SLAC BEAM LINE

Here is the world, sound as a nut, perfect, not the smallest piece of chaos left ... but the theory of the world is a thing of shreds and patches.
—Ralph Waldo Emerson.

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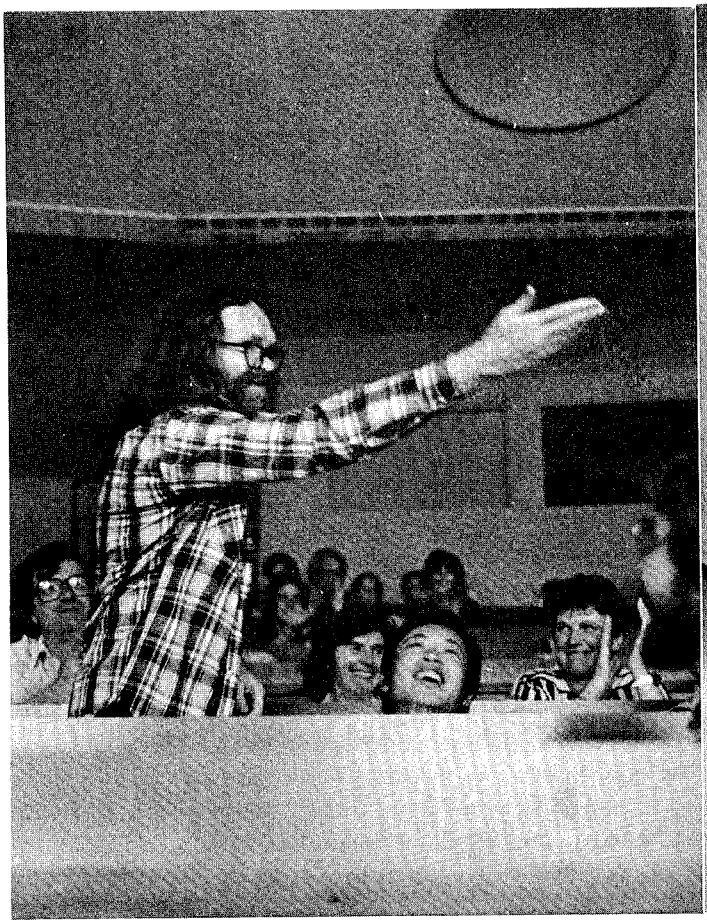

