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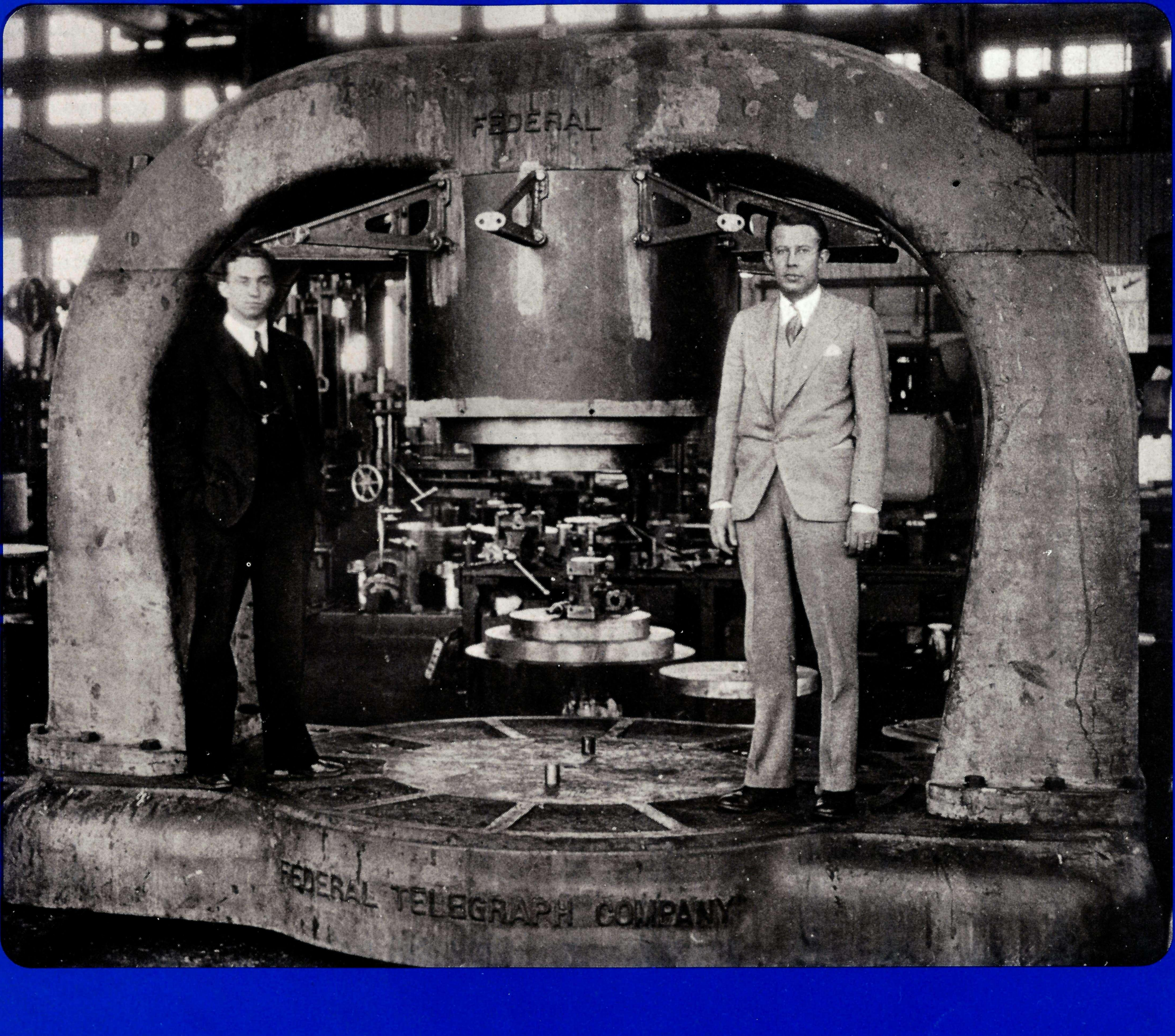

