SLAC BEAM LINE

Science walks on two feet, namely theory and experiment.
Sometimes one foot is put forward first, sometimes the other.
— Robert Millikan

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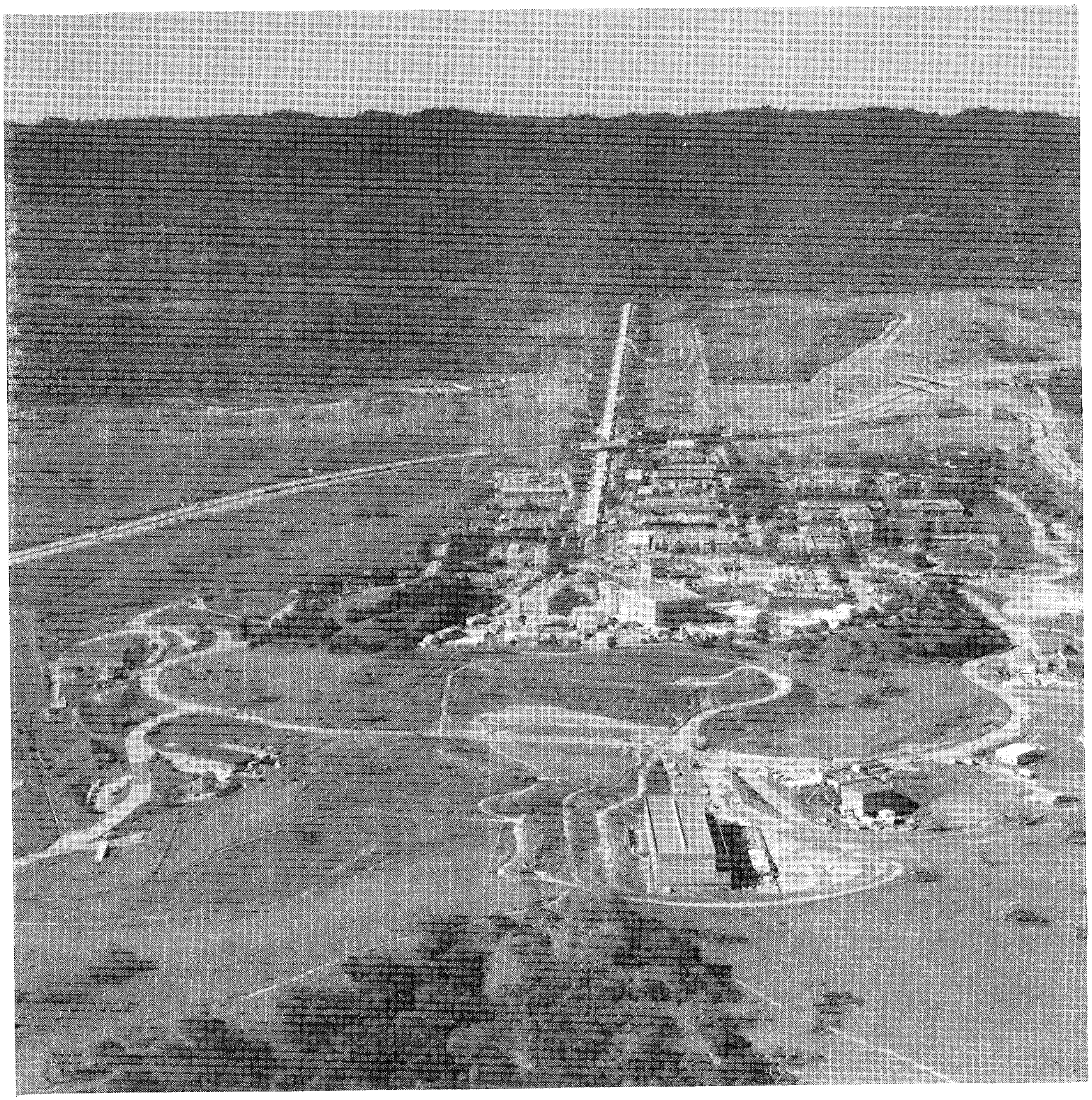

SLAC in the SLC Era

THE *BEAM LINE* RETURNS

With the impending start-up of physics research on the Stanford Linear Collider, we are reviving an old tradition: the *SLAC BEAM LINE*. This newsletter of SLAC activities will be published quarterly at first—in March, June, September and December. If the demand exists and time permits, we hope to go to a bimonthly publication schedule by mid-1989.

Science Information Officer Michael Riordan, the author of *THE HUNTING OF THE QUARK*, is the new Editor of the *BEAM LINE*. He is assisted by Nina Adelman and Bill Kirk. Special thanks on this issue are due Bill Ash, Dorothy Edminster, Joe Faust, Walter Zawojski, Shirley Boozer and Kevin Johnston—plus all the others in the Publications Department who helped put it together.

Heading the issue is an article beginning on page 3 about the physics research to be done on the SLC. Written by David Coupal of Experimental Group C, it summarizes what physicists hope to learn from the Z° particles this collider produces over the next few years. On the last three pages are several short articles of general interest to the SLAC community.

We invite contributions from the entire community —physicists, staff, and visitors. Articles should be short, no more than 1000 words in all, and be of interest to a significant portion of the total readership. Please submit them to Michael Riordan (Mail Bin 80, Central Lab Room R101C, *EMR* at *SLACVM*). Deadline for the September issue is August 15.

Thank you for all your help and continued interest.

—the Editors

IN THIS ISSUE:

COVER PHOTO: Aerial view of the Stanford Linear Accelerator Center as the SLC begins operation. At top is the two-mile linac, which terminates in the Research Yard, center. The Collider Experimental Hall, housing Mark II and SLD particle detectors, is the large building at the bottom, just right of center. (Photo by Joe Faust)

SLAC BEAM LINE, x2282, Mail Bin 80

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

STATUS OF THE SLC

After a three-month shutdown to roll the Mark II detector into position and fix some thorny problems with the machine itself, the commissioning of the Stanford Linear Collider resumed in mid-January. Steady progress was made with the electron beam. By the end of February it had reached the interaction point with a record size of 3 microns wide by 5 microns high (in radius). For comparison, a human hair is about 25 microns in diameter.

The positron beam took longer, finally reaching the interaction point in early April. Its cross section has been comparable but slightly larger. Whereas 10 billion electrons per beam pulse are routinely transported to the end of the collider, the positrons have barely exceeded 5 billion per pulse. A factor of two improvement here is expected soon.