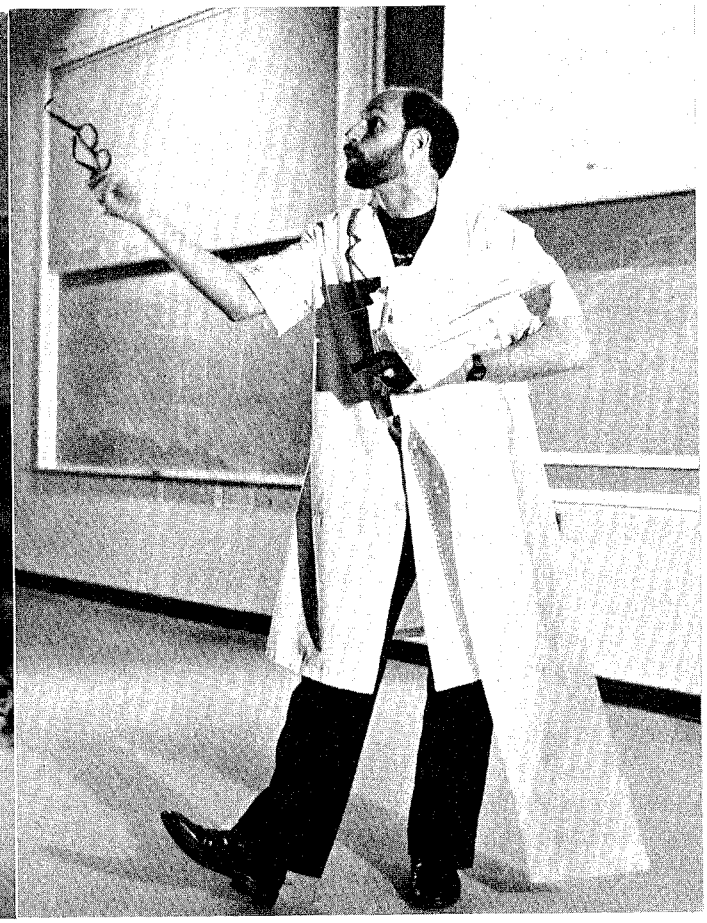

A LANGUID LOVE FOR LEPTONS DOES NOT BLIGHT ME

Theorist John Ellis, at left, modified the words of a familiar Gilbert & Sullivan piece that was then sung by the Stanford Savoyards' Ed Glazier, at right. This bit of physics and vocal ingenuity concluded an evening's entertainment arranged by Rita Taylor for the Eleventh SLAC Summer Institute. More lyrics and a story on the more traditional physics aspects of the Institute are inside. (Photos by Joe Faust.)

INSIDE ...

SLAC Beam Line, x2979, Mail Bin 94

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Illustrations: Publications Department.

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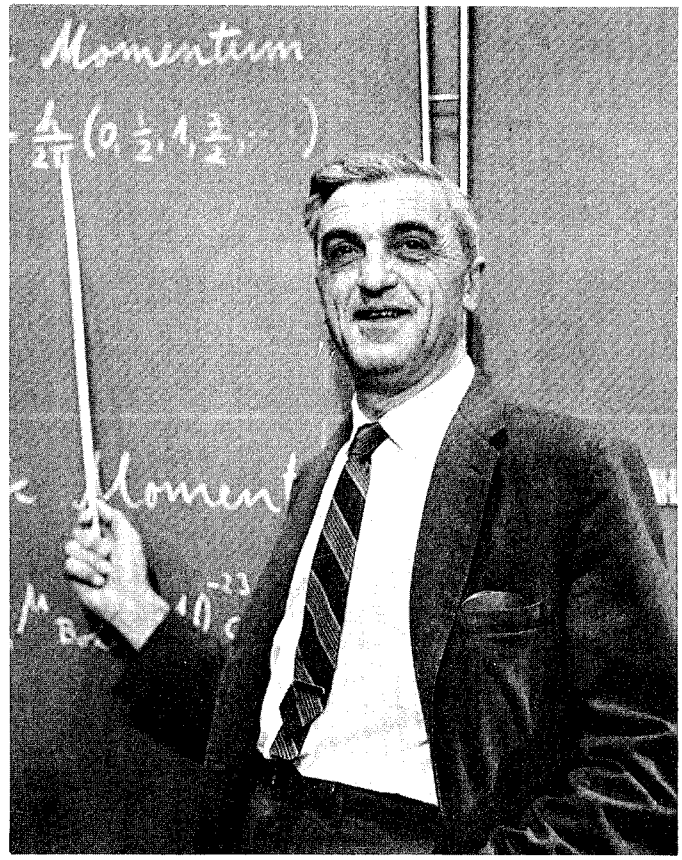
FELIX BLOCH, 1905-1983

Felix Bloch, Emeritus Stanford Physics Professor and Nobel Laureate, died in Zurich on Saturday, 10 September. Bloch was a central force in the development of the Stanford physics department and was involved in the early planning and thinking which led to SLAC. The following tribute is excerpted from an editorial in the *San Francisco Chronicle.*

Modern physics owes much to Dr. Felix Bloch, the Stanford University physicist who died last week in Zurich, where he was born and from which he came to America in 1933 as a scientific refugee from Hitlerism.

Bloch arrived at Stanford only a few months after Hitler came to power in Germany. He had been studying at the University of Leipzig when the Nazis took over. The noted Werner Heisenberg, his teacher, encouraged him to accept Stanford's offer of a 'trial job' because that would put him near the University of California's cyclotron. So Bloch taught in the underequipped Stanford physics laboratories by day and did much of his early pre-war work at nighttimes at E.O. Lawrence's Berkeley lab.

