

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 8

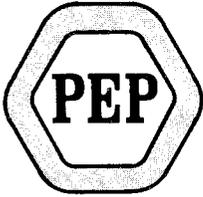
August 1976



This photograph shows "the mole," a Robbins tunnel-boring machine that was used in the construction of the new 400-GeV proton accelerator that recently began operation at the CERN laboratory in Geneva, Switzerland. A very similar machine will be used at SLAC in boring the tunnel for PEP, the 18 GeV electron-positron colliding-beam storage ring. Although first operation of PEP is still some 3½ to 4 years away, the planning of experiments is already beginning--see pages 2-3. (Photo CERN.)

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LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CA 94720

STANFORD LINEAR ACCELERATOR CENTER
STANFORD UNIVERSITY
STANFORD, CA 94305

CALL FOR PROPOSALS

June 9, 1976

Dear Colleague:

Our purpose in writing to you is to bring you up-to-date on the current state and progress of the LBL-SLAC positron-electron colliding-beam facility (PEP) and to notify all prospective users that the laboratories are now ready to receive experimental proposals for the first-round use of this important new tool.

Progress on the design, management and funding aspects of this project has been gratifying to date, and we expect an outside Architect-Engineer-Management firm to be aboard by August, 1976. We hope that colliding-beam physics will begin early in 1980. Although this date may seem far in the distant future to some, our experience in planning for the construction of major detection equipment shows that decisions regarding the early program will have to be made no later than June 1977. With this in mind, we have set December 30, 1976 as the deadline for submission of the first round of proposals to be considered by the Experimental Program Committee.

In the following we briefly review the state of the project.

(1) Design--A successful joint study of the SLAC and LBL accelerator groups has been under way for the past three years. Early in 1974 a formal agreement for the continued collaborative effort in the construction and operational stages of PEP was negotiated. The Regents of the University of California and the Trustees of Stanford University approved this cooperative venture, which is most recently and most completely described in the PEP Conceptual Design Report (LBL-4288, SLAC-189), February 1976.

(2) Funding

(a) Machine

\$0.9 million for PEP construction was authorized but not funded by the Congress in Fiscal Year 1975. In FY 1976, \$2.9 million was authorized and appropriated, and is now available at SLAC and LBL for engineering work and procurement of long-lead-time items. \$25 million has been requested for PEP construction for FY 1977; this has been authorized by the Congress and the appropriation process is progressing. We are hoping for favorable action by early July. Total estimated construction cost is \$78 million. [Congress did approve the appropriation of the \$25 million for PEP construction in FY 1977.]

(b) Experimental Facilities

The laboratory directors, through their letter of February 26, 1976, have submitted an estimate to the Assistant Director for High Energy Physics, ERDA, that approximately \$28 million of equipment money might be required for funding the initial round of facilities and other equipment-funded items at PEP. This estimate was derived from the type of facilities identified in the two previous Summer Studies but actual requirements may be lower or higher, depending on the actual proposals received. The estimate is independent of the source of the funding, be it ERDA or NSF. Of these funds we estimate that about 15 to 20% would have to cover general equipment such as mini-computers, cryogenic equipment, shielding, electronics pool items, etc. Such items will be procured by PEP staff, presumably under direct funding from ERDA. The balance of equipment funding provided will be allocated on an equitable basis to proponents in accordance with the decisions made by the directors on advice of the Experimental Program Committee.

\$650 thousand equipment money earmarked for PEP will be made available for FY 1977. The remaining equipment funding, hopefully matching the amounts estimated above, will have to be acted upon in subsequent budget years.

(3) Committees--As called for in the Stanford-UC Cooperative Basic Agreement for the project, a single PEP Policy Committee (PPC) composed of non-SLAC, non-LBL members has been appointed and has met for the first time in May 1976. Formation of the Experimental Program Committee (EPC) also called for in the Agreement, is presently under way and should be completed this month. First formal deliberations, dealing with received proposals, will begin in January 1977, but the EPC will meet several times before that date.

(4) Time Schedule for Experiments and Facilities

(See Table I on next page)

We look forward to your participation in a colliding-beam physics program in what is sure to be a very exciting new energy range. We should like to remind you of the 1976 PEP Conference that is scheduled for June 23-25 at SLAC, which is designed to give proponents of experiments or facilities the opportunity to interact with the laboratories and each other in exploring ways to use PEP.

W. K. H. Panofsky
Stanford Linear Accelerator Center

Sincerely,

Andrew M. Sessler
Lawrence Berkeley Laboratory

TABLE I - SCHEDULE FOR EXPERIMENTS AND FACILITIES			
Date	Long Lead Time		Short Lead Time
	Facilities	Experiments	Experiments and Facilities
June 1976	Call for proposals		
June 23-25 1976	PEP Conference open to all experimenters interested in submitting proposals		
Dec. 30, 1976	Deadline for first-round consideration by EPC		
January 1977	EPC recommends which proposals should be considered facilities, and calls for Workshops		
March 1977	Workshops to allow input from users to affect the design, allow coalitions to form, and allow additions and modifications to facilities' proposals		
May 1977	Deadline for revised proposals		
June 1977	Decisions committing no more than two interactions areas for newly constructed detectors		Call for proposals for experiments and short-lead-time facilities
January 1978*			Deadline
April 1978*			Decisions
June 1979*	EPC starts meeting regularly, at least once every six months, to consider all proposals		
April 1980*	Start of significant machine time for physics (~25% at the beginning, building to ~80% during the following year)		

* Tentative dates

GERMAN ACCELERATOR RACES AHEAD

PETRA, a new West German accelerator designed to collide 19-GeV electrons and positrons with each other, is being constructed at a hectic pace. Only last October PETRA was still a paper project in competition with EPIC, Britain's version of the same thing; now the German site, at the Deutsches Elektronen Synchrotron laboratory (DESY) near Hamburg, is cleared, buildings are going up, and contracts are placed for accelerator parts. The accelerator tunnel is growing at the rate of 72 metres per week.