On April 17 the two beams finally clashed with both spot sizes less than 10 microns in radius. But attempts to find the slight deflection of one beam by the other, expected to occur under these conditions, at first proved unsuccessful. This failure caused much concern, because attaining beam-beam deflections was a necessary final step before high-energy physics research could begin.

Another worrisome problem was the background particles hitting the Mark II detector. Because both beams came out of the arcs too big, they scraped metal surfaces in the final focus and sent sprays of penetrating muons into the big detector. This problem seems to have been solved, to some extent, by trimming off the beam extremities further upstream—at the beginning of the arcs.

After a short shutdown in mid-May to make last-minute improvements, the SLC came back into service once again. On Sunday, June 5, unmistakable evidence for beam-beam deflections showed up at last, to the great relief and obvious pleasure of everybody involved. After more than a year of often frustrating work commissioning the new collider, it is almost ready to begin doing high-energy physics.

—Michael Riordan

THE PHYSICS AT SLC

by David Coupal

Since 1983 a large fraction of SLAC manpower and money has gone towards construction of the Stanford Linear Collider (SLC). For the rest of this decade, the SLC will be the highest energy electron-positron collider in the world, capable of generating collisions at energies up to 100 billion electron volts (or 100 GeV). This expensive and powerful tool is designed to be a copious source of Z° particles, which at a mass-energy of 92 GeV are the heaviest elementary particles yet discovered.

To understand the thrust and scope of the SLC physics program, we need first to establish some background. No experiment to date has definite and reproducible results in conflict with a theory of subatomic particles called the *Standard Model*, whose fundamental particles and interactions are listed in Table 1. The particle interactions (i.e., the forces one particle exerts on another) result from the exchange of a carrier of force (Figure 1). The electromagnetic force is carried by the familiar photon, the weak force by the neutral Z° and its two charged cousins, and the strong force by the *gluon*. The Standard Model

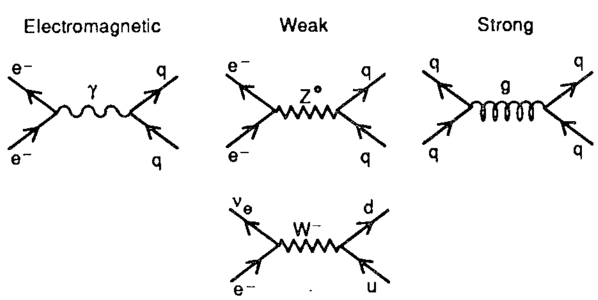


FIGURE 1. The forces of the Standard Model. As illustrated by Feynman diagrams, the forces between particles are thought to result from the exchange of a force-carrying particle: the photon (γ) for the electromagnetic force; the Z°, W^- and W^+ for the weak force; and the gluon (g) for the strong force. The symbol q stands for a quark.

is actually the combination of two separate theories: the electroweak theory which combines electromagnetism and the weak force into a single force, and quantum chromodynamics (QCD) which describes the strong force. These three forces, which twenty years ago seemed so unrelated, are now couched in a remarkably similiar mathematical form.

The elementary constituents of matter fall into two groups: *leptons*, which exert only electromagnetic and weak forces, and *quarks*, which can interact via all three forces. In addition these particles come in foursomes called *generations*. The Standard Model has three such generations, each consisting of two leptons and two quarks. Everyday matter consists only of particles in the first generation; atoms are made up of a first-generation lepton, the electron, plus protons and neutrons, which consist of first-generation up and down quarks. Second- and third-generation particles have been produced only in experiments at particle accelerators and by energetic cosmic rays striking the atmosphere.

Carriers of Force:

Force(Carrier)	Symbol	Mass(GeV)	Electric Charge
Electromagnetism (photon)	γ	0	0
Weak (weak vector bosons)	Z^0	93	0
	W^+	82	+1
	W^-	82	−1
Strong(gluon)	g	0	0

Leptons:

Name	Symbol	Mass(GeV)	Electric Charge
electron	e^-	0.000511	−1
electron neutrino	ν_e	0	0
muon	μ^-	0.106	−1
muon neutrino	ν_μ	0	0
tau	τ^-	1.784	−1
tau neutrino	ν_τ	0	0

Quarks:

Name	Symbol	Mass(GeV)	Electric Charge
up	u	0.31	$+\frac{2}{3}$
down	d	0.31	$-\frac{1}{3}$
charm	c	1.50	$+\frac{2}{3}$
strange	s	0.51	$-\frac{1}{3}$
top	t	> 26	$+\frac{2}{3}$
bottom	b	5.0	$-\frac{1}{3}$

Higgs Particle: H^0

TABLE 1. The particles of the Standard Model. The masses are given in units of GeV (billion electron volts). A GeV is about 10^{-24} grams.

Quarks are tightly bound by the strong force to other quarks or antiquarks to form *hadrons* — a class of composite particles. Hadrons are divided into two groups: *baryons* (protons and neutrons for example) consisting of three quarks, and *mesons* (pions and kaons for example) consisting of a quark-antiquark pair.

In addition to the quarks, leptons and carriers of force, the Standard Model requires the existence of a particle in a class all by itself: the Higgs particle, H°. It arises as consequence of the mechanism used to generate masses for the other particles and is a crucial aspect of the Standard Model. Hence finding the Higgs particle is an important test of our present understanding of Nature.

If no experiments conflict with the Standard Model, why go to such trouble to test it further? Well, as a fundamental theory of Nature the Standard Model is not very satisfactory. It does not explain *why* there are three generations of quarks and leptons, nor does it predict their masses. And the model cannot explain the 19 arbitrary parameters it requires. Physicists are driven by the idea that a truly fundamental theory should be simple, with few arbitrary parameters.

The SLC provides an opportunity to put the Standard Model to strict tests. A discrepancy or inconsistency may point to a larger, more fundamental theory underlying it.

The SLC will collide a beam of electrons with a beam of positrons (the electron antiparticle) at energies tuned so that the annihilation of an electron and a positron will produce a Z°, the neutral carrier of the weak force. The Z° immediately disintegrates into a particle-antiparticle pair such as $\mu^+\mu^-$ or a quark and its antiquark. Standard Model predictions for how often the Z° will decay into the various possible pairs are listed in Table 2.

Decay Mode	Percent of Decays
$\nu_e\bar{\nu}_e$, $\nu_\mu\bar{\nu}_\mu$, $\nu_\tau\bar{\nu}_\tau$	6.1%
e^+e^-, $\mu^+\mu^-$, $\tau^+\tau^-$	3.1%
$u\bar{u}$, $c\bar{c}$, $t\bar{t}$	10.6%
$d\bar{d}$, $s\bar{s}$, $b\bar{b}$	13.6%

TABLE 2. The decay modes of the Z°. The listed percentages refer to the fraction of Z°'s that decay according to each of the three modes given on that line.