More than 40 years ago, while working in wartime research on radar at Harvard, Bloch developed a device to penetrate the heart of the atomic particle to reveal and measure its magnetic properties and to show what have been called 'the strange relationships between matter, electricity and magnetism.' He shared the 1952 Nobel Prize with E.M. Purcell for that work (which both men had done independently). It has lately led to the development of one of the recent wonders of medicine, a diagnostic device called NMR (for Nuclear Magnetic Resonance). This gives sophisticated images of human tissue similar to those of the CAT scanner, but without the disadvantage of exposing the patient to x-rays.



Felix Bloch, teaching in 1959.

He was a brilliant, charming man, deeply involved at one time in supporting the recognition of Israel as a nation, and at all times in support of disarmament of nuclear and chemical weapons.

SLAC Deputy Director Sidney Drell and Director W.K.H. Panofsky recall their association with Felix Bloch:

Felix Bloch was one of the giants of twentieth century physics, both theoretical and experimental. He brought modern quantum physics to Stanford University when he came here in 1934, and he continued his association with the university for almost 50 years.

After the war he did the work which led to his Nobel Prize for the discovery of nuclear magnetic resonance. He was always interested in spinning atomic systems. He liked to tell the story of a cruise on which he was idly asked by someone in the next deck chair what he did. "I am interested in magnetic moments," was his reply. "Oh," came the response, "Is that a new perfume?"

Felix Bloch was also a very clear and very careful teacher, a great teacher. He was a physicist who stayed a physicist all his life.

. . .

The original planning and thinking about a very large accelerator began around 1955. The early group consisted of Leonard Schiff, Edward Ginzton, Robert Hofstadter, Felix Bloch, and myself. The named coined for the machine, which became the Two Mile linac of SLAC, was the 'Monster.' Felix once told me, "If you must build a monster, build a good monster."

He maintained a general interest in the field and in 1954-1955 served as the first Director General of the European high-energy physics laboratory CERN.

Years later, on a visit to SLAC, he recalled his early remark and said "Pief, I have to agree you built a good monster."

Statics and Dynamics

ELEVENTH SLAC SUMMER INSTITUTE

Over 300 physicists attended the Eleventh Annual SLAC Summer Institute on Particle Physics held at the laboratory on July 18-29. The topic of this year's school was 'Dynamics and Spectroscopy at High Energy.'

Dynamics is the study of things in motion. In the case of high-energy physics it concerns the actual processes which take place during the collision of particles: how, for example, jets or streams of particles are produced in the collisions between electrons and positrons or between protons.

Spectroscopy, on the other hand, is the study of discrete combinations of particles, such as the pair of charmed quarks that make up the family of ψ (psi) particles of SPEAR fame. In this situation the quarks are relatively slow, or static, and a completely different approach is used to study these arrangements.

Bob Hollebeek, SLAC, discussed the experimental side of jets in electron-positron collisions. In the simplest process a positron and electron annihilate into energy from which a pair of quarks can be produced. As these energetic quarks separate the force between them grows and, in a process not fully understood, creates additional quarks. The detectable result of the collision is a characteristic pattern in which two streams of particles called jets are produced. Although the pattern of jets in these collision is vivid evidence of a basic two-quark production process, there are many additional details, such as the variety and energy of the particles within the jets, which must be understood.

Jets are also produced in the collisions of protons with other protons or anti-protons. Here the effects, as discussed by Roy Schwitters of Harvard and Fermilab, are more complicated. The proton is not an elementary particle, but is itself composed of quarks. In proton collisions a single quark from one proton and an anti-quark from the other can annihilate in a way similar to an electron-positron collision. This annihilation can produce a pattern of two jets, but the remaining quarks in the two protons recombine as they leave the collision point to produce additional jets. The results are more complicated and difficult to understand than the jet events resulting from e^+e^- collisions. On the other hand the energy involved in proton collisions is much greater than that with electrons using present machines.