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VOLUME 21 N° 8 OCTOBER 1981

Lawrence Berkeley Laboratory 1931–1981

50 years of one of the world's most prestigious physics centres

Physics monitor

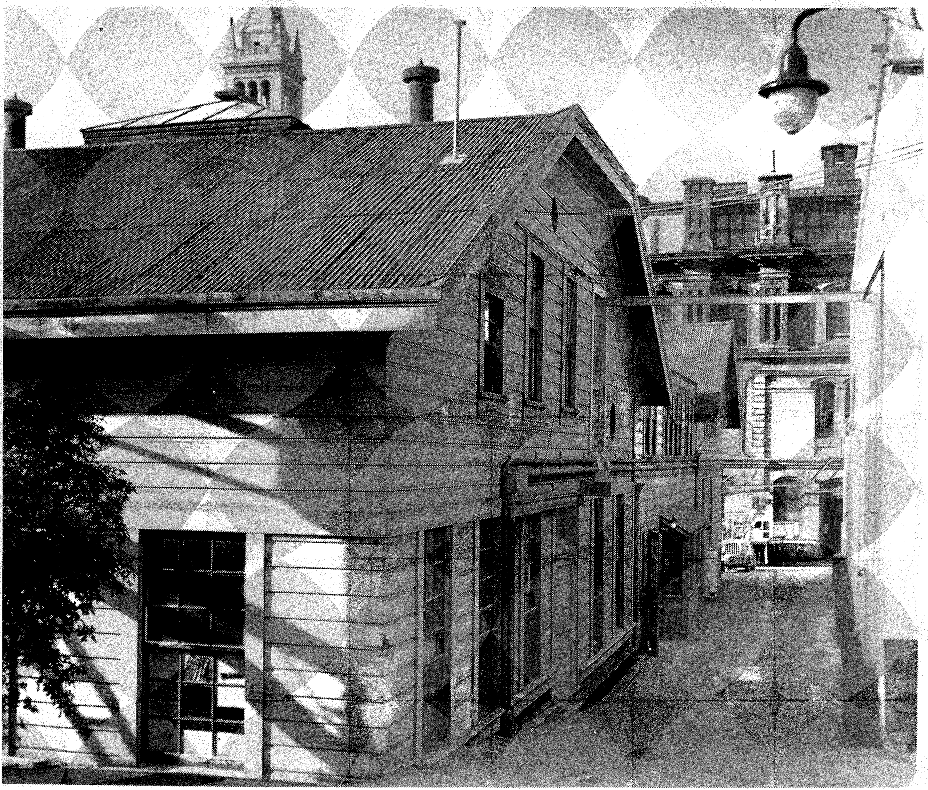
Around the Laboratories

Cover photograph: Stan Livingston (left) and Ernest Lawrence with the magnet donated by the Federal Telegraph Company for building the first cyclotron at Berkeley. This was the beginning of the famous Lawrence Berkeley Laboratory whose 50th anniversary we celebrate in this issue. (Photo LBL)

Lawrence Berkeley Laboratory 1931—1981

This month we celebrate the fiftieth anniversary of one of the most famous research centres in the world—the Lawrence Radiation Laboratory (LRL) which was renamed the Lawrence Berkeley Laboratory (LBL) in 1971. (The Laboratory is operated by the University of California under contract with the US Department of Energy.) It was the scene of pioneering work in accelerator technology and high energy physics and is now adapting to other needs of the modern world. In this issue we carry the story of many of the major events in the Laboratory's history (by J.L. Heilbron, R.W. Seidel and B.R. Wheaton of the Office for History of Science and Technology, Berkeley), and a review of the present activities of LBL's Physics Division (from material supplied by George Trilling). In our next issue we will include shorter articles on other present activities at Berkeley.

The old 'Radiation Laboratory' which was allocated to E.O. Lawrence by the University on 26 August 1931. It got its name in 1932 when the first 27 inch cyclotron went into operation. The development of the cyclotron and the first tests of the synchro-cyclotron technique took place in this building.



A strong interaction between science and society: 1931—1981

The Lawrence Berkeley Laboratory was the first major accelerator installation and for over twenty years the world's leader in high energy physics. It has grown from a small cyclotron centre into a vast complex of diversified and interdisciplinary research programmes covering scores of sciences and technologies, employing about 3000 people, and enjoying an annual budget of almost $150 million.

The story of the conception and growth of the Laboratory, and of its successful adaptation to the changing constraints and opportunities to which it has been exposed, has more than regional or even national interest. The story is intermeshed with major forces in modern history: economic cycles, social revolution, war and the fear of war, growing bureaucracy, medical scientism, and, most recently, concern with pollution of the environment and with conservation and multiplication of energy sources. In adapting to these forces, the Laboratory has devised not only novel machines and uses for them, but also new ways of organizing science. As the exemplar of large-scale team research in an academic environment, it has had an important influence on scientific research throughout the world.

The Old Radiation Laboratory

The six periods into which we divide the Laboratory's history correspond to major social and political events in society at large. Because of the intermeshing mentioned, this punctuation also often coincides with turning points in the Laboratory's research and with important changes in its internal organization.

The early 1930s, when Ernest O. Lawrence established his Laboratory, would not appear to have been a propitious time. The United States was sliding into the depths of the Depression. Raising money for his projects would in any case have required ingenuity, for in the United States at that time the government gave negligible amounts for the support of academic physics. But Lawrence, an entrepreneur with contagious enthusiasm, got things moving by skilful mobilization of industry, philanthropy, and the University.

The industry in question was radio, whose rapid development during the 1920s helped Lawrence in two quite different ways. First, it made powerful radiofrequency oscillators available without which a useful cyclotron would not have been possible. Second, a method of long-range transmission that required huge electromagnets was made obsolete. A local firm, the Federal Telegraph Company, gave one of these white elephants to Lawrence. The University set aside a disused engineering testing laboratory as a Radiation Laboratory. The Research Corporation, a philanthropic foundation established on the proceeds of the patents of a former Berkeley professor, and the Chemical Foundation, which held German chemical patents seized in World War I, gave enough to move the magnet and to outfit it for use in an accelerator.

The purpose of the accelerator and X-ray tube, developed in the early years by Lawrence and his graduate students M. Stanley Livingston and David Sloan, was to reach high potentials with the hope of improving medical therapy and of developing a new source of energy. Or so Lawrence told his financial backers. But for coworkers — primarily Berkeley students or staff and visitors willing to labour for nothing — the Laboratory's purpose was the excitement of building machines at or just over the edge of technology, and the prospect of using them to learn something about the nuclei of atoms.

