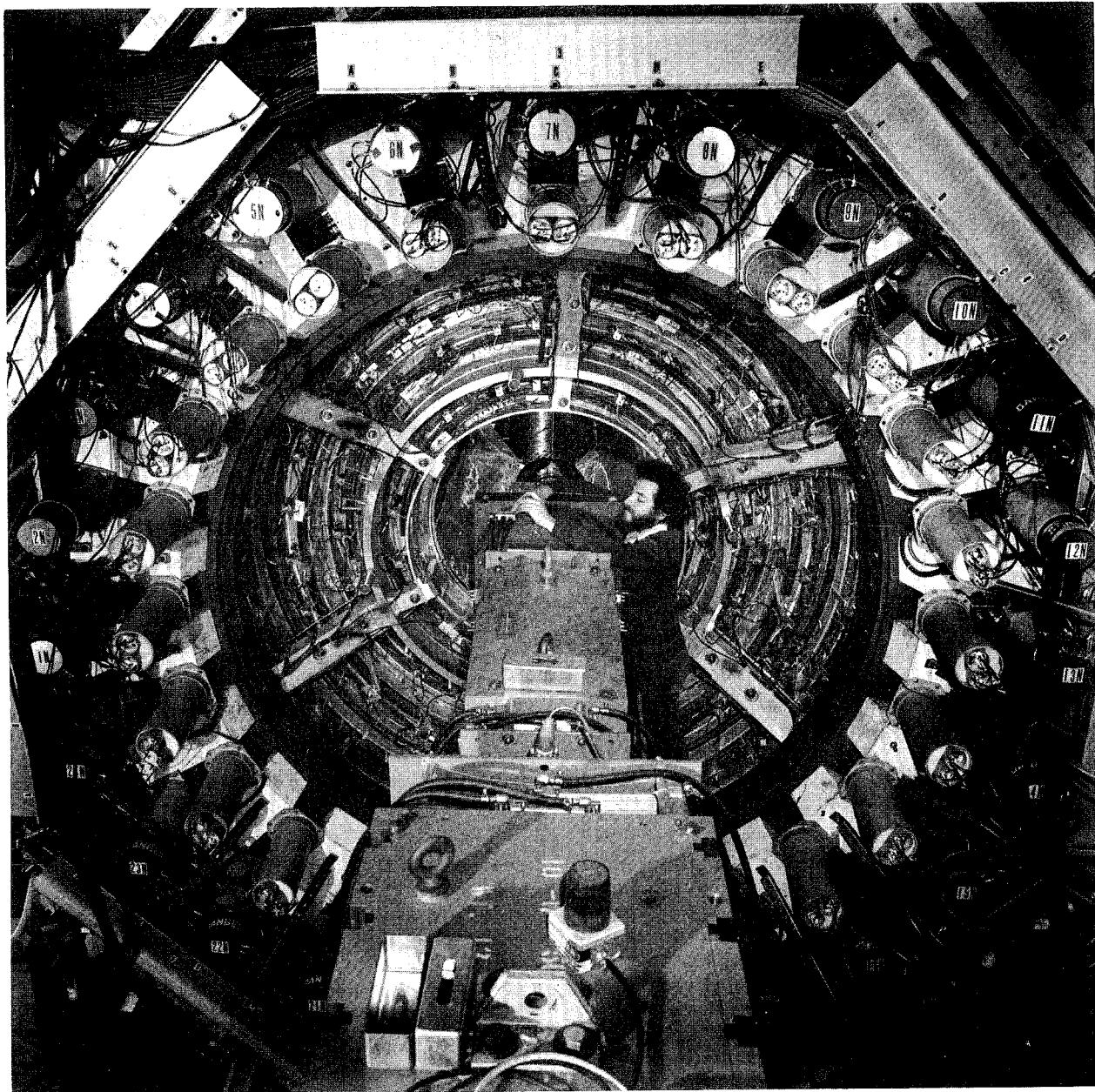


# SLAC BEAM LINE

"There are therefore Agents in Nature able to make the Particles of Bodies stick together by very strong Attractions. And it is the Business of experimental Philosophy to find them out." Isaac Newton, Opticks (1704)

Volume 7, Number 6

June 1976



Walter Zawojski's photo of the SPEAR Mark I magnetic detector shown above (with LBL physicist Carl Friedberg) was chosen for this month's cover for two reasons. The first reason is that a new SPEAR detector, the Mark II, is described on pages S-1 through S-4 of this issue. The second reason you can probably guess--yes, the SLAC-LBL experimental group at SPEAR has again come up with some remarkable new physics results. See pages 2-3 for a brief report.

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# Charmed Particles

[Note: The following information was prepared for release to news media on June 8.]

LAWRENCE BERKELEY LABORATORY  
UNIVERSITY OF CALIFORNIA

STANFORD LINEAR ACCELERATOR CENTER  
STANFORD UNIVERSITY

A new subatomic particle believed to be the long-sought "charmed" particle has been found by a group of physicists at the University of California's Lawrence Berkeley Laboratory (LBL) and the Stanford Linear Accelerator Center (SLAC).

Evidence for the existence of the new particle was obtained in an experiment performed over the past two years at SLAC's electron-positron colliding beam storage ring called SPEAR.

The new particle, not yet named by the physicists, has a large mass (nearly twice that of the proton, the nucleus of the hydrogen atom) and lives for a relatively long time before decaying into lighter, more common particles.

These properties, and the manner of its decay, suggest that it is a member of an entirely new family of subatomic particles known as "charmed" particles. Charmed particles have been predicted theoretically but, until now, none has been isolated.

Charm is believed to be a new property of matter, analogous to electric charge. Until all of the properties of the newly discovered particle have been measured, the scientists cannot definitely establish it as the charmed particle predicted by theory. But the observations clearly establish a particle with a new property--whether or not it turns out to be identical to the predicted charm.

Previous indications for the existence of charmed particles have come from experiments performed at the Brookhaven National Laboratory in New York, the CERN Laboratory near Geneva, Switzerland, and the Fermi National Accelerator Laboratory near Chicago. These experiments, all involving beams of neutrinos, showed many of the features expected of charmed particles, but have not established their masses or decay modes. [See "Neutrino experiments may point toward charm" in the April 1976 *Beam Line* for a description of these neutrino experiments.]

In the LBL/SLAC experiments, beams of electrons are made to collide head-on with their antiparticles, positrons. In the ensuing collision, the electron and positron annihilate each other to form a state of pure energy. Out of this energy, particles of matter are created in various combinations, subject only to well-known laws of physics.