The creation and subsequent decay of the Z° was first observed at the CERN proton-antiproton collider near Geneva, Switzerland. More have been produced recently in the Tevatron Collider at Fermilab. But Z°'s are produced fairly infrequently in proton-antiproton collisions. After several years of running, for example, the CERN experiments have witnessed several hundred Z°'s. By contrast, the SLC is designed to produce over 100,000 per year. Other Z° decay modes besides e^+e^- and $\mu^+\mu^-$ can be studied easily at the SLC; most are very difficult to observe at a proton-antiproton collider.

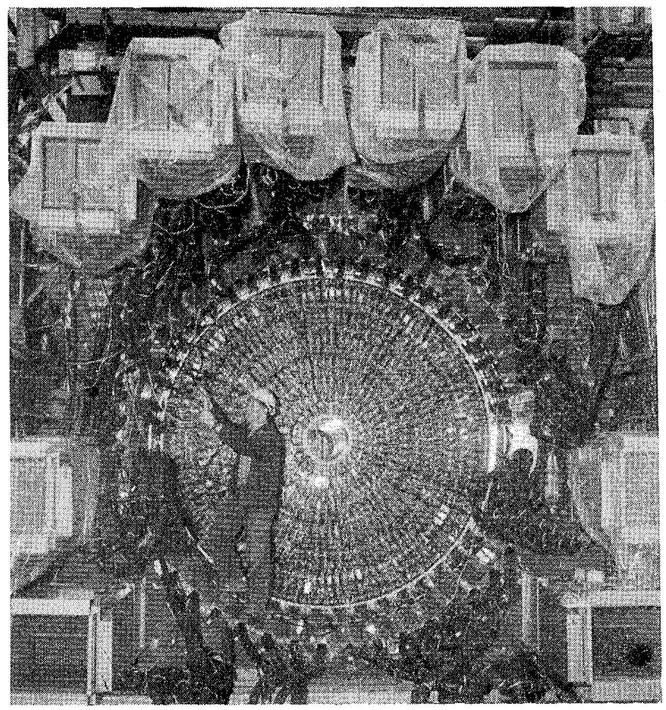


FIGURE 2. The Mark II detector at the SLC. Electron and positron beams clash inside the small cylinder behind Sean Dyer. Emerging particles leave tracks in the big central drift chamber surrounding this interaction point.

Two other features of the SLC also make it a unique and powerful tool. The first is its capability of producing polarized electron beams — in which the electron spins tend to be uniformly aligned. The second noteworthy feature is the tiny beam size where the two beams collide. Designed to be 3 microns (0.00012 inch or about a tenth the size of a human hair) across, it precisely pinpoints the location of the e^+e^- interaction.

TESTING THE STANDARD MODEL

Because the Z° is a carrier of the weak force, its mass, width and decay properties provide precision tests of the electroweak theory. But its usefulness for testing the Standard Model does not stop there. As the Z° decays mainly into quark-antiquark pairs, it provides a clean data sample with which to test QCD. As yet undiscovered particles such as the top quark and the Higgs particle should be easily detectable if their masses are low enough. Through these and many other studies, the SLC will test the Standard Model with a precision unmatched by any existing accelerator.

Mass and Width of the Z°

The mass of the Z° is a fundamental parameter of the Standard Model. Based on experiments at the CERN proton-antiproton collider, it is known to be 92.0 ± 1.8 GeV. If the total energy of the two SLC beams (called the center-of-mass energy, E_{cm}) is well below this value, the interaction of e^+ and e^- is dominated by annihilation to photons, which then decay to particle-antiparticle pairs (see Figure 1). As E_{cm} approaches the Z° mass (M_Z), there is enough energy available for the e^+ and e^- to begin producing the Z°. The rate of e^+e^- interactions (called the *total cross section*) increases sharply at $E_{cm} = M_Z$, as shown in Figure 3.

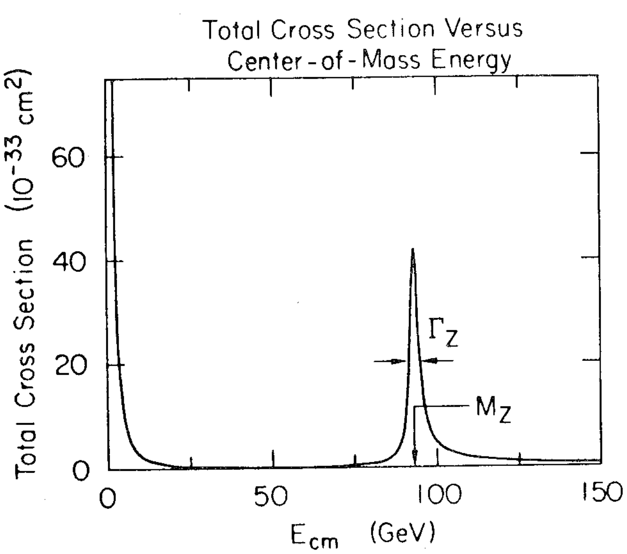


FIGURE 3. The e^+e^- total cross section versus the center-of-mass energy E_{cm}, as expected from the Standard Model.

The position and width of the Z° peak (M_Z and Γ_Z in Figure 3) will be among the first measurements made at SLC. To determine them the accelerator will be run at a set of different energies near 92 GeV. At each E_{cm} the rate of e^+e^- interactions will be recorded and the total cross section calculated. Figure 4 shows an expanded view of the peak with simulated data points indicating how well the total cross section can be measured assuming one week of running at each value of E_{cm} with the SLC operating at 1% of its design performance. With enough Z°'s, we can measure M_Z to an accuracy of 0.05% (0.045 GeV) or better—forty times more precise than was possible at the CERN collider. Comparing the value obtained from the peak position with other, indirect methods of determining M_Z (discussed below) will test whether this model is self-consistent.