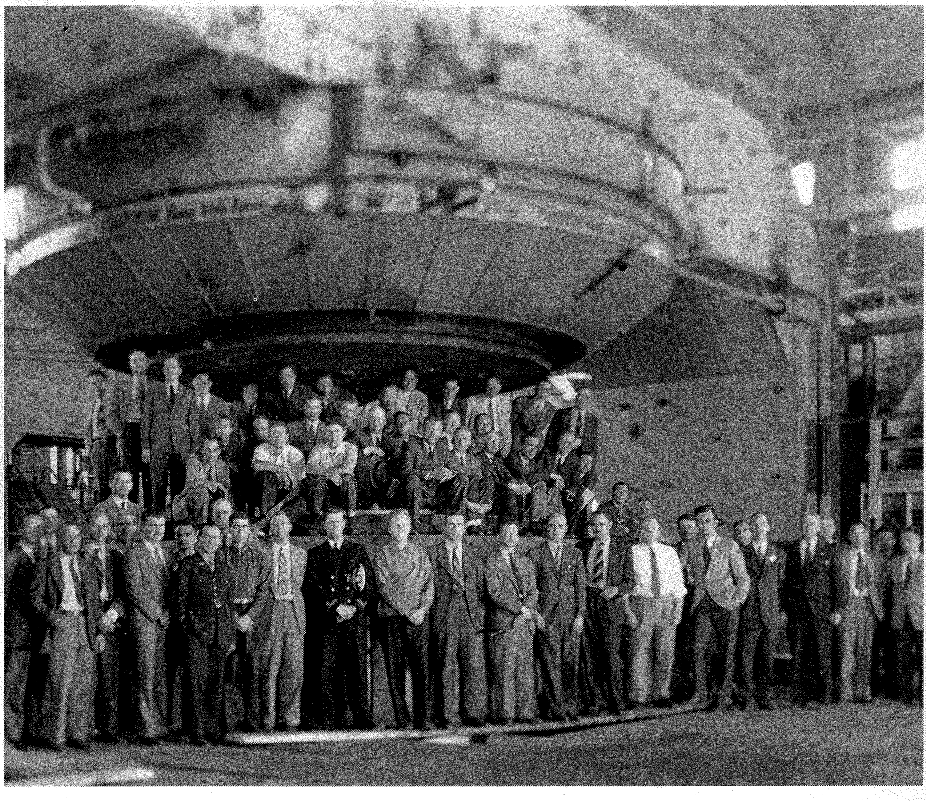
The difference in perception between the backers and the workers explains much about the successes and the failures of the Laboratory during the 1930s: its rapid growth and technical excellence, and its missing of major discoveries in nuclear physics, from artificial disintegration to nuclear fission.

The disparity between the objectives of most of the staff and Lawrence's commitments to his backers gradually became more evident. In 1934, following the discovery of artificial radioactivity by Irène and Frédéric Joliot, Lawrence emphasized the creation of radionuclides that might be useful in medicine or as tracers in biological research. The shift brought the Laboratory the support of the Macy and the Rockefeller foundations, who were interested in the application of physics to biology, and brought the staff the obligation to manufacture isotopes useful in medical and physiological research.

In 1935, with the help of his brother John, a physician, Lawrence turned his attention to the possibilities of treating cancer with cyclotron beams and in 1936, as part of the concessions to retain Lawrence against an offer from Harvard, the University acquired money for a 'medical cyclotron'. The resultant 60 inch accelerator, which came into service in 1939, was then the most powerful in the world.

Meanwhile more and more time on the machines using the old Federal Telegraph magnet (a 27 inch cyclotron until 1937, then a 37 inch) went to making isotopes for biological experiments and to searching for more useful ones. Important results came from this work: on the supply side, the synthesis of many new nuclear species, including cobalt 60, technetium 99, and carbon 14; on the application side, treatment of polycythemia vera and other diseases.

Experience in detecting and identifying minute quantities of new radionuclides — as well as experience in operating the machines to create them — made possible the discoveries of neptunium and plutonium within two years of the announcement of nuclear fission. Some excellent physics included measurement of the neutron's magnetic moment, proton-proton scattering, and the discovery of nuclear transformation via capture of orbital electrons.



Lawrence poses with the shop crew during World War II days with the 184 inch cyclotron, then under construction, as a backdrop.

But on the eve of the Second World War the Laboratory was by no means dominated by nuclear physics, or even by nuclear physics and nuclear chemistry. It was devoted to a unique hybrid of physical and biological science, medicine, and high technology—a hybrid created by Lawrence to bring about the advancement that none of its constituents could achieve alone.

Meeting the demand for biologically useful radioisotopes for use in Berkeley and elsewhere required organization. In May 1937 an owl shift (11 pm to 3 am) was added to the two day shifts on the 27 inch cyclotron; in July it began to operate around the clock. The staff, who had arranged their hours casually, now established formal schedules. Experiments had to be arranged around the ongoing programme of isotope manufacture. Scheduling of time on the machine—already standard at the great telescopes—thus entered nuclear physics, or at least the Laboratory, not because it had too many experiments to accommodate, but because a large fraction of the machine's running time was required to make good its finances. That Lawrence could hold all this together is a measure of his entrepreneurial skill and enthusiasm that built a flourishing, convivial, exciting Laboratory in the depths of the Depression.

Mobilization and transformation

An indication of what the Second World War meant for the Laboratory may be gleaned from the story of the 184 inch accelerator. Lawrence began to gather money for it in 1939 from his usual backers, among whom the Rockefeller Foundation were the most generous (some $1.15 million). The grant came despite criticism that the machine would have difficulty reaching the energies Lawrence aimed at—between 100 and 200 MeV—because at such energies the relativistic increase in mass of the particles would destroy the cyclotron resonance. The Laboratory planned to reduce the effects of loss of synchronization by several inelegant methods, for example, by raising the maximum strength of the field, thus decreasing the number of turns necessary to achieve the design energy and consequently decreasing the opportunity for falling out of resonance.

The magnet for the 184 inch cyclotron (the dimensions were determined by the size and cost of steel plates ordinarily milled at that time) would not fit on the campus. The University provided a place in the hills above Berkeley, overlooking San Francisco Bay, and on that site, around which was to grow the present Laboratory complex, 10 000 tons of concrete were poured during October 1940 as a pad for the huge machine. The press, which reported the pouring, linked it presciently but impertinently to the European war. It was observed that the discovery of fission had opened the possibility of nuclear explosives, and that cyclotrons were in operation or under construction in Germany and Japan.

