have suggested that there are only three different species of light neutrinos, with a fourth still possible but not likely. The number of different neutrinos affects the rate of expansion during the Big Bang, which in turn affects the amount of helium produced during the first three minutes of existence. From the amount of helium found in the Universe today, cosmologists make conclusions about the likely number of neutrinos. With the announcement of the Mark II results, high-energy physics has pulled ahead of cosmology on this question, while confirming its prediction of this number. The SLC-based measurement of N_ν stands now at about the same level of accuracy, with none of the ambiguities that occur in cosmological arguments.

In all, it has been an impressive debut for physics research on the SLC. In its first five months of operation, this unique e^+e^- collider has almost doubled the world's supply of Z°'s and provided key insights into their behavior that cannot be had from proton colliders — no matter how many of these particles are eventually produced. What the Mark II Collaboration has been able to wring from its first sample of Z°'s illustrates the major advances that can be expected soon from e^+e^- colliders in precision studies of Standard Model parameters. In the coming months, the far greater numbers of Z° particles issuing from the SLC and LEP may well alter the landscape of high-energy physics.



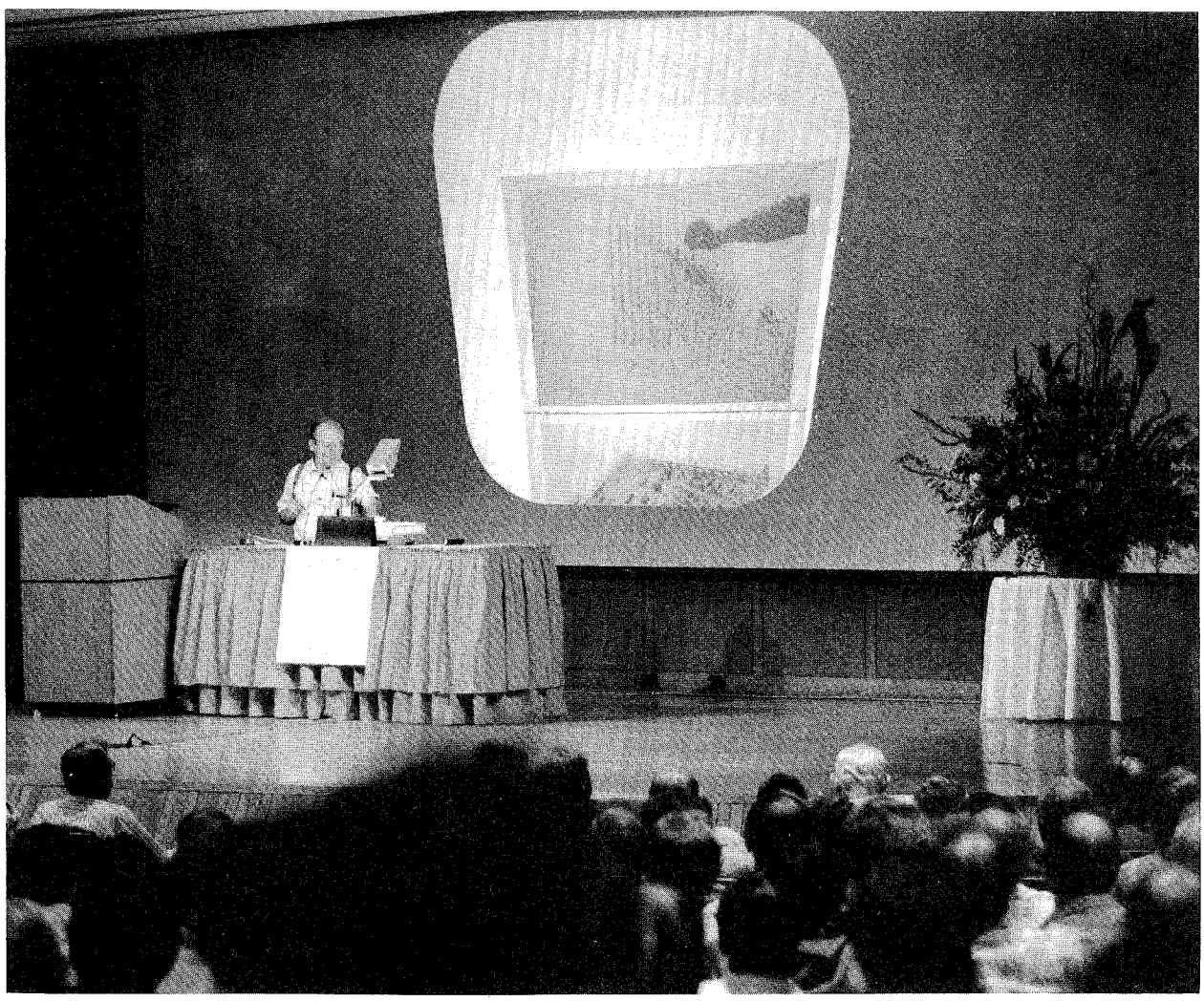
Alan Weinstein reveals the Mark II results on leptonic and hadronic decays of the Z° particle. (Photos on these pages by Harvey Lynch)

14th INTERNATIONAL LEPTON-PHOTON SYMPOSIUM HELD AT STANFORD UNIVERSITY

In 1975 SLAC served as host for one of the most exciting conferences ever to occur in the field of high energy physics. The 7th International Symposium on Lepton and Photon Interactions held that year was the principal gathering at which many of the surprising new results on the revolutionary ψ particles were revealed, discussed and debated. It was the moment when the physics of lepton beams finally came of age.

Fourteen years later this biannual conclave, which takes place in the odd years between the Rochester conferences, returned to Stanford once again. Held from August 7th through 12th in Kresge Auditorium, the very same hall as before, it attracted about 600 physicists from more than 50 countries throughout the world. Although this year's Symposium didn't quite measure up to its predecessor for sheer intensity, it was still a memorable event at which many new and important results were presented for the first time.

In his opening address Monday morning, "A Perspective on Lepton-Photon Physics," Pief Panofsky chose to stress the overall *unity* of lepton and hadron physics while noting the strengths and weaknesses of the two approaches. He then took a glance toward the future — at the impending difficulties of doing experiments on the SSC. "Some interesting fish will certainly get away," he quipped, "but its net can be cast much further into the ocean."



In his opening address, Pief Panofsky illustrates the "biomechanical" techniques used to record events in the good old days. (All photographs in this article by Harvey Lynch)

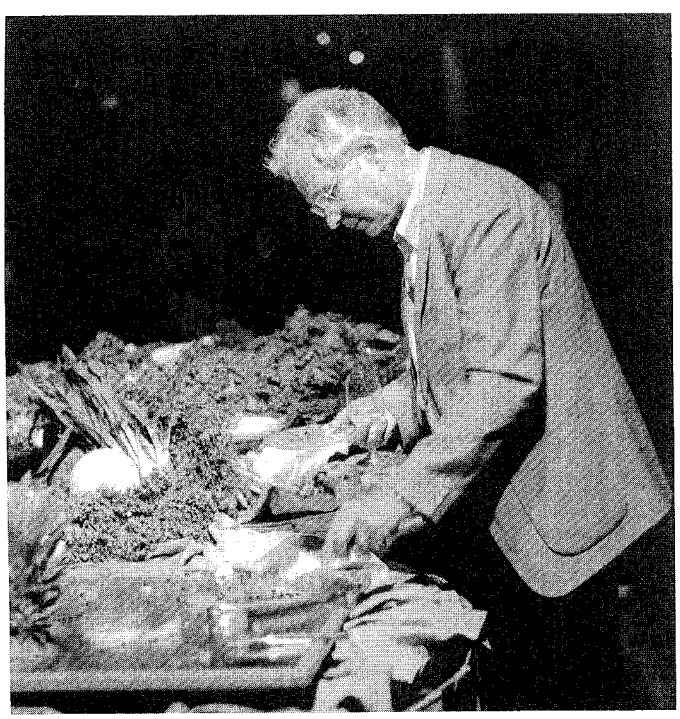
Joel Feltesse of Saclay then reviewed the status of structure function measurements, now the bread-and-butter work of large collaborations at CERN, Fermilab and SLAC. A new, combined analysis of all the SLAC data on electron scattering from hydrogen and deuterium (done by Larry Whitlow of Stanford) seemed to agree with the higher-energy muon scattering data from the CERN collaboration BCDMS — at least in Feltesse's opinion. Apparent discrepancies occuring at large values of the Bjorken parameter x and moderate values of Q^2 could be explained by noting that the BCDMS data were less accurate in that kinematic range.