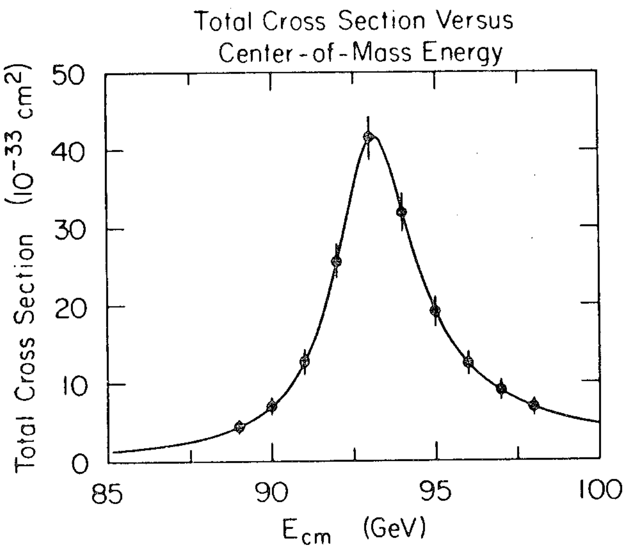


FIGURE 4. The e^+e^- total cross section near the Z° peak versus E_{cm}. The vertical error bars on these simulated data points represent the expected precision with which we can measure the total cross section in one week's running at each value of E_{cm} with the SLC operating at 1% of design performance.

The width of the peak is a measure of the Z° lifetime, which in turn depends on the total number of decay modes available. The more ways it can decay, the faster it vanishes, and the wider the Z° peak becomes. With three generations of quarks and leptons, the Standard Model predicts a width of 2.7 GeV. If there is a fourth generation with a light neutrino (so the Z° can decay into this neutrino and its antineutrino), then the width will be 0.16 GeV larger. Thus a careful measurement of this width will help constrain the possible number of generations. If the width is greater than expected, it implies only that the Z° decays into into *something* not contained in the three-generation Standard Model. This does not tell us what that something is; it does, however, indicate the presence of some new phenomenon.

An important consideration in determining the peak position and width is radiative corrections. As the energy of the collision increases, so does the probability that an incoming or outgoing particle will emit a sizable fraction of its energy as photons. This radiation reduces the peak height by 30% and shifts its position slightly. The asymmetric shape of the resonance peak in Figure 4 is due to these effects. Although corrections for this radiation have been calculated, they introduce some uncertainty in the measured values of M_Z and Γ_Z.

Tests of the Electroweak Theory

The Standard Model makes definite predictions about how the Z° couples to leptons and quarks. This coupling determines how often the Z° decays to the different particle-antiparticle pairs (Table 2) and the angles at which they are most often produced. Because it is a simple function of M_Z, measuring the coupling provides another way to determine M_Z that can be compared with the value derived from the peak position.

The angular distribution of decay remnants can be characterized by a parameter called the *forward-backward asymmetry* (A_{FB}). This is the difference in rates for a particle to emerge in the forward direction (relative to the electron beam) versus the backward direction. Using the $\mu^+\mu^-$ decay mode and assuming a million Z° decays, A_{FB} can be measured to an accuracy of 12%, which will determine M_Z to 0.3% (0.28 GeV). Unless something is amiss, this result should equal the Z° mass determined from its peak position.

The Standard Model also predicts that the coupling should be the same for different generations, a principle called *universality*. To test universality, the value of M_Z determined from the muon forward-backward asymmetry can be compared with the asymmetry determined from other decay modes ($Z^\circ \to e^+e^-, \tau^+\tau^-, q\bar{q}$).

Polarization of the SLC electron beam provides an even stronger test. In a polarized beam, the electron spins are aligned predominantly in a single direction: either *along* or *opposite* their direction of motion, as illustrated in Figure 5.

The *left-right asymmetry* (A_{LR}) is the change in the e^+e^- interaction rate between these two cases.

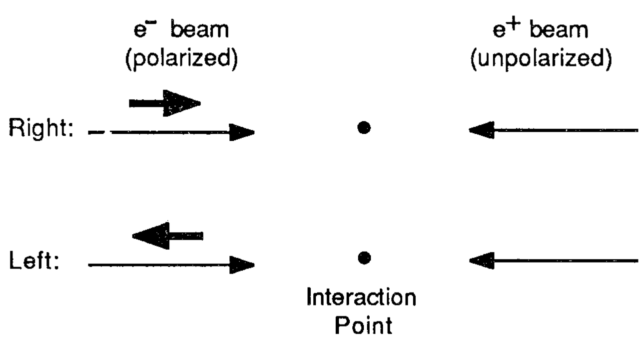


FIGURE 5. Polarized beams at SLC. Electron spins can be oriented predominantly along or opposite the particles' direction of motion.

With about 100,000 Z°'s, it should be possible to measure A_{LR} to 5% accuracy, which will determine M_Z to a precision of 0.25% (0.23 GeV). To get the same precision by measuring the forward-backward asymmetry would require over a million Z°'s.

Studies of Quantum Chromodynamics

The strong forces between quarks can also be studied at SLC. Approximately 70% of all Z° particles decay into quark-antiquark pairs (see Table 2), with the possible emission of one or more additional gluons. The quarks and gluons themselves, however, are never observed. As quark and antiquark separate, the energy in the bond between them materializes as additional quark-antiquark pairs, and sprays of hadrons called *jets* emerge along the direction of the original quarks. A radiated gluon will also appear as a jet of hadrons. This process of quarks and gluons forming into hadrons is called *fragmentation*.

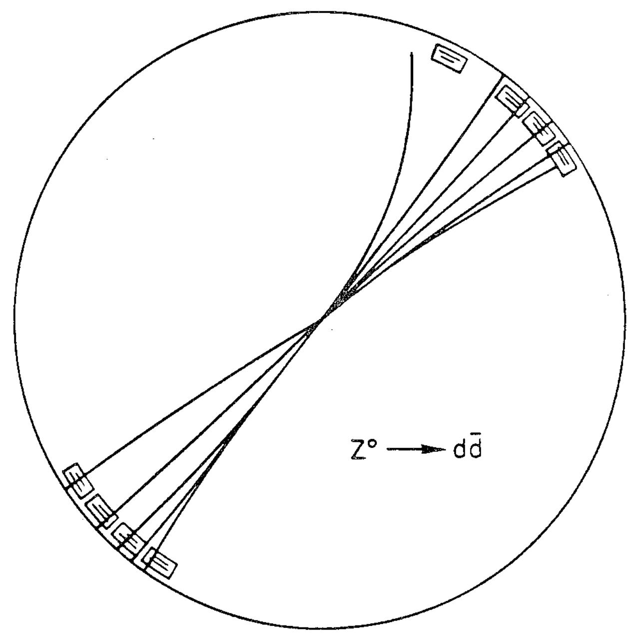


FIGURE 6. Tracks of charged particles emerging from a simulated $Z^\circ \to d\bar{d}$ decay.