The first impact of the War on the Laboratory was when there was trouble procuring the steel and copper for the magnet of the new accelerator. Although the United States had not yet entered the War, it had started to stockpile and to ration strategic materials. No accelerator would be built on that concrete pad in the Berkeley hills unless the University could obtain a high priority for the purchase of the necessary metal.

Priority—eventually highest priority—came through the good offices of the National Defense Research Council, which in 1940 took over the 'uranium project', the first stage of the American effort toward a nuclear bomb. (For security reasons, the 'Manhattan Engineering District' (MED) disguise was adopted.) The Council determined that the big magnet should be completed in order to test designs for a method to separate the explosive lighter isotope of uranium (U-235) from its much more plentiful companion (U-238). Lawrence urged the method of electromagnetic separation, using all his optimism and patriotism. Perfecting it became the chief work of the Laboratory from 1941 until the establishment of the process in 1944 on an industrial scale at Oak Ridge, Tennessee.

The production elements for the process, called calutrons after the institution in which they were designed, amounted to large mass spectrographs. They were arranged in 'racetracks' (96 to a track), each track controlled by a magnet consuming a hundred times as much power as the magnet of the 184 inch cyclotron. When not enough copper could be found to bring the current that fed the magnets, 14 000 tons of pure silver were acquired from the federal treasury. Almost all the fissile material in the bomb that fell on Hiroshima passed through the calutrons.

The 184 inch accelerator was completed after the war with its discharge pay—a grant of $170 000 from the MED. Its final design had none of the original stopgaps. Instead it incorporated the principle of synchronous acceleration developed towards the War's end by Edwin McMillan (and, independently, by V.I. Veksler in the Soviet Union). The principle accommodates relativity by modulating the frequency of the accelerating electric field, or by changing the strength of the controlling magnetic field, or both. Since the magnet had already been built, the first alternative was adopted for the 184 inch 'synchro-cyclotron'. That brought its energy to double the maximum Lawrence had aimed at in 1939.

The number of Laboratory staff increased briskly during the War, owing principally to the calutron project, but also to work on other topics of interest to the MED. The most significant for the Laboratory's future were studies of the biological effects of fissile materials and their products and examination of the effects of high temperatures on materials of possible use in nuclear reactors. At its wartime high, the staff numbered 1170, including 65 guards. Security precautions remained obtrusive for many years, and have not disappeared entirely from the Hill despite the end of all classified research there.

The Laboratory's most remarkable legacy from the War was its size. In plans for the future that he drew up in 1944, Lawrence assumed that the Laboratory would continue as a part of Berkeley's physics department and proposed a separate division for medical physics. He expected to have only a small staff and to reimplement the frugal policy of allowing students and visitors to do most of the work.

As for the budget, he anticipated making do with $85 000 a year and some war-surplus equipment. In 1945, however, Lawrence realized that science would be honourably discharged and held in ready reserve for the national defence and welfare. Four months before the successful test of the plutonium bomb in New Mexico, he wrote to the MED offering to accept $7 to $10 million for the Laboratory's first year of postwar operation, a hundred-fold increase over the budget he had estimated the year before. After the test, which confirmed his confidence in dealing with the MED, he set the postwar staff at 239. Its minimum, in 1946, was twice that. The Laboratory expanded further under the MED's successor, the Atomic Energy Commission (AEC), and under the AEC's descendants, until reaching its present size, a staff and an operating budget six times (in constant dollars) what Lawrence had in 1946.

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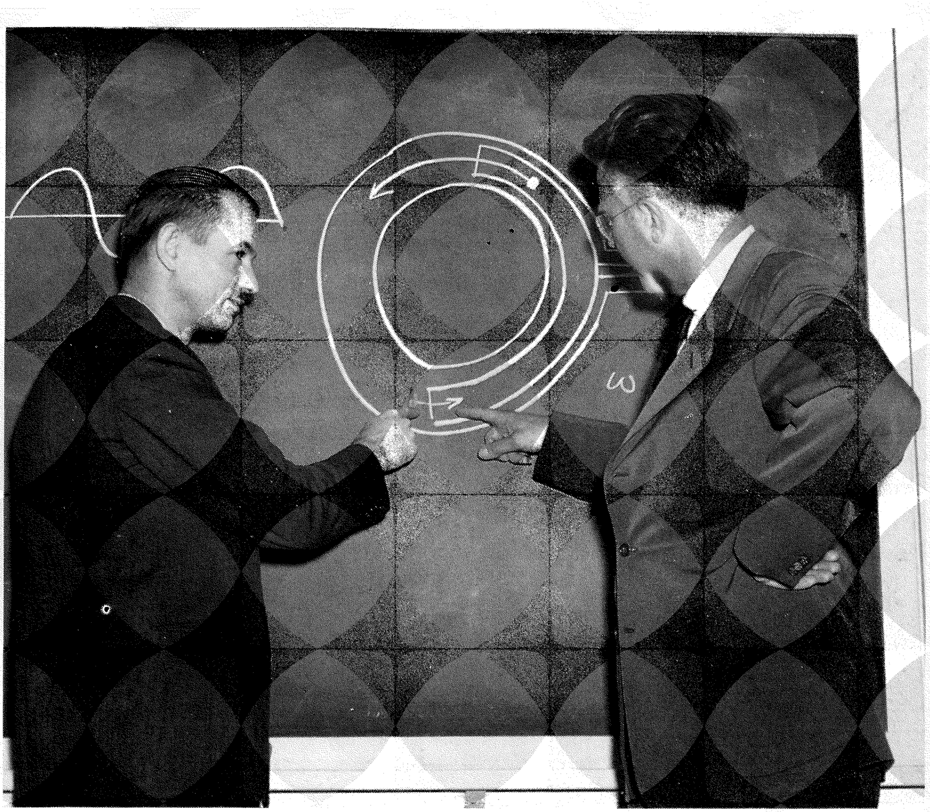
Demobilized science