The German physicists have also delighted their European colleagues by taking a generous

attitude to the division of future experimental time on PETRA. It seems likely that DESY will allow international competition for time on all four of PETRA's collision regions.

The first experiments at PETRA are expected to start in mid-1979. That may well be ahead of PEP, PETRA's US equivalent, whose construction has not yet begun despite Presidential approval earlier this year. So Hamburg may be destined, for a short time at least, to become the particle physics centre of the world.

--New Scientist
1 July 1976

BEAM DELIVERANCE CELEBRATION

[Note: Last May 21 there was a festive luncheon held at Sector 6 of the accelerator to celebrate the tenth anniversary of the first full operation of the SLAC accelerator. This occasion was called the beam "deliverance party." Gloria Cardenas took the photographs shown below, and Greg Loew made the following remarks to the assembled celebrants.]

Last night, before going home, I peeked into Charlie Kruse's office and found him gleefully counting up all the money that you had paid him for this luncheon. He asked me if I had my speech ready for today, and when I answered "No" he gave me a dirty look and threatened to cut me off without a hamburger. So with that kind of a threat hanging over my head, I decided to share with you some brief but vital SLAC statistics, just to give you something to think about this afternoon. To put some semblance of order into these statistics, I've classified them into 3 different categories:

- (1) What we have done during the last ten years.
- (2) What we think we are doing now.
- (3) What we should be doing in the future.

In order to find out what we've been doing during the last ten years, I went to the Planning Office, Larry Kral's place, where they keep all the numbers, and this is what I learned:

Since 1966 we have run our accelerator for a total of about 6000 shifts, which means that the klystrons that supply the high-power to the beams have operated for about 11 million klystron hours. During those shifts, the machine was pulsed about 6×10^{10} times. If we make the assumption that the average beam current during the pulse was something like 5 milliamps, then your hard work and dedication has resulted in the delivery of about 3×10^{21} electrons or almost 500 coulombs of electric charge during these past ten years. But just in case you feel overly impressed with these large numbers, let me remind you that carrying 500 coulombs from the injector to the research areas represents a total mass transit of 27×10^{-10} grams--which is a job that most any old ant could have accomplished with the greatest of ease.

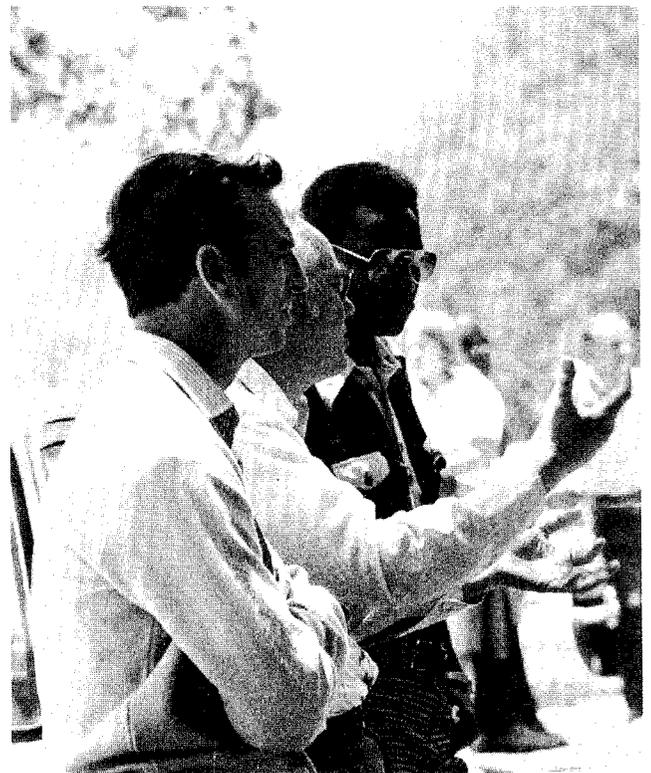
Now, what have all these electrons and occasional positrons done for us? Well, first of all, they allowed us to make the momentous discovery that some of these particles don't like the idea of traveling all the way to the end of the machine. This phenomenon is called "beam breakup."

Second, our 500 coulombs have made it possible for physicists from SLAC's Research Division and from about 50 outside scientific institutions to entertain themselves by proposing and



then carrying out a total of about 125 particle-physics experiments. Some of these have of course been more successful than others, but all in all the experimenters deserve some credit for discovering--among many other things--an internal structure to the proton, two remarkable new psi particles along with many intermediate metastable states, and very recently (according to widespread rumor) a new resonance bump that may be endowed with a quality called "charm."