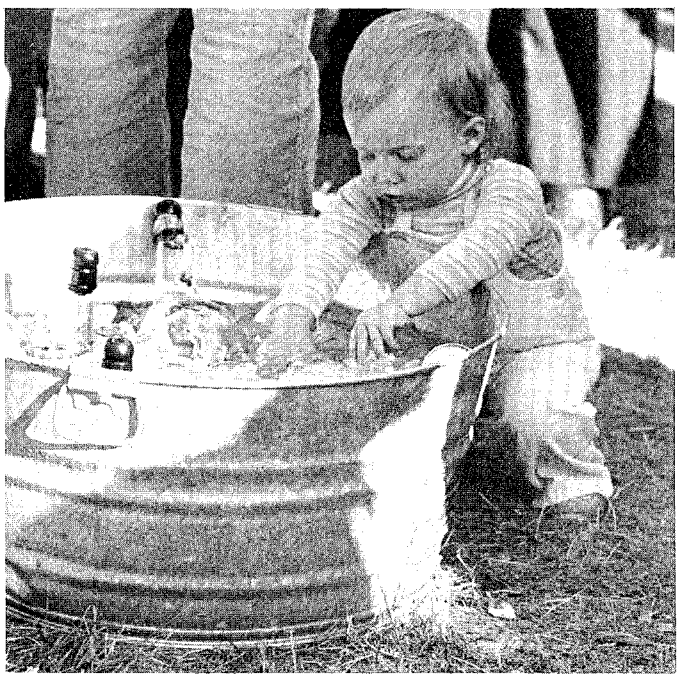
Steve Ellis, University of Washington, discussed the theorist's perspective of jets using the theory of quark forces, QCD (Quantum Chromo Dynamics). There are two different parts of the process with quite different behavior: the initial formation of the quark pair while the force between them is small, and the later formation of conventional particles which make up the jets. Some jet properties are determined in the early time and have been predicted. One quark, for example, may shake off or radiate the particle (called a gluon) which carries the force between quarks. This will produce a final pattern of three jets and such three-jet events have been seen. The other regime is much more complicated. Several calculational tools that show the conversion of the quarks into the particles of jets have been developed. These Monte Carlo programs are very useful in analyzing experiments, but they do not come from fundamental calculations of the theory.

Michael Peskin, SLAC, and Murdock Gilchriese of Cornell discussed the theoretical and experimental work in heavy quark systems, particularly the systems formed by the fifth, or b, quark. The first such combination of b and anti-b quarks was discovered at Fermilab in 1977, and was equivalent to discovering the b quark. The different combinations of these quarks comprise the Υ (upsilon) family of resonances which is like the ψ family discovered and still being studied at SPEAR. The simplest picture of these systems has the two quarks circling each other in much the same way as the proton and electron of the hydrogen atom. Calculations and approximations are much easier to make for this relatively static situation. The experiments also have a similarity to atomic studies with transitions between different states. The detailed measurements are being made at the storage rings DORIS at the German lab DESY and CESR at Cornell.

The final theoretical contribution to the school was '... And for our Next Spectroscopy?' by John Ellis of CERN. This dealt not with combinations of quarks and the like but with the understanding of the basic particles themselves. There is an enormous difference in the strength and behavior of the weak and electromagnetic force on one hand and the strong force of quarks on the other. Two approaches to understanding this difference predict new particles with masses around 1000 GeV. One idea introduces a heavier set of particles (Technipartcles). Another scheme, called Supersymmetry or SUSY, proposes the existence of one new particle for every existing particle. Such supersymmetric partners would have quite different properties than their familiar counterparts. The proposed particles are named by prefixing an *s* or by adding *ino* to the normal name. Thus, the photon has a partner called the photino, the electron has a selectron, the quarks have squarks, and so on. There is no experimental evidence for this new family of particles. If such particles exist, however, they might show up at PEP and PETRA energies, and searches have begun.

This year's Institute included talks on technology as well, specifically calorimetry by Paul Mockett of the University of Washington and tracking devices by Albert Walenta, University of Siegen. Calorimeters, which measure the energy of most charged and neutral particles, work better at higher energies. The colliders now being used and built have made this technique very important. Charged particle tracking has continued to be the mainstay of any general purpose detector. Advances in understanding the ionization in special gases and better construction techniques have made such detectors useful as well in measuring very short lifetimes of particles containing heavy quarks and the tau lepton.