That afternoon Martin Perl of SLAC summarized the current state of knowledge on the leptons — the electron, muon, tau and their respective neutrinos. Two new upper limits had just been reported on the mass of the electron neutrino: 13.4 eV from the Los Alamos group, and 11.0 eV from INS/Tokyo. He finished up with some observations on decays of the tau lepton and argued for the construction of a high-luminosity "tau-charm factory" (see related story, page 12) to help resolve some of the remaining questions about this heaviest known lepton.

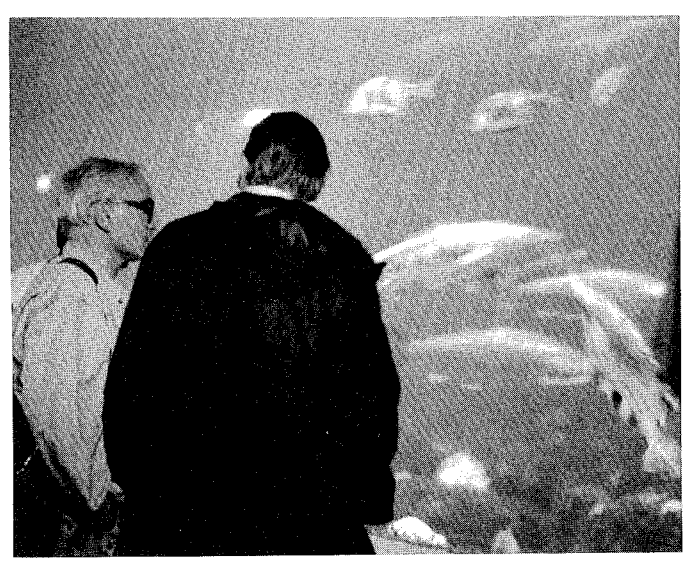
On Tuesday morning David Kreinick of Cornell and Michael Danilov of the Institute of Theoretical and Experimental Physics in Moscow presented the most recent data from the CLEO and ARGUS collaborations, which are studying B physics in decays of the Υ particles. The two groups are now in rough agreement on the degree of $B^0 - \bar{B}^0$ mixing, with an average value of 0.18 ± 0.05 given for the key mixing parameter r. The most important new result to issue from these experiments, however, was the first convincing evidence for $b \rightarrow u$ quark transitions, which were witnessed in semileptonic B decays by both collaborations. More data is needed to improve the statistical significance of both results, but the fact that they were in good agreement was fairly strong proof that these much-sought transitions had finally been observed.

In the afternoon session Bruce Winstein of Chicago revealed the long-awaited results of Fermilab experiment E731, which measured the direct CP-violation parameter ϵ' in kaon decays. The value he reported, based on an analysis of 20 percent of their data, was a bit of a surprise: $\epsilon'/\epsilon = (-0.5 \pm 1.4) \times 10^{-3}$. The next speaker, Daniel Fournier of Orsay, reiterated the non-zero result measured earlier in the CERN kaon-decay experiment $\epsilon'/\epsilon = (3.3 \pm 1.1) \times 10^{-3}$, which leaves a discrepancy of about two standard deviations between these two key measurements. The final resolution may have to wait until the E731 group finishes its analysis or NA31 completes additional data-taking now in progress.

Wednesday was a day off, so most of the participants clambered aboard buses for tours of Monterey, Carmel, Point Lobos and Big Basin Redwoods before gathering that evening at the Monterey Bay Aquarium on famed Cannery Row. Accompanied by spouses and children, they enjoyed a sumptuous "strolling buffet" of gourmet delicacies — while schmoozing with the sharks, ogling the otters and octopi, and befriending the bat rays in the petting pools (which had been situated right next to the sushi bar!).



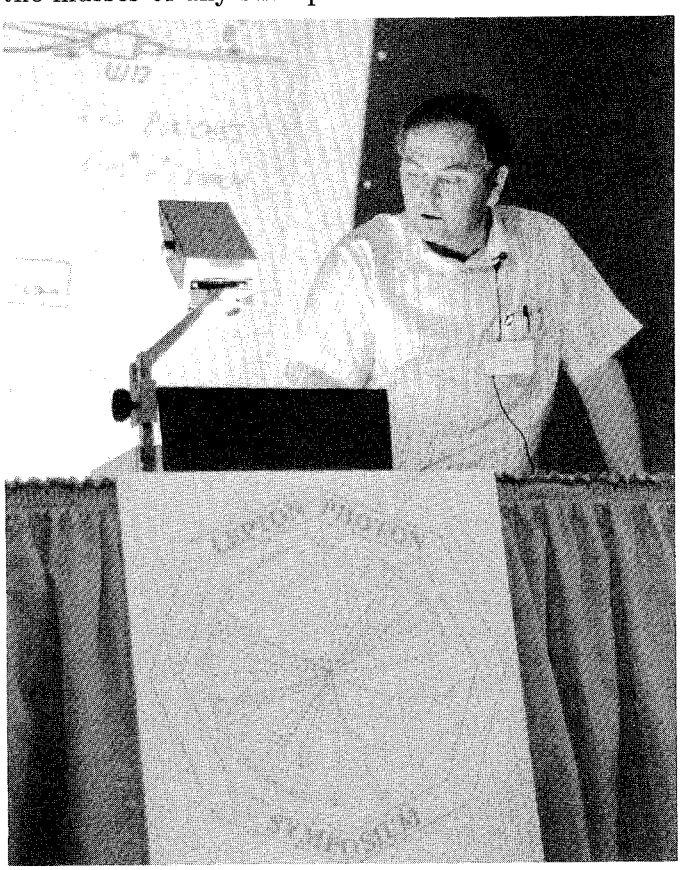
Paul Söding of DESY helps himself to the last remnants of the Aquarium's 'strolling buffet.'



Two physicists at the Monterey Bay Aquarium reminisce about the fish that got away.

The principal highlight of the Symposium had to be the first results of the Mark II collaboration on the detailed physics of Z° particles produced at the SLC. On Thursday morning Gary Feldman of SLAC reported to a jam-packed auditorium that the mass of the Z° was 91.17 ± 0.18 GeV, based on a sample of 233 events recorded through August 7 (see related story, page 3). A Standard Model fit to these data showed the number of light neutrinos to be $N_\nu = 3.0 \pm 0.9$. This means that a fifth quark-lepton family is definitely excluded, and that only one additional family is possible beyond the three presently known.

Immediately following Feldman, Alan Weinstein of Cal Tech disclosed the Mark II results on decays of the Z°, including the first-ever measurements of its leptonic/hadronic branching ratios. The ratio of muon/hadron decays came in about as anticipated in the Standard Model, but there was a substantial excess of tau decays and fewer e^+e^- decays than expected. More events are needed, however, before any firm conclusions can be drawn about these ratios. No evidence could be found in these data for the missing top quark, a charge 1/3 quark of a possible fourth generation, or a neutral heavy lepton; Weinstein placed lower limits of about 40 GeV on the masses of any such particles.



Friedrich Dydak of CERN recounts the lessons recently learned in the commissioning of LEP.

Symposium Secretary Vera Lüth chatting with Nicola and Paola Cabibbo at an evening reception in the Rodin Sculpture Garden.

The expected first Z°'s from the "pilot physics run" at LEP unfortunately failed to materialize before the Symposium's end. Speaking at the close of the Thursday morning session, Friedrich Dydak of CERN explained what had delayed the startup of the world's largest scientific instrument. CERN accelerator physicists, he noted, are indeed human after all. (A little more than a day after the Symposium ended, however, LEP produced its first Z°'s — only *thirty* days after its commissioning had first begun.)