For example, the total mass of these particles cannot exceed the energy available from the annihilating electron and positron, and their net electric charge must be zero. The particles then fly away from the interaction point and are recorded by the experimental detection apparatus. In this way, properties of subatomic particles can be studied under controlled conditions. Many of these particles are hadrons, the class of subatomic particles involved in the nuclear binding force known as the strong interaction.

About a year ago, it was observed that when the energy of SPEAR was raised above 4 GeV (1 GeV equals one billion electron volts), the rate of producing hadrons was seen to increase markedly. This increase has been widely interpreted as reflecting the production of pairs of new hadrons and their antiparticles, each with a mass near 2 GeV, which would decay into already well-established types of particles.

Unfortunately, preliminary searches to pinpoint the nature and properties of such new particles by the LBL/SLAC team were unsuccessful. Searches at other laboratories using different methods also remained inconclusive.

When more data became available, physicists Gerson Goldhaber and Francois Pierre, both of the LBL group, again looked for evidence of new particles, using a method which improved the sensitivity of the search. This time, out of 24,000 examples of electron-positron annihilations resulting in hadrons, they found approximately 100 cases showing clear evidence of the brief existence of the new particle, with a mass of 1.86 GeV, and its decay into two familiar hadrons.

They alerted their colleagues, and other team members joined in the effort to establish the properties of the new particle. In short order, a second type of decay, leading to a final state of four hadrons, was also observed, and a great many checks were performed to insure that the effect was real and not some artifact of the apparatus.

Word of this discovery was passed rapidly through the community of high energy physics, and other groups around the world are also looking for the new particle.

If the new particle is definitely shown to be "charmed," it will represent the first time in more than 25 years that a fundamental new property of strongly interacting matter . . . has been identified. The last instance was in the early fifties, when a long series of experiments and discoveries led to the introduction of a new physical quantity called "strangeness."

Strangeness, like charm, is not manifested by matter under ordinary conditions on earth; both are directly observed only in matter that has been excited to very high energies. It is believed, however, that strangeness, charm, and perhaps other new properties yet to be discovered, play an important part in the basic nature of matter.

The definite establishment of charm would also represent a dramatic success for the quark theory of matter. In this theory, all hadrons (there are several hundred known at present) are thought to be built out of combinations of more fundamental constituents known as quarks.

Quarks were originally invented in the early 1960's by Murray Gell-Mann and George Zweig, both of Caltech. In their theory, only three kinds of quarks (one carrying strangeness) were necessary to account for all of the hadrons known at that time.

In 1964, Sheldon Glashow of Harvard and J. D. Bjorken of SLAC proposed a fourth quark, the charmed quark, on theoretical grounds. Subsequently, Glashow and co-workers developed this charmed-quark theory to explain various problems inherent in the older theory.

No one has ever observed an isolated quark. Nevertheless, patterns among the hadrons strongly suggest an underlying quark structure.

High energy physics has been in a ferment ever since the discovery of another kind of particle, the psi/J, almost two years ago. The discovery of the psi/J, by the same LBL/SLAC team and independently by a team from Brookhaven National Laboratory and MIT, was interpreted as evidence in favor of the charmed-quark hypothesis. It set off a world-wide search for other phenomena that might help in understanding the new discoveries.

The discovery of another psi and related particles by the LBL/SLAC group and by other groups working at the DORIS storage ring of the DESY laboratory near Hamburg, Germany, also supported the notion of charmed quarks. Other hypotheses besides the charm theory were also advanced as a result of the psi/J discoveries.

In the charmed-quark theory, the psi particles and their relatives, known collectively as psions, are thought to be formed from a charmed quark and its own antiquark, which are bound together. This combination does not actually exhibit charm directly, since the quark and antiquark cancel each other in this respect. But if the theory is correct, then it must be possible to bind the charmed quark not only with its own antiquark but also with one or more of the other three quarks--and it is these combinations that would actually exhibit charm.

This is precisely what the new particle appears to be--the electrically neutral combination

of a charmed quark with an antiquark of the original three: a charmed particle. Thus the new discovery strongly bolsters the appeal of the charm theory over competing theories.

Much experimental work remains to be done to prove beyond all doubt that this new particle is indeed "charmed," or, if it is not, how it differs from the charm conjecture. Additional kinds of charmed particles, both electrically charged and neutral, are also expected to be present, and must be observed in order to confirm the theory. At present, there is great excitement among physicists over the new discoveries and a feeling of hope that they are on the verge of a profound understanding of what was thought only two years ago to be the chaotic world of subnuclear particles.

The team of scientists involved in the discovery includes members from the Lawrence Berkeley Laboratory, the University of California Physics Department, and the Stanford Linear Accelerator Center. Gerson Goldhaber is a professor of physics at UC and a group leader at LBL. Francois Pierre, currently a member of the LBL team, is on leave from the Departement de Physique des Particules Elémentaires, Saclay, France.