Older participants at the SLAC Summer Institute discuss a theoretical point while a candidate for a future school gets down to experimental facts.



The seven-day school was followed by three days of shorter talks on current results and experiments. This has been an exciting year in experimental high-energy physics. The proton-antiproton collider at CERN has discovered both the charged and neutral carriers of the weak force, the W^+, W^-, and Z^0. Nearly 100 W's and 10 Z^0's have been detected by the two experiments (UA1 and UA2) this year, allowing measurement of the masses and widths. These groups are now searching their data for evidence of the t-quark, but nothing has yet been reported.

Experiments at PEP have given the first lifetime measurements of the B meson. This number, which is basically the lifetime of the b-quark, is very important in the present theory which relates quark lifetimes, masses, and other effects. Another interesting result came from the Mark III detector at SPEAR. This group has found a very rare decay of the ψ to a photon and two K mesons. The decay apparently signals a new, heavy, and narrow resonance.

The Institute, which is sponsored jointly by the US Department of Energy and Stanford University, represents SLAC's commitment to the continuing education of young high-energy physicists. The participants are mainly in the final year of PhD study or the first three years of post-graduate study and come from universities and laboratories in the United States and around the world.

ASME AWARD TO SLAC

Engineering has been called the Handmaiden of Science. The expression is especially applicable to SLAC where the only objective is the pursuit of knowledge of the physical universe and where all engineering effort is directed to assist in that quest. Engineering at SLAC is a strange mixture of the massive, crude, and extremely reliable with the most delicate, precise and novel.

The success of SLAC in its primary mission is beyond question, but the excellence of its engineering is rarely recognized. The American Society of Mechanical Engineers (ASME) has taken a step to remedy that neglect. The National History and Heritage Committee of the ASME has named SLAC a National Mechanical Engineering Landmark. SLAC will be presented with a bronze plaque so designating it, and a commemorative brochure will be published by the ASME. There will be a public presentation ceremony later this year.

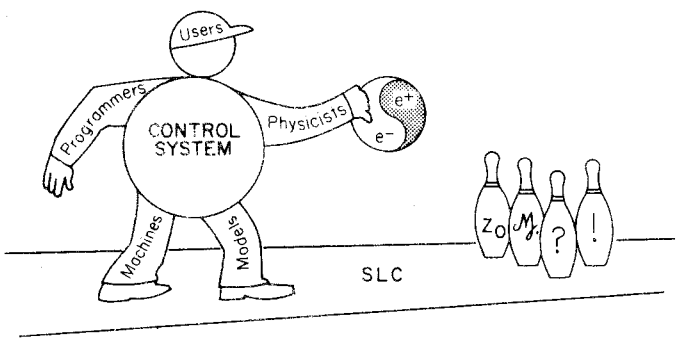
"They also serve . . .," and sometimes they get a little recognition.

-H.A.W.

MACHINE MODELS FOR BEAM CONTROL

When SLAC's first e^+e^- storage ring SPEAR was under construction, Burt Richter insisted that it be computer controlled from the beginning. This meant that changes in machine parameters would be made through a computer rather than by adjusting magnet power supply settings manually as had been done in the past. John Rees, then in charge of SPEAR, assigned Martin Lee to work on an on-line control scheme. Thus was launched the era of machine control using computer models.

The technique worked well and contributed to the remarkable success of SPEAR. The same philosophy of control was adopted by the larger storage ring PEP, and has been copied by other laboratories including Brookhaven, where it is used in the operation of the National Synchrotron Radiation Laboratory.



A Modeler for the SLC

Computer control of the SLAC Linear Collider (SLC) presents a somewhat different challenge. For SPEAR and PEP, the 2 mile accelerator is essentially just a source of high-energy electrons and positrons. Once every few hours the storage rings are filled and thereafter the particles circulate at nearly the velocity of light until the collision rate drops below an acceptable level, at which time more particles are injected by the Linac. The circulating beams are shaped and guided by magnets under the control of the computer. Since the particles circulate in the rings for many hours, it is possible to make tiny and progressive changes, observe the effect on beam parameters, and make corrections.