The War left the Laboratory not only with the trappings of big science under government auspices — organization, security, hierarchy, impersonality, and great resources — but also forced a change in research emphasis. The nuclear and high energy physicists had become the heroes of the hour, the magicians able to make the most devastating explosions from the most insignificant bits of matter. Their big accelerators were misunderstood to be essential to the national defence and the need to collaborate in teams to operate and use these machines admirably suited the size and structure of the Laboratory.

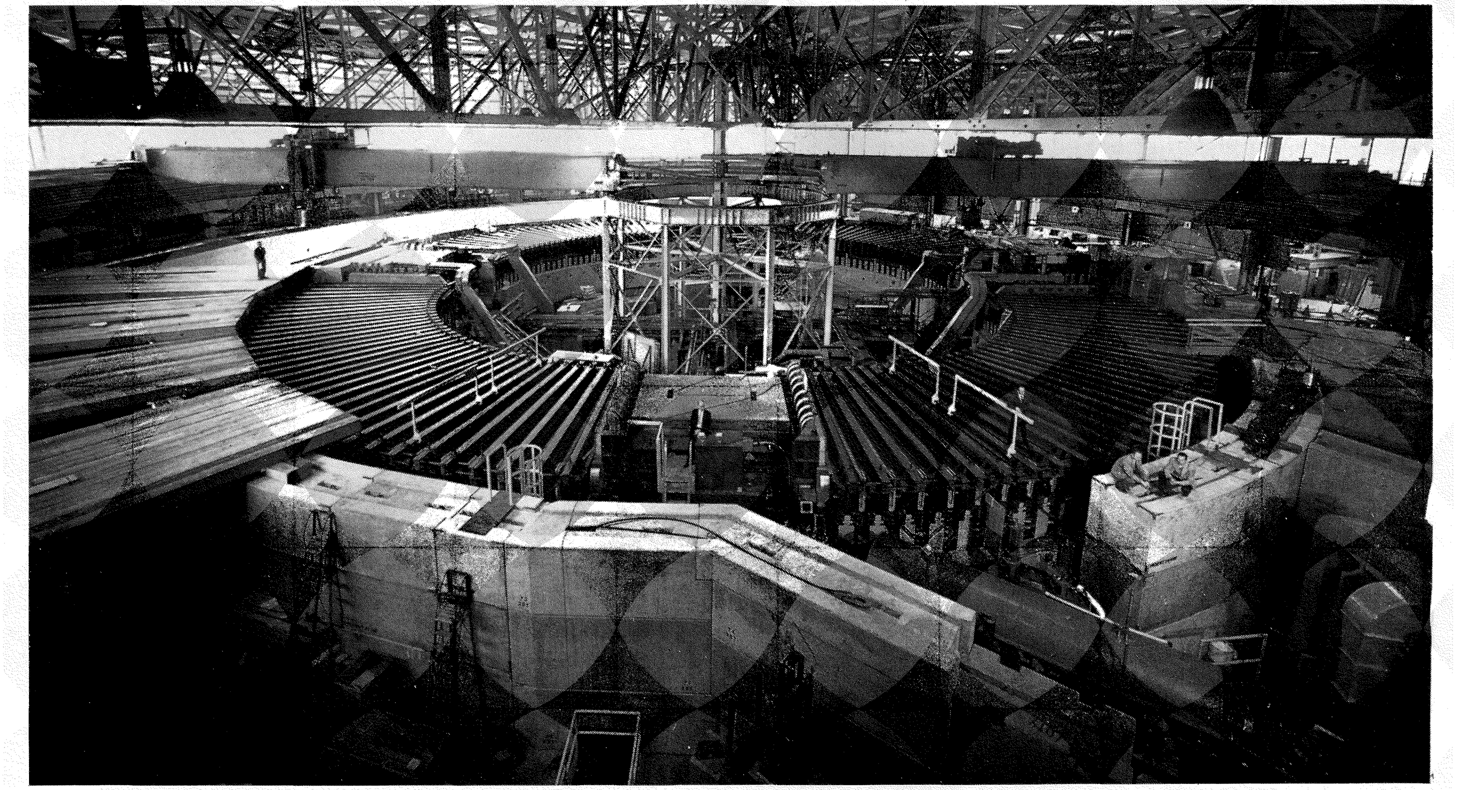
Another factor favouring high energy physics was the interest and generosity of the MED. It made available $230 000 in cash and almost as much again in surplus capacitors for McMillan's electron synchrotron, and awarded a pilot grant and 750 surplus radar generators worth $1.5 million for Luis Alvarez' proton linac. High energy physics and accelerator design took precedence at the Laboratory over their former equals, nuclear chemistry and nuclear medicine.

This is not to say that chemistry and medicine did not prosper during the hegemony of high energy physics, which lasted until the early



A major step forward in accelerator technology came with the concept of phase stability. It was developed at Berkeley by Ed McMillan (left) and, independently, by Vladimir Veksler. McMillan is seen here explaining to Lawrence these ideas which opened the door to higher energy machines.

With the Bevatron 6 GeV proton synchrotron, the research at Berkeley dominated the high energy physics scene in the 1950s. It is still in action as part of the Bevalac complex for research with accelerated heavy ion beams.