In Figure 6 you see the simulated tracks of hadrons resulting from the decay of a Z° into a down quark and its antiquark. Notice the 2-jet character of the decay, one jet arising from the quark and the other from the antiquark. The SLC provides several advantages over lower-energy e^+e^- colliders such as PEP and PETRA in studies of QCD. Because the quarks and gluons will be produced at higher energies, the jets that emerge will tend to be narrower and therefore easier to distinguish. The higher energy also makes it more likely that a quark radiates one or two gluons, making more 3-jet ($Z^\circ \rightarrow q\bar{q}g$) and 4-jet ($Z^\circ \rightarrow q\bar{q}gg$) events. This wealth of 2-, 3- and 4-jet decays can be used to test different models of the fragmentation process. In particular, 3-jet and 4-jet decays may reveal differences between quark and gluon fragmentation, which would be crucial tests of QCD.

A fundamental parameter of QCD is the strength of the coupling between gluons and quarks, written α_s. It can be determined by several methods (from the ratio of 3-jet to 2-jet decays, for example) and compared with measurements made at other machines. The SLC measurements of α_s will suffer from different systematic problems, so comparisons between these measurements will provide valuable insights.

Heavy Quarks

Mesons containing the heavy quarks (c, b and t) provide additional insights into the Standard Model. Particularly useful are their *semileptonic* decays, whose products include leptons. For example the D° meson, consisting of a quark c and antiquark $\bar{u}$, can decay into an electron, kaon and neutrino. Such semileptonic decays provide a means of identifying events where the Z° decays into heavy mesons.

The lifetimes of these heavy mesons are important to measure because they provide constraints on the electroweak theory. But their short lifetimes mean they travel very short distances before disintegrating. The extremely small SLC beam sizes permit particle detectors to sit very close to the interaction point. A heavy meson that travels some distance before decaying will produce tracks which do not point back to the interaction point. Such a displaced origin of selected tracks is called a *secondary vertex*. The detectors to be used at SLC can pinpoint displacements of less than 1 millimeter, so lifetimes of about a picosecond (10^{-12} second) can be determined.

The Top Quark

If we are lucky, we may also encounter the top quark t at SLC. The Z° will decay into a $t\bar{t}$ pair if the top quark mass is less than half of M_Z. So far, the top quark mass is known to be greater than 26 GeV, and recent experiments suggest it may be substantially higher. Because of its huge mass, the top quark will be slow and ponderous, producing jets that are much fatter than those of the other, lighter quarks. Figure 7 shows a simulation of two jets resulting from the decay $Z^\circ \rightarrow t\bar{t}$. Compare this event to the decay $Z^\circ \rightarrow d\bar{d}$ shown in Figure 6. Such a difference in jet shape can be used to distinguish these decays, if one is careful to account for 4-jet decays ($Z^\circ \rightarrow q\bar{q}gg$) that could look similar. The semileptonic decays mentioned above will provide another independent method of isolating $Z^\circ \rightarrow t\bar{t}$ decays. Relatively few Z°'s (around 5000) are needed to test whether or not the top quark can be produced at the SLC.

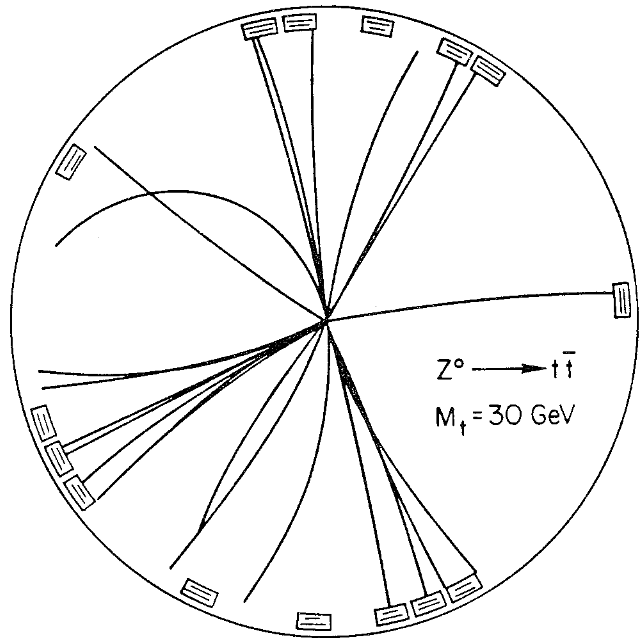


FIGURE 7. Tracks of charged particles emerging from a simulated $Z^\circ \rightarrow t\bar{t}$ decay.

If the top quark mass is indeed below 50 GeV, the SLC energy can be set to scan for a very narrow peak in the total cross section due to the creation of *toponium*—a meson consisting of a bound $t\bar{t}$ pair. The position of this peak precisely determines the top quark mass. Like the ψ peak discovered at SPEAR in 1974, this peak is expected to be extremely narrow, about a millionth the width of the Z° peak.

The Higgs Particle

The Standard Model requires the existence of at least one Higgs particle H°, but does not predict its mass. Because its coupling to other particles is what generates their masses, an H° should decay mainly into the heaviest elementary particle-antiparticle pair with a total mass less than its own. If the H° mass is less than M_Z, then it could be produced in Z° decays such as $Z^\circ \rightarrow H^\circ e^+e^-$ or $Z^\circ \rightarrow H^\circ \mu^+\mu^-$. In these examples the H° mass could be calculated from the effective mass of lepton pair, but this method works only if the H° mass lies between 10 and 40 GeV. It is more difficult to prove that the particle accompanying the lepton pair is indeed a

Higgs particle. One must observe the H° decay and show that it disintegrates predominantly into heavy particles.

SEARCHING FOR NEW PHYSICS

Although testing the Standard Model is an important and challenging task, most experimenters would like to observe a new particle or other sign of new physics. Many theories and and variations upon them have been proposed; here we can mention only a few. As discussed in the previous section, an early hint of new physics would be a Z° peak slightly wider than expected.

Measuring $Z^{\circ} \rightarrow$ *nothing*

There are a number of ways that the Z° can decay leaving no tracks at all in the surrounding detector. For example, we can predict just how often the Z° will decay into neutrinos, which escape completely unnoticed. If the measured rate of $Z^{\circ} \rightarrow$ *nothing* exceeds predictions, it must indicate some kind of new physics—possibly the neutrino of a fourth generation.

How do we measure the rate of $e^+e^- \rightarrow Z^{\circ} \rightarrow$ *nothing*? We make use of the fact mentioned above that the electron or positron will often radiate a photon *before* annihilating. If the Z° produced subsequently decays into *nothing*, then all that can be seen leaving the interaction point is the radiated photon.