At SLC, on the other hand, the electrons and positrons are dumped after passing through the interaction region just once, so the particles must be delivered with exquisite precision. Consequently, it is necessary to augment the instrumentation and control of the accelerator so that it will be far more stable than it has been in the past and so that changes in beam parameters can be made almost instantaneously—under the control of a computer, naturally.

This computer will also control the Damping Rings and the Collider arc transport systems. Simply put, a computer program has been written which describes a model or analog of the system being controlled. The model can simulate the response of the real machine to changes in operating parameters. Conversely the control system can specify the operating parameters necessary to achieve a desired beam configuration and can alter the machine settings accordingly.

The model designed for the Damping Ring is a good example. The Damping Ring lattice was designed by Helmut Wiedemann using a magnetic lattice design program called MAGIC. This program solves for the strength of the six families of quadrupole magnets in the machine in order to obtain a set of 5 numbers which define the operational configuration. These numbers are values of the horizontal tune, the vertical tune, the horizontal beta function, the vertical beta function and eta. (There is a sixth parameter which is used to impose the condition of periodicity of the horizontal beta function in the periodic portions of the magnetic lattice.)

The tune is the number of oscillations per turn. Obviously the horizontal tune can be different than the vertical tune. The beta functions are proportional to the beam size in the horizontal and vertical directions. Eta is the ratio of the change in a closed orbit to a change in the beam energy. In this discussion we will refer to these configuration parameters as the tune, beta,and eta value of the ring. Using MAGIC, the design of the lattice was studied and a suitable set of the tune, beta, and eta were chosen to be the design values. The object is for the control system to set the magnets to their setpoint values and then measure the configuration parameters. If the configuration parameters equal their design values, the control system is operating correctly. In the case of the Damping Ring the configuration parameters did not equal the design values!

This puzzle could be studied on-line using a simpler version of MAGIC called COMFORT which could be run on the Damping Ring's computer. This allows the operator to call for changes in eta, beta and tune. COMFORT calculates the corresponding magnet gradients and calculates the power supply settings to produce those gradients.

When Ted Fieguth and his associates first tried to store beam using the design values for magnet set points they were disappointed— it didn't work. In desperation they reverted to manual control of the magnet power supplies and managed to store an electron beam. They measured the configuration parameters in the successful arrangements and also calculated them using the model with the magnet strengths which they had em-

pirically determined. They found that the model machine has no tune: there was no stable beam storage configuration. Something was clearly wrong with the model. The model did not represent the damping ring with sufficient accuracy. Two possible sources of errors were investigated: The first was the end effects of the bending magnets which are shaped to produce sextupole field compensation. The second was the possibility of an error in calibration of one of the families of quadrupoles.

The model was modified to include a quadrupole at each end of each bending magnet to simulate the end effects. Using COMFORT , Martin Lee calculated the strengths of the quadrupoles and the magnitude of an assumed error in the strength of a magnet group which would produce the measured values of vertical tune, horizontal tune and vertical beta. Many different assumptions of the nature of the error in strength were tried. All of the simulations gave totally unreasonable solutions except when it was assumed the error was in the strength of the horizontally defocusing quadrupoles at the injection and extraction regions. However, the magnitude of the error was somewhat large to be believable. Fortunately, the calculated values of the end-effect quadrupoles were not too unrealistic. These studies created a new model which needed to be tested experimentally.

The chance came during the last shift of the spring running cycle. In this shift, the beam was happily stored in the configuration found experimentally. With such a beautiful beam coming down from LTR , Gerry Fischer and Ted Fieguth suggested it was time to let the empirical model set up a configuration which had the same value of tunes, betas and eta as in the design and take the beam there. This seemed an impossible task because the values of beta were nowhere near the design values. Bravery paid off. Under the skillful guidance of the beam by Lenny Rivkin and expert manipulation of the modeling program by Mark Woodley and Martin Lee, they succeeded in taking a stored beam half way there.