That afternoon representatives of the UA2 and CDF collaborations doing research on the CERN and Tevatron $p\bar{p}$ colliders weighed in with their own results on the Z° and W bosons. The values of the Z° mass reported by Anthony Weidberg of CERN and Myron Campbell of Chicago agreed within errors with the more precise Mark II result presented earlier in the day. And they both found the W mass to be 80.0 GeV, with Weidberg quoting a total UA2 uncertainty of 1.3 GeV and Campbell giving the CDF error as 0.6 GeV.

In the final lecture of the day, CERN theorist Guido Altarelli discussed the implications of the recent CERN, Fermilab and SLAC measurements of these vector boson masses for precision tests of the electroweak theory. Organizing his talk around their impact on the all-important Weinberg angle, he concluded that a "light" top quark (having a mass less than that of the W), while not yet completely ruled out, had become far less probable as a result of the day's revelations.

Columbia's Frank Sciulli wraps up the meeting.

Thus it was a bit anticlimatic the next morning when members of the UA1, UA2 and CDF collaborations told listeners they had obtained no evidence for the elusive top quark during their 1988-89 collider runs. The best limits on its mass came from CDF, presented by Pekka Sinervo of Pennsylvania, who concluded that a top quark decaying according to dictates of the Standard Model was excluded (at the 90 percent confidence level) up to a mass of 78 GeV. The coffin had all but banged shut on light top.

"We find ourselves in a very frustrating situation," remarked Frank Sciulli of Columbia in his conference-ending summary talk Saturday afternoon. "We can't complete the Standard Model with an experimental top quark, and every indication seems to say it will be a while before we find it." The 1989 Lepton-Photon Symposium will probably go down in the history of high-energy physics as the moment when its practitioners became resigned to the inevitability of a heavy top quark, with a mass well beyond that of the W boson.

Symposium Chairman Richard Taylor, Secretary Vera Lüth and Deputy Chairman Fred Gilman did a magnificent job of organizing and managing this conference. Ably assisted by Maura Chatwell, Karen Rogers, and a great host of others, they took care of the literally thousands of details that require attention in putting together an affair of such magnitude. Thanks to their untiring efforts, the hundreds of participants could return to their home institutions with fond memories of friendships made and renewed, and important new insights into the behavior of matter at the 100 GeV scale.

— *Michael Riordan*

FROM THE DIRECTOR (continued from p. 2)

After a uniquely productive career as a particle-physics research facility, SPEAR is now finishing up this aspect of its work; we expect that in 1990 it will become totally dedicated to the synchrotron radiation research program of our sister laboratory SSRL. The PEP ring will continue to be productive in several ways: through high-energy physics research on the TPC detector; through continuing parasitic use of its synchrotron radiation by SSRL; through the possible use of a new gas-jet internal target facility called PEGASYS (see April 1988 *Beam Line*, p. 12), which has been proposed by a group of nuclear and high-energy physicists; and perhaps as part of a new B-factory colliding-beam facility mentioned below.

Another major initiative under intensive study is a possible proposal to build at SLAC a new storage ring that would advance the luminosity frontier (i.e., high counting rate) rather than the energy frontier. There are two competing possibilities — a tau-charm factory (see p. 12) and an asymmetric B factory. Either of these new, medium-sized facilities would enable physicists to study certain of the fundamental quarks and leptons in fine detail. Within the next few months, we will have to reach a decision on which of these two attractive projects to pursue. Even under the best of circumstances, however, it is unlikely that such an advanced storage ring could be ready for operation before the mid-1990s.

A Word of Caution. Although we can foresee an important and well-defined future program for the laboratory to pursue, there is no assurance that events will happen that way. The new SSC laboratory now getting started in Texas will probably come to be seen as the centerpiece of the U.S. high-energy physics program, and you all know the general pressures that exist in Washington to reduce budget deficits. We can make a persuasive case to continue SLAC's role as the leading center for electron physics in this country, and that is what we plan to do.

The importance of electron physics is recognized in the physics community, but we have a selling job to do in Washington to maintain our support in spite of these budget pressures. To succeed we need an effective program for the present and a clearly articulated program for the future.

The past year has been a difficult one for everyone, but we have succeeded in turning the SLC into a productive physics research tool, and we have demonstrated to all that linear colliders are workable machines. There is much more to do if we are to remain competitive, and I am sure that we can do it.

— *Burton Richter*

THE TAU CHARM FACTORY

Recently a successful workshop took place at SLAC whose aim was to explore the idea of a high-luminosity e^+e^- collider operating between 3.0 and about 4.2 GeV. Called the "Tau Charm Factory," it could produce up to 10^{10} ψ particles, 10^8 charmed mesons and almost 10^8 τ leptons per year at its design luminosity of 10^{33} cm^{-2} s^{-1}. First proposed by Jasper Kirkby of CERN, such a collider is now under consideration at SLAC (see next page) — and by institutions in Japan, Spain and the Soviet Union — as a logical next step in storage ring development.

The workshop attracted almost 200 participants from 12 countries, including 40 accelerator physicists. It began with plenary sessions on the first day, after which individuals broke up into working groups that examined the various aspects of machine design, physics prospects and detector design.

Machine Design

The machine discussions began with the design of CERN's John Jowett, who advocated a double-ring machine with a single clashpoint and using electrostatic separators to enable it to carry 24 bunches and a stored current of half an ampere. Other designs were proposed based on this two-ring scheme. Gus Voss of DESY suggested using about 400 bunches and "crab crossing" to increase the luminosity. Susumu Kamada of KEK outlined the idea of a Tau Charm Factory in the TRISTAN Accumulator Ring.

Discussions of the machine physics were held in the mornings, while detailed calculations were done in the afternoons and sometimes far into the night. Karl Brown, Ewan Paterson and Matt Allen of SLAC played liaison roles among the groups. Matt Sands asked many difficult and stimulating questions.

Physics Prospects

While the accelerator physicists deliberated how to build a Tau Charm Factory, the rest of the participants studied how to use it for research. CERN's Alvaro de Rujula launched discussions among the physics and detector groups with a colorful and challenging talk. He reminded listeners there were *two* frontiers in particle physics — high-energy *and* high luminosity — both with promising insights.

The working group on tau physics stressed the fact that the τ lepton and its neutrino are understood far less than the other leptons — largely because of the small supply available. Current measurements of τ properties and decays still allow large deviations from the Standard Model, and potential "new physics" effects could manifest themselves with higher statistics. At a Tau Charm factory, too, the mass of the τ neutrino may ultimately be constrained to less than 1 MeV, much better than the current ARGUS limit of 35 MeV.

Led by Rafe Schindler, the charmed meson working group examined precision measurements of Kobayashi-Maskawa matrix elements, leptonic decays of D mesons, $D^0 - \bar{D}^0$ mixing and rare D decays. There was also plenty of interest in the possibility of observing direct CP violation, or CP violation through mixing in the D meson system.

Fifteen years after its discovery, the analysis of charmonium remains an exciting field. A group led by Walter Toki examined those topics that could be scrutinized at a Tau Charm Factory — including QCD studies of glueballs, hybrids and exotic four-quark states. The truly enormous number of ψ and ψ' decays that could be produced at such a facility would also allow important tests of the potential model of charmonium.

Detector Design

Organized by Kirkby, the detector group was able to design a detector using fairly low-risk technologies that still satisfied the stringent constraints imposed by the physics and accelerator groups. Its components would include a high-resolution central tracking chamber with large solid angle (90 percent of 4π steradians) and a crystal electromagnetic calorimeter. Uniform, redundant particle identification would be implemented and hermeticity stressed.

On the final morning of the workshop, John Jowett summarized the conclusions of the machine builders present. A double-ring e^+e^- collider operating in the tau-charm energy range could indeed be built with the desired luminosity, but it would require a dedicated injector/accumulator to permit operators to "top off" the beams frequently in order to keep the machine operating near its peak luminosity. At the highest currents, much attention would have to be devoted to multibunch instabilities and ion trapping in the electron ring.

In the final summary talk Martin Perl of SLAC, who discovered the tau lepton more than a decade ago, estimated that a Tau Charm Factory would have a useful research lifetime of 10 to 15 years. The physics to be done with such a collider, he observed, "would be broad, deep and exciting."