Third, as a result of these and many other successes, some of us here have been encouraged to keep working on the design of new machines. I count a total of 8 different machine designs that have been worked on: Stages 1-1/2, 1-3/4





and 2 of the two-mile accelerator; the Superconducting Accelerator; the Recirculating Linear Accelerator (RLA); SPEAR, SLED and PEP. The last 3 of these machines have been, are being, or will be built. This gives a 37½% yield, which I guess we ought to be satisfied with.

Fourth (always according to the Planning Office), we have been able to attract to our site a large number of important visitors. The latest count includes one Paleoparadoxia, over 100,000 high school students, 30 to 40 primates along the accelerator, one French President, and at least four Personnel Directors.

We come now to part two--what do we think we are doing now? This is a much trickier question because in principle it involves your personal freedom and privacy. For this reason, I have decided to scan the latest *Beam Line* issues and use only information that is already public. Referring to our directors, I detect over the years a major but healthy preoccupation with food, which I believe is reassuring. One director seems to have been working for several years on a theory involving raspberry jam with seeds in it, while another frequently talks about peeling onions. . . . Among the lower echelons, we also seem to detect something of a preoccupation with that three-letter word, s-x, since certain of our theoretical physicists insist on talking about hardcore models of the proton and neutron.

Finally, what should we be doing in the future? Well, for one thing I certainly recommend that you all study your latest performance reviews, which should include at least some of your goals for the future. I have diligently studied my own review goals, and I list several of them here in the hope that they may inspire you to ever greater efforts. Goal one states that I should be sure that we increase the efficiency of the accelerator; as a sound bureaucrat I have passed this word on to Charlie Kruse and have asked him to authorize a good deal more overtime without pay. My second goal was that during the coming year I should be certain to get the SLED show on the road; this will be achieved through the assignment of Harry Hogg and his crew to drive up and down El Camino with a couple of SLED cavities in the back of a pickup

truck. Goal number three was that I should be particularly vigilant about Affirmative Action in the months ahead; my forthcoming memo on this subject will require that no fewer than twice each week all of the male members of the Accelerator Physics staff will appear for work in mini-skirts.

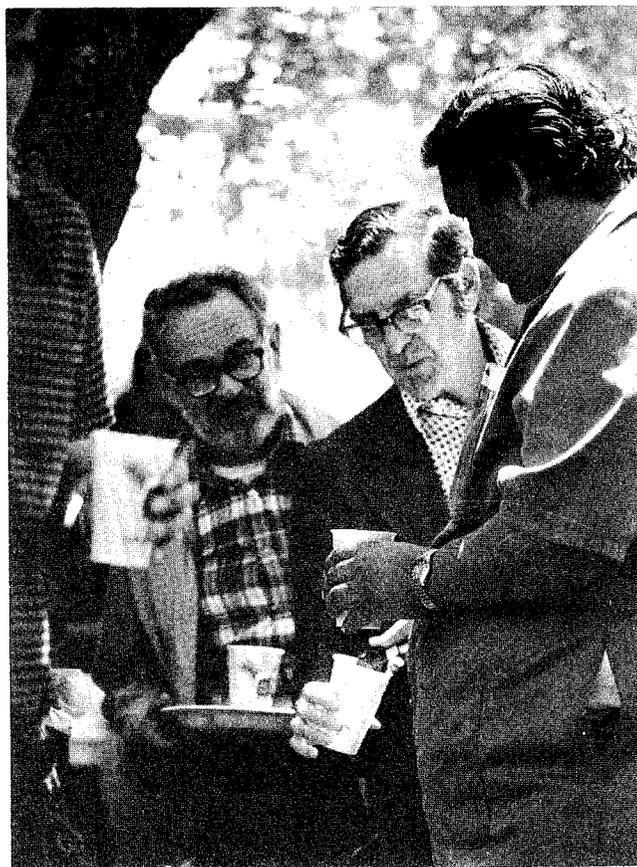
With these simple goals so easily disposed of, my only remaining concern is with the future activities of Dr. Jean Lebacqz who, I am told, is likely to spend the next several years developing a new low-frequency klystron for use in the PEP storage ring. Since one of his laboratories is directly below my office and that of C. Kruse, and also since a frequency of about 75 MHz probably means a klystron that is 15-feet tall, I shudder to think what will happen when the first test model is erected.

To conclude, let me refer you again to the May 1976 issue of the *Beam Line*, in which SLAC's Director quotes a Chinese physicist (who later turned out to be none other than Chairman Mao!) as saying, with reference to the purpose of High Energy Physics:

"You have to look further than the end of your nose."

I certainly agree with him, but just think about how Roger Miller and Ron Koontz must feel about their noses as they sit at the Injector and peer downstream!

--Greg Loew



If you smokers at SLAC wonder why I sometimes get on your case, let me expose you to an editorial published in the July 1976 issue of the Western Journal of Medicine.

--Charles Beal, M.D.

LEST WE FORGET: SMOKING REVISITED

Our reading material, medical and otherwise, is increasingly filled with descriptions of newly recognized threats to our health. Not to detract from the importance of these, we should periodically put them in perspective by being reminded of the sheer impact of a danger which is surely the most important to be yet recognized, both because of its impact and because of its preventability.

Whatever the benefits, the costs of smoking more than one pack of cigarettes a day include, as a conservative minimum, the following:

- Huge (by factors of 8 to 12) increases in the risk from cancer of the lung, buccal cavity, pharynx and larynx.