1960s. In the case of chemistry, the work on high temperature thermodynamics, a continuation of the war work on reactor materials, went on until it combined with other projects around 1960 to make a new division for material and molecular research.

In nuclear chemistry Glenn Seaborg, returning from the MED in 1945 with $75 000 for a special facility to handle intensely radioactive isotopes, carried on the work on actinide chemistry that he had begun during the War, and synthesized a number of new transuranium elements. Two of these, berkelium and californium, bear names that celebrate the science of the Far West. As for medicine, John Lawrence and his associates continued cancer therapy by cyclotron beams and made use of the carbon-14 available in plenty from the Hanford reactors to label and follow molecules in biological processes. The most dramatic work in this field was the complete mapping of photosynthesis by Melvin Calvin and his colleagues.

The amount and achievement of these lines of work are crude indicators of the effort that went into the Laboratory's main research programme in the decade and a half after the war. In 1946 three different sorts of accelerators, each the largest of its type, were either under construction or in final planning. These were the 184 inch synchro-cyclotron (completed that November to give 200 MeV deuterons), the 32 MeV proton linac completed the following November, and the electron synchrotron, first operated in December 1948 to give 335 MeV gamma rays. While these machines were coming on line, the Laboratory's chief engineer, William Brobeck, was drawing up plans for a proton synchrotron in the GeV range. In April 1948 the AEC authorized construction of two such machines, one for 2 to 3 GeV at Brookhaven and the other for 6 GeV or more at Berkeley.

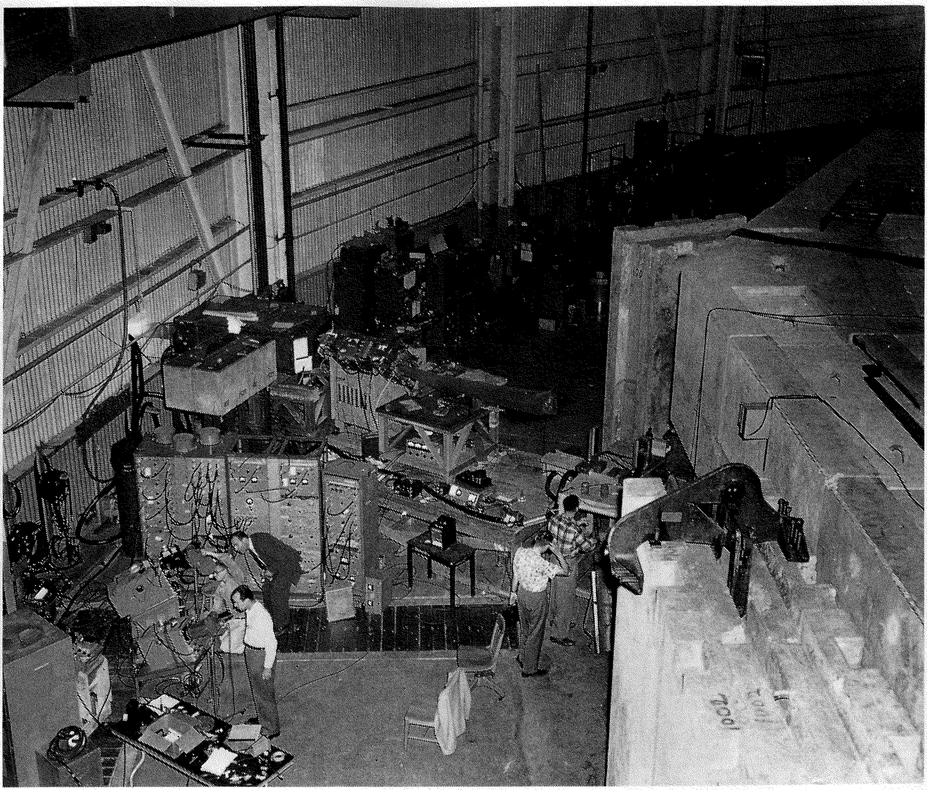
A partial remobilization

Among the achievements of this first generation of postwar accelerators was the wresting of the initiative in particle physics from investigators of cosmic rays. Early in 1948 charged mesons (pions) were detected in abundance among the shrapnel from targets struck by the beam of the synchro-cyclotron; late in 1949 experiments at the same machine made very plausible the existence of a neutral pion; and in 1950 a similar find using the electron synchrotron put the matter beyond doubt. In 1952 the more energetic Brookhaven Cosmotron came on line, and was soon making the kaons first identified in cosmic rays.

The proton linac became the spearhead of the Laboratory's counter to the detonation of the first Soviet nuclear bomb in August 1949. The explosion shocked and even panicked Western politicians even as it vindicated their technical advisers. In the subsequent paranoia, security was tightened, loyalty oaths imposed, dismissals made and a cash and crash programme authorized for the hydrogen bomb. Lawrence, who himself had never demobilized—he had continued to urge the upgrading of the calutron process and the stockpiling of radiological warfare material—helped lead the rush toward a superweapon. After the AEC quashed his plan for a heavy-water reactor, he proposed ensuring a plentiful supply of material for fusion and fission bombs, and for radiological warfare, by making it in an accelerator.

Lawrence's plan, which he submitted to the AEC on New Year's day 1950, called for the construction of a machine that would produce a gram of neutrons a day. The neutrons would fall on various targets, depending on the destructive material desired—on lithium to produce tritium (for fusion bombs), on bismuth to produce polonium (for radiological warfare), and on uranium to produce plutonium (for fission bombs). The last purpose probably weighed heaviest with the AEC, which worried that the United States might someday find itself without natural uranium, for which it then depended on foreign suppliers.