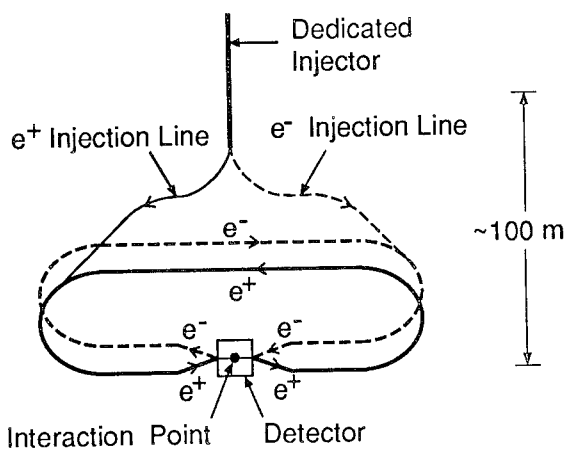
— *Rafe Schindler*

(Editor's note: The Proceedings of the Tau Charm Factory Workshop will soon be available from SLAC Publications as Report No. SLAC-343.)

One of the main conclusions from the Workshop is that a Tau Charm Factory with a luminosity of 10^{33} cm^{-2} s^{-1} can be designed and built now. The principal components of such a facility are shown schematically in the figure below.

Collider and Injector

The collider has separate e^+ and e^- rings, each carrying many bunches with total beam currents of about 0.5 amperes. The simplest design has one interaction point opposite a long straight section that contains the RF system. Two interaction points can be designed but that increases the collider costs by about 30 percent. A better design might be one interaction point with a "push-pull" arrangement for two detectors.



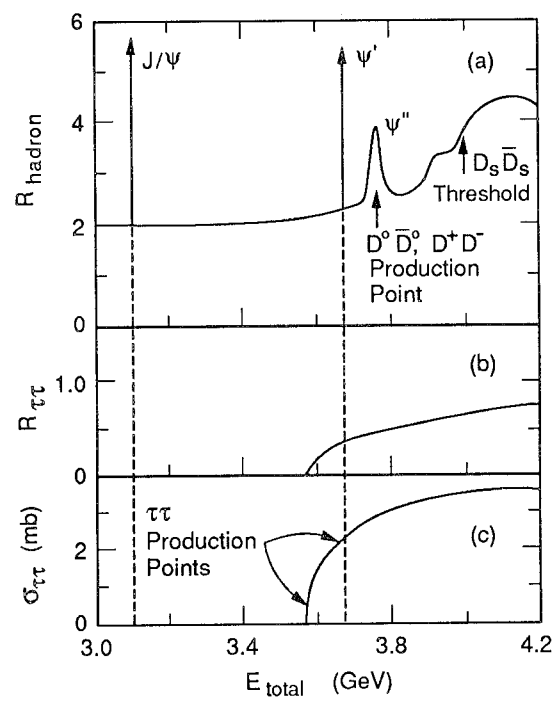
The average luminosity should be at least 75 percent of the peak value, which requires frequent injection (every hour or so) from a dedicated e^+ and e^- injector. Injection would occur at the full beam energy so that the beams can be "topped off". The injector facility would be primarily a linear accelerator. Keeping the average luminosity close to the peak luminosity requires easily maintained and highly efficient collider components and a high-quality control system.

At 0.5 ampere total beam currents, there are two design issues that need particular attention. The RF cavities must be designed to avoid multibunch instabilities, and ion trapping in the electron beam is an important constraint.

Energy Range and Particle Production

At a Tau Charm Factory, there are special energies at which each kind of particle is produced. The ψ and ψ' are produced at their respective resonance energies, where the production cross section is enormous and backgrounds are negligible. The D^0, $\bar{D}^0$, and $D^\pm$ are produced at the ψ'' resonance where the cross section is large, the D's are produced in pairs (which can be definitively tagged), and there is the important constraint $E_D = E_{beam}$. The optimum energies for $D_s^\pm$ and $D_s^{*\pm}$ are not established; existing cross section measurements are maximum for $D_s^+ D_s^-$ at 4.03 GeV and for $D_s^{*\pm} D_s^{*\mp}$ at 4.14 GeV.

There are three preferred energies for producing $\tau^+\tau^-$ pairs. At $E_{total} \approx 3.67$ GeV, just below the ψ', the cross section is $\sigma_{\tau\tau} \approx 2$ nb and there is no background from D decays. The second energy is just above τ pair threshold. Since radiative corrections give $\sigma_{\tau\tau} > 0$ at threshold, $\sigma_{\tau\tau} \approx 0.5$ nb just 2 MeV above threshold, and the τ's are produced almost at rest. The third energy, 4.2 GeV, is best for spin-related studies.



These special energies are crucial for full use of the large data sets that will be produced at a Tau Charm Factory. The physics goals for these data include very precise measurements of particle properties and decays, studies of rare decay modes, and searches for unexpected properties and decays. The special energies allow experimenters to move the energy off the production point to test for event contaminations and backgrounds.

With the emphasis on these energies the main operating range of the Tau Charm Factory is limited to 3.0 to 4.2 GeV. This narrow operating range allows high luminosity throughout. The collider design will probably set the maximum luminosity at a total energy of 4.0 GeV.

— Martin Perl

RECENT SLAC PUBLICATIONS

The following is a list of SLAC publications issued during the second quarter of 1989, from April 1 through June 30. This list was prepared by the staff of the SLAC Library. It is 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. Please be sure to specify author and publication number in your request.

Experimental High-Energy Physics

MARK III Collaboration: J. Adler et al., "Observation of $D_S^+ \to \bar{K}^0 K^+$ and $D_S^+ \to \bar{K}^{*0} K^+$ and an Upper Limit on $D_S^+ \to K^0 \pi^+$," (SLAC-PUB-4952, May 1989; Submitted to Phys. Rev. Lett.)

H. Band et al., "Neutrino Counting with the SLD at the Stanford Linear Collider," (SLAC-PUB-4990, Jun 1989; Presented at the Int'l. Symp. on the Fourth Family of Quarks and Leptons, Santa Monica, CA, Feb 23-25, 1989).

S. Bethke et al., "Studies of Jet Production Rates in e^+e^- Annihilation at $E_{CM} = 29$ GeV," (SLAC-PUB-4944, Mar 1989; Submitted to Z. Phys. C).

Crystal Ball Collaboration: H. Janssen et al., "The Michel Parameter for the Decay $\tau \to e\nu\bar{\nu}$," (SLAC-PUB-4958, May 1989).

M.L. Perl, "The Search for Charged Lepton-Specific Forces at the PEGASYS Facility," (SLAC-PUB-4881, Feb 1989; Presented at Topical Conf. on Physics with Internal Targets at Electron Storage Ring, Stanford, CA, Jan 9-12, 1989).

M.L. Perl, "The Tau Charm Factory and Tau Physics," (SLAC-PUB-4971, Apr 1989; Presented at Rencontres de Physiques de la Vallee d'Aoste, La Thuile, Italy, Feb 26 - Mar 4, 1989).

MARK II Collaboration: K. Riles, "Review of 'Close-Mass' Heavy Lepton Searches," (SLAC-PUB-4985, May 1989; Invited talk given at 24th Rencontres de Moriond: Electroweak Interactions and Unified Theories, Les Arcs, France, Mar 5-12, 1989).

K. Riles, "A Search for a Close-Mass Lepton Doublet," (SLAC-0342, Apr 1989; Ph.D. thesis).

N.A. Roe et al., "A Measurement of the Radiative Width of the η and η' Mesons with the ASP Detector," (SLAC-PUB-4931, Mar 1989; Submitted to Phys. Rev. Lett.)

F. Rouse et al., "Measuring the Mass and Width of the Z° : the Status of the Energy Spectrometers," (SLAC-PUB-4977, May 1989; Contributed to Int'l. Symp. on the 4th Family of Quarks and Leptons, Santa Monica, CA, Feb 23-25, 1989).

R.H. Schindler, "Physics of a High-Luminosity Collider Operated Near Charm and Tau Pair Thresholds," (SLAC-PUB-4996, Jun 1989; Invited talk given at 12th Int'l. Workshop on Weak Interactions and Neutrinos, Ginosar, Israel, Apr 9-14, 1989).