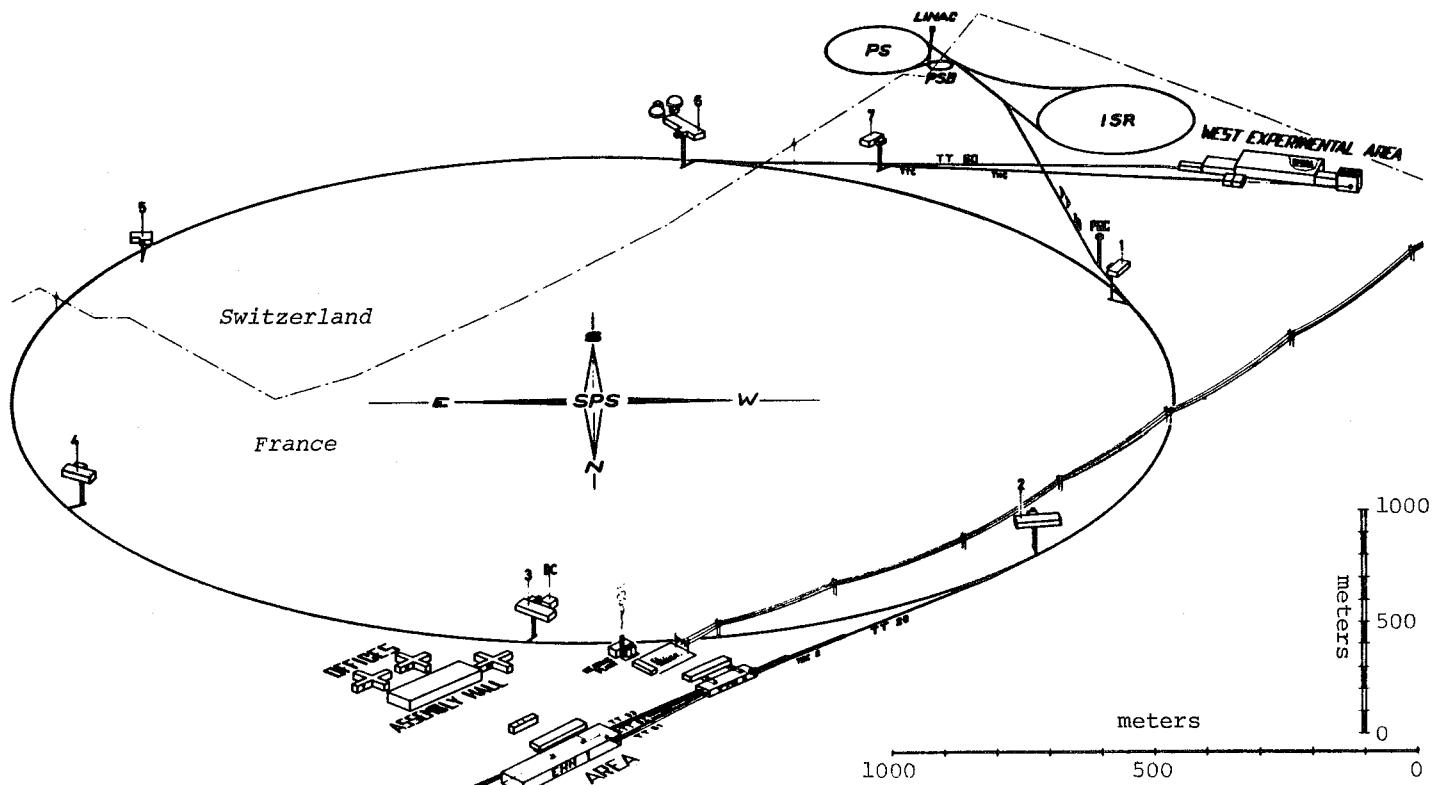
The other team members are G. S. Abrams, W. C. Carithers, W. Chinowsky, S. C. Cooper, R. G. DeVoe, C. E. Friedberg, A. D. Johnson, J. A. Kadyk, R. J. Madaras, H. K. Nguyen, P. Sadoulet, G. H. Trilling, J. S. Whitaker, F. C. Winkelmann and J. E. Wiss of LBL; and S. Alam, A. M. Boyarski, M. Briedenbach, J. Dorfan, G. J. Feldman, G. E. Fischer, D. Fryberger, G. Hansson, J. Jaros, B. Jean-Marie, R. R. Larsen, D. Lüke, V. Lüth, H. L. Lynch, C. C. Morehouse, J. M. Paterson, M. L. Perl, I. Peruzzi, M. Piccolo, T. P. Pun, P. Rapidis, B. Richter, R. Schindler, R. F. Schwitters, J. Siegrist, W. Tanenbaum and F. Vannucci of SLAC [Experimental Groups C & E].

#### Editor's Notes:

1. We hope to have a *Beam Line* article on this new discovery ready within the next month or two.

2. There is a second major new physics development presently brewing at SPEAR: continuing analysis of the so-called "mu-e" events seems to be converging upon the interpretation that they are caused by another new kind of particle, a heavy lepton. This work will also be described in a coming *Beam Line* article.

3. Much of the background information needed to understand what is happening at SPEAR is contained in the article "More New Particles," which appeared in the October & November 1975 *Beam Line*. Copies of this article are available from Bill Kirk, Bin 80.



#### CERN SPS NEARS COMPLETION

The Super Proton Synchrotron (SPS) at the CERN laboratory in Geneva will soon come into operation as the highest energy accelerator in Europe. Similar in size and general design to the Fermilab proton accelerator near Chicago, it will be able to reach beam energies up to about

400 GeV. Construction of the SPS is now nearly completed. Early last month (May 3), a beam of protons was successfully guided around the full 6900-meter (about 4.3-mile) circumference of the machine for the first time.

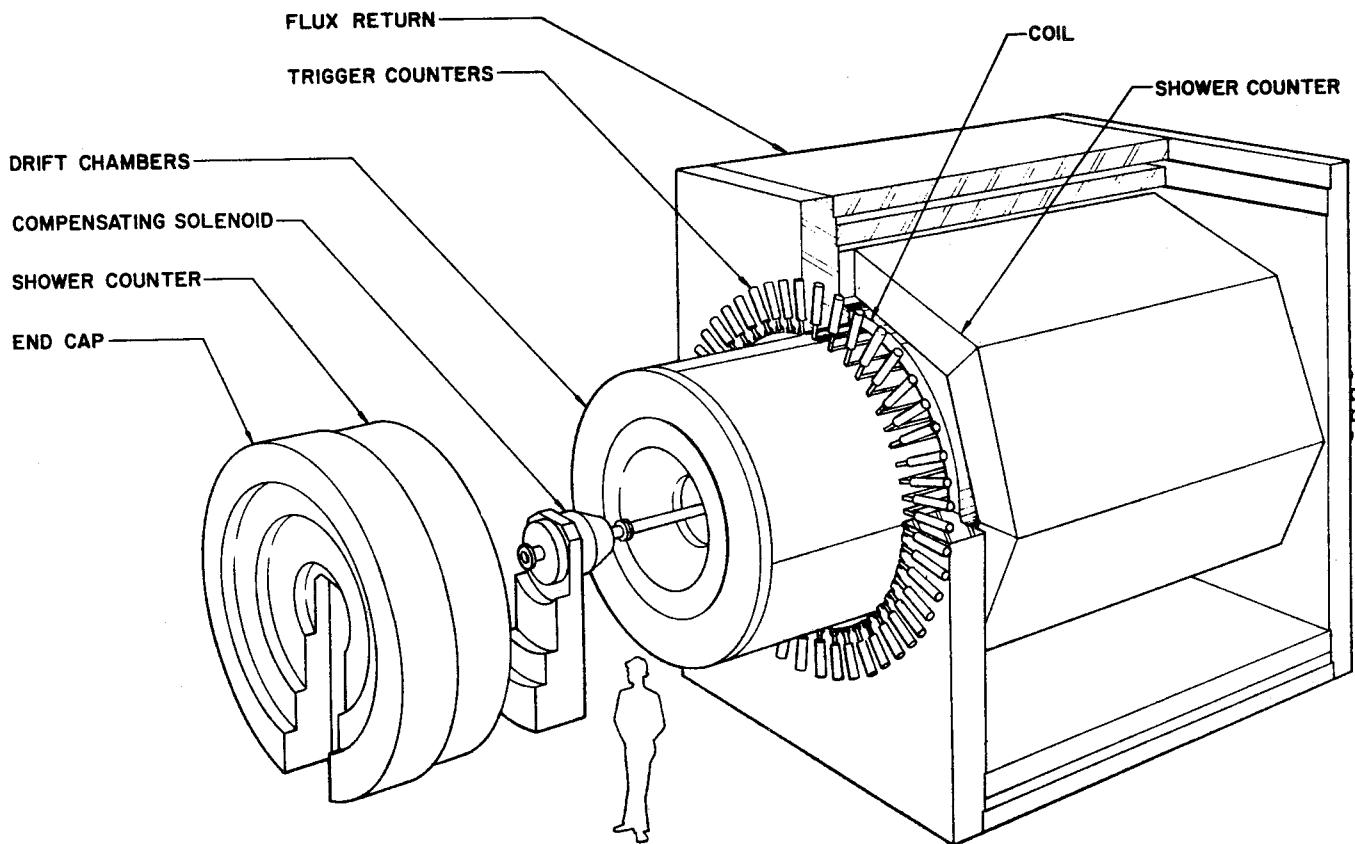
As shown in the sketch, there will be two main experimental areas (North and West) where primary and secondary beams from the SPS will be used with various experimental detection devices. The older PS machine at CERN (28 GeV) will act as an injector into the SPS accelerator--a role it also fills for the ISR storage rings.