The prospect held out by Lawrence of making something useful from the practically inexhaustible tailings from reactors of uranium impoverished in U-235 had so strong an appeal that the Commission authorized the construction of a prototype neutron factory. The project, code named Materials Testing Accelerator (MTA), was set up about 45 miles from Berkeley at a former naval air station in Livermore, California.



The Bevatron energy was just right for the production of antiprotons. Their discovery in October 1955 in the detection system seen here was one of the Laboratory's greatest physics discoveries.

The prototype, or Mark I, was an Alvarez linac, essentially a resonant cavity filled with an electromagnetic field that accelerates particles as they cross gaps between protective drift tubes suspended from the cavity wall. Mark I, which cost over $20 million, contained the largest nothing in creation, an evacuated space 60 feet long and almost 60 feet in diameter. Its power consumption, 18 megawatts, could have met the needs of a community of 20 000. The largest of its drift tubes weighed 40 tons and the beam focusing magnets alone required 100 tons of copper windings.

And Mark I was but a toy to the projected full-scale production accelerator, Mark II, a cavern 1500 feet long and almost 60 feet in diameter. It would have cost more than $ 300 million exclusive of its target. Power alone would cost $14 million a year. Lawrence thought that ten of them should be built, in different parts of the country, each surrounded by concrete shielding 80 feet high and between 7 feet and 20 feet thick.

While the AEC debated the merits of this proposal, Lawrence suggested another kind of neutron factory, Mark III. It was to be a cyclotron built on the untried principle of sector focusing devised by L.H. Thomas in 1938 to meet the constraints of relativity. The Commission authorized a feasibility study, and the Laboratory built two scale-model electron cyclotrons that demonstrated the principle. But in 1952 the AEC killed the production accelerator and reduced the prototype, Mark I, to a small programme in its research division. It had found a much cheaper way to acquire fissile materials. By offering bonuses for discovery of new ore and higher prices for uranium it had inspired prospecting that uncovered rich deposits on the Colorado plateau. The United States did not need an emergency operation to make plutonium from scrap uranium.

The MTA project had major consequences for the Laboratory. First, it brought a permanent increase in staff, which rose from 900 in 1949 to almost 1600, a third more than the wartime maximum, in 1952. From that level another sharp rise began, again in response to a Soviet initiative — the announcement of a 10 GeV accelerator at Dubna in 1956.

A second consequence was the establishment of the Livermore site as a branch of the Laboratory. Livermore took on most of the Laboratory's applied science, including projects Whitney (weapons development), Pluto (nuclear rockets), Plowshare (peaceful applications of nuclear explosives), and Sherwood (controlled thermonuclear reactions). Classified research passed gradually from Berkeley to Livermore, which in 1971 became a separate institution run by the University for the AEC.

A third set of consequences concerned nuclear physics and accelerator design. Experience from MTA informed the plans for sector-focused research cyclotrons throughout the world, including the 88 inch machine for nuclear chemistry completed at Berkeley in 1961. Severance pay for MTA, some $ 350 000, enabled the Laboratory to increase the magnetic field of the synchrocyclotron to 23 kilogauss so that protons could be accelerated to 750 MeV. Perhaps most important, know-how gained in the MTA project and material salvaged from it assisted the completion of the long-awaited Bevatron at an energy almost double that planned in 1950.

Bumper crop

The Bevatron started up in 1954. For the next five years, until the CERN and Brookhaven proton synchrotrons began to operate, the Bevatron was the highest energy machine in the Western world, and by far the most prolific in terms of particle physics results. Also, because of its advanced systems for detection and analysis — particularly large bubble chambers and their electronic data-analysis systems — the Bevatron remained competitive for several years after it had lost the lead in energy.

Many of the experiments done during the Bevatron's first year, 1954, concerned the life history of the kaon. Six different sorts of kaons had been identified in cosmic rays, each distinguished according to its progeny. The question arose whether physicists had to accept a half dozen kaons as elementary, or whether the several sorts of offspring reflected not independent ancestors, but the several ways in which a single indecisive parent might divide its estate of energy.

Experiments established that all kaons have about the same mass, and that all positive kaons have about the same lifetime. Against the obvious inference that there exists but one sort of kaon with different ways of disappearing stood the consideration that two of these modes, called theta and tau, could not both conserve parity.