- Large (more than twofold) increases in the risk from cancer of the esophagus, bladder, liver and biliary tree, and pancreas.

- Increases in the risk from cancer at most other sites. Overall, the person taking up smoking probably increases his or her long-term risk (before 65) of cancer from about 12 to about 25 percent.

- Large (more than twofold) increases in the risk from chronic obstructive pulmonary disease, chronic bronchitis, and peptic ulcer. The lifelong increment in risk probably amounts to at least 1 to 2 percent.

- Most important of all, large (more than twofold) increases in risk from coronary heart disease. Men who smoke cigarettes increase their long-term risk of a premature (before age 65) major coronary disease event from about 8 percent to over 25 percent.

The sum of these increases in morbidity works out to be about a 30 percent chance of an unnecessary and premature serious disease. Whatever the influence on morbidity, the coldest and hardest fact is that the increase in the probability of premature death from any cause is such that smoking entails about a 20 percent chance of premature and unnecessary death.

Moreover, the dangers of cigarette smoking are even greater for persons already finding themselves at increased risk for other reasons. For example, risk from lung cancer is not measurably increased after exposure to asbestos in non-smokers, whereas in smokers it is astronomically high. Smoking synergistically increases the coronary heart disease risk in hypertensive patients and those with elevated blood lipids.

Although quantitation is difficult, the practice of smoking also is costly to non-smokers. Because of the foregoing, non-smokers insurance premiums are increased in direct proportion to the number of their fellow citizens who smoke. Some evidence suggests that smoking is detrimental to children *in utero* and to non-smokers in the vicinity of smokers. It has been estimated that smoking is the most important cause of fires in buildings and of fire casualties. Thus some of the direct and indirect costs of accident morbidity and mortality (including fire insurance premiums) must be added to the total.

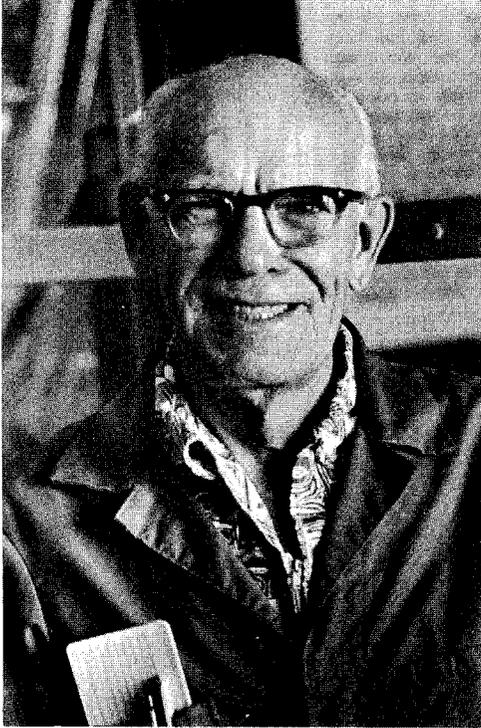
No doubt the list could go on, but it need not. The smoking of cigarettes is surely a formidable contender for the prize of the biggest optional detriment to the quality of American life, and that fact must not be allowed to get lost in the discussion of newly recognized dangers, whether the discussions are between physicians, or between physician and patients.

--Thomas M. Mack, M.D.

. . . In this long and--for our purposes--infinite stretch of time, the substance called Thought has,--like the substance called water or gas,--passed through a variety of phases, or changes, or states of equilibrium, with which we are all, more or less, familiar. We live in a world of phases, so much more astonishing than the explosion of rockets, that we cannot, unless we are Gibbs or Watts, stop every moment to ask what becomes of the salt we put in our soup, or the water we boil in our teapot, and we are apt to remain stupidly stolid when a bulb bursts into a tulip, or a worm turns into a butterfly. No phase compares in wonder with the mere fact of our own existence, and this wonder has so completely exhausted the powers of Thought that mankind, except in a few laboratories, has ceased to wonder, or even to think. The Egyptians had infinite reason to bow down before a beetle; we have as much reason as they, for we know no more about it; but we have learned to accept our beetle Phase, and to recognize that everything, animate or inanimate, spiritual or material, exists in Phase; that all is equilibrium more or less unstable, and that our whole vision is limited to the bare possibility of calculating in mathematical form the degree of a given instability.

Thus results the plain assurance that the future of Thought, and therefore of History, lies in the hands of the physicists, and that the future historian must seek his education in the world of mathematical physics

--Henry Adams, *The Degradation Of The Democratic Dogma* (1910)



HAL NICOLS LEAVES--AGAIN!

Hal Nicols, SLAC's most popular Storekeeper with almost everyone, is back again at Stores for a short time. He has been filling in for Frank Menezes, who is on his honeymoon, for two months. Hal retired last October, but the news didn't reach the *Beam Line* at that time.

Hal is originally from Chicago, but he left the Windy City to move to Fort Dodge, Iowa, where he completed his high school and college education. It was while in Fort Dodge that Hal married a school teacher (in order to finish high school?).

The Nicols settled in San Jose in 1950, and Hal then entered the real estate and insurance business. In 1966 Hal sold his business and decided to retire, but after a few years of rest and travel he decided to jump back in again. He joined SLAC in 1968 and stayed with us until his retirement last year.

It's good to have Hal here again, even if it is only temporarily.