A. Snyder et al., "Search for B Decay to Higgs Bosons for Higgs Boson Masses Between 50 MeV/c^2 and 210 MeV/c^2," (SLAC-PUB-4986, Jun 1989).

S. Wasserbaech, "Hadronic Decays of the D_S Meson," (SLAC-0345, Jun 1989; Ph.D. thesis).

S. Wasserbaech, "Results on D and D_S Decays from MARK III," (SLAC-PUB-5012, Jun 1989; Presented at 24th Rencontres de Moriond: Electroweak Interactions and Unified Theories, Les Arcs, France, Mar 5-12, 1989).

G. Zapalac, "Status of PEP and TPC/2γ," (SLAC-PUB-4998, Jun 1989; Contributed to 12th Int'l. Workshop on Weak Interactions and Neutrinos, Ginosar, Israel, Apr 9-14, 1989).

Theoretical Physics

R. Blankenbecler et al., "Pair Production from Photon Pulse Collisions," (SLAC-PUB-4954, Mar 1989; Submitted to Phys. Rev. D).

S.J. Brodsky and P. Hoyer, "The Nucleus as a Color Filter in QCD Decays: Hadroproduction in Nuclei," (SLAC-PUB-4978, May 1989; Submitted to Phys. Rev. Lett.)

S.J. Brodsky and G.P. Lepage, "Exclusive Processes in Quantum Chromodynamics," (SLAC-PUB-4947, Mar 1989; Contribution to *Perturbative Quantum Chromodynamics*, edited by A.H. Mueller, to be published by World Scientific Publishing Co.)

C.G. Callan and L. Thorlacius, "Open String Theory as Dissipative Quantum Mechanics," (SLAC-PUB-4972, May 1989; Submitted to Nucl. Phys. B).

C. Dib et al., "Strong Interaction Corrections to the Decay $K \to \pi\nu\bar{\nu}$ for Large M_T," (SLAC-PUB-4840, Mar 1989; Submitted to Phys. Rev. Lett.)

L.J. Dixon et al., "$N = 2$ Superconformal Symmetry and $SO(2,1)$ Current Algebra," (SLAC-PUB-4884, Mar 1989; Submitted to Nucl. Phys. B).

L.J. Dixon et al., "On Effective Field Theories Describing (2,2) Vacua of the Heterotic String," (SLAC-PUB-4959, Apr 1989; Submitted to Nucl. Phys. B.)

W. Fischler et al., "Quantum Mechanics of the Googolplexus," (SLAC-PUB-4957, Apr 1989; Submitted to Nucl. Phys. B).

F.J. Gilman, "Heavy Quark Physics," (SLAC-PUB-4955, Apr 1989; Invited lectures given at 3rd Mexican School of Particles and Fields, Cuernavaca, Mexico, Dec 5-16, 1988).

F.J. Gilman, "CP Violation in K Decays," (SLAC-PUB-4973, May 1989; Invited talk given at Int'l. Symp. on the Fourth Family of Quarks and Leptons, Santa Monica, CA, Feb 23-25, 1989).

D. Issler, "Nonrenormalization of the Chiral Anomaly in Chiral Perturbation Theory," (SLAC-PUB-4943, Apr 1989; Submitted to Nucl. Phys. B).

C.-R. Ji and F. Amiri, "Perturbative QCD Analysis of the Pion Form-Factor Using a Frozen Coupling Constant," (SLAC-PUB-4869, Mar 1989; Submitted to Phys. Rev. D).

D.B. Kaplan and I. Klebanov, "The Role of a Massive Strange Quark in the Large-N Skyrme Model," (SLAC-PUB-4964, May 1989; Submitted to Nucl. Phys. B).

I. Klebanov and L. Susskind, "The Googolplexus," (SLAC-PUB-4991, May 1989; Invited talk given at 10th and Final Workshop on Grand Unification, Chapel Hill, NC, Apr 20-22, 1989).

D. McGoveran and H.P. Noyes, "On the Fine Structure Spectrum of Hydrogen," (SLAC-PUB-4730-Rev., Mar 1989; Revised version. Submitted to Phys. Rev. Lett.)

Y. Nir, "Quark Mass Ratios in Semileptonic Quark Decays," (SLAC-PUB-4983, May 1989; Invited talk given at Int'l. Symp. on the Fourth Family of Quarks and Leptons, Santa Monica, CA, Feb 23-25, 1989).

Y. Nir, "What Do We Know (And How) About the CKM Matrix," (SLAC-PUB-4987, May 1989; Invited talk given at 12th Int'l. Workshop on Weak Interactions and Neutrinos, Ginosar, Israel, Apr 9-14, 1989).

H.P. Noyes, "Finite and Discrete Relativistic Quantum Mechanics," (SLAC-PUB-4951, Mar 1989; Submitted to 3rd Int'l. Symp. on Foundations of Quantum Mechanics, Tokyo, Japan, Aug 27-31, 1988).

H.P. Noyes, "On-Shell Scattering Theory with Empirical Input," (SLAC-PUB-4174, May 1989; Submitted to Phys. Rev. C).

J. Sonnenschein, "Topological Quantum Field Theories, Moduli Spaces and Flat Gauge Connections," (SLAC-PUB-4970, Apr 1989; Submitted to Nucl. Phys. B).

M.L. Swartz, "Limits on Doubly Charged Higgs Bosons and Lepton Flavor Violation," (SLAC-PUB-4878, Mar 1989; Submitted to Phys. Rev. D).

P. Voruganti, "Stable Static Solitons in the Nonlinear Sigma Model with a Topological Term," (SLAC-PUB-4807-Rev., Mar 1989; Revised version. Published in Phys. Lett. B).

E. Yehudai, "Probing the $WW\gamma$ Vertex at a 1 TeV e^+e^- Collider Using the Process $e\gamma \to W\nu$ (SLAC-PUB-5008, Jun 1989; Submitted to Phys. Rev. D).

Accelerator Physics

C. Adolphsen et al., "Beam-Based Alignment Technique for the SLC Linac," (SLAC-PUB-4902, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

M.A. Allen et al., "Relativistic Klystrons," (SLAC-PUB-4861, Mar 1989; Invited talk given at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

M.A. Allen et al., "Reliability and Lifetime Predictions of SLC Klystrons," (SLAC-PUB-4863, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

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

P. Bambade, "Optical Tuning in the Arcs and Final Focus Sections of the Stanford Linear Collider," (SLAC-0340, Mar 1989; Ph.D. thesis).

K.L. Bane and R.D. Ruth, "Bunch Lengthening Calculations for the SLC Damping Rings," (SLAC-PUB-4905, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

D.L. Burke, "The Stanford Linear Collider: Fall 1988," (SLAC-PUB-4851, Apr 1989; Invited talk given at Mtg. of Div. of Particles and Fields of the APS, Storrs, CT, Aug 15-18, 1988).

P. Chen and V.I. Telnov, "Coherent Pair Creation in Linear Colliders," (SLAC-PUB-4923, Mar 1989; Submitted to Phys. Rev. Lett.)

P. Chen et al., "Final Focusing and Enhanced Disruption from an Underdense Plasma Lens in a Linear Collider," (SLAC-PUB-4746-Rev., May 1989; Submitted to Phys. Rev. D).

J.E. Clendenin, "High Yield Positron Systems for Linear Colliders," (SLAC-PUB-4743, Apr 1989; Invited talk given at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

P.L. Corredoura et al., "An Active Feedback System to Control Synchrotron Oscillations in the SLC Damping Rings," (SLAC-PUB-4862, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

H. Deruyter et al., "Damped Accelerator Structures for Future Linear e^+e^- Colliders," (SLAC-PUB-4865, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

R.A. Early et al., "Design Calculations and Measurements of a Dipole Magnet with Permendur Pole Pieces," (SLAC-PUB-4883, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

R. Erickson, "Monitoring in Future e^+e^- Colliders," (SLAC-PUB-4974, May 1989; Invited talk given at 3rd Joint US-CERN School on Particle Accelerators: Frontiers of Particle Beams, Observation, Diagnosis and Correction, Capri, Italy, Oct 20-26, 1988).