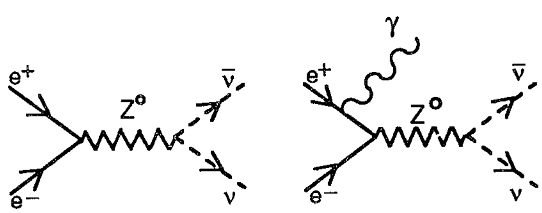


FIGURE 8. Feynman diagrams for the decay of the Z° into neutrino-antineutrino pairs. Such a process goes undetected unless either the incoming electron or positron emits a photon.

As you may well imagine, this measurement requires a detector with as few holes as possible where particles can slip away undetected. If an incoming electron or positron radiates a significant fraction of its energy, the remaining energy may not be enough to create a Z°; thus this measurement is best done with the beam energies increased so that E_{cm} is slightly greater than M_Z.

The number of neutrinos will be a measure of the number of quark and lepton generations, since each generation has an associated neutrino. The total number of generations is of great importance to particle physicists and cosmologists. At this time there exists no other facility in the world capable of this fundamental measurement with nearly the precision afforded by the SLC.

New Quarks and Leptons

If a new quark is found at the SLC, we must distinguish whether it is indeed the top quark or the lighter quark of a fourth generation. Measuring its electric charge is one way to tell. Based on the three known generations, we expect the heavier quark to have charge $+\frac{2}{3}$ and the lighter quark to have charge $-\frac{1}{3}$. Thus the top quark has charge $+\frac{2}{3}$ whereas the lighter quark of a fourth generation should have charge $-\frac{1}{3}$. Because the forward-backward asymmetry depends on the quark charge, it can help to distinguish between these two options.

Fourth-generation charged leptons can also be produced at SLC if their masses are less than half M_Z. Such leptons could be detected by looking for their decays into electrons, muons or taus.

Supersymmetry

Supersymmetric theories postulate a whole new class of particles—a partner for each particle in the Standard Model. The supersymmetric partners of the electron, photon and quark are called the *selectron*, *photino* and *squark*. Unfortunately, these theories do not tell us what to expect for the masses of these particles. Consequently, there are many possible decay modes to consider, depending on what the masses may be.

If the selectron is heavier than the photino, for example, then we might look for Z° decaying to selectron and antiselectron followed by their decay into electron, positron and two photinos. Representing supersymmetric partners by a " ˜ " over the normal symbol, this process is denoted as:

$$e^+e^- \rightarrow Z^{\circ} \rightarrow \tilde{e}^+\tilde{e}^-$$

$$\rightarrow e^+\tilde{\gamma} + e^-\tilde{\gamma}$$

Being neutral and weakly interacting, the photinos would escape undetected. The characteristic signal for this process would be electron and positron tracks with missing energy carried off by the photinos. Here again, it is important to have a detector with as few gaps as possible.

Charged Higgs Particles

There may also be more than just a single, neutral Higgs particle. Some theories, including supersymmetry, call for *charged* Higgs particles, H^+ and H^-. The decay $Z^\circ \to H^+H^-$ should occur if they exist and have a mass less than half of M_Z. With a mass of 20 GeV, for example, there should be around 7500 $Z^\circ \to H^+H^-$ decays per million Z° decays. The H^+ and H^- would decay into two heavy quarks each, appearing as an excess of 4-jet events over that expected from QCD.

SUMMARY

The SLC offers a wide variety of avenues in our pursuit of a fundamental theory of Nature. In its first full year of operation, we should be able to measure the Z° mass and width. If the top quark mass is low enough, it too should show up. With additional Z°'s we can perform a stringent test of the Standard Model through the measurement of asymmetries and use the copious production of quark-antiquark pairs to study QCD. We can also search for Higgs particles, new quarks or leptons, and supersymmetric particles.

Two detectors will be used to study Z° physics at SLC. The upgraded Mark II detector, previously situated at PEP, will be the first to log data. It will be replaced in 1990 by the SLD (pictured below), a more powerful detector being built from the ground up that is optimized for operation at SLC.

In summary, the SLC provides an unprecedented level of precision for testing the Standard Model and great potential for the discovery of new phenomena. Even in the absence of new physics, important advances will be made in our fundamental understanding of Nature.

David Coupal is a research physicist in Experimental Group C, who works on the Mark II detector.