--John Barreiro

SLAC TRIES OUT MOTORIZED BIKE

SLAC has recently purchased a Moped (motorized bike) for evaluation as an alternate mode of transportation. It will be loaned out to various groups and vehicle pools in order to determine whether this means of transport can be a viable alternative for meeting some of SLAC's requirements. If so, additional mopeds will be purchased and assigned out to suitable groups. It is hoped that by using mopeds, the need for four-wheeled vehicles at SLAC will be reduced, thereby reducing overall gasoline consumption.

The transportation needs at SLAC are unusual. In general, the site facilities and experimental areas result in the need for numerous short trips, often less than a mile. Most of the trips are to and from the Research Yard. Because of the combination of distance and difference in elevation, walking and the use of reg-

ular bicycles is not quite acceptable to many people, especially those who feel committed to tight schedules. This frequently results in the use of pickup trucks or other full-size vehicles that are overmatched to the actual needs. It is also rather hard on the larger engines, which don't have a chance to warm up properly on the short trip.

To operate a Moped, a California driver's license is required. The Moped itself is not a licensed vehicle; its operation is restricted to speeds under 30 mph, which should not be a disadvantage for on-site travel.

Instructions will be given in the operation of the Moped. New riders should take the time to ride carefully around the loop road at SLAC, or in the A&E parking lot, before making a trip down into the Research Yard. The Yard is not the place to learn how to operate the Moped.

--Gordon Ratliff

The record of boiler explosions kept in this office since our last annual report shows 139, by which 191 persons were killed and 267 injured. The principal kinds of boilers involved in the explosions are as follows: railroad locomotives (23 explosions, 40 killed, 51 injured), steamboats and tugs (18 explosions, 30 killed, 31 injured), saw mills (17 explosions, 34 killed, 52 injured) and threshing machines (9 explosions, 28 killed, 10 injured).

--Scientific American
August, 1876

The first century of the United States closed last month. It has been a century of development unparalleled in history. The population has increased from 2,750,000 to 44,675,000. The area has been extended from 800,000 to 3,603,844 square miles. The development of agriculture under the pressure of immigration and the stimulus of mechanical invention has been utterly without precedent. The value of manufactures has advanced from \$20,000,000 to \$4,200,000,000.

--Scientific American
August, 1876

A SECOND BEAM LINE FOR SSRP

A second tangential beam line leading from SPEAR to the Stanford Synchrotron Radiation Project (SSRP) was put into operation on June 30, 1976. In preparation for about one year, this new beam line will accommodate four or more x-ray experiments simultaneously, providing much needed relief of the pressure from users on the first beam line (which began operation in May 1974).

The second beam line was funded by the National Science Foundation. One of the major experimental devices for the new beam line, a rapidly tunable channel-cut crystal monochromator system, is already in operation. Two additional, similar systems, with added focusing capability, are presently being constructed.

The SSRP program*, which operates symbiotically during colliding beam runs of the SPEAR storage ring, has grown rapidly during the past two years. At present there are about 150 research workers, 64 active proposals, and 35 different institutions represented in the work. The scientific demand continues to exceed the available time on existing facilities. The new beam line should help this problem in the case of those experimenters who work with x-ray beams. In addition, discussions are now under way at SSRP about the possibilities of expanding the research potential in the lower energy (vacuum ultraviolet) part of the spectrum sometime in the foreseeable future.

Proposals have been submitted to funding agencies for continued expansion of the SSRP experimental facilities during the period from 1978 through 1980. There is also a possibility that SPEAR will be used on a part-time basis as a dedicated synchrotron radiation source after the new PEP storage ring at SLAC has come into research operations.

SSRP has demonstrated the research potential of a multi-GeV storage ring as a synchrotron radiation source for research in a wide variety of scientific fields (surface physics, catalytic chemistry, structural biology, etc.), and this demonstration has led to a broad national interest in providing additional research capability in the U.S. At the present time a select panel is preparing a report for the National Research Council that will assess the national need for additional synchrotron radiation research facilities.

--Herm Winick

*The January 1975 issue of the *Beam Line* contains a special pull-out section that describes the SSRP facility and its early research program. Copies of this article on SSRP can be obtained from Bill Kirk, Bin 80, or Herm Winick, Bin 69.

THREE TYPES OF ENERGY-SYSTEM PLANNING AND DEVELOPMENT PROGRAMS

There are three kinds of insects in this world, each having a different methodology for preparing his energy-supply program, namely:

1. The spider, who sits in the center of a net placed at a strategic position, waiting for the flies and ants to deliver the required energy.
2. The ant, who diligently collects and stores all kinds of seeds and crumbs in caves, ready for future consumption. Some of his efforts may never serve their intended purpose.
3. The honeybee, who busily collects pollen and natural syrups, converting them to honey, and stores them properly in a honeycomb for present, future and other creature's use.

The present strategy of waiting for the breeder- and fusion-reactor technology breakthroughs reminds us of the spider.

The way we are now digging for coal, oil, natural gas and uranium reminds us of the ant. Some of the energy losses may not be recovered for centuries.

The methodology used by the honeybee provides insight into converting the hydrocarbon energy from the sun and earth, digesting and converting them to biologically acceptable energy. This kind of chain energy is renewable. The honeybee's working society provides us with the guidelines for our own energy-system planning and development program.