Z.D. Farkas and P.B. Wilson, "Dynamics of an Electron in an RF Gap," (SLAC-PUB-4898, Mar 1989; Contributed to IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

T.H. Fieguth, "The Optical Design of the Spin Manipulation System for the SLAC Linear Collider," (SLAC-PUB-4924, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

W.E. Gabella et al., "Beam Dynamics with the Hamiltonian-Jacobi Equation," (SLAC-PUB-4934, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

E. Gero et al., "Beamstrahlung as an Optics Tuning Tool at the SLC Interaction Point," (SLAC-PUB-4930, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

J. Haissinski et al., "Phasefix: Correcting the Tunes of the SLC Arcs," (SLAC-PUB-4928, Apr 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

R.K. Jobe and H. Schwarz, "RF Phase Distribution Systems at the SLC," (SLAC-PUB-4893, Apr 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

J. Kent et al., "Precision Measurements of the SLC Beam Energy," (SLAC-PUB-4922, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

R.F. Koontz et al., "Anomalous Electron Loading in SLAC-5045 Klystron and Relativistic Klystron Input Cavities," (SLAC-PUB-4867, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

W.A. Koska et al., "Beam-Beam Deflection as a Beam Tuning Tool at the SLAC Linear Collider," (SLAC-PUB-4919, Apr 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989, Submitted to Nucl. Instrum. Methods).

M.E. Levi et al., "Precision Synchrotron Radiation Detectors," (SLAC-PUB-4921, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

K.-Y. Ng and R.L. Warnock, "Longitudinal Impedance of a Smooth Toroidal Chamber at Low and Intermediate Frequencies," (SLAC-PUB-4932, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

K.-Y. Ng and R.L. Warnock, "Reactive Impedance of a Smooth Toroidal Chamber Below the Resonance Region," (SLAC-PUB-4783-Rev., Apr 1989; Revised version. Submitted to Phys. Rev. D).

K. Oide, "Design of Optics for the Final Focus Test Beam at SLAC," (SLAC-PUB-4953, May 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

S. Rajagopalan et al., "Applications of a Plasma Lens with Bootstrap Disruption," (SLAC-PUB-4882, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

T. Raubenheimer and R.D. Ruth, "Analytic Estimates of Coupling in Damping Rings," (SLAC-PUB-4914, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

T. Raubenheimer, "A Formalism and Computer Program for Coupled Lattices," (SLAC-PUB-4913, Apr 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

D. Ritson, "Nonplanar Machines," (SLAC-PUB-4946, May 1989; Invited talk given at 3rd Joint US-CERN Accelerator School on Particle Accelerators: Frontiers of Particle Beams, Observation, Diagnosis and Correction, Capri, Italy, Oct 20-26, 1988).

J. Rolfe et al., "Long Ion Chamber Systems for the SLC," (SLAC-PUB-4925, Mar 1989; Contributed to IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

M.T. Ronan et al., "Timing and RF Synchronization for Filling PEP/SPEAR with the SLC Damping Rings," (SLAC-PUB-4906, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

R.D. Ruth, "Summary of the Linear Collider Working Group," (SLAC-PUB-4868, Jan 1989; Presented at DPF Summer Study: Snowmass '88 High Energy Physics in the 1990s, Snowmass, CO, Jun 27 - Jul 15, 1988).

R.D. Ruth, "Linear Collider Working Group Reports from Snowmass '88," (SLAC-0334, Mar 1989; Papers Extracted from DPF Summer Study: Snowmass '88, High Energy Physics in the 1990s, Snowmass, CO, Jun 27 - Jul 15, 1988).

R.D. Ruth, "Report on the International Workshop on Next Generation Linear Colliders," (SLAC-PUB-4975, May 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

R.D. Ruth, "An Overview of Collective Effects in Circular and Linear Accelerators," (SLAC-PUB-4948, Apr 1989; Invited talk given at 3rd Joint US-CERN School on Particle Accelerators: Frontiers of Particle Beams, Observation, Diagnosis and Correction, Capri, Italy, Oct 20-26, 1988).

J. Seeman, "Beam Dynamics Issues in Linear Colliders," (SLAC-PUB-4886, Jun 1989; Invited talk given at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

J. Seeman et al., "The SLAC Linac as Used in the SLC Collider," (SLAC-PUB-4890, Jun 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

J. Sodja et al., "Timing Jitter Measurements at the SLC Electron Source," (SLAC-PUB-4938, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

J. Spencer and H. Stucki, "Magnets for High-Energy Colliders," (SLAC-PUB-4850, Mar 1989; Contributed to IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

J. Spencer, "Accelerator Diagnosis and Control by Neural Nets," (SLAC-PUB-4849, Jan 1989; Contributed to IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

K. Thompson and R.D. Ruth, "Transverse and Longitudinal Coupled Bunch Instabilities in Trains of Closely Spaced Bunches," (SLAC-PUB-4872, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

N. Toge et al., "Recent Commissioning Experience on the SLC Arcs," (SLAC-PUB-4926, Apr 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

F. Villa, "A New Switched Power Linac Structure," (SLAC-PUB-4894, Mar 1989; Invited talk given at 4th Workshop: Pulse Power Techniques for Future Accelerators, Erice, Italy, Mar 4-9, 1988).

D.R. Walz et al., "Beam Dumps, Stoppers and Faraday Cups at the SLC," (SLAC-PUB-4967, Apr 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

D.R. Walz et al., "Momentum Slits, Collimators and Masks in the SLC," (SLAC-PUB-4965, Apr 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

H.V. Walz et al., "Distributed Supervisory Protection Interlock System," (SLAC-PUB-4936, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

R.L. Warnock, "Construction of Symplectic Full-Turn Maps by Application of an Arbitrary Tracking Code," (SLAC-PUB-4933, Mar 1989; Presented at IEEE Particle Accelerator Conf. Chicago, IL, Mar 20-23, 1989).

S. Watson et al., "Precision Measurements of the SLC Reference Magnets," (SLAC-PUB-4908, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

K. Yokoya and P. Chen, "Electron Energy Spectrum and Maximum Disruption Angle Under Multi-Photon Beamstrahlung," (SLAC-PUB-4935, Mar 1989; Presented at IEEE Particle Accelerator Conf., Chicago, IL, Mar 20-23, 1989).

Instrumentation and Techniques

G.S. Abrams et al., "The MARK II Detector for the SLC," (SLAC-PUB-4558, Mar 1989; Submitted to Nucl. Instrum. Meth. A).

C. Adolphsen et al., "An Alignment Method for the MARK II Silicon-Strip Vertex Detector Using an X-Ray Beam," (SLAC-PUB-4961, Apr 1989; Presented at European Symp. on Semiconductor Detectors, Munich, Germany, Feb 21-23, 1989).

R.C. Agostini et al., "PLC-Based Interlock System for Superconducting Magnets," (SLAC-PUB-4976, May 1989; Presented at Conf. on Real Time Computer Applications in Nuclear Particle & Plasma Physics, Williamsburg, VA, May 16-19, 1989).

J. Alexander et al., "The MARK II Vertex Drift Chamber," (SLAC-PUB-4852, Mar 1989; Presented at Fifth Int'l. Wire Chamber Conf., Vienna, Austria, Feb 13-17, 1989).

SSC Liquid Argon Calorimeter Working Group: D. Bederede et al., "Conclusions from the Engineering Subgroup of the SSC Liquid Argon Calorimeter Working Group," (SLAC-PUB-4939, Jun 1989; Contributed to SSC Workshop on Calorimetry for the Superconducting Super Collider, Tuscaloosa, AL, Mar 13-17, 1989).

A. Boyarski et al., "Particle Identification Using dE/dx in the MARK II Detector at the SLC," (SLAC-PUB-4956, Apr 1989; Presented at Fifth Int'l. Wire Chamber Conf., Vienna, Austria, Feb 13-17, 1989).

D. Briggs et al., "A Calorimeter Software Trigger for the MARK II Detector at SLC," (SLAC-PUB-4940, Apr 1989; Invited talk given at Conf. on Computing in High Energy Physics, Oxford, England, Apr 10-14, 1989).