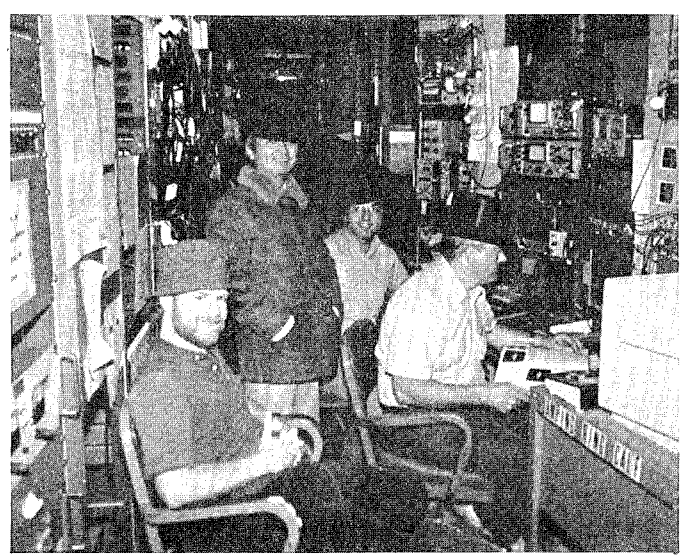
A couple of hours later, they managed to store beam into the final configuration. Everybody got rather excited – there were four very happy souls in the control room. The moral of this event is that manual beam parameter changes are ok, while manual tweaking of the magnet power setpoints usually is not ok. When the parameters are modified, the model calculates new settings of all of the magnets which produce the desired changes.

The model can be used successfully to make local changes such as beta and eta, as well as the tune. However, it has been found that changes in orbit at each position monitor, as produced by a corrector, are not predictable from the model. The measured changes in orbit have indicated that there may be other errors in the ring lattice which have not been discovered yet.

Work has just been started to look for asymmetrical errors; there will be more simulation studies to find quadrupole strength errors in an individual magnet which can produce the measured eta. What has been described so far is the use of models and simulations to represent and understand the imperfections of the machine. It is also possible, in some cases, to use models to control the machine without understanding its imperfections.

If the unknown imperfections are not too large, their effects can be corrected by iteration. For example, the orbit correction can be made to work if the correction is applied repeatedly by applying a fraction of the solution and remeasuring the orbit in each attempt. If this also fails, the orbit changes at all of the position monitors can be measured by experimentally powering one corrector at a time. With this result, the correction can be calculated to produce any orbit the users may wish.

A lot of this work has been completed by the modelers Martin Lee, John Sheppard, Mike Sullenberger,and Mark Woodley who have been working on machine models for LTR , RTL , and the Linac. Much more work will be needed; SLAC will need many more beam control models to make the operation of SLC a success.



Happy times in the Damping Ring control room, with (left to right) Mark Woodley, Martin Lee, Lenny Rivkin, and Ted Fieguth.

Photo by Gerry Fischer and processing by Tom Nakashima.

GILBERT & SULLIVAN & ELLIS

Theorist John Ellis used physics principles (tried, true, and otherwise) to modify the text of *Bunthorne's Song* from Gilbert & Sullivan's operetta *Patience*. The full creation was sung by Ed Glazier at a performance by the Stanford Savoyards given on July 26 for the SLAC Summer Institute. Below are some choice excerpts.

Am I alone and unobserved? I am.
Then, let me own, I'm a scientific sham!

This air so keen is but a cunning scheme.
This knowing smile is but a wile of guile.
This output stacked is but an act, in fact.

A languid love for leptons does not blight me.
Glueballs and narrow peaks do not excite me.
I do not long for lego plots—well, not a lot.
I do not care for all those Zee's that Carlo sees.
I am not fond of uttering platitudes in theorist's attitudes.
In short, my enthusiasm's affectation,
Born of a desire for Nobel-ization.

If you're anxious for to shine in the part'cle physics line
As a man of science rare
Your must get up all the germs of the supersymmetric terms
And plant them everywhere.

You must ask in all the sessions some abstruse and novel questions
Whose answers they can't find.
The meaning doesn't matter if it's only baffling chatter of a supers'metric kind
And everyone will say, as you talk your GUTS away,
"If this young man expresses himself in terms too deep for me,
Why what a very singularly deep young man this deep young man must be."