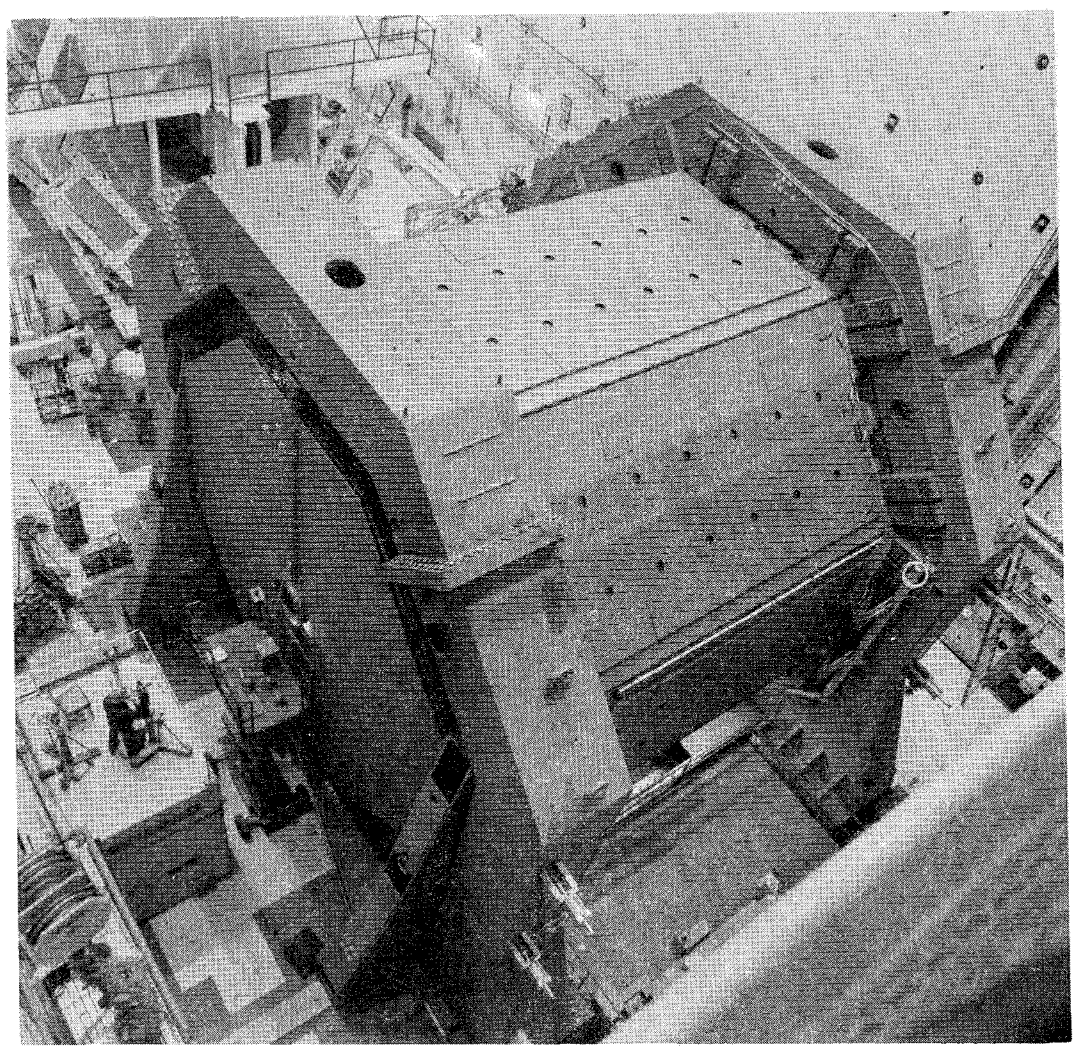


FIGURE 9. The SLD, a state-of-the-art particle detector under construction at the Collider Experimental Hall. It should go into operation in late 1989 or early 1990.

A NEW LEASE ON LIFE

This past April Stanford and the U.S. Department of Energy renewed the agreement whereby the University operates and manages SLAC. The contract was amended and extended through September 1992.

At ceremonies in Portola Valley on April 27, representatives of DOE and Stanford officially inked the new contract. Among those present were Donald W. Pearman, Deputy Manager of the San Francisco Operations Office and head of the DOE negotiating team, and SLAC Director Burton Richter.

The continuing contract was first executed in 1962, when Stanford began construction of the two-mile linear accelerator on 480 acres of University property. It has been renewed every five years.

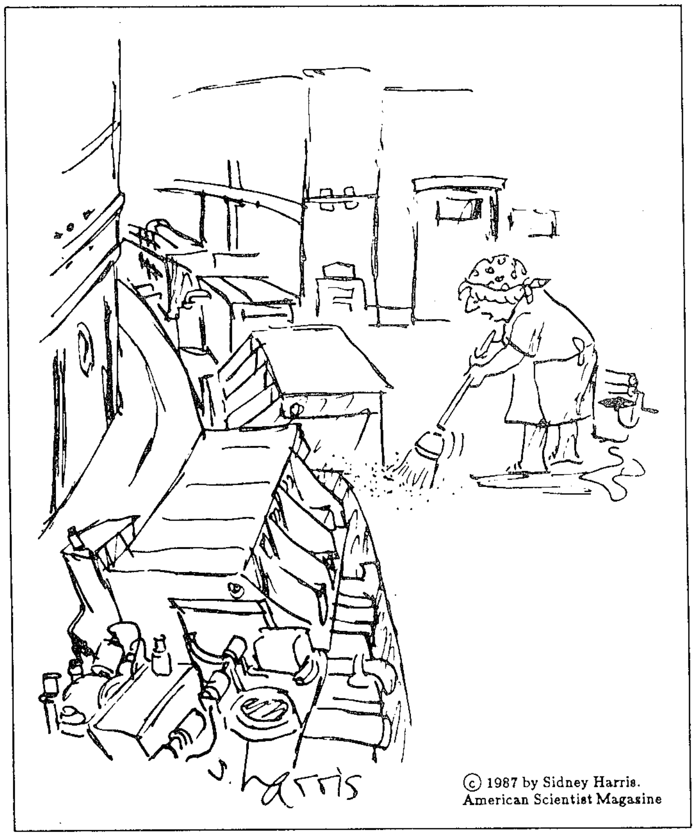
Negotiation of the new contract began before the previous five-year contract expired on September 30, 1987. The Stanford negotiators were headed by Director Emeritus Wolfgang "Pief" Panofsky, an old hand at these quinquennial affairs. Other members of the Stanford team included Associate Directors Kaye Lathrop and Eugene Rickansrud, Staff Counsel Lloyd Sides, and C. Frederick and Steven Goode, both of the University's Sponsored Projects Office.

Thanks to their efforts, SLAC's continued operation under Stanford auspices is now extended into the early 1990's.

—Michael Riordan

Dates to Remember

SLAC Summer Institute	July 18–29, 1988
SSRL Users Meeting	August 27–28, 1988
Experimental Program Advisory Committee Meeting	November 4–5, 1988
International Workshop on Next-Generation Linear Colliders	November 28 to December 9, 1988
Fortran Standards Committee Meeting	February 13–17, 1989
International Symposium on Lepton and Photon Interactions	August 6–13, 1989



"Particles, particles, particles."

MOBILE BLOOD DRIVES

The Stanford University Blood Bank (SUBB) has been running mobile blood drives at SLAC for years. The March 1988 SLAC drive hit a new high, with 88 people successfully donating a pint of blood.

SUBB has added cholesterol testing as a routine part of the miniphysical given at the time of the donation. The volunteers do their best to make giving blood a pleasant experience, and the IT'S IT ice creams don't hurt any.

For the rest of the year we have blood drives on a quarterly basis:

Thursday, June 23
Wednesday, September 14
Tuesday, December 13.

So whether you just want a cookie and cup of coffee, or are truly driven by humanitarian compassion, keep the above dates in mind. On them, the mobile unit will be set up in the Auditorium lobby from 9:00 a.m. to 4:00 p.m. Please make an appointment at x2204 to lessen the wait. This will also assure you of a reminder call on the day of the drive.

An especially warm thanks to all the regulars who make these drives so successful.

—Nina Adelman

ED GARWIN HONORED

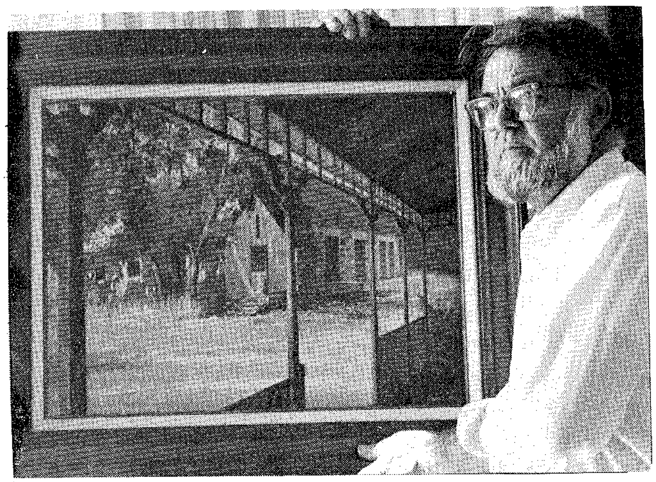
On May 12 Burton Richter conferred a SLAC Achievement Award upon Edward Garwin in a short ceremony held at the Director's Office. Garwin, the leader of the Physical Electronics group, and former Research Associate Ali Nyaiesh were honored for their invention of a "stabilized chromium oxide film" for use on high-power klystron windows. For this innovative work they were issued U.S. Patent No. 4,719,436 on January 12, 1988.