S. Gaalema et al., "Silicon Pin Diode Hybrid Arrays for Charged Particle Detection: Building Blocks for Vertex Detectors at the SSC," (SLAC-PUB-4942, Apr 1989; Presented at Int'l. Industrial Symp. on the Super Collider, New Orleans, LA, Feb 8-10, 1989).

G. Hanson et al., "Triggering and Data Acquisition Aspects of SSC Tracking," (SLAC-PUB-4966, Apr 1989; Presented at Workshop on Triggering and Data Acquisition for Experiments at the Supercollider, Toronto, Canada, Jan 16-19, 1989).

A. Harvey, "Radiation Hardening of Magnet Coils," (SLAC-PUB-4910, Jun 1989; Presented at TRIUMF Kaon Factory Design Workshop, Vancouver, Canada, Oct 3-5, 1988).

S. Jadach and B.F.L. Ward, "YFS2: the Second Order Monte Carlo for Fermion Pair Production at LEP/SLC with the Initial State Radiation of Two Hard and Multiple Soft Photons," (SLAC-PUB-4834, Dec 1988; Submitted to Comput. Phys. Commun.)

M.E. Levi et al., "Precision Measurements of the SLC Spectrometer Magnets," (SLAC-PUB-4654, Mar 1989; Submitted to Nucl. Instrum. Meth. A).

R. Mir et al., "Study of Straw Chamber Lifetime with Argon Ethane," (SLAC-PUB-4857, Mar 1989; Presented at 5th Int'l. Wire Chamber Conf., Vienna, Austria, Feb 13-17, 1989).

R.H. Schindler and R.D. Watt, "Signal Feedthroughs and Cryogenic Systems," (SLAC-PUB-4982, Jun 1989; Contributed to SSC Workshop on Calorimetry for the Superconducting Super Collider, Tuscaloosa, AL, Mar 13-17, 1989).

Other Topics

J. Dixon, "End-User Interactive Telecommunications Management Systems," (SLAC-PUB-4988, May 1989; Submitted to Business Commun. Rev.)

R.J. Donahue, "Calculation of Internal Radiation Exposures at a High-Energy Electron Accelerator," (SLAC-PUB-4941, Apr 1989; Submitted to Radiat. Prot. Dosim.)

J.H. Friedman, "Multivariate Adaptive Regression Splines," (SLAC-PUB-4960, Apr 1989; Submitted to Ann. Stat.)

SLAC Environment and Safety Office: "Annual Environmental Monitoring Report: January - December 1988," (SLAC-341, Mar 1989).

1989 SUMMER SCIENCE PROGRAM

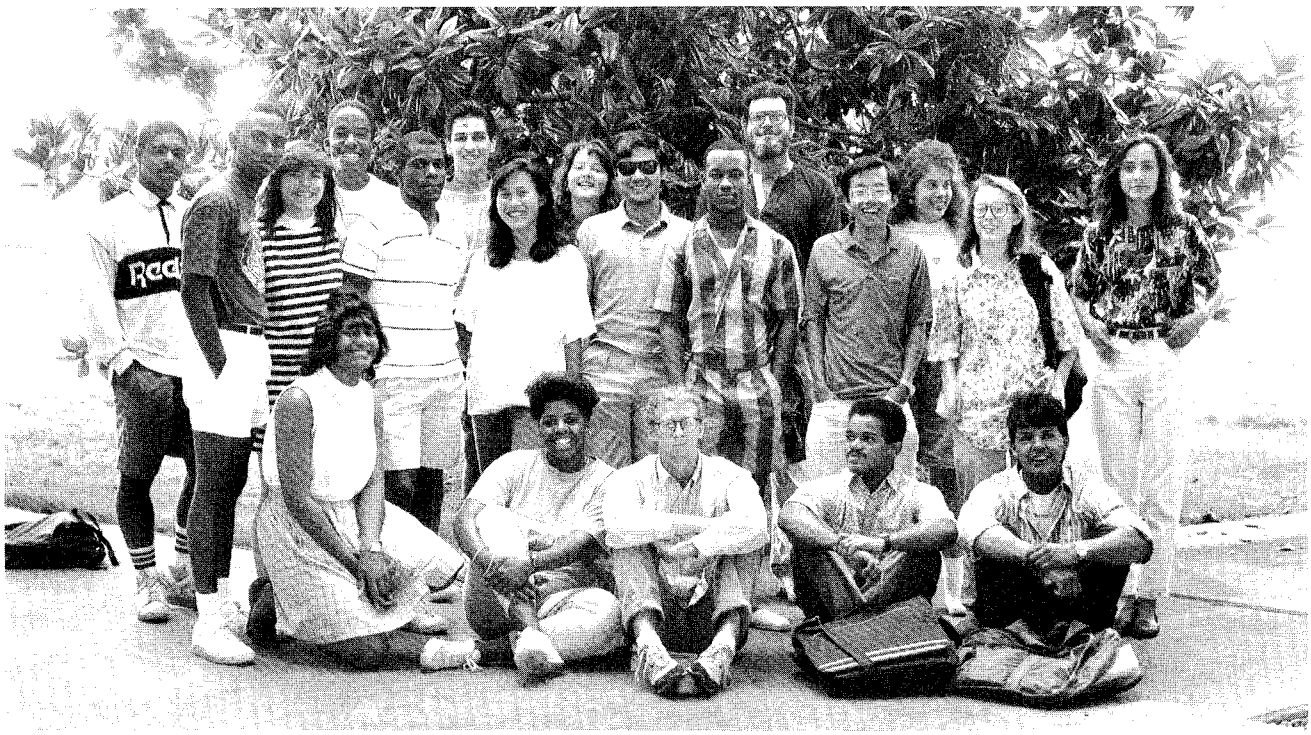
This year marks the 20th anniversary of the SLAC Summer Science Program. It was established in 1969 with the goal of providing training opportunities for minority, female and other groups underrepresented in science and engineering.

A total of 20 students from 15 colleges and universities (see photograph below) participated in this year's program, held from June through August. Harvard and Tuskegee University led the field in representation, each placing three students in our honored group.

As in years past, we tried to reach beyond formal classes and give these summer students first-hand experience in science and engineering by letting them participate in the research activities at SLAC. The program combined a technical work assignment with a lecture series offered by SLAC staff and noteworthy guests. Regular tours were also made of local research and industrial laboratories.

This year's Director, physicist Rudy Larsen of Experimental Group C, was the driving force behind the summer program. He was a source of many new ideas and challenges for the students, who responded warmly to his tutelage.

— *Beth Raines*



The 1989 summer science students. Standing (l to r): Jerome Ware, Steven Jones, Gretchen Bendix, Michael Dorsey, Darryl Whitlow, Edward Reynes, Ying Fung, Ann Corneliusen, Joshua Li, Derek Shepherd, Andy Standen, Louis Tao, Amy Plofker, Eva Silverstein and Carla Slater. Seated: Kelly Moore, Ingrid Fogle, Robert Marx, Norman Rivera and Hector Garcia.

SLAC PEOPLE IN THE NEWS

During its sessions this summer at Brookhaven, the U.S. Particle Accelerator School awarded Karl Brown of the Research Division its 1989 Prize for Achievement in Accelerator Physics and Technology. Consisting of a check and a plaque, the prize was presented to him at a banquet on August 3. He was honored by his colleagues in the accelerator physics community for his "insights into particle beam transport and for introducing formalisms in use throughout the world."

Brown's deep involvement with accelerator physics, which began at Stanford in the late 1940s, has closely paralleled the development of linear accelerators and colliders ever since. In 1949, he wrote a master's thesis on klystron design, with Marvin Chodorow as his advisor; four years later he finished his Ph.D. on electron scattering under Pief Panofsky. After that he worked at HEPL as a Research Associate, becoming one of the principal figures involved in the design of a two-mile accelerator then known as "Project M," and joined SLAC at its inception. He was made Adjunct Professor in 1974 and named Professor (Applied Research) in 1982.

Karl was the first to apply matrix methods to solve problems in the transport of charged particle beams through a system of magnets. A computer program based on these methods, TRANSPORT, has been used worldwide in the design and analysis of particle beams and magnetic spectrometers. This program and the methods behind it have become basic tools of the trade for both accelerator and high-energy physics; it is difficult to imagine how these disciplines could have evolved to their present status without them.