If your sentimental passion of a perturbative fashion is computing QCD,
An attachment à la Feynman for a tricky little diagram
In the not too U-U-V.

Though experimenters mutter, you will rank as just a nutter
In the higher loopy band,
If you walk around in theory with a smile all bright and cheery,
Calculator in your hand.

And everyone will say, as you walk your graphic way,
"If he's content with a perturbative graph, which would certainly not suit me,
Why what a very perspicacious theorist this theorist must be!"

The Stanford Savoyard's next full production will be *Iolanthe* at the Dinkelspiel Auditorium on November 11-13 & 18-20. Tickets are available from Tresidder Ticket Office, 497-4317. Open auditions will be held on September 26-27; contact Rita Taylor at extension 2411 or 857-1345 for further information.

VAL BOERIU RETIRES

SLAC is a cosmopolitan institution with visitors from all over the world, but it is unlikely that any of them has travelled more widely than Val Boeriu.

Val earned a degree in Electrical Engineering from the Polytechic Institute of Timisoara, Rumania. He graduated in 1941, in the middle of the second world war, and went to work at the General Gas and Electric Company of Bucharest as a junior engineer. In the last year of the war he worked as an electrician at an airfield in Germany.

After the war he was employed by the Military Government of the French occupied zone of Germany. Stationed in Baden-Baden, he monitored raw material distribution and industrial production. He went back to school in 1946, studying mathematics and physics at the Polytechnic Institute in Munich, Germany. In 1949 he went to Sao Paolo, Brazil, where he worked for the Cobast Department of Hydro Construction on the expansion of the Cubatao Power House. By 1952 he was in Montreal, Canada, working as a senior electrical engineer for the Canadian Comstock Company. From 1962 to 1968 he served as head of the Electrical Section at the Princeton-Penn Accelerator (PPA).

Val came to SLAC in 1968. He worked in the electrical group in Plant Engineering, participating in the design and installation of major additions to the SLAC electrical distribution system. His experience at PPA was especially valuable to SLAC when we acquired two 3-megawatt 'portable' power supplies which have since provided excellent service at SPEAR and for the MKI and MKII detectors.

Val and his wife, Mara, hope to find a retirement home near Medford, Oregon, where they can enjoy the natural environment and satisfy Val's vegetarian inclinations. They have our best wishes for the their happiness in the coming years.

–Alex Tseng

NEWS AND EVENTS

SLAC ACCELERATORS

The SLAC Accelerators, our own slow-pitch baseball team, begins the winter season with new uniforms thanks to the efforts of the SLAC Personnel Department. All they need now to be the best is your support. Please come to Kelly Park in Menlo Park to cheer them on. For game times, call Tom Kamakani or James Alexander, x2371.

SLAC FOOTRACE

The twelfth running of the SLAC footrace is scheduled for Thursday, December 1, at noon. It will consist of two legs on the north side of the Klystron Gallery for a total of 3.8 miles or 6 kilometers. The winners will have their names engraved on the perpetual trophy and all finishers will receive ribbons.

SLAC Race T-shirts will be sold at cost and refreshments will be available. If you're a competitor, come and compete, if you're not, come out for a fun run.

STANFORD EMPLOYEE DAY

Stanford University's Employee Appreciation Day will be held on Saturday, September 24. The gates to Frost Amphitheater will open at 11 am with music and beverages supplied. Complimentary tickets for the Stanford-San Jose State football game at 1:30 pm are available at the SLAC Information Office until September 19.

AN INVITATION TO SLC GROUNDBREAKING

OCTOBER 31, 3:00 PM

Join your colleagues at the SLC Groundbreaking Ceremony, October 31 at 3:00 pm, on the green at SLAC. The principal speaker at this in-house celebration will be the US Secretary of Energy, Donald Hodel. William Kimball, Chairman of the Stanford Board of Trustees, and Dr. Alvin Trivelpiece of DOE will give brief talks. Festivities will be hosted by the SLC Project Director John Rees, and Pief will be on hand to offer congratulations. Light snacks and beverages will be served after the ceremony.