--Alex Tsang

FAMOUS PREDICTIONS

The demonstration that no possible combination of known substances, known forms of machinery and known forms of force, can be united in a practical machine by which man shall fly long distances through the air, seems to the writer as complete as it is possible for the demonstration of any physical fact can be.

--Simon Newcomb (c.1895)

DeForest has said in many newspapers and over his signature that it would be possible to transmit the human voice across the Atlantic before many years. Based on these absurd and deliberately misleading statements, the misguided public . . . has been persuaded to purchase stock in his company.

--U.S. District Attorney (1913)

As far as sinking a ship with a bomb is concerned, you just can't do it.

--U.S. Rear Admiral Clark Woodward (1939)

CHROMODYNAMICS

A colorful and charming tale of particle physics, which at least some theorists hope is both beautiful and true

[Reprinted from *Science News*, June 26, 1976]

By Dietrick E. Thomsen

"Big fish eat little fish, and prey on 'em and bite 'em.
Little fish eat littler fish and so on
ad infinitum."

It's not very good poetry, but it could illustrate the dilemma of science in its search for the ultimate underlying structure of matter. Each time they cut open a fish, scientists find a smaller one inside. It has been clear for decades that what chemists considered the ultimate building block, the atom, was not fundamental at all. More recently physicists have found that what they, perhaps in an access of hubris, had decided to call elementary particles are not the fundamental level either. And lately it is beginning to seem that the structure the physicists developed to deal with that disappointment may in its turn not be the ultimate. It looks like there's an even littler fish inside of it.

To rehash a little bit, the majority of physicists prefer to regard the 100 or more "elementary" particles they have discovered as no longer elementary (with the exception of four of them--more about those in a bit). Underneath this multiplicity of particles, whose existence itself is often evanescent, must lie a simpler structure. For both mathematical and physical reasons theorists came to a small group of entities, which have been dubbed quarks, with a bow in the direction of the most famous Irish wake in English literature.

At first three quarks sufficed for the theorists' imagination. (Indeed it was the line: "Three quarks for Muster Mark" that gave them their name.) The original quarks were called "up," "down" and "strange," and it turned out that various combinations of them and the three corresponding antiquarks could explain the behavior and structure of all the known particles but four. The up and down quarks by themselves could explain garden variety particles like neutrons and protons. The strange quark was necessary to explain the behavior of a class of odd-ball particles which, because of their behavior had been denominated strange particles.

Recently a fourth quark has entered almost everybody's calculations. It comes about because changes in the theory of the forces that animate the particles (specifically the unified field theory of electromagnetic interactions and the weak subatomic interactions) require the strange particles to behave even more strangely. Namely it introduces certain processes in which their amount of strangeness might otherwise be

expected to change but actually does not. (In life it is impossible to be a little bit pregnant, but in physics a particle can be one unit strange or two units strange. If the terminology seems weird, remember that James Joyce is its literary patron saint.)

To account for this new behavior requires a new characteristic of particles, which has been called charm, and along with charm comes a fourth, charmed, quark. Having four quarks is nice for mathematical reasons because a fundamental group of four is more symmetrical than one of three. It is also nice because there are four particles that do not have quarks. The particles that are supposed to be made of quarks are called hadrons, and those of them that can be caught long enough to study show evidence of the kind of internal structure that the quark theory might lead one to expect. The four particles called leptons (the electron, the muon and the two kinds of neutrino) show no evidence of internal structure. They are not supposed to have quarks in them, but are regarded as equally fundamental. Four quarks and four leptons thus make a nice balance. Two different kinds of fundamental entity, each of which comes in four flavors. Very neat.

Now it becomes necessary to color the picture. The reason that theory must color quarks arises from the statistical formulations used to predict the behavior of particles. These come in two kinds, called Bose-Einstein statistics and Fermi-Dirac statistics. As a physicist who once compared physics with hotel-keeping put it, Fermi-Dirac Towers is very exclusive, but the Bose-Einstein Haus is renowned for *Gemutlichkeit*.

What that means is that particles subject to Fermi-Dirac statistics (electrons are an example) obey Pauli's exclusion principle: no two of them with exactly the same values of the properties we have been discussing, the same set of quantum numbers to use the physicists' terminology, can be in the same place at the same time. No double rooms or rollaway beds at Fermi-Dirac Towers. Bose-Einstein statistics allow such crowding together, like a ski-lodge dormitory.

It happens that quarks, by their hypothetical properties, are fermions, members of the class subject to Fermi-Dirac statistics. And that caused a theoretical rub. In many hadrons (neutrons and protons, for example) there are three quarks, and these quarks all appeared to have the same quantum numbers, a direct violation of Fermi-Dirac statistics. The solution to the dilemma was to propose a

new quantum number that could make each quark different and so obey the law.

The triadic structure of neutrons and protons makes this new quantum number a bit special. Since neither neutron nor proton shows any such exotic property, the sum of the new quantum number over neutron or proton must be zero. Yet the structure requires something that has three different aspects, which, taken together, yield neutrality. A bipolarity with positive and negative like electricity would not do. Some kind of triangular symmetry was necessary.

What was hit upon was an analogy to the primary colors. Mixing red, blue and yellow in equal proportions gives white or colorlessness. So the new quantum number was called "color." (For reasons possibly of patriotism, American, French or British as you please, theorists tend to say "red, white and blue" rather than "blue, yellow and red.")