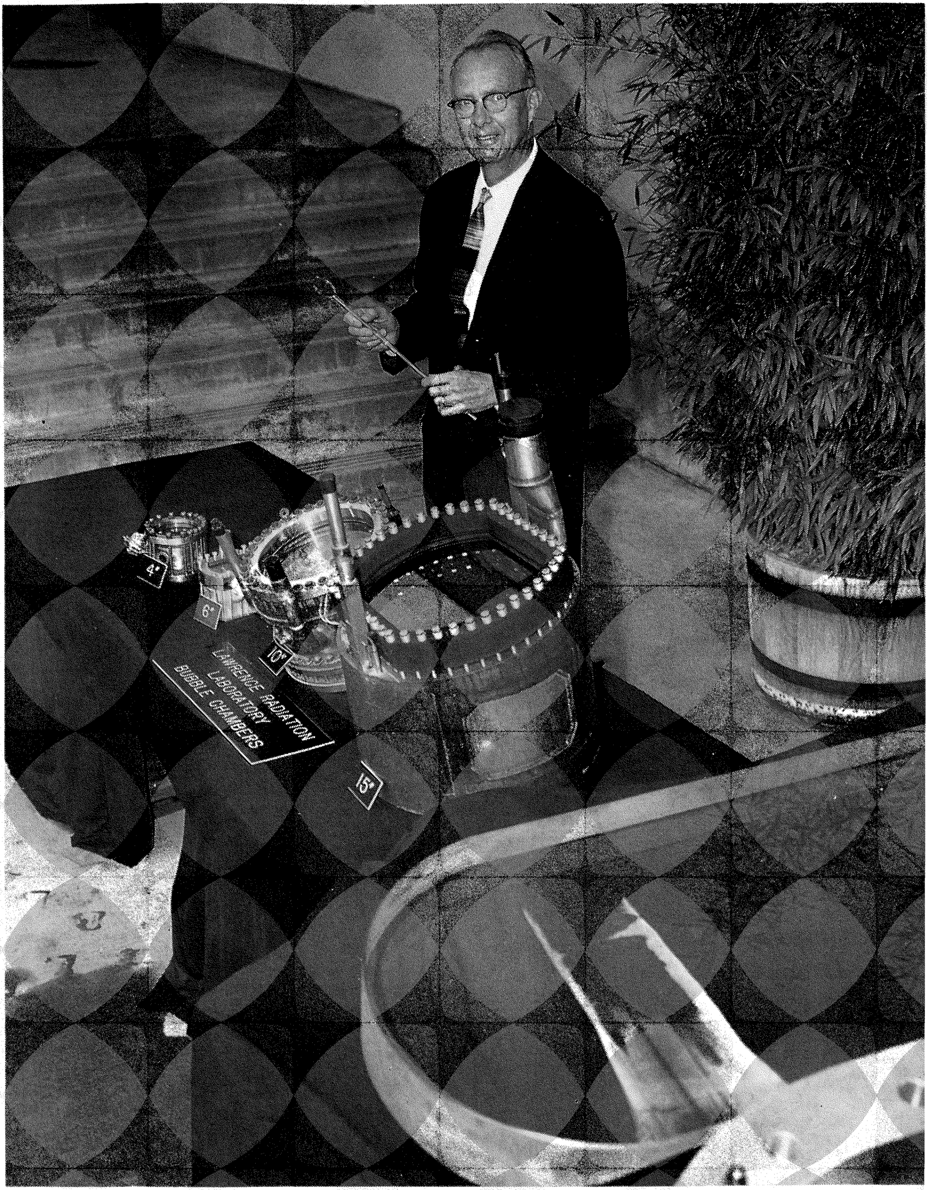
The conclusion by T.D. Lee and C.N. Yang that parity need not be conserved in certain weak interactions resolved the tau-theta puzzle sharpened by the Bevatron's work. Other kaon puzzles found solutions in the introduction of a new quantum number, strangeness, by Murray Gell-Mann and others. Further work with the Bevatron confirmed the theory, for example by showing the violation of parity in hyperon decay.

The study of kaons, though exciting and rewarding, had in one respect an air of déjà vu — once again a great accelerator made possible the detailed study of particles first found in cosmic rays. Another quest beckoned — the detection of a particle of fundamental importance not yet found among nature's products — and several groups began to look for the antiproton in 1955. The Bevatron's design energy of 6.2 GeV made it virtually certain that if such particles could exist, the machine could make them.

The trick was to find the very few negative protons among the great quantity of secondary particles created where the Bevatron's beam struck a suitable target. In the method that succeeded first in October 1955 an elaborate set of bending and focusing magnets, and of scintillation and Cherenkov counters, connected by state-of-the-art coincidence circuitry detected one antiproton against a background of 50 000 negative mesons. A year later a second bit of antimatter, the antineutron, was discovered among the particles produced by the Bevatron.

For some purposes the new fast electronic detectors could not replace the slow old ways using cloud chambers and nuclear emulsion. In particle physics, as elsewhere, a picture is often worth a thousand words or clicks. But, to realize the full promise of the projectiles from the Bevatron, a track detector faster than the cloud chamber and more discriminating than the emulsion was needed.

The answer, the bubble chamber, first proposed by Donald Glaser, was developed into a versatile machine by Alvarez and his colleagues. Their first chamber, built in 1953, was an inch and a half in diameter. Their largest, authorized in 1955 and finished



Much of the Laboratory's success in particle physics was due to the development of the bubble chamber. The major driving force was Luis Alvarez who posed here with the succession of chambers which grew from just one and a half inches to 72 inches across during the years of the high energy physics programme at the Bevatron.

in 1959, measured 72 × 20 × 15 inches. It was viewed through the largest piece of clear optical glass ever made, which had to withstand 100 tons of pressure from the liquid hydrogen it confined. Along with the chambers, Alvarez' group built increasingly powerful automated instruments to handle the prodigious amount of data.

Among the many important items of evidence captured in the bubble chamber pictures were demonstrations of the violation of parity and of charge conjugation in hyperon decay, the discovery of the elusive neutral ksi, and the detection of a series of new resonances. The first of these brief encounters, the Y* hyperon, found in 1959, aroused great interest when reported at the Rochester Conference on High Energy Physics in 1960. In the ensuing rush to create a spectroscopy for the heavier elementary particles, the Bevatron made the most notable contributions until the energy required exceeded its powers.

From the systematics of the spectroscopy worked out independently by Gell-Mann and Yuval Ne'eman, the existence of an undetected particle, the omega minus, could be inferred. Since the particle, named in the belief that it would be the last of its kind, would confirm a central point in the spectroscopic system or 'eightfold way', it was eagerly sought. Its creation lay beyond the abilities of the Bevatron, and its discovery at the Brookhaven AGS in 1964 may be seen as the end of the Bevatron's leadership in particle physics.

The Laboratory expected to recover that leadership by constructing a 200 GeV accelerator. Planning for it began in 1953, when Brookhaven and CERN were already busy with alternating gