SLAC BEAM LINE

If I could remember the names of all these particles, I'd be a botanist. --Enrico Fermi

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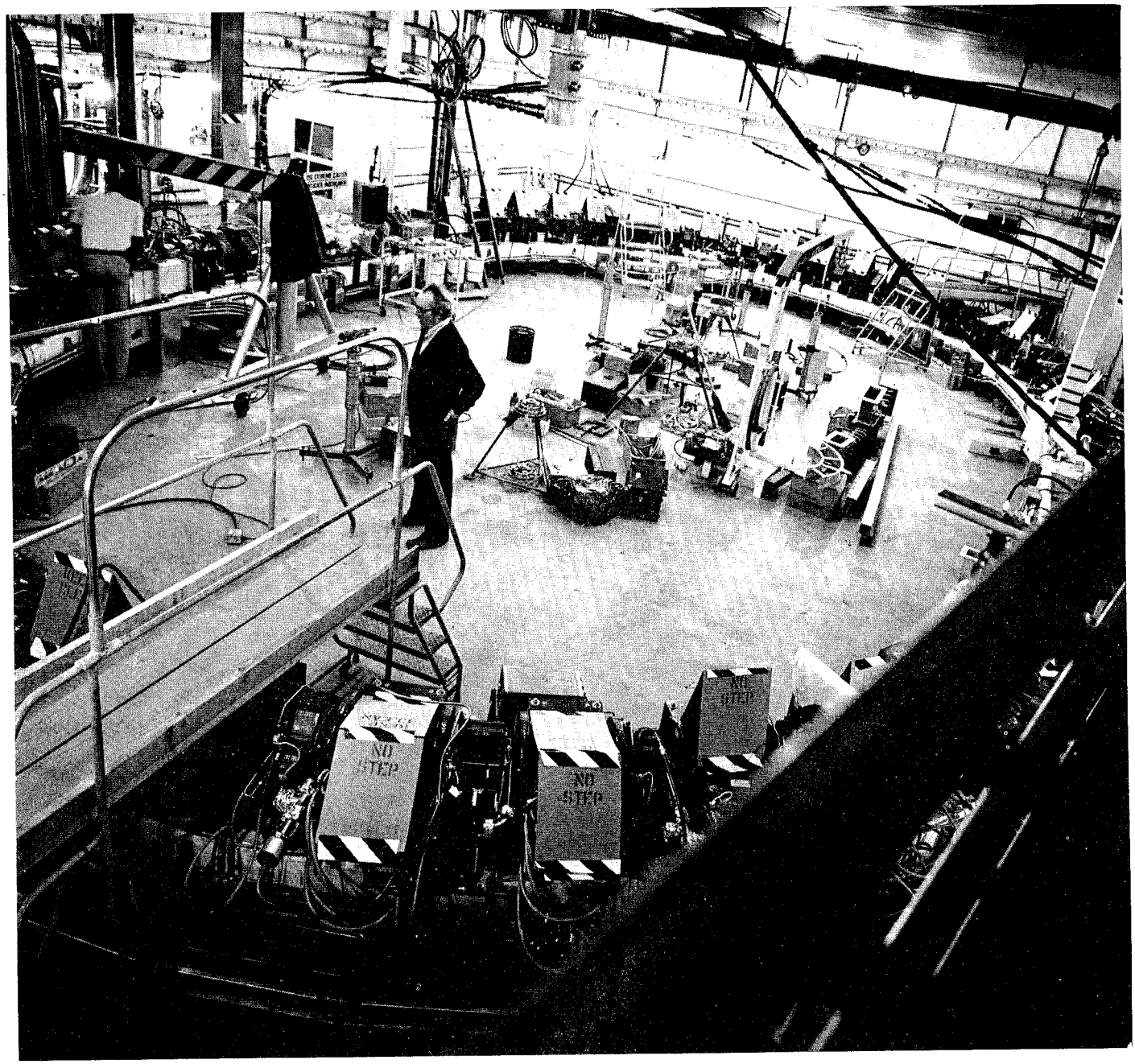


BEAM INJECTED INTO SLC DAMPING RING

The Damping Ring took its first turn of electrons last month in another big step toward the SLAC Linear Collider. The SLC is discussed as part of the State of SLAC talk by W.K.H. Panofsky reprinted in this issue.

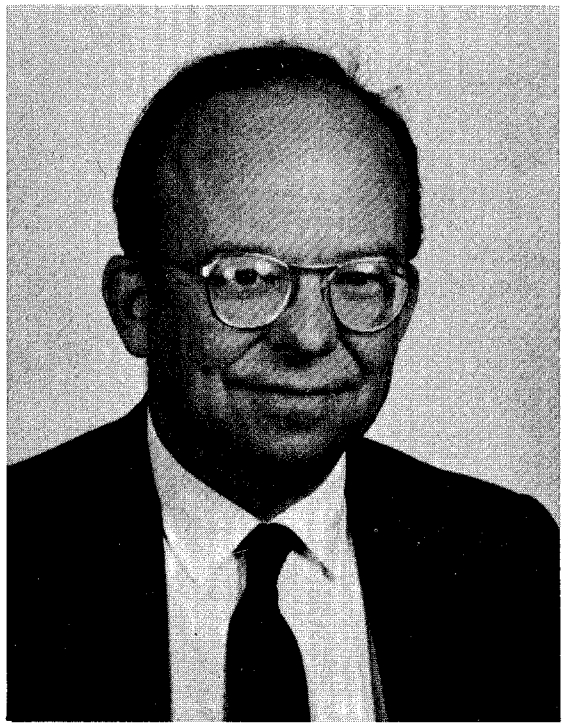
THE STATE OF SLAC

(The following is the text of the annual State of SLAC address delivered by SLAC Director W.K.H. Panofsky on February 1, 1983)

Following the usual custom I would like the SLAC staff to be the first to know the meaning for the future of SLAC of the budget message delivered by the President to the Congress on January 31, 1983. This time the President's budget has a great deal of particularly pithy information for SLAC. Before outlining all this let me again give a word of caution: SLAC is part of Stanford University, and we are all members of the staff of the university. However, the funding for SLAC all comes from the government, with the university carrying out its role on a no-gain-no-loss basis. This means that the resources we ultimately have available for our work depend on what the Congress of the United States appropriates. Following the President's budget message various Congressional committees hold hearings relevant to the portions of the budget under their jurisdiction, and finally the actual appropriations are made. Many things can happen between the President's budget message and final Congressional action. Anyone reading the newspapers knows that on budgetary matters there is much commotion between the Congress and the President, and it is even more difficult than usual to make a firm forecast about SLAC's future based specifically on the President's message.

Let me give you an example as to what happened last year. The President delivered his budget message to the Congress on February 8, 1982 for the Fiscal Year 1983 (which started October 1, 1982 and which is one-third gone); nevertheless, the Congress has not yet passed that budget. Rather, the lame duck session of Congress in December of 1982 passed what is known as a Continuing Resolution which permits spending to continue at certain levels but which generally does not permit any new major initiatives. Thus not only do I have to caution you that the President's budget message for the next fiscal year may suffer modifications, but I have also to tell you that the budget which is supporting our work today is not yet fully firm. However, all these uncertainties and risks notwithstanding, let us look at the President's budget at face value.

The most exciting part of the President's budget is that it recommends authorization to commence construction of the SLAC Linear Collider in FY1984. It specifically recommends that $40 million be appropriated for this first year of construction. This is very close to the amount which we had requested.



W.K.H. PANOFSKY

Therefore, should the Congress follow the President's recommendations, we can say that the speed with which we can get SLC construction work underway will be limited mainly by our ability to perform, rather than by any external financial limitation. In other words, to quote Pogo, "We have seen the enemy and he is us."

Happily we should be able to move ahead with the SLC construction quite rapidly once the next fiscal year begins in October 1983, provided, of course, that the Congress has indeed acted favorably. In contrast to the situation which some of you remember in respect to PEP, we will be able to complete this fiscal year, that is before October 1983, the detailed design of the various "civil works" which are needed to house the SLC. Thanks to the work of our engineers and that of our architectural-engineering subcontractor, the Tudor Engineering Company, steady progress has been made in preparing final design drawings for the SLC tunnel and the junction of these tunnels into the SLAC beam switchyard. Thus, if things go as planned, we will issue competitive bids to the construction industry even before the end of this fiscal year to be able to get a running start on the work by this fall.

We also have been in good communication with our neighbors. We have in fact made several major modifications of the SLC layout in response to con-

cerns expressed in various meetings with community organizations dealing with the possible impact of the SLC installation on the surrounding community. I am happy to report that the current design appears acceptable to almost everyone. We have submitted an Environmental Impact Assessment, and after the changes mentioned, have received a "Finding of No Significant Impact" by DOE. All this means that we are not anticipating that environmental concerns will impede the construction in any way. I can assure our neighbors that we can build the SLC without causing them any problems. Let me note that SLC is a job roughly one-half the magnitude of PEP.

The SLC is technically an extremely difficult but also important and exciting undertaking. It pioneers a new direction for obtaining very high energy electron-positron collisions and at the same time gives physicists from many institutions a new tool to reach what is currently believed to be the most critical energy region in which new phenomena are expected.

Just because the technology to reach both a new realm of energy at moderate cost and to do physics research with the SLC is so challenging, our ability to meet the schedule of completing all construction activities by the end of 1986 depends critically on pushing as hard as possible our current research and development program designed to solve the technical problems. Thus we are faced with the dual task of advancing this R&D effort rapidly while at the same time keeping up with operating our facilities which support both our physics program and that of many other institutions in the United States and abroad.

Doing the best possible physics research with what we now have remains the highest priority of the laboratory. SLAC continues to be a single-function laboratory solely dedicated to research in high energy physics and associated topics. All our work is open, access to our facilities is available to all, and the results of what we do—be it scientific or technical—are published just as soon as the quality of the results warrants dissemination (or even before!). Scientists from 43 nations participate in our work including those from Socialist countries. There is no intention of any kind of changing our single-minded dedication to basic open science.

The table below shows that an increasing fraction of the high energy physics community has become dependent on support from SLAC's beam and other facilities. The reason for this increased involvement is primarily due to the growing opportunities given by our facilities. It has also been influenced by the fact that some of our sister institutions have been converting some of their accelerators and colliders to reach higher operat-

	Jan. '77	Jan. '78	Jan. '79	Jan. '80	Jan. '81	Jan. '82	Jan. '83
				↑ PEP turn-on April 1980			
Institutions							
U.S.							25
Foreign							10
Total							35
Physicists Participating in SLAC Program							
U.S.							231
Foreign							69
Total	151	130	115	190	295	300	300
Students							
U.S.							73
Foreign							16
Total	30	30	35	55	80	85	89
Users in Residence at SLAC	80	75	75	110	150	190	190

ing energies in the future. In contrast to what we hope to achieve with the SLC, the upgrading process at other institutions has made it necessary to curtail their ongoing operations, thus decreasing opportunities for experiments as construction progresses. We expect that this type of conflict can be avoided in building the SLC. We hope to schedule the break-in into the SLAC structure and joining the SLC ring to that structure during our regular summer shutdown, similar to the procedure which we executed with PEP. Once this break-in and junction has been successfully accomplished, the technical interaction between the SLC and the ongoing SLAC activities will consist mainly of carrying out tests in the linear accelerator and making major revisions to its installations and control system. These improvements are necessary to have the SLC live up to its expectations, but will at the same time improve the performance of the 2-mile linac in its own right.

However, this is not all. In addition to giving the green light on the SLC, the President's budget also provides funding for FY'84 for two other important new projects: a very substantial growth in SSRL's facilities, and an off-axis injector that will make it possible to generate low energy beams in End Station A for use by nuclear-structure physicists and others needing beams of energy no greater than 3 GeV. At the same time the off-axis injector will make it possible to inject into

The PEP program is in full swing. The TPC facility is installing the superconducting coil shown above as it arrived at Region 2. Photo by Fred Catania

EVOLUTION OF THE SLAC FY1983 AND FY1984 BUDGETS

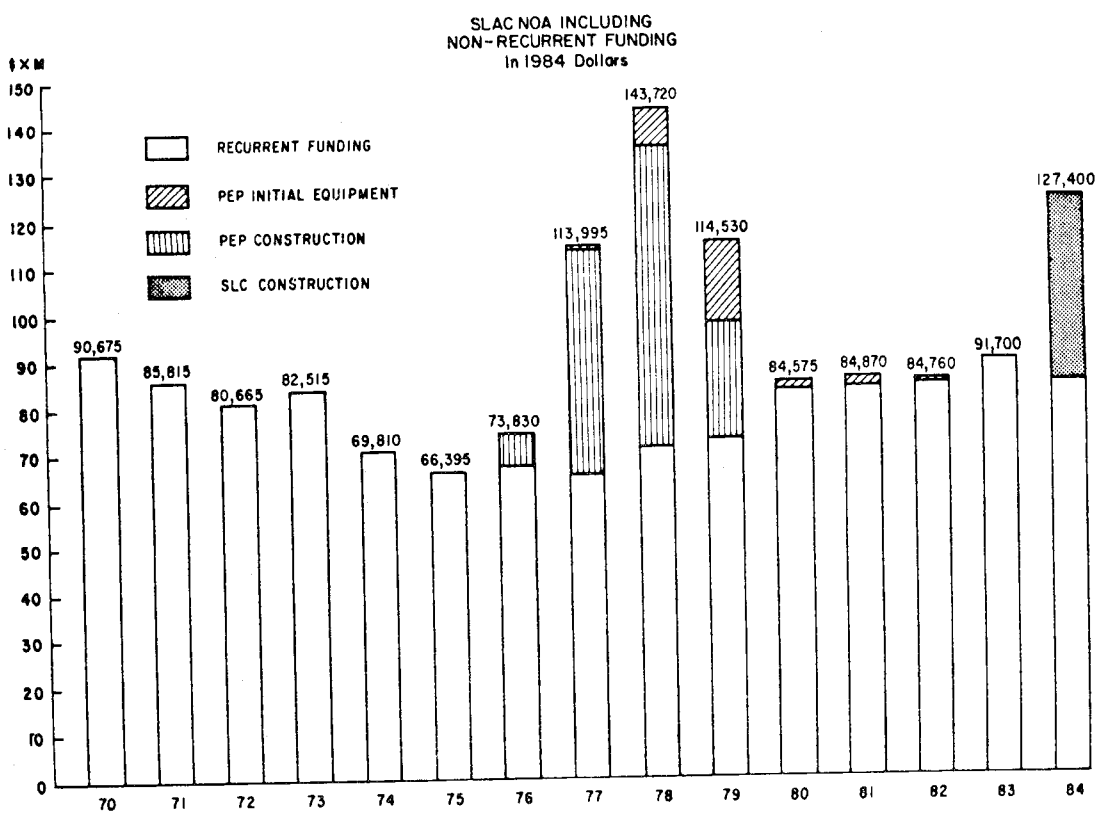
	FY1983 For Reference (Dollars in Millions)				FY1984 President's Budget
			FY1983 Budget as Referenced in FY1984 Pres. Budget Message		
Category	FY1983 Pres. Budget	Continuing Resolution	In FY1983$	In FY1984$	
Operations					
Res	10.0	9.0	9.8	10.7	10.3
Ops	48.0	39.0	44.2	48.3	49.2
Tech	18.0	13.2	20.0	21.8	16.5
Total	76.0	61.2	74.0	80.8	76.0
Equipment	9.0	6.55	7.0	7.6	8.2
GPP	1.0	.85	1.0	1.1	1.3
AIP	2.0	1.6	2.0	2.2	1.9
SLC					40.0
Total	88.0	70.2	84.0	91.7	127.4

the SPEAR ring without having to power the entire accelerator. As a result of this new scheme it might well be possible in the future to operate SPEAR (and therefore SSRL) together with the low energy program in End Station A during the summer months, when we are highly restricted in the use of electric power. This should greatly increase our scheduling flexibility, in particular once SLC becomes operational.

SSRL is planning to expand its operations substantially over the next few years. Let us be clear about the relationship of SSRL to SLAC. SSRL and SLAC are each independent laboratories reporting to the University administration, with each determining its own program under the general policies of the University. These policies, in turn, specify that the work shall be free from any secrecy restraints and that results shall be published with minimum delay. SSRL, although an independent laboratory, depends on a reimbursable basis on SLAC for technical support in many areas. As SSRL expands, questions are raised whether this type of relationship will continue to serve the needs. Accordingly, the Provost has just appointed a committee under the chairmanship of Dr. Sidney Drell, Deputy Director of SLAC, to make recommendations to the University on the long-range future relationship between SSRL and SLAC. Obviously, since this committee has just been formed, there are no results to report.

All this means that SLAC staff will be involved in three major construction activities—the SLC, the off-axis injector, and whatever help we can give SSRL in connection with the SPEAR upgrading program in support of synchrotron radiation work. Nonetheless, the ongoing particle physics program will continue with highest priority. This combination generates a major load on SLAC's technical and administrative staffs, and I hope that the confidence which the government has shown in us in giving us the green light on all of these ventures will be vindicated.

Now let us turn to more details. The table at left shows the actual budget figures for FY'84 as compared to FY'83 relating to SLAC for its regular operations, equipment and various construction line items. The FY'83 entry is shown in three different ways: what the President originally proposed, what we would receive if the FY'82 figure applied to FY'83, and what we actually anticipate receiving if the DOE carries out the shifting of funds as permitted under the "Continuing Resolution." You can see that indeed the current (FY'83) figures have changed a great deal and might change even more. A graph of this and the preceding budgets, both corrected for inflation, is shown below. Although we know what inflation has been in the past,



we certainly do not know what it will be in the future. The assumption made in this plot is that inflation for the fiscal year 1984 starting in October 1983 will have eroded the buying power of the dollar by about 9.2% relative to the current year. This relatively large inflation estimate is influenced by the fact that SLAC's electric power costs are expected to increase very substantially during this period.

The figure below is a rough estimate of how the "in house" resources of SLAC for the next fiscal year will compare with the funds we have available this year. When we undertake a large construction project, obviously a substantial part of the work is done by local industry and other contractors. In particular, the largest amount of the first year funding for the SLC will have to be in the form of a construction subcontract for the tunnel work and other construction on the SLC site. With the exception of some engineering, supervision and administrative activities, little of these funds support work done directly within SLAC. The same thing is true to a different extent for the smaller construction activities. Thus an estimate of actual resources directly supporting SLAC's work during the next year depends on a large number of assumptions which at this time have to be quite uncertain: inflation, the fraction of work which will be done by outside contractors, and the rate at which we can actually make progress. In addition, our future electric power costs are subject to many uncertainties—even greater than the ones we all face at home. Thus, understanding of the impact of the President's budget on SLAC's staffing levels is beset by many uncertainties, quite apart from the uncertainty having to do with the likely difference between Congressional action and the proposals contained in the President's budget. Let me remind you that in this age of high Federal deficits it is particularly difficult to predict how Congress will respond.

FUNDS AVAILABLE FOR SLAC-MANAGED EXPENDITURES[1]
(In Millions of Dollars)

Category	FY1982	FY1983	FY1984
Operating	61.3	74.0	76.0
Other Sources[2]	6.5	6.7	6.9
Equipment	5.6	6.2	7.8
Accelerator Improvements	2.0	1.7	1.9
General Plant	1.2	.9	1.1
SLC PE&D	.7	.8	---
SLC Construction[3]	---	---	12.0
Total Resources	77.3M$	90.3M$	105.7M$

1) Funds are considered "expended" in the Fiscal Year in which they are committed by the lab to an outside entity. Plant and capital figures above are "net" expenditures including effects of funds carried in from prior years and carried out to subsequent years.

2) Other sources include those associated with a joint development effort with the Japanese, SSRL support of 50% of SPEAR operations, and other work for SSRL and various other organizations.

3) Construction funding for the SLC in FY1984 is expected to total 40M$. Of the amount 20M$ will be applied to certain externally managed subcontracts, 8M$ will fund major technical components, and the remaining 12M$ will go to activities directly pursued by the laboratory staff.

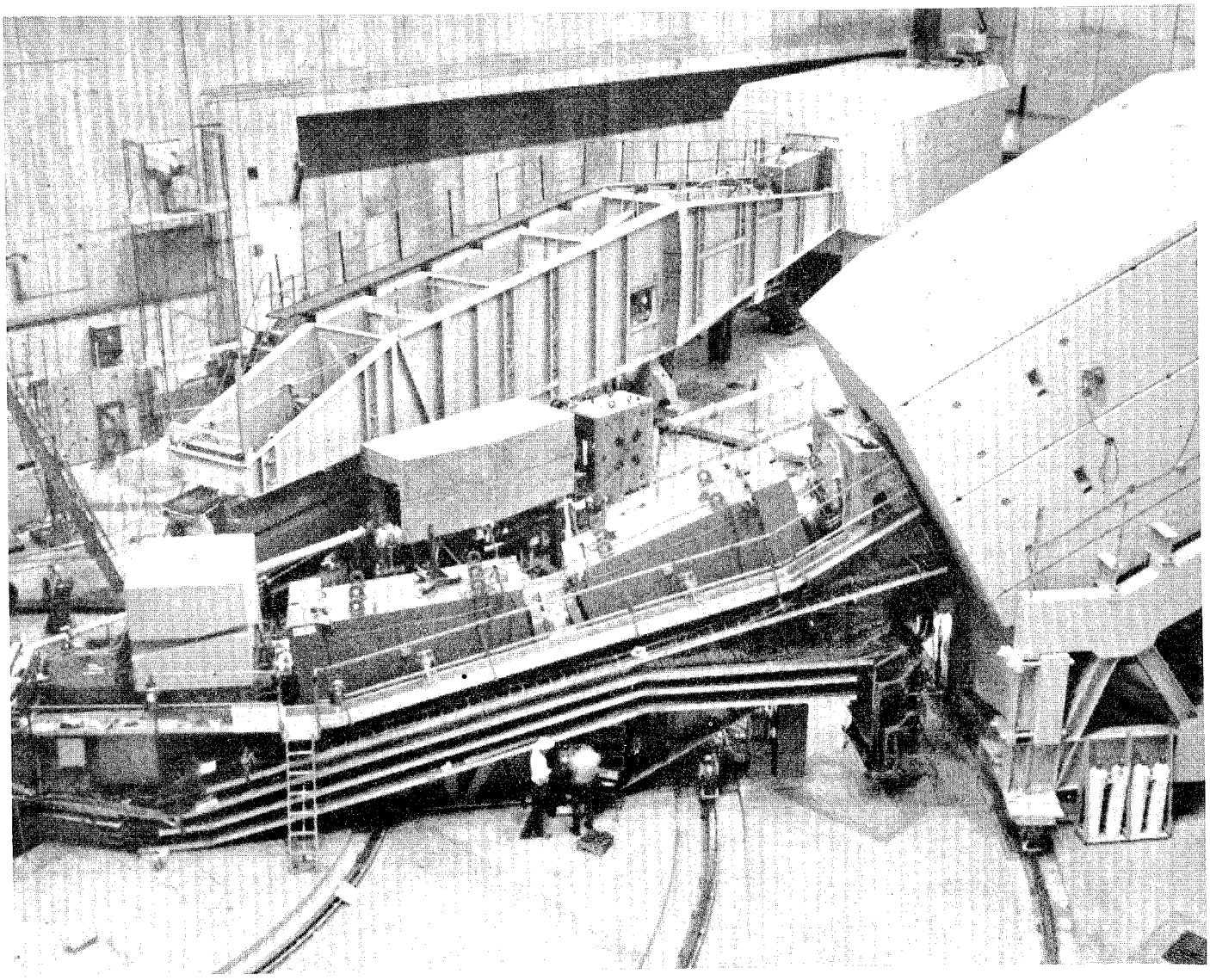
Despite the very good budget news these uncertainties make it very difficult for me to predict how staffing at SLAC will be affected as a result of the new construction activities combined with the heavy load on our continuing programs. It is extremely unlikely that our staff levels will decrease, but we simply have not had the time to analyze in what categories, if any, increases are warranted. It does appear, however, that the total amount of detailed engineering will be increasing substantially over the next year if we are to meet our schedules.

The SLC is indeed a great new opportunity for SLAC, and we are pleased that as a result of the universal support for the SLC idea by the various review committees advising the government, authorization and construction are being supported in the President's budget. I will dedicate the second half of this talk to explain the SLC in simple terms. Let me first mention, however, one basic issue. The SLC has only one point at which beams collide, and therefore at any one moment only one experiment can be conducted in the interaction hall of the SLC. Thus even with today's large collaboration of physicists the total number of people who can participate in experimentation with the SLC is considerably smaller than the total number of physicists now participating in SLAC's program. We are now in the arduous process of reviewing proposals for the use of the SLC interaction hall for research and have reached the decision that the first detector using the new facility will be a modification of the Mark II detector now at PEP. Neither SLAC not the scientific community can afford to have the entire research program of the laboratory funnel into this single area of experimentation, and we are determined that many of the other activities of the laboratory shall continue or be supplemented by new programs. It is in this connection that, among other experimental proposals, the new initiatives for lower energy nuclear-structure physics in End Station A and the increased activities of SSRL will play an important role. However, above all we are definitely going to continue our normal high energy physics activities both with stationary targets and colliding beam storage rings into the future and will con-

tinue to probe new directions. Naturally the details of doing so depend on developments in science and the proposals we will receive from the scientific community.

Currently the PEP program is proceeding full steam. Recently the luminosity attained by PEP has exceeded that during our final spurt up to the summer 1982 shutdown, and we hope to accumulate an integrated luminosity during the current run in excess of that recorded by any colliding beam installation in the world during any one year. All detectors at PEP are actively gathering data, and obviously we cannot predict what the total physics results will be. Thus the PEP program is healthy. Similarly, the SPEAR high energy physics program now has a new lease on life with the initiation of data taking by the Mark III detector.

We have all been spoiled by the great spurt of discoveries and exploration at SPEAR following the unsuspected new phenomena that began to emerge at the end of 1974. In contrast, the region of energies accessible to PEP has thus far not shown up anything truly unsuspected or qualitatively new. All the results obtained at PEP and at our sister institution PETRA in Germany have improved our quantitative understanding of many phenomena. However, none of these new measurements have shocked the physics com-



The 8 GeV and 20 GeV spectrometers in End Station A have been used in electron scattering and photoproduction experiments since the beginning of SLAC. This area will be used for nuclear-structure physics with beams delivered by the proposed Off-Axis Injector.

munity into changing the basic view of things which had emerged previously. It is on the basis of this picture—excellent performance of PEP and its instruments but thus far not too rich a field for new surprising results —that I cannot forecast how long the PEP program will continue once the SLC is fully operational. Naturally we have to be fully flexible on this subject pending analysis of those measurements now in progress at PEP and PETRA.

THE SLC PROJECT

I would now like to spend some time again describing the project that will be shaping our lives here at SLAC in the near future—the Stanford Linear Collider, or SLC. This project not only involves building major new rings and tunnels but also requires a thorough reworking of the linear accelerator which is the core of SLAC. I will not be able to give a complete description of such a broad subject in this talk. Instead, I would like to give an overall picture by answering the traditional set of questions: why, what, where, how, who, and when?

Why a New Machine?

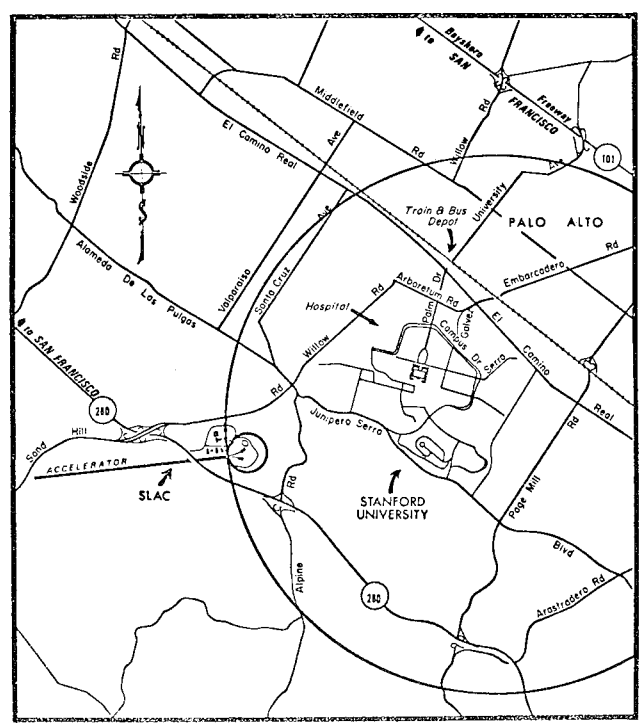
The answer to this question is always the same. We are exploring the universe of the very small, trying to understand how the world is put together. We have come a long way on this path. Observation started with man's unaided senses; then instruments were invented starting with the magnifying glass, leading to today's accelerators and colliders. In the last hundred years or so we have come from molecules composed of atoms, to atoms composed of electrons and nuclei, to nuclei composed of protons and neutrons, and to protons composed of quarks. A principle of physics relates the size of the things we can "see" to the energy (and size) of the devices we must use to see them. The smaller the object, the bigger the "microscope." It is no accident that our field of research—the study of the very small—is called high energy physics.

So, although we have not come to the end of our studies with the SLAC linac, SPEAR, and PEP, the next step beckons. That next step is particularly intriguing: hints from our present machines and our theoretical understanding tell us that we should be able to get well into the region where the weak interaction, which used to be the "little brother" to the familiar electric force, becomes dominant. As part of this, a new particle called the Z^0 should be produced. We can learn about this new world by studying the reactions in which the Z^0 participates. This is as exciting as anything we have learned about the world so far.

What is the SLC?

The technique which has been most productive in particle studies in the past decade has been that of colliding beams of high energy particles, electrons and positrons in particular. When the electron collides with its anti-particle, the positron, the two particles disappear into a bundle of energy from which new particles emerge. The energy density of these collisions has been compared to that of the Big Bang at the beginning of the universe, although it is of course of vastly smaller scale.

In the SLC project, electrons and positrons from the linac are focused into single pass collisions with energies up to 100 GeV, compared to the roughly 30 GeV from PEP and the 8 GeV with SPEAR. But the SLC is quite different from those two machines in the way these collisions are made. Before describing how, let me answer the question of why we don't just build a larger PEP. The rough map of the area shown below explains why. As we went from SPEAR to PEP, the machine size increased by about ten times. We would require the same jump to get to the next energy region of 100 GeV; a super-PEP would encompass the Stanford campus and then some. The reason for this is that it is very hard to bend high energy electrons in a tight circle because they lose much of their energy on each turn. The solution of making the circle bigger is expensive and eventually becomes unrealistic.

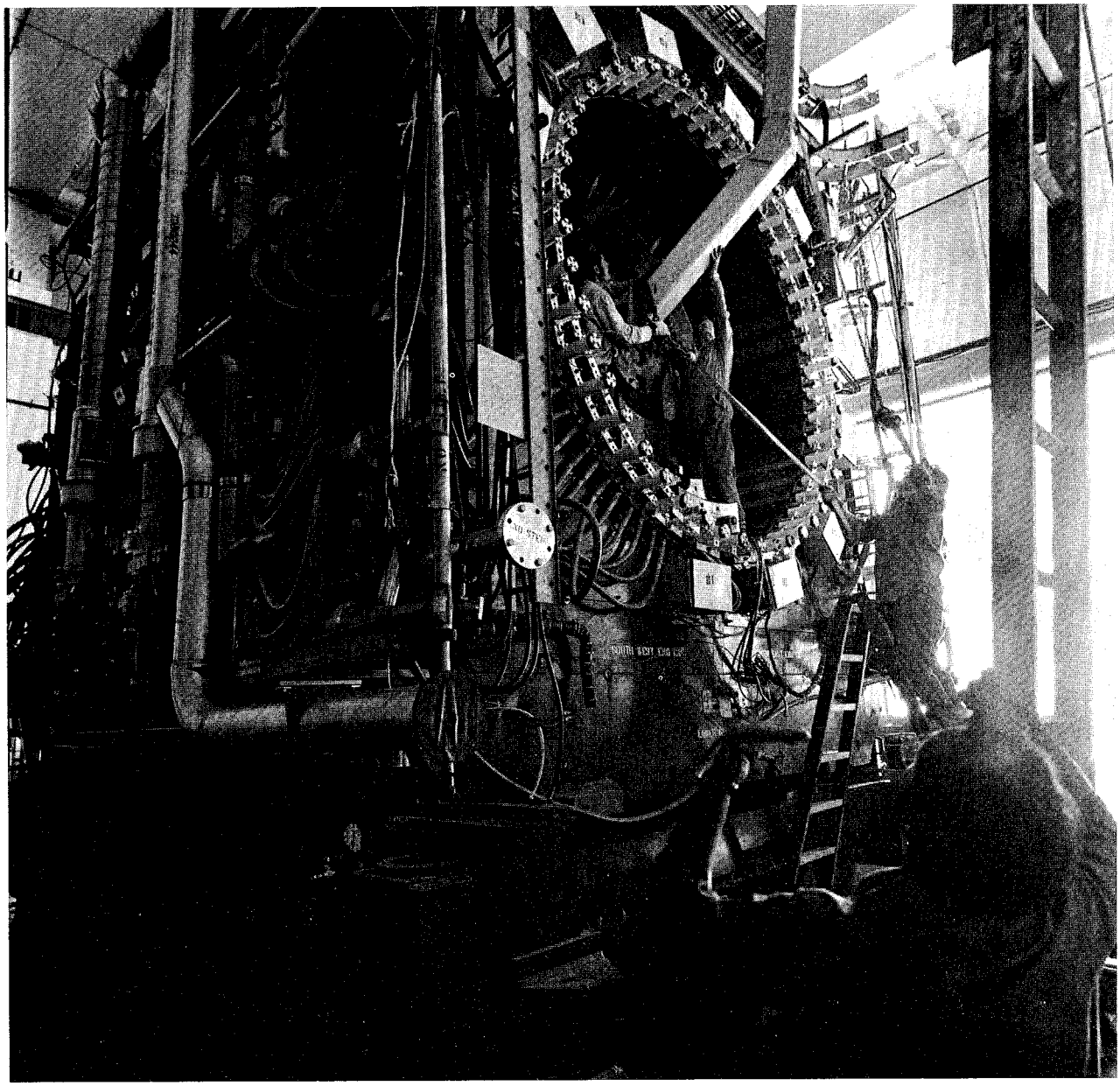


A PEP-like machine to reach 100 GeV would require the enormous ring sketched above. The SLC by contrast fits comfortably on the site shown by the small ring.

The idea of a *linear* collider is to collide the beams from two linacs head-on without trying to store them in a ring. Why has not such a simple idea been tried before? The answer is that making electrons and positrons *really* collide is difficult.

An electron and positron must come very close together in order to collide and produce an interesting event. Even with tens of billions of electrons and positrons in a bunch, the chance of a close enough hit in one pass is very small. In a storage ring, like PEP, the beams circulate and pass through each other almost a million times per second, so the rate of collisions which produce something interesting becomes reasonable, say once per second or so. Linacs can produce beams, or bunches, only a few hundred times per second, so the collision rate would occur ten thousand times less often than in a storage ring.

There is a way to overcome this, however. Linac beams can be much more tightly controlled than those of a storage ring, and they can be squeezed down into such a tiny spot that the rate of collisions becomes again high. But this isn't easy, and it is only now being tried for the first time.



The Mark II detector is shown during installation at PEP. This facility will be the basis for the first experiment at the SLC

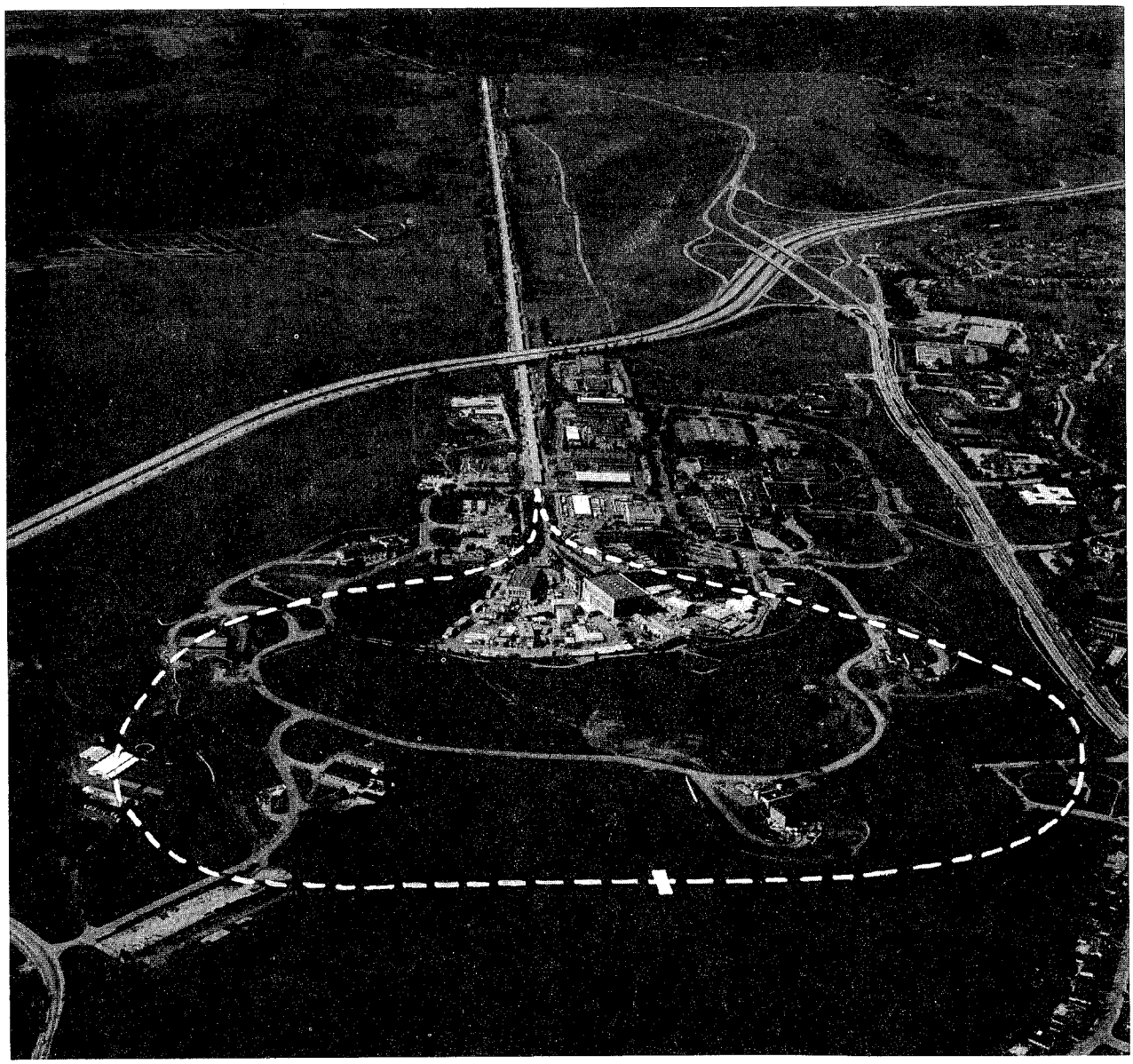
Where is the SLC?

The SLC site is shown on the aerial photograph of the SLAC site below. The two curves are the paths of the electrons and positrons from the linac as they are brought around to collision. Now we did say a linear collider was supposed to use two linacs, and that you couldn't bend electrons and positrons of such high energy into a circle that stayed on this side of El Camino Real. What's going on? Well, it is true that the electrons will lose energy in this tight circle, but since we are only going around this path *once* for each collision, the energy loss is not enough to hurt. It is only when you must circulate beams continuously as in a storage ring that the loss is unacceptable. So, we are able to make a linear collider with only one linac.

This photograph at the bottom is actually a bit misleading. It implies that the SLC is this new dotted line, an appendage to the linac. Actually, as we will see, the SLC involves just about every piece of the linear accelerator from the injector on.

How Does It Work?

How the SLC works can be explained by the schematic at the right which shows the linac and the new components. The SLC cycle begins at the two damping rings, which are located one above the other in an underground vault on the south side of the linac near the injector end. One ring contains two bunches of electrons and the other two bunches of positrons. At the beginning of the cycle one positron bunch and



both the electron bunches are extracted from the rings and injected into the linac. The three bunches are accelerated down the linac in the order: positron, electron, electron. This part of the cycle is similar to normal linac operation except that the particles are gathered into three tight bunches, or buckets, instead of being spread over the thousands of buckets available in the regular linac pulse.

At the two-thirds point the trailing electron bunch is extracted from the linac and sent to a positron production target. I'll say more about this later. The two lead bunches, one of positrons and one of electrons, are accelerated all the way to the end of the linac, by which time they have reached an energy of 50 GeV. They are separated by a magnet and sent through the two arcs. On the far side the beams pass through an elaborate system of magnets which focus the beams to the tiny collision spot. The physics experiments surround this region, just as in the interaction regions in our storage rings. After the collision the two beams continue through the opposite arc a short distance to a dump.

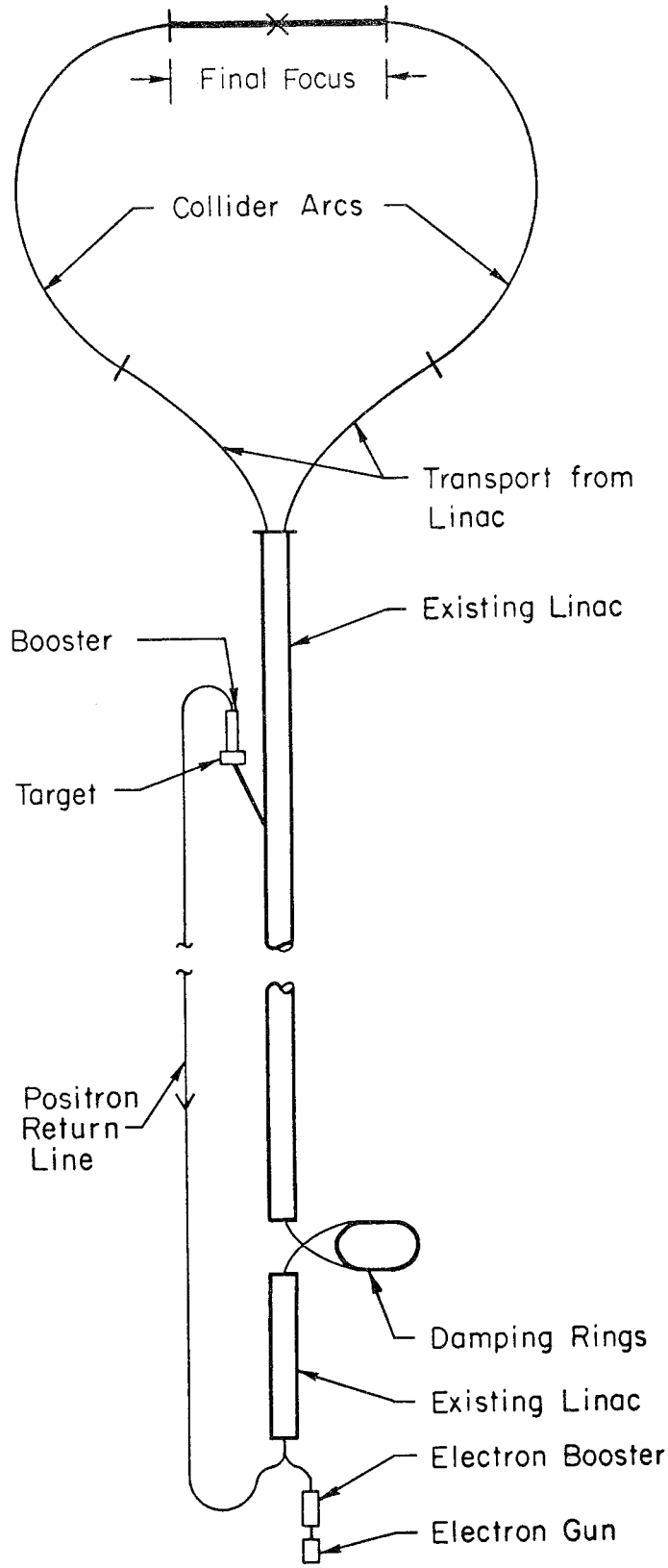
One of the challenges of this project is to make that collision spot very very small to compensate for the fact that the collisions happen only a few hundred times per second compared to the millions of times in a storage ring. This spot will have to be between one and two microns across. A micron is one millionth of a meter, about twenty-five times smaller than the thickness of a hair. This is close to the limit of what can be seen through an optical microscope.

Let us continue with the rest of the cycle. The positrons which were produced by that third, or "scavenger" bunch of electrons hitting the target are focused, accelerated to 200 MeV, bent around, and sent back to the injector end of the linac in a small evacuated transport pipe located in the linac tunnel. They are bent around again, accelerated to 1.2 GeV by the short first section of linac, and injected into the positron damping ring. The way we produce positrons sounds very messy, and it is. The positron beam is very fat at this point and could not be directly used in the SLC. As the bunch circulates in the damping ring, however, its size decreases or "damps" down.

At this time a special electron gun injects two bunches of electrons which are accelerated in that short first section of linac and then injected into the electron damping ring.

Now we are back to the starting point with the two damping rings filled. This cycle repeats 180 times per second.

As this description of the cycle shows, we are using



SLC SCHEMATIC

nearly all our facilities and expertise in the SLC. We can divide this project into seven major and challenging pieces.

• The electron gun must supply electrons in much shorter pulses than in regular linac operation. Such a new gun has been built and has produced the necessary current in tests last spring. In addition, a new kind of gun using a high power laser beam to boil off polarized electrons has been built and is ready for testing. Collisions with polarized electrons give a powerful new physics handle which may be unique to linear colliders.

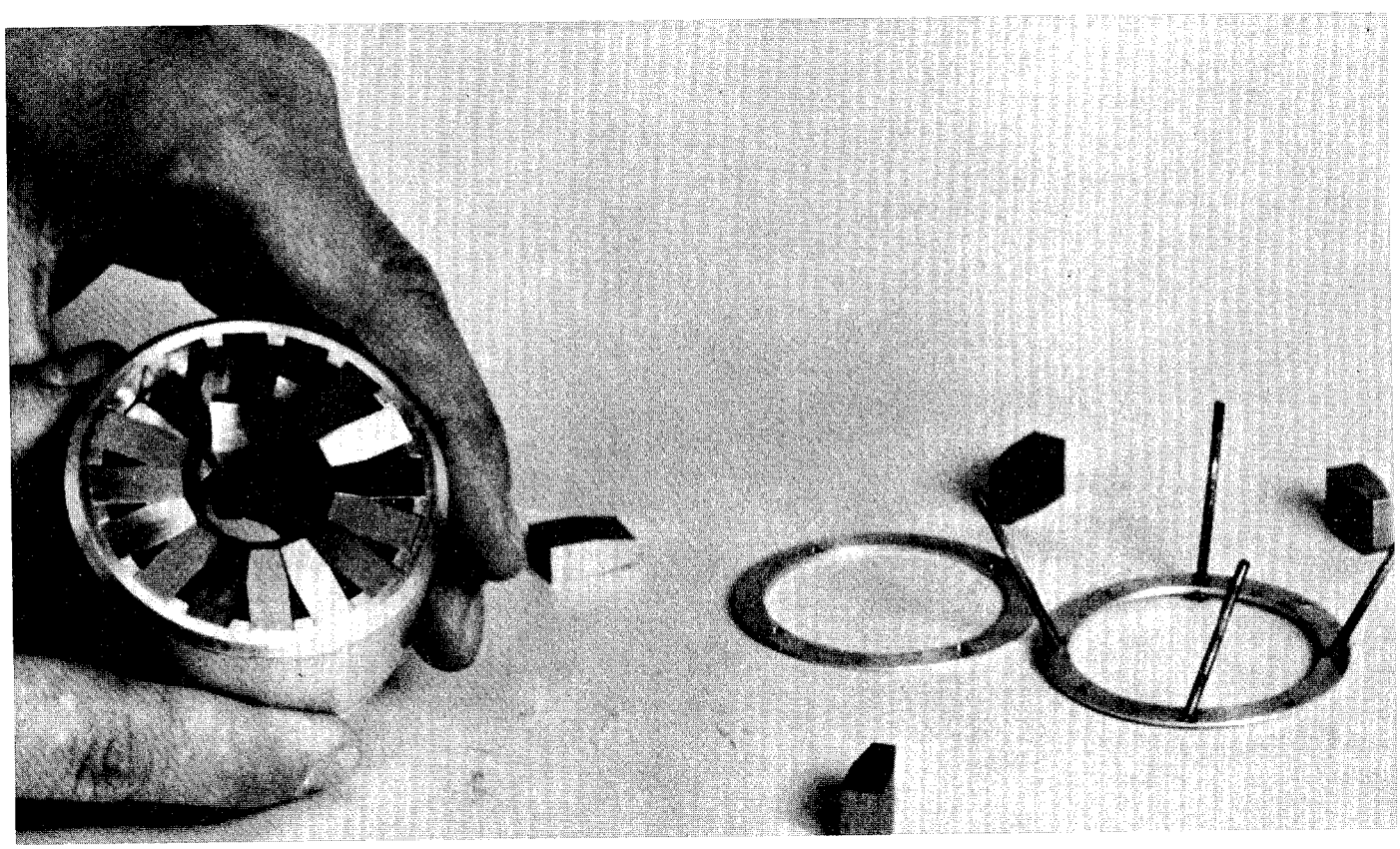
• The positron system must be very efficient to make a decent beam from the debris of a high energy collision. The heart of the system is the target itself which is very small. This disk must take the full power of the SLAC electron beam. This is close to the limit of strength of most materials. We have successfully tested targets of this kind in End Station A.

• The accelerator now has a top energy of about 32 GeV. In order to get to the higher energy of 50 GeV we need more rf power. The 240 klystrons which now supply this power along the length of the machine are already more powerful versions of the original tubes used at SLAC. We are working on a new design now and have tested some of the existing tubes at higher power.

• The beams for the SLC must be very carefully controlled during the acceleration to maintain the high quality delivered by the damping rings. Since the beams are more tightly compressed, the effects which distort the bunches are stronger as well. We need new kinds of position monitors and correcting magnets, and a fast computer control system to make it all work together. We have accelerated SLC-type beams in part of the linac and successfully measured and controlled these effects.

• The collider arcs are the biggest apparent piece of the new machine. These arcs will be in small tunnels underground. The very small size of the SLC beams allow these arcs to be made of very small magnets; a lamination from one of them fits on the projection screen. We are also able to bend the beam up and down as we go, so we can follow the dips of the terrain and stay beneath the hilly surface of the site. We are well along in the magnet design and the civil engineering that is needed for this tunneling.

• The final focus system must take these beams and bring them down to a final tiny spot. This also ties in with the experimental detectors through which the beams must pass on the way to and from the collision. And we must be able to steer the beams into



the collision and monitor how well they hit. One of the novel possibilities for part of the focusing system is permanent magnet quadrupoles. Compare the size of the prototype pictured at bottom left to the large blocky electromagnets used in our storage rings and transport lines.

• And, finally, there are the damping rings. These rings and transport lines are comparable to SPEAR in size, but have many complications. The electron lines, for example, must be made with special angles and solenoidal magnets to preserve the polarization, or spin direction. The vault and tunnels were completed last year and the first ring is complete. Our Christmas present was the bringing of a beam from the linac through this complicated line to the damping ring.

Who Will Build It?

The SLC is a big project, touching as it does all our existing equipment as well as building new pieces. It will involve the whole laboratory. Therefore, instead of setting up a new division within SLAC to carry it through, we organized a project. This is managed by a core of people for the several subprojects, with John Rees as project director, as shown below. These people will draw on the resources of all the SLAC divisions. So the answer to the question of "Who?" is "All of us."

When Will We Build It?

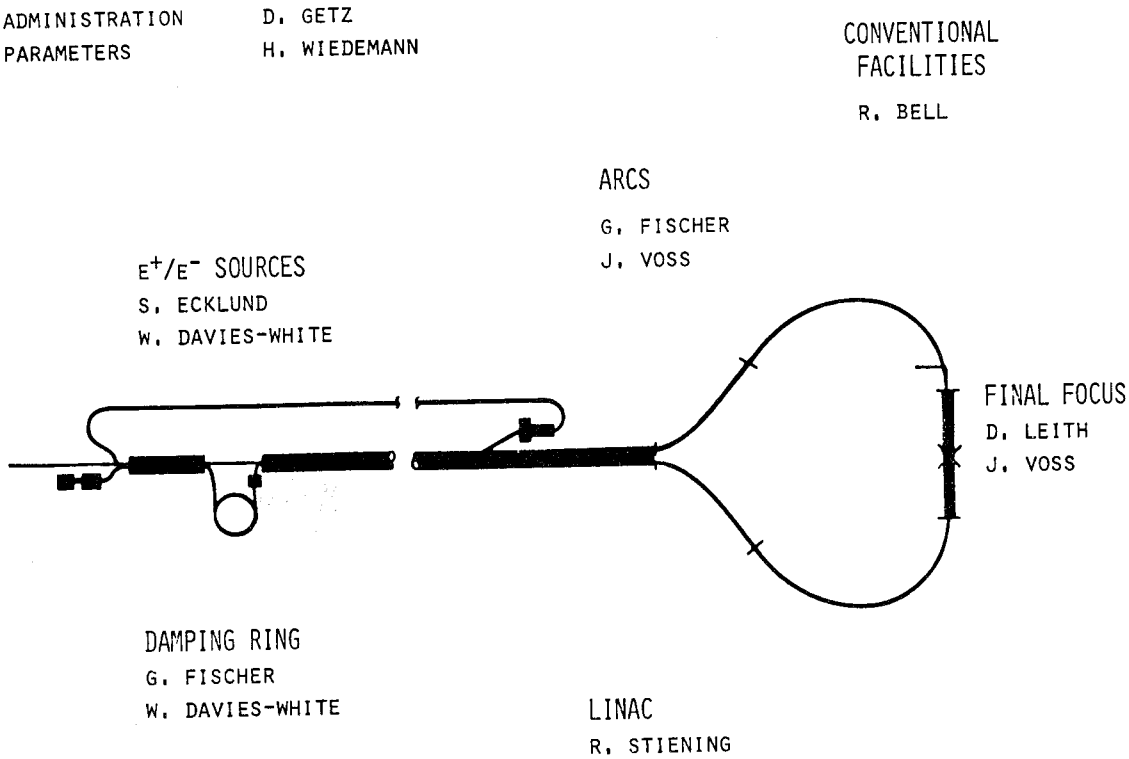
As I mentioned earlier the news about funding is good. We expect to pursue the SLC vigorously and on a schedule leading to turnon in late 1986. This schedule is not just set internally. As many of you know, our colleagues at the large European laboratory CERN have begun to build a storage ring for this same energy range. Yes, it will be as big as the one I indicated on our local map earlier in the talk. It will be about 17 miles around, cost more than 500 Million dollars and will straddle the boundary between two countries! That machine is scheduled for startup in late 1988.

Summary

Let me summarize this survey of the SLC by defining our two goals. We will build a new kind of machine which will make possible the continuation of particle physics research to still higher energies, and we will do the tremendously exciting physics which we think awaits us at this next step. It is a bold venture for all of us. At the same time a large part of the national and international high energy physics research community continues to depend on SLAC's linac, SPEAR, and PEP. We expect to serve them well in the years ahead and are hoping for more insight about the smallest pieces of the universe and what holds them together.

SLAC LINEAR COLLIDER ORGANIZATION

PROJECT DIRECTOR	J. REES
ADMINISTRATION	D. GETZ
PARAMETERS	H. WIEDEMANN

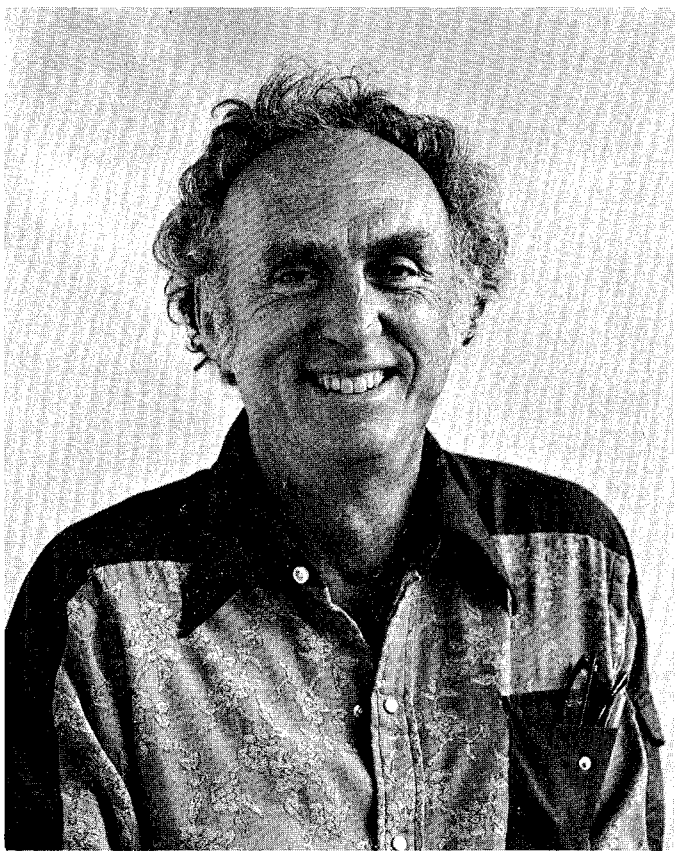


PERL, LEDERMAN AWARDED WOLF PRIZE IN PHYSICS

The Wolf Foundation has awarded its 1982 prize in physics to SLAC Professor Martin Perl for his discovery of the tau lepton at SLAC in 1975. Perl shares this year's award with Leon Lederman, the Director of Fermilab, who is being honored for discovering the fifth, or *b*, quark.

The Wolf Foundation, located in Israel, awards the prizes for " outstanding contributions on behalf of mankind ... To promote science in all fields and art in all its forms." Five prizes of $100,000 each are awarded annually in agriculture, physics, chemistry, medicine and mathematics. The official presentation of the prizes takes place at the Parliament of Israel on May 8, 1983.

Perl's discovery began with his pursuit of a class of unusual events in the original SLAC-LBL magnetic detector (the Mark I) at SPEAR. In constrast to the events with many particles which were the main interest, a few had just two tracks—an electron and a muon. This combination was so unexpected that much work went in to conventional explanations of these as background or misidentification. As the evidence grew and other methods corroborated the effect, the anomalous events were attributed to a "U" particle and then the τ (for *triton* or third) lepton.



MARTIN PERL

Leptons are one of the two kinds of particles which make up all matter, the other class being the quarks. The electron is the charged member of the first lepton family. The muon, discovered around 1935 is in a second family. Perl's tau started a third. The electron family is essential in constructing ordinary matter, but there is no understanding yet of the role of the other two families.

The laboratory held a celebration for Martin Perl in the auditorium on January 11. Perl's talk on that day is printed below. A special issue of the *Beam Line* on the discovery of the tau will be out in about two months.

THE DISCOVERY OF THE TAU

(The following informal talk was given to the SLAC staff by Martin Perl shortly after the announcement of the award of the Wolf Prize for his discovery of the tau lepton.)

I would like to review where this discovery stands in history and in contemporary research at SLAC. The first lepton, the electron, was discovered at Cambridge University in England in the 1890's using what we would today call a cathode ray tube. By today's standards the apparatus is very simple and would take a day or so to build. In all only 4 or 5 people were involved.

The second lepton, the muon, was found in an experiment with a cloud chamber at Caltech in the 1930's. This device is more sophisticated than the cathode ray tube, and shows the individual tracks of charged particles. The modern equivalent would be the bubble chamber. Perhaps 10 or 20 people were involved.

The third lepton, the tau, was discovered here at SLAC in the 1970's using a 2 mile linear accelerator, an electron-positron storage ring, and a large magnetic detector. There are 36 names on the first paper announcing the evidence for the discovery, and many more who helped in the construction of the experiment and the operation of the machines.

My part of the story began in the early 60's when I was at the University of Michigan. I received a job offer from SLAC and asked my advisors about the work out

here. California is a strange place, I was told. They work with electrons out there, and everyone else uses protons. I have always tended to do the different thing, so I came out.

Some amazing things came out of SLAC. Dick Taylor's experiments with the electron beam and hydrogen targets uncovered the quark structure of the proton. This caught most of the physics world by surprise, although work by SLAC theorist James Bjorken had anticipated it. Then storage rings came into their own as a result of work by Richter, Pief, Ritson and others on campus.

Richter had the idea of building a large general purpose detector to use at the storage ring SPEAR. Everyone else thought that smaller, special purpose detectors would be better. Again, I stayed away from the crowd and decided to work with the big detector. The names that come to mind in building that experiment are Bill Davies-White, Roy Schwitters, and Marty Breidenbach. The ψ was found; Gerson Goldhaber found a charmed meson; Gail Hanson found jets.

By now everyone was looking carefully at the complicated events coming out of SPEAR. So, I decided to look at the simple ones— the two track events. We found the anomalous events with an electron and a muon, but there were backgrounds to check. We used a system designed by Gary Feldman to check for the chief suspect for background and found that it was not the source of our events.

We published these results, but were not yet convinced that this was something brand new. We noted simply that "We have no conventional explanation for these events." And, as the last sentence: "A possible explanation for these events is the production and decay of a pair of new particles, each having a mass in the range of 1.6 to 2.0 GeV/c^2." I recall that it took longer to agree on that sentence than to write the whole paper. That last sentence turned out to be right, and by 1978 there was a list of other experiments that had found this tau lepton.

What now? We have built at SLAC a series of machines: the linac itself, SPEAR, PEP, and now the SLC is coming. PEP is running extremely well with high luminosity. One of the pieces of physics from PEP is the measurement of the lifetime of the tau lepton, using now some nice apparatus made by John Jaros. PEP has many things to offer yet. Are there more leptons? Are there *neutral* leptons? Some of these questions will be easier to answer at higher energy with the SLC. So we will continue in this new direction with a machine which is different from anyone else's. It's a tradition I enjoy.

NEW PEP LUMINOSITY RECORD

PEP posted its highest luminosity in mid-January as a result of trying a new operating point for the machine. The luminosity (which measures how many events the experiments get in a run) is nearly twice the best performance achieved last year. PEP can hope to accumulate more integrated luminosity during the current run than recorded by any colliding beam installation in the world in any one year.

The increase was not just good luck. During the last summer shutdown the second of a pair of quadrupole magnets which help focus the PEP beams into the interaction region was moved closer to the collision point. Two magnets for each of the six interaction regions had to be moved as part of this "mini-beta" project. The idea is that moving these focusing magnets, or lenses, closer to the focus would squeeze the beams to a smaller spot and increase the collision rate. A similar project the year before had moved the first of the quadrupole pair in, but the results were disappointing. It appeared that both quads had to be moved to do the job. When PEP turned on again this fall, it matched the acceptable performance achieved last year but gave no big dividends for the summer's work. There were still some other changes needed.

As the beam circulates in a storage ring it wobbles around the true center line in response to the focusing action of the quadrupole magnets. The number of wobbles per complete turn is called the tune of the machine and is the chief adjustment in running a storage ring. There are separate tune numbers for wobbles up-and-down around the beamline (the vertical tune) and for wobbles back-and-forth (the horizontal tune). PEP's tunes are numbers around 20. The natural thing to try after any big change would be to vary the tune. Unfortunately, it takes time to try each new tune, and that time cannot be used by the experimenters. Moreover, the two tunes must be picked separately so the number of combinations is very large. But there was another project going on that would help.

A CERN computer program was adapted to trace beam particles through a mathematical equivalent of the PEP storage ring. The program was run on the PEP control computer during the summer when it was idle. The program is complicated and slow and it takes a weekend of computer time to make one graph, but that beats using PEP itself. The program indicated that with the new quad positions PEP would run better at lower tunes. The new tunes were tried and the machine worked even better than the program had predicted. This success is particularly sweet for it provides a tool which can be used for getting more understanding of the storage ring in the future.

NEWS & EVENTS...

SUNDAY FLICKS

- Mem Aud at 7:00pm and 9:30pm $1.50
- Feb.13 A Midsummer Night's Sex Comedy
- Feb.20 Fast Times at Ridgemont High
- Feb.27 Author, Author
- Mar. 6 Diamonds are Forever

MUSIC AT STANFORD

- Tues., Feb. 15., Stanford Chorale, Mem Chu, 8:00pm $4.00
- Fri., Feb. 18., Stanford Chamber Orch., Dinkelspiel Aud, 8:00pm $4.00
- Sat., Feb. 26., Stanford Symphony Orch., Dinkelspiel Aud, 8:00pm $4.00
- Fri., Mar. 4., Stanford Chorus, Bach's St. John Passion, Mem Chu, 8:00pm $4.00 (also Sun., Mar. 6)

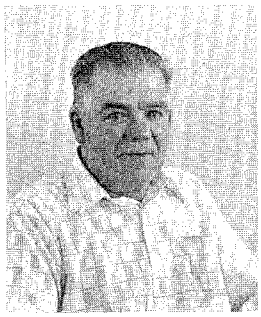
DRAMA AT STANFORD

- Feb. 16-19, 23-26.. Euripides, "The Cyclops", Little Theater, 8:00pm $4.00

VARSITY BASKETBALL

- Maples Pavilion at 8:00pm $5.00 or $6.00
- Feb. 7 Arizona State
- Feb.12 Cal
- Feb.24 Washington State
- Feb.26 Washington

RECENT RETIREES



Hardy Bowden from Mechanical Fabrication Precision Assembly came to SLAC in Oct. 1961.

Carl Dubbert, a mechanic with the Mechanical Utilities Group had been at SLAC since Nov 1968.

BAY-TO-BREAKERS' ACCELERATOR

There is a movement *afoot* to create a centipede entry for the 72nd running of the Bay-to-Breakers race in San Francisco. It is hoped that we can simulate a linear accelerator.

Centipede entries are groups of runners linked together to create a design idea (something like a float in a parade). Examples from last year's race: the Golden Gate Bridge, 10 pins and a bowling ball, a BART train.

Any SLAC person wanting to run is welcome and anyone wanting to help with the design is also welcome. Please call Bob Gex, x2411 or Ken Witthaus, x2468.

NEW ASSISTANT ACCOUNTING OFFICER

Chris Ferrari

LBL COURIER SERVICE

The LBL courier service operation will now be located in the SLAC mail room. The weekly pickup and delivery day will remain Monday. Please send all mail destined for LBL to the Mailroom.

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