Color turned out to be more fundamental than simply a device for getting around Fermi-Dirac statistics. It could serve, in analogy to electric charge, as a kind of charge that would be the source of the forces that held quarks together inside the hadrons. As the theory developed, theorists postulated intermediate particles that would carry the force between quarks. These intermediaries are called gluons. The whole theory is called chromodynamics and it introduces an important change in how physicists regard the class of force they call the strong interaction.

The strong interaction first manifested itself as the force that holds protons and neutrons together in an atomic nucleus. It was later seen to exist among all hadrons. Physicists tended to believe that the force between neutrons and protons was the fundamental manifestation of the strong interaction. Now with chromodynamics they are beginning to see the nuclear binding force as a secondary manifestation of chromodynamics.

A parallel from electromagnetism will help clarify the point. The fundamental and strongest manifestation of electric force is between two charged bodies, for example, the force that binds electrons into orbit around an atomic nucleus. But there are weaker, secondary electromagnetic interactions between neutral bodies, for example, the forces that prevent atoms from interpenetrating each other. On these secondary forces are built all of our solid structures. Because of them, books do not pass through bookshelves, and human bodies do not pass through walls.

Similarly, the fundamental aspect of the chromodynamic force is taken to be that between quarks of different colors. The forces that bind neutral-color neutrons and protons into nuclei are considered secondary as are the

interhadronic forces by which hadrons affect each other's motion.

It seems to be generally conceded that it is impossible to break hadrons into their constituent quarks, which would then come out exhibiting their colors, or to materialize gluons. But there are secondary ways to look for confirmation of the color hypothesis. One of these is in the collision and annihilation of beams of accelerated electrons and positrons.

These electron-positron collisions should create both hadrons and leptons. When such experiments were first set up in storage-ring facilities it was thought that the ratio of hadrons produced to leptons produced would be constant over a long range of energies of the colliding particles. The value of this constant would tell whether the color hypothesis was true and in which of its detailed ramifications. The experiments found constant levels, but they found more than one, and in between constant levels they found even bigger surprises: sudden narrow peaks in which the hadron production went up enormously. These peaks are resonances, and they indicate the creation of new particles of fleeting existence that gather up the available energy and form channels for much easier and extremely more copious hadron production. These resonances are the famous psi particles, and theorists seized on them as examples of the working of charm. The psi particles are supposed to contain both charm and anticharm, so that overall they are neutral with respect to it, and do not display charm openly or "nakedly." Just recently, a new particle has been found in the electron-positron collision experiments that seems to display naked charm and thus would form a much stronger experimental argument for the concept.

Meanwhile, between the resonances, the hadron-lepton ratio exhibits flat stretches that do not represent the same value, but rise in stepwise fashion as the energy goes up. This indicates to some theorists that other new quantum numbers beyond charm and color are at work. At least two. Beyond charm and color, says one theorist, come "truth" and "beauty." These would require two new quarks, a true, or maybe truthful, quark and a beautiful one. We would then have six quarks: u, d, s, c, t and b.

There is also another reason why six quarks are desirable. The new experiments have found what appears to be a new lepton, the so-called U particle, which is exceptionally heavy for a lepton and may be one of the things the newer theories of lepton physics are looking for. According to the lepton economy, if the U exists, then there should be a U neutrino to go with it. That makes six leptons. With six fundamental units on the

lepton side of the fence, physicists have an incentive to seek six on the hadron side, six quarks.

Now it is time to do a little arithmetic. The six quarks are the most fundamental manifestations of hadronic matter, but the three colored states that each can take are only slightly less fundamental. Three times 6 is 18. Furthermore, there are 18 corresponding anti-quarks. Makes 36. On the lepton side, 6 leptons and 6 antileptons add 12 more. The total of 48 begins to look too numerous and complex to be the truly ultimate fundamental building blocks. So physicists are beginning to talk of quark spectroscopy as in the early part of the century they talked of atomic spectroscopy, and are beginning to think there is maybe a still lower level.

In an after-lunch speech at the recent meeting of the American Physical Society, Sidney Drell, assistant director of the Stanford Linear Accelerator Center, put it in terms of the disagreement between the ancient Greek philosophers Demokritos and Anaxagoras. Demokritos believed that if one examined the structure of matter one would eventually come to fundamental unstructured objects out of which everything else was made. These he called *atomos*, uncuttable. It has long been clear that what chemists chose to call "atoms" are not the *atomos* of Demokritos, nor are the particles physicists discovered in the atomic nucleus. For a while physicists had thought that in quarks they had come at last to the *atomos*. Now they are not sure, and some say maybe Anaxagoras was right. His picture of material structure was a series of nested seeds. In one seed is a smaller one, inside that yet a smaller one and so on *ad infinitum*.

Whether Demokritos or Anaxagoras be correct, and whether, if the former, we shall ever reach the true *atomos* remain open questions. Benjamin W. Lee, who leads the theorists at the Fermi National Accelerator Laboratory, and who spoke at the same festivity as Drell, is pessimistic about seeing an answer in his lifetime--and he is still quite a young man. Perhaps the last word should be given to St. Paul (who also said it in Greek): "Now we see through a glass, darkly; then we shall see face to face."

It has been assumed, too hastily we think, that the growth of the country in population has received a serious check. This conclusion is based on the returns of a part of the census taken last year. . . . it is safe to estimate that the increase during the last five years has been five millions, making our total population in the middle of 1875 something more than forty-three millions.