The new chromium oxide film helps suppress secondary electron emission and consequent overheating of the klystron windows. This process has been a primary cause of window breakage on high-power klystron tubes. A titanium nitride film is currently coated on all such windows to avoid this problem. Garwin suspects the old film may encounter difficulty at the high power levels (above 50 megawatts) and repetition rates (120 pulses per second) planned for the new 5045 klystrons that were installed as part of the SLC upgrade. This new chromium oxide film may be the needed solution.

Garwin has been at SLAC almost since its inception. He arrived here in November of 1962, sporting M.S. and Ph.D. degrees in physics from the University of Chicago. Ed is perhaps best known for the pivotal work he did with Charlie Sinclair in the late 1970's, designing and building the polarized electron gun that was a crucial element in SLAC Experiment 122. Led by Charlie Prescott, this experiment established the existence of parity violation in electron scattering.

Ed is the holder of five other patents. This latest was filed on behalf of him and Nyaiesh by Department of Energy patent attorneys at the Lawrence Livermore Laboratory. DOE has recently been promoting the dissemination of new technologies from its research labs to private industry. "Technology transfer is very important to us," said Richter in the short ceremony, calling Garwin "one of our most practical scientists."

—Michael Riordan



GLENN HUGHES RETIRES

Glenn Hughes, who retired from Plant Engineering in February of this year, had worked at SLAC since its inception. He came here from the Bechtel Corporation in 1962 and set up the laboratory's Model Shop. His scale-model renditions of the accelerator housing and klystron gallery enabled the rest of the staff to proceed with detailed design and construction of the original Linac.

Subsequently, Glenn made important contributions to the conceptual layout of numerous other SLAC facilities, including SPEAR, PEP and the SLC. His knowledge and experience in precision model making and conceptual drafting proved invaluable in the early stages of these projects.

An accomplished artist, Glenn has exhibited his work in private showings at various times during his career. With his knowledge of art and architecture, he contributed greatly to the aesthetic and landscaping features of the SLAC site.

Glenn's hobbies include golf, travel and camping. Since his retirement, he has undoubtedly been indulging in all three.

—Glenn Tenney

EXPERIMENT TOPPLES THEORY AGAIN, 13–11

History repeated itself on May 15, as the SLAC Softball Game occurred on the field before Central Lab. The underdog Theory team tried gamely to end Experiment's long dominance of this annual clash, but at the finish it was baseball-as-usual.

Long on cunning but short on depth, the upset-minded theorists figured to maximize their firepower by stacking all their big bats early in the lineup. The strategy seemed to work wonders as Theory leapt to an astonishing 5–0 lead in the 1st inning, spurred by a 3-run homer by Howie Haber of Santa Cruz. Worried faces could be seen among the shell-shocked empiricists after their side was retired in order in the bottom of the inning.

But Experiment battled back and whittled away at the lead, scoring 3 runs apiece in the 3rd and 5th innings. Two more runs in the bottom of the 6th finally put them ahead at 8–6.

Theory, however, was not finished yet. It erupted for 5 more runs in the top of the 8th, capped by a towering 2-run drive by Russ Kaufmann that almost hit the A&E Building. With ace hurler Jonathan "Fireball" Dorfan headed for an early shower, things looked bleak for the nuts-and-bolts crowd.

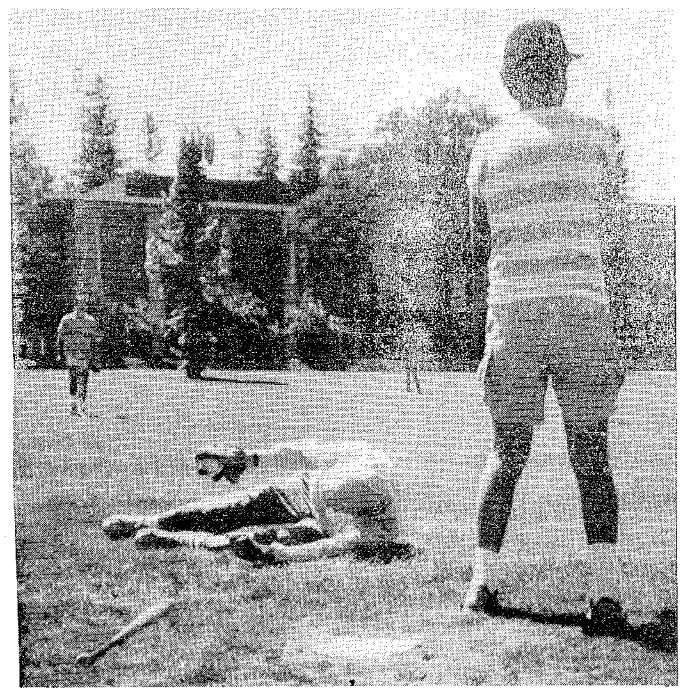
Theory's lack of depth finally began to show, however, in the bottom half of the inning. Five unearned runs poured across the plate as its defense collapsed. Losing pitcher Bryan Lynn joined Dorfan in the showers as Sid "Scoop" Drell came on to retire the side with some late-inning fielding heroics.

But it was too little and much too late. Relief pitcher Dale Pitman set down the theorists 1-2-3 in the top of the 9th, preserving the 13–11 Experiment victory, its 28th in the 31 years this contest has taken place.

The empiricists were clearly relieved to escape by such a narrow margin. Though obviously disappointed at the loss, Theory could still take pride in a valiant effort. "It was a tremendous moral victory for us," crowed Drell as he invited everybody to his house for beers. "Wait til next year!"

—*Michael Riordan*

Bryan Lynn (no relation to Fred) grounds into the only double play in the game's long history.



Sid Drell snares the final out in the bottom of the 8th, but it was too late to make any difference.

17th Annual SLAC Race

By popular request (23 to 9) the Annual SLAC Race will occur on the first weekend of November. Details will be announced in October.

The deadline for the tee-shirt design contest has been extended to July 5, so there's still time to get that great idea on paper. Call Dave Bostic (x2977) or Herb Weidner (x2521) for rules and details.

—*SLAC Race Committee*