#### TEN YEARS OF BEAM AT SLAC

On May 21, 1966, at about 4:00 AM, an electron beam was accelerated through the full 10,000-foot length of the SLAC linear accelerator for the first time. The photograph shown here was taken shortly after this historic event had occurred. (The Beatles were very big in those days, so someone decided to add a few Beatle haircuts, a guitar, and a piano keyboard to the original photo.) Those shown in the photo are, from left to right, standing, "Pieff" Panofsky, Gary Warren, Donn Robbins, Dick Neal, Jim Bjorken and Ken Crook; from left to right, seated, Matt Sands, Greg Loew, (don't know) and Dieter Walz. It seems like only yesterday.



# SPEAR MARK II MAGNETIC DETECTOR



The remarkable physics discoveries of the past few years at the SPEAR storage ring at SLAC have stimulated a desire to study the electron-positron ( $e^-e^+$ ) annihilation process with higher precision, and to ask new experimental questions that the present Mark I Magnetic Detector at SPEAR was not designed to answer. A new device, called the Mark II Detector Facility, is therefore now being built by members of the continuing collaboration between SLAC and the Lawrence Berkeley Laboratory (LBL). The Mark II Facility will incorporate several interesting new detector technologies that will make it superior to the Mark I in a number of respects, and also more versatile in its ability to accommodate outboard (or "hung on") experiments.

An ideal detector for an  $e^+e^-$  storage ring would be able to measure with high precision both the energies of and the paths followed by all of the particles that emerge from the interaction region. This would include both neutral and electrically charged particles. Such a device would also be able to identify unambiguously each particle by type--electron, muon, pion, or whatever. Although no practical device can fulfill these ideal requirements perfectly,

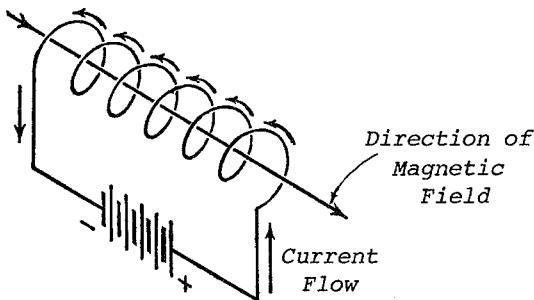
the Mark II will be a significant step forward toward that goal.

In the following sections we shall give a brief description of each of the main components that make up the complete Mark II Facility, along with an explanation of how each component plays its part in the measurement of particle energy, path determination, or particle identification. Each of these main components is pointed out in the telescoped drawing of the Mark II that appears on this page.

## 1. MAGNET

The momentum of an electrically charged particle can be measured by tracking the path followed by the particle as it is deflected by a magnetic field. In both the old Mark I and the new Mark II Detectors the form of the magnetic field is a *solenoid*--that is, a cylindrical coil of wires which produces a magnetic field that is directed along the axis of the cylinder. (See sketch on next page.) The coil for the Mark II magnet will be made of aluminum conductor and will be about 3 meters in diameter and 3 meters long. Within the volume of this solenoid there will be a magnetic field of about 4000

gauss--nearly the same field strength as the Mark I. The magnetic flux return path for the new magnet consists of the two large steel end plates and the double slabs of steel at both the top and bottom of the magnet.



This sketch illustrates a basic solenoidal magnetic field, in which a flow of current through a cylindrical coil of wire produces a magnetic field directed along the axis of the cylinder.

The Mark II magnet design is more open and flexible than that of the present Mark I, as can be seen by comparing the Mark II drawing on the previous page with the similar telescoped view of the Mark I that is shown below. With the new Mark II there will be much greater latitude in mounting subsidiary pieces of detection apparatus to be used in conjunction with the main detector.

Since the direction of the magnetic field in the Mark II solenoid is parallel to the direction traveled by the circulating electron and positron beams, these beams would not, in prin-

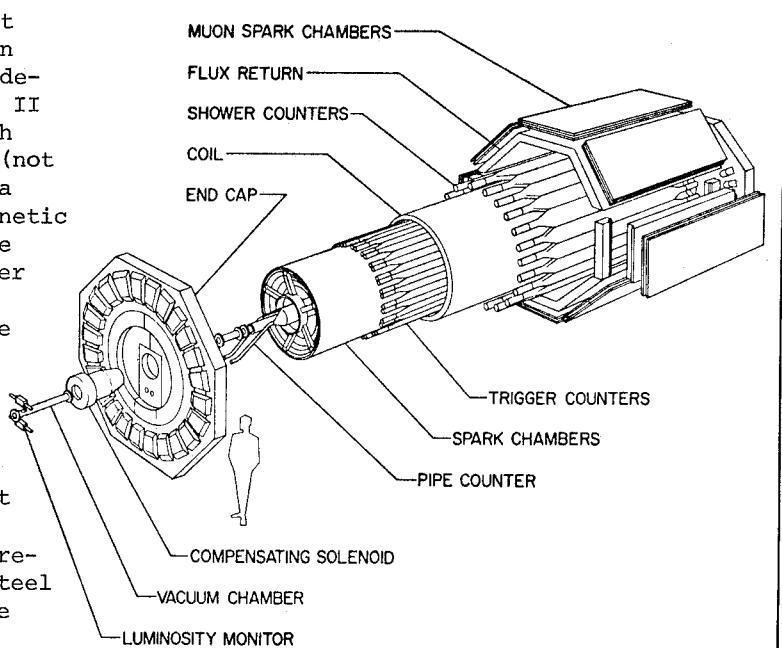
ciple, be deflected away from their stable orbits in passing through the solenoid. In practice, however, the beam paths will not coincide exactly with the magnetic axis of the solenoid; and for this reason it is necessary to use a pair of small compensating solenoids at the ends of the larger magnet to assure stability of the circulating beams.

## 2. DRIFT CHAMBERS

The circulating  $e^+$  and  $e^-$  beams in SPEAR pass through the detector within the confines of an evacuated beam pipe that is a few inches in diameter. When an  $e^+e^-$  collision of interest occurs, the scattered or newly created particles from this interaction penetrate through the thin walls of the vacuum pipe and enter a region that is filled with a series of drift chambers that are arranged in successive cylindrical layers. These drift chambers are designed to track the trajectories of any charged particles that pass through them, and they accomplish this task in the following way.

A typical drift chamber cell is a few centimeters across, and each cell has a fine wire running down through its center. The chambers are filled with a special kind of gas, and a voltage is applied to the center wires of each chamber cell. When an electrically charged particle passes through a cell, it ionizes some of the gas molecules along its path. (Ionization is the process by which one or more electrons are knocked loose from their parent atom, thus leaving the atom--now an ion--with a net positive charge.) After the particle has passed through a cell, it takes a certain amount of time for the ions to drift to, and be collected

This telescoped drawing of the present Mark I Magnetic Detector at SPEAR is shown here for comparison with the new Mark II design. In gross size, the Mark I and Mark II are roughly comparable. In addition, both use solenoidal magnets with conventional (not superconducting) coils, and both produce a field of about 4 kilogauss within the magnetic volume. The major differences between the Mark I and Mark II are (1) the use of newer particle-detection devices such as liquid argon counters in the Mark II; and (2) the more open construction pattern of the Mark II magnet, which should make it a good deal more versatile than the Mark I in the kinds of experimental configurations that can be achieved. This latter advantage comes largely from the fact that the magnetic flux return path is confined to top and bottom double steel slabs, whereas in the Mark I design only 2 of the 8 steel flux-return slabs could be removed to make room for additional detection equipment.



by, the central wires. The drift chamber determines the position of the particle by measuring the time interval between the passage of the particle and the arrival of the ions at the central wire. Because the interval measurement is quite precise, the position of the particle can be pinned down to within a distance of about 200 micrometers ( $\approx .01$  inch).

The drift chamber wires are arranged in concentric cylindrical layers, as noted, with the wires in some of the layers canted at a small angle to allow stereo measurement of the particle-track coordinates. With the excellent spatial resolution that can be achieved by this technique, the reconstructed particle track can be used to determine the particle's momentum to an accuracy of about 1%. For example, the momentum of a 1 GeV/c particle can be resolved to within about 10 MeV/c.

#### Trigger Improvement

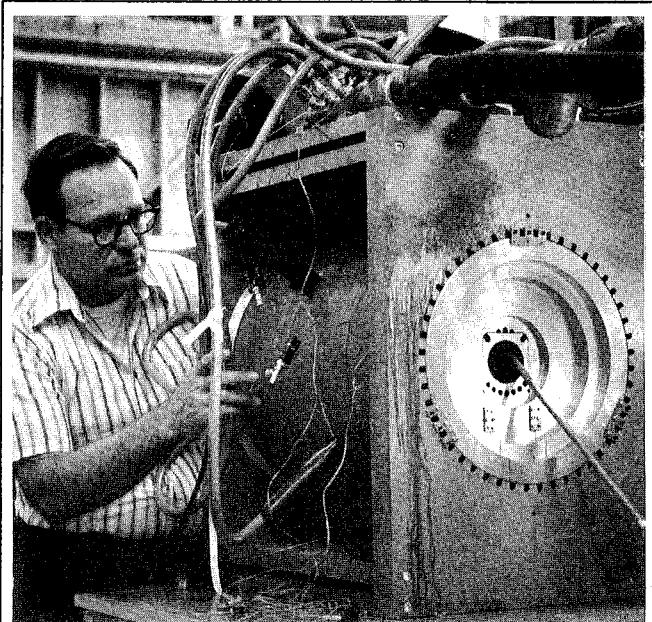
The function served in the Mark II Facility by the drift chambers was handled in the Mark I by magnetostrictive spark chambers, which are pulsed-operation rather than continuous devices. The change to the newer, continuous drift chambers will make it possible to design a more effective "trigger" system for the Mark II. (The trigger system in an experiment makes use of information from various particle-detection devices to decide very rapidly whether or not a particular interaction or "event" is interesting enough to be recorded. The means of recording can be logging data into a computer, or taking a bubble chamber photograph, etc.) With the Mark II Facility, the trigger decision will be divided into two parts or tiers:

1. The first tier will consist of very loose criteria for events of possible interest, such as the crossing of the  $e^+$  and  $e^-$  beams plus detection of at least one "hit" in the drift chambers. Such a simple scheme provides a preliminary, unbiased trigger for the class of events that is of major interest at SPEAR,

$$e^+ + e^- \rightarrow \text{hadrons} (\pi, K, p, \psi, \text{etc.})$$

but from previous experience it is clear that most of the events that are selected on this simple basis will not be interesting (beam scattering from gas molecules in the vacuum system, or Bremsstrahlung radiation from the beam particles, etc.) This first, loose trigger will likely pass event-candidates through at a rate of several thousand per second.

2. In order to cut the rate of events from the simple, first-tier trigger to a manageable level, the second-tier logic will monitor six layers of drift-chamber cells in order to decide--within 30 microseconds--whether at least one full-fledged, valid track appeared in the detector. If the answer is "yes," then that



Wayne Shetler of SLAC's Magnet Assembly Shop is shown here with the 1/8 scale model of the Mark II magnet that was built to test out the properties of magnetic-field symmetry, iron saturation, and leakage-field distribution for this design. (Photo by Joe Faust.)

particular event will be recorded by reading the data into a computer. Such valid tracks are likely to be found at SPEAR at a rate of something like 1 to 10 per second.

#### 3. SCINTILLATION COUNTERS

The kinds of strongly interacting particles (hadrons) that turn up most frequently in the  $e^+e^-$  annihilation process at SPEAR are  $\pi$ - and  $K$ -mesons and protons. Those which are electrically charged ( $\pi^+, \pi^-, K^+, K^-, p, \bar{p}$ ) will be identified in the Mark II Facility by an array of 48 scintillation counters which measure the time-of-flight of a particle from the interaction region to the counter. (These scintillation counters are called "trigger counters" in the drawings on pages 1 and 2.) This time-of-flight naturally depends on the velocity with which the particle is traveling. Information on the particle's velocity can be combined with the information on momentum that was obtained in the drift chambers to determine the particle's mass:

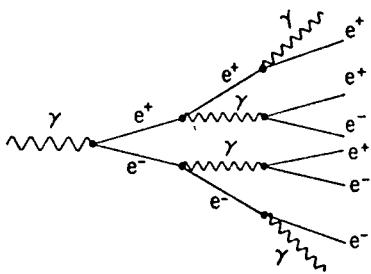
$$\text{mass} = \text{momentum} / \text{velocity}$$

Thus measurement of both velocity and momentum for each particle track determines the mass of the particle and therefore its identification.

#### 4. LEAD/LIQUID ARGON SHOWER COUNTERS

The regions outside of the magnet coil and at the ends of the magnet in the Mark II Facility will be occupied by a new kind of device for

detecting electromagnetic radiation called a lead/liquid argon shower counter. There will eventually be 10 such counters on the Mark II: 8 arranged in the form of a cylinder around and outside the magnet coil, and 2 located just inside the two end caps of the magnet. The counters themselves consist of 2-mm-thick layers of lead arranged in strips and separated by gaps that are filled with liquid argon at a temperature of about 85° K. When gamma rays ( $\gamma$ ) or electrons ( $e^-$ ) or positrons ( $e^+$ ) of high energy enter the counter, they strike the lead strips and produce a cascade of new radiation and  $e^+e^-$  pairs that is called an electromagnetic "shower" --like this:



These shower particles then pass into the liquid argon, where they ionize some of the argon atoms that lie in their path. The ions are then collected on the lead strips by an applied high voltage.

The amount of ionization that is collected by the lead strips is directly proportional to the energy of the particle or gamma ray that initiated the shower, and thus gives a measure of that energy. The accuracy with which this incoming energy can be measured in lead/liquid argon counters is expressed in the following peculiar way:

$$\frac{9\%}{\sqrt{\text{Energy in GeV}}}$$

As an example, let's take a 4 GeV particle:

$$\frac{9\%}{\sqrt{4}} = \frac{9\%}{2} = 4\frac{1}{2}\%$$

So the energy of a 4 GeV particle can be measured, or resolved, to within about 4½% or about 180 MeV. This energy resolution is actually not as good as that obtainable with such other materials as sodium iodide crystals or special leaded glass, but cost is also an important factor when such large areas have to be covered. The lead/liquid argon counters planned for the Mark II Facility will cost about 30% as much as a comparable lead-glass installation.

One of the important virtues of the lead/liquid argon technique is that it permits detailed observation of the spatial characteristics of electromagnetic showers. At the front of the device, the shower spreads radially over several of the lead strips, which allows a measurement

of the point where the initiating particle or gamma ray entered the counter with an accuracy of only a few millimeters. This property will make these counters particularly valuable in reconstructing the masses of particles that decay by emitting a gamma-ray photon. This includes not only the mundane types such as  $\pi^0$  but also those of exceptional interest such as the several  $\chi$  (chi) states that have been discovered recently with masses between the  $\psi$  and  $\psi'$ .

It should also be possible with the lead/liquid argon counters to detect the differences in penetration characteristics between electromagnetic showers and the "hadronic" showers produced by pions, protons, etc. Such differences are another handle that can be used in distinguishing  $e^+$  and  $e^-$  from hadrons, and may prove very useful in isolating the so-called "U" particles or in searching for direct lepton production in  $e^+e^-$  annihilation at SPEAR.

## 5. MUON COUNTERS

Muons ( $\mu^+$  and  $\mu^-$ ) can be thought of simply as "heavy electrons," and it is important to be able to distinguish muons from hadrons for exactly the same reasons as given above. Muon identification techniques take advantage of the fact that muons are able to penetrate into matter much more deeply than either electrons or hadrons before being stopped. The top and bottom sides of the Mark II detector will incorporate muon counters that will consist of long, triangular-shaped proportional tubes interleaved with large slabs of steel. (These muon counters are not shown in the Mark II figures used here.) The large steel slabs are in fact the flux-return paths for the Mark II magnet that we discussed earlier. The proportional-counter tubes will fit into the slots between the top and bottom double slabs, and also above and below the outer slabs. A similar array of steel and tube counters will be mounted vertically against the open sides of the magnet and carried on rails so that they can be moved to allow access to the central sections of the detector. The steel thickness is such that any particle which penetrates through to the outside counters can be identified as a muon with a high degree of certainty.

## 6. SCHEDULE & SUMMARY

The Mark II Facility will be installed at SPEAR during the late summer and early fall of 1977. Its merits, in brief, are its extended solid-angle coverage, improved triggering, better momentum analysis of charged particles, ability to measure accurately the energy and direction of gamma rays, and improved lepton-hadron discrimination. With these things going for it, the Mark II should be able to answer some of the tantalizing questions that have been raised by the pioneering experiments with the Mark I, and perhaps also to pose a few new ones of its own.

--Dave Hitlin

## GROUP MEETS IN USSR ON VERY BIG ACCELERATOR

[Reprinted from *Physics Today*, May 1976]

This month, beginning on 17 May, an international study group will meet in Serpukhov in the Soviet Union to discuss the prospects and possibilities of constructing a "Very Big Accelerator" by a world collaboration among many different countries. It would be a machine with much higher energy than any accelerator being planned by an individual nation.

In March 1975 a meeting was held in New Orleans, attended by about 25 physicists from the US, Western Europe, the Soviet Union and Japan, to discuss various forms of international collaboration. The future development of high energy physics was discussed, and many participants emphasized the desirability of extending the energy frontier beyond the limits presently available or recently proposed. Many fundamental problems seem to require this extension for their solution, such as the question of the existence of a quantum of the weak interaction, the relation between the weak and electromagnetic interaction, and problems related to the quark hypothesis.

Many believe that national and regional authorities may no longer be willing to support projects that are considerably larger than those presently in existence or in the planning stage. Thus the Very Big Accelerator is being discussed.

At the meeting this month in Serpukhov, the American participants are expected to be J. D. Bjorken (SLAC), Robert E. Diebold (Argonne National Laboratory), Leon Lederman (Columbia University), Wolfgang K. H. Panofsky (SLAC)\*, Victor Weisskopf (MIT) and Robert R. Wilson (Fermi National Accelerator Laboratory).

The international group will consider the possibility of building a proton accelerator of the order of 10 TeV [a beam energy about 500 times that of the SLAC accelerator] or an electron-positron colliding beam device with each beam of about 100 GeV. Weisskopf emphasized to us that much of the discussion will probably focus on the best choice for an instrument and an energy range. To that end, the group is expected to consider the physics problems requiring higher energy and the numerous technical problems of achieving it.

"A world collaboration on the Very Big Accelerator," Weisskopf said, "would have important significance besides the mere scientific values, as a symbol of common human values beyond competition and strife, and as an example of intensive international collaboration across ideological frontiers." The former director of CERN said that the history of that laboratory has

shown that high energy physics is very conducive to such efforts because of its distance from commercial and military applications. There are many obvious political and social difficulties and problems in the way of such a project. But, he feels, it is advisable to begin with this international study group.

Weisskopf urges that the vision of the Very Big Accelerator should not interfere in any way with further development of national or regional high-energy facilities. "Indeed," he says, any international effort can be successful only if it is based upon well-developed national and regional research activities."

ERDA and the National Science Foundation are sponsoring the American participation.

### ESCHEW OBFUSCATION

Every new physicist must learn early that it is never good taste to designate the sum of two quantities in the form

$$1 + 1 = 2 \quad (1)$$

Anyone who has made a study of advanced mathematics is aware that  $1 = \ln e$  and that  $1 = \sin^2 x + \cos^2 x$ . Furthermore,

$$2 = \sum_{n=0}^{\infty} \frac{1}{2^n}$$

Therefore, Eq. (1) can be expressed more scientifically as

$$\ln e + (\sin^2 x + \cos^2 x) = \sum_{n=0}^{\infty} \frac{1}{2^n} \quad (2)$$

This may be further simplified by use of the relations

$$1 = \cosh y (1 - \tanh^2 y)^{1/2} \quad \text{and} \quad e = \lim_{z \rightarrow 0} (1 + z^{-1})^z$$

Equation (2) may therefore be rewritten

$$\begin{aligned} \ln[\lim_{z \rightarrow 0} (1 + z^{-1})^z] + (\sin^2 x + \cos^2 x) &= \\ \sum_{n=0}^{\infty} \frac{\cosh y (1 - \tanh^2 y)^{1/2}}{2^n} & \end{aligned} \quad (3)$$

At this point, it should be obvious that Eq. (3) is much clearer and more easily understood than Eq. (1). Other methods of a similar nature could be used to clarify Eq. (1), but these are easily discovered once the reader grasps the underlying principles.

[Reprinted from the April 1976 issue of the *American Journal of Physics*, where it was adapted from the November 1974 issue of *The Ohio State Engineer*.]

\*[Professor Panofsky was unable to attend.]

### MILLS' TRAILER VACATED

The big yellow trailer behind the Central Lab is now uninhabited. Bob Mills has finally realized his long-time ambition--retirement.

Bob was born in Fresno, California, in 1920, and it was not until 1937, when he joined the Civilian Conservation Corps, that he began to consider retiring. However, with the attack on Pearl Harbor in 1941, Bob decided to postpone retirement for awhile when he enlisted in the Navy.

The Navy is quick to recognize talent when they see it, so without as much as two days spent in Boot Camp Bob was given a 2nd Class rating and shipped directly off to the South Pacific. During his tour of duty Bob distinguished himself as crew chief on anti-submarine patrol missions carried out with lighter-than-air "K" ships (260-foot-long helium-filled blimps).

After his discharge from the Navy in 1946, Bob immediately took another lofty job with the Otis Elevator Company. He also married in 1946, and he and his wife, Goldie, have recently celebrated their 30th wedding anniversary.

In 1953 Bob temporarily left the electrician trade to become a Police Officer in San Mateo County. His most dangerous assignment during the six years he spent on the force (according to him) was the apprehension of a psychotic cat.

Although Bob still maintained his life-long interest in retiring, he decided that he would prefer to retire from a more exciting job than police work, so in 1959 he joined the staff of the High Energy Physics Lab at Stanford. He moved over to SLAC in 1962, and since that time he has been plying his electrician's trade mostly on projects for the Research Division.

During Bob's 16 years at Stanford, he has been responsible for the installation and maintenance of a vast variety of electrical systems



Goldie and Bob Mills. (Photo by Earl Hoyt.)

and equipment. On many occasions he has also found the spare time to help out with the installation and improvement of the wiring systems in the homes of many different SLAC employees. Many of us will continue to call on Bob when we need assistance with wiring problems. However, it's a good bet that Bob and Goldie will not let these electrical jobs interfere too seriously with their principal avocation--fishing.

Bob and Goldie will be at Clear Lake until mid-June, and after that they will move into the Sierra to fish the Truckee, Hope Valley and Blue Lakes regions. In August and September of this year they will try their luck on some of the fine fishing waters in Canada.

Bob's many friends at SLAC wish him and Goldie a very happy retirement, with lots of good fishing. They planned it that way, and it will certainly be well deserved.

--Earl Hoyt

### HOGANAUER AND MINOR JOIN LOAN COMMITTEE

Gloria Hoganauer, Data Analysis, and Joan Minor, Personnel, were recently appointed to the SLAC Emergency Credit Committee (SELCC) as replacements for Frankie McLaughlin and Ken Stewart.

The SELCC helps SLAC people to obtain loans from the Stanford Federal Credit Union when both of the following conditions exist:

1. The employee has an emergency financial problem.

From Ghoulies and Ghosties and Longlegged Beasties and things that go Bump in the Night, Good Lord deliver us. [From an old Scottish Litany.]

2. The Credit Union has already rejected a loan request for that problem.

With the new appointments, the present membership of the committee is:

Louise Duffy, Experimental Facil. Dept.  
Bob Gex, Library  
Roque Hilomen, Plant Office  
Gloria Hoganauer, Data Analysis  
Joan Minor, Personnel

### CREF UNIT VALUES

Dec. 1975	\$36.44	Feb. 1976	\$39.76
Jan. 1976	40.31	Mar. 1976	\$40.75

## PHYSICISTS VS. MATHEMATICIANS: A THEORY OF GROUPS

[This article is reprinted from *Science News*, Volume 109, page 110, March 1976.]

To the casual leafer through the literature, mathematicians and physicists often look like similar breeds of cat. They use many of the same words. Their publications are full of similar arrays of arcane symbolism that often come in several layers and use up all the letters of the Latin and Greek alphabets and some of the Hebrew and Cyrillic as well. Mathematics is the language of physics, and every physicist must learn to speak it. Physical problems have often been the genesis of mathematical development.

Yet the two species of feline are really basically different in attitude. Physicists are interested in material connections among phenomena and their physical description. Mathematicians are interested in the relations of numbers. Experiment is the physicist's ultimate judge; logic is the mathematician's only constraint. See what happens when one of them gets among the others.

The mathematician in this case is Irving E. Segal of the Massachusetts Institute of Technology, who came before a gathering of astrophysicists to attack dogma number one of their cosmology, the expanding-universe hypothesis. The expanding universe goes back to Edwin Hubble, and it arose from his observations of the redshifts of distant galaxies. One of its prime data supports is the so-called Hubble diagram, a graph of luminosity vs. red-shift. Hubble proposed that the farther a galaxy is from us, the greater should be its redshift. A law of optics says that the farther away a luminous object is, the dimmer it looks. So a diagram of apparent luminosity vs. redshift should yield a straight linear relation between the two, the greater the redshift, the dimmer the galaxy.

In fact it does so only by arm-twisting. The data points look very different from a straight line. The physicists say this is not because Hubble was wrong but because the galaxies so far recorded are not a truly representative sample. In other words, physicists will save their simple physical relationship even at the cost of man-handling the data somewhat.

The mathematician, Segal, says let's not do this finagling. He sees two sets of numbers that have a functional relationship to each other and asks himself what sort of function best fits the numbers. Statistical analysis leads him to a nonlinear, square relationship that makes hash out of the expanding universe.

The physicists jump all over him for this. Not that they hate statistics. They love statistics, use them all the time. But a physicist's statistics have ultimately to illustrate a physical connection, and the assembled astrophysicists

find none behind Segal's square function. So they tell him he is using an unfair sample.

Sometimes the interdisciplinary tension is more fruitful. In a recent lecture, Raymond W. Hayward of the National Bureau of Standards outlined some of the history of the unification of the theories of the weak interaction and the electromagnetic interaction, two classes of force that particle physicists have to deal with.

The theories of such interactions or parts of them are often written in what mathematicians call group theory. A very important group in this instance is the intermediary particles that embody the forces of these interactions and carry them from place to place. In the older theories there were three such particles, one, the photon, for electromagnetism, and two, positively and negatively charged W particles for the weak interaction.

Mathematically these particles are members of a group that ought to have a fourth member. Mathematicians and mathematically minded physicists ached to complete the group. The characteristics of that fourth member made it to be a neutral intermediary for the weak interaction. Inclusion of this particle, usually designated B, was one of the things that made theoretical unification of the two interactions possible, but it demanded the existence of weak-interaction processes that had never been seen, the so-called neutral-current processes. Physicists thought the unified theory a beautiful accomplishment, but few of them would have staked their oath on it until experimenters, inspired by the mathematics, began to find the neutral-current processes.

Another example is so old it's in the textbooks. Maxwell's equations, which were published a hundred years ago, summarize classical electrodynamics. One of the things they predict is radio waves. Curiously, the equations for a transmitter radiating waves are symmetrical. In addition to waves radiating away from the transmitter, which are easy to understand physically, the equations predict infalling waves, arriving at the transmitter from an infinite distance. Physicists have no way of understanding these infalling waves so they calmly throw them out as unphysical. When this is presented by a physics teacher to mathematics majors, they jump up and down and scream: "How could you throw away perfectly good solutions to perfectly good equations?" The physicist's reply is that you have to have some experience with your hands in the dirt to know what is physical and what is not.

Or do you?

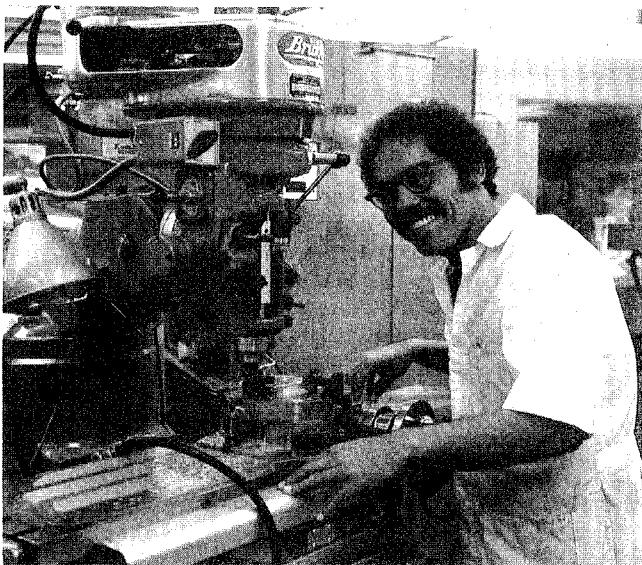
The equations for special relativity yield solutions for particles that go faster than light. But the rest masses of such particles are represented by imaginary numbers. Nobody

could see how an imaginary rest mass could be physical, so the solutions were ignored for a long time. Then some physicists began to point out that if these faster-than-light particles were always in motion and never at rest, it didn't matter what kind of number represented their rest mass since that quantity would never affect the actual physics. What mattered was that the energy and momentum of these particles (which were dubbed "tachyons") were represented by real numbers and could therefore be physical. So now there are experimenters looking for tachyons. . . . You never know.

--Dietrick E. Thomsen

The number of deaths in New York (population 1,060,000) in the four weeks ending October 23, was 2,226. Of this number 932 were deaths of children under five years. The remaining deaths were distributed among the following causes: violence, 97; small-pox, 41; diphteria, 186; scarlatina, 16; measles, 4; croup, 75; whopping-cough, 32; typhoid fever, 50; typhus fever, 4; puerperal diseases, 17; diarrhoeal diseases, 224; consumption, 318; lung diseases other than consumption, 230.

--*Scientific American*  
December 1875



--Photo by Walter Zawojski

### DINO PIMENTEL ADVANCES TO JOURNEYMAN MACHINIST

Pasqual (Dino) Pimentel has successfully completed the Apprentice Machinist Training Program in SLAC's Mechanical Fabrication Shops and has recently filled an opening for a Journeyman Machinist in the Central Lab Machine Shop.

Dino joined SLAC in 1967, and during his first nine months here he worked in the Labor Pool. During this early period he began to attend evening trade-school classes in order to become familiar with the machinist trade. In July 1968 Dino transferred to the MFS group, where he was assigned work in the Light Machine Shop under Marion Adams. Starting in March 1969, Dino's SLAC career was interrupted by a two-year tour of duty in the Army.

Shortly after his return to SLAC in 1971, Dino enrolled in the Apprentice Machinist Training Program, and during the course of this training he was rotated through both the Light and Heavy Machine Shops, the Cryogenics Machine Shop and the Central Lab Machine Shop. In each of these assignments he gained valuable experience in the varieties of jobs, machine tools and styles of supervision that these four separate and distinctive shops have to offer. In addition to the on-the-job training offered at SLAC, Dino's program included classroom studies at the John O'Connell vocational school in San Francisco.

With the training program now completed, Dino is presently working as a Journeyman Machinist in the Central Lab Machine Shop on a number of different Research Division projects. Dino is a very valuable asset to SLAC's machine shop effort and has the ability to go far in his chosen trade.

--Ray Pickup

SLAC Beam Line  
Stanford Linear Accelerator Center  
Stanford University  
P. O. Box 4349, Stanford, CA 94305

Published monthly on about the 15th day of the month. Permission to reprint articles is given with credit to the *SLAC Beam Line*.

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