--Scientific American
March 1876

CYLINDER ELLA

[Reprinted from the *SLAC Computing Services Bulletin*, July 15, 1976.]

Once upon a time, in a far-away kingdom known as Disk, there lived a forlorn Cylinder Ella. Cylinder Ella was always being accused of being off the track by her three ugly alternates.

One day, when it seemed that she had been going in circles for hours, a message arrived at her home address to say there was to be a collation of important characters at the home of Prints Charming. Of course, she was excited. But how could she go, defective as she was? She looked as though she lived in a dump.

At the moment of her deepest despair, her fairy god monitor appeared. "What you need is a good surface analysis, Cylinder," said FGM. "I usually do my magic with a decimal hex or a super zap, but what you need is a binary switch, and I'm not a bit too early. Just a moment, and I'll patch you right up. Now, shift left and byte down hard, while taking a deep breath There, you look beautiful for going to see Prints Charming. But, you must seek home by midbyte, as that Prints circulates in very fast company--he's a sector maniac, you know!"

Cylinder Ella felt as though she'd been re-initialized. She felt every bit as good as any of her alternate systems.

When she arrived at the home of Prints, the alternates looked up and agreed they had no I.D. of who she was. Prints had never seen anyone so lovely, and optically recognized immediately that she was a special character. She was having such a good time that she forgot about the Time-of-Day clock. Just as Prints was going to ask about some data with her, she was magically interrupted and transferred to old home address.

Days went by and she heard nothing from Prints. Finally, through a channel, she received another message which said, "I'm in the mode for love, and want to servo you forever. Tonight I will have the carriage return for you. I will carry the imprint of your image forever." Cylinder almost had power failure, as she fell back on her matrix.

"He is Asciiing me to be his Prints S! My world revolves around him, too. I am touched to the core, the very nucleus of my system. This is definitely the logical right shift for me. I will move immediately." And she did.

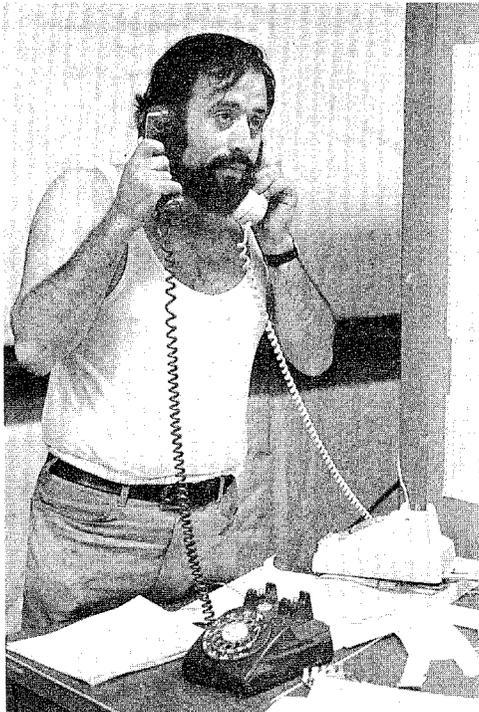
And they went around like that, happily ever after. Disk, disk.

1776-1876-1976

SLAC Publication Number 1776, issued in July 1976, describes the discovery at SPEAR of a new particle with a mass of 1876 MeV.

DISNEYLAND & GREAT AMERICA DISCOUNTS

Marie Arnold in Personnel (ext. 2357) has both Magic Kingdom (Disneyland) and Carousel Club (Great America) cards that are available to SLAC employees. Both cards entitle the bearer to a 10% discount.



The User's lot is a hard one--3000 miles from home, shirts not back from the laundry yet, curious administrative procedures designed, apparently, to impede Physics to the maximum possible extent. Here Leo Resvanis, from the University of Pennsylvania, one of SLAC's most frequent and long-lived Users, makes a last valiant effort to Beat The System by talking out of both sides of his mouth at the same time. But it doesn't appear, to judge from his expression, that the black phone is connected to anything except the nearby white phone. Hang in there, Leo. Perhaps better days are coming. (Photo by Joe Faust.)

This is a note to express our appreciation for the wonderful response and kindnesses received in our request for blood for our son, William Wadley, Jr. The boost to his morale has been tremendous. He is doing surprisingly well. He has responded to the medication as hoped, making surgery unnecessary, and we are very grateful for your help in making this possible.

--BILL & GENELL WADLEY

RETIREMENT INFORMATION

The Benefits Office has available a new booklet called "Where to Live, a Guide For Senior Adults." Employees of SLAC who are reaching retirement age, or who have taken responsibility for their parents, may find this booklet very helpful. If you would like to have a copy, drop by the Benefits Office, Room 238, A&E Building.

Surely it is not stretching a point too far to say that the automobile is the greatest economic factor in American life. The automobile bill of the American people is more than 14 billion dollars a year. Our annual investment in automobiles is greater than the annual value of farm crops and more than twice the annual investment in new buildings. Hence the automotive industry has risen to the position of the leading industry in the United States. This startling fact should not surprise us when we learn that the last annual registration of automobiles was about 20 millions. Not only is the industry stupendous in itself but also its effects on other industries are in proportion, in road-building for example, where the programme now in the course of execution calls for the expenditure of about a billion dollars a year, and in the upbuilding of suburban communities where the new construction, in the case of many cities, is larger than that in the urban district itself.

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