* * *

Adding again to his already long list of laurels, Wolfgang K. H. Panofsky has been invited to join the French Academy of Sciences as a Foreign Associate. Hardly six months earlier, he received a similar invitation from the USSR Academy of Sciences (see April 1988 *Beam Line*, p. 19).

This fall Pief formally retires from SLAC, becoming Professor Emeritus in addition to Director Emeritus, but that doesn't mean we'll see any less of him hereabouts. From his office on the first floor of the Central Lab, he will continue to work on disarmament, international relations, future particle accelerators, and whatever else captures his unquenchable imagination.

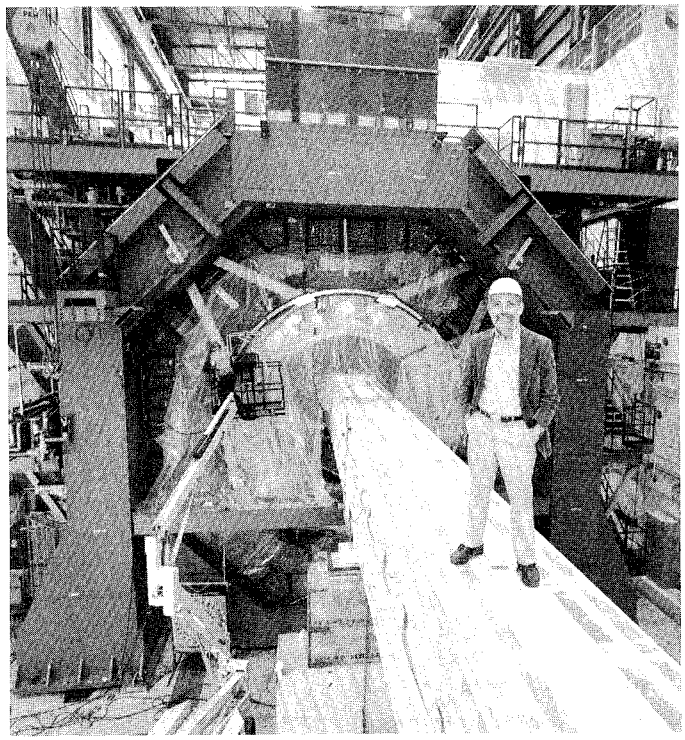
* * *

Also honored recently was Stan Brodsky of the SLAC Theory Group, who has been named a Foreign Scientific Member and External Scientific Director of the Max Planck Institute for Nuclear Physics in Heidelberg, Germany. Since 1987 he has been spending part of each year doing research there, thanks to the Alexander Humboldt Foundation, which presented him one of its Senior U.S. Distinguished Scientist Awards in 1987. He served as Visiting Professor at Heidelberg from March to October, 1988, and will return there again next month for a short stay.

* * *

Finally, it was a pleasure to learn that Martin Breidenbach was named full Professor at the June 9 meeting of the SLAC faculty. Marty, as everybody here knows him, has been a prominent figure at SLAC ever since he came here in the 1960s as an MIT graduate student working on the MIT-SLAC deep inelastic electron scattering experiments. In 1971 he joined Experimental Group C as a Research Associate and was centrally involved in the revolutionary ψ particle discoveries. More recently, he has been serving with Charles Baltay as co-spokesman of the SLD Collaboration.

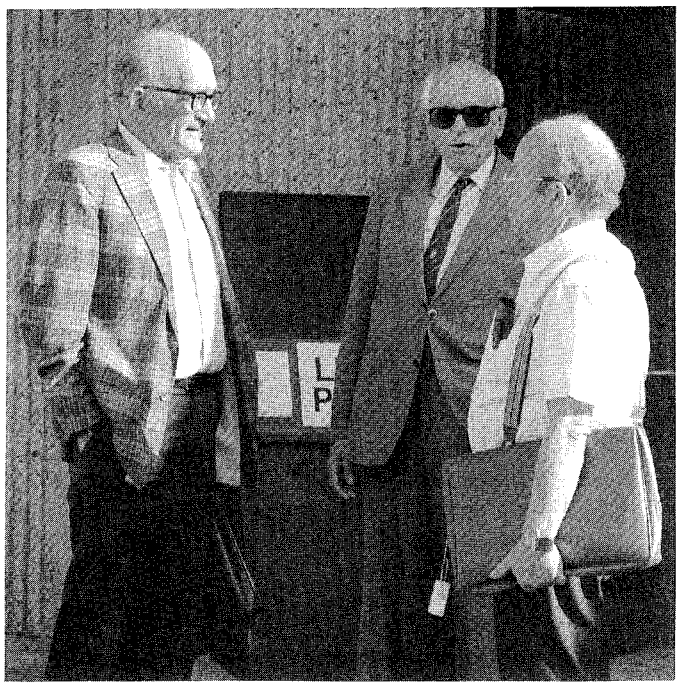
— *Michael Riordan*



Marty Breidenbach stands in front of the SLD.

SAKHAROV VISITS *SLAC*

Soviet physicist and famed human-rights advocate Andrei Sakharov paid a short but memorable visit to SLAC last month. Arriving at Stanford on Friday, August 11, he was able to attend the final sessions of the International Lepton-Photon Symposium in Kresge Auditorium (see article, p. 8), one of more than twenty Russians there. Afterwards he stayed in the Stanford area until the following Tuesday.



Sid Drell, Andrei Sakharov and Pief Panofsky conversing at the Lepton-Photon Symposium.

On Monday Sakharov came to SLAC accompanied by SLAC Deputy Director Sidney Drell and other physicists. During the morning he toured the laboratory to see the latest developments of the Stanford Linear Collider and discuss the SLC's newly achieved results on the Z^0 particle. Sam Kheifets of the Accelerator Theory group served as translator.

The next three hours were spent in informal seminar discussions, mainly with theoretical physicists, over a broad range of topics covering recent developments in particle physics, string theory and cosmology. With Stanford physicist Leonard Susskind, Sakharov debated the description of the universe by a Schrödinger wave function and the possibility of creating new universes by quantum tunneling. Vadim Kaplunovsky of the SLAC Theory Group assisted as translator and devil's advocate. "It was a very stimulating session," said Drell, "with a rich exchange of views on recent advances in physics."

— *Nina Adelman Stolar*

THEORY OUSTS EXPERIMENT, 7–4

(YES, YOU HEARD IT RIGHT, 7–4!)

A small turnout and some big bats combined to deal the powerful experimental team only their third loss in over thirty years of the traditional SLAC Softball Game. Held unusually late this year, on Saturday, August 26, the annual contest hardly attracted enough participants to field two teams. Here the empiricists made a major strategic error, allowing their slugging first baseman Bill Kirk to play on the theorist side in a gesture of good will. His bat and glove were to be sorely missed.

The cloud-niners leapt on this golden opportunity and sent a daunting fusillade of home runs sailing over the stunned real-worlders' heads. Rookie sensation Lance Dixon strung a pair of line drives into Panofsky Grove and Russ "Cannonball" Kaufmann continued his siege of the A&E Building with a towering blast to left-center.

Meanwhile, veteran southpaw hurler Lefty O'Drell methodically mowed down the empiricist batters who meekly came up to challenge him on their side of each inning. When the dust had finally settled after nine painful innings, the score was a puny 7–4 in favor of the third-floor crowd, the lowest score in the long and honorable history of the game.

Afterwards the disgruntled experimenters drowned their sorrows in beer, served up at the O'Drell house down on campus, while licking their wounds. Several of their number were overheard grumbling that the victory margin wasn't even statistically significant. Other soreheads complained that the score was actually a draw, within errors.

But most of the experimenters agreed they'd been soundly thrashed, fair and square. They immediately began plotting their revenge for next year's game, which will hopefully be held in May before we've all left for summer vacations. Theorists beware!

— *A Disgruntled Experimenter*

18th Annual SLAC Race

The annual SLAC Race will be run along the linac on Thursday, November 9, come rain or shine. There will be prizes for winners in the various categories and SLAC Race ribbons for all participants.

Please show up at Sector 30 at noon to register. Everybody in the community is invited to run for fun or to compete for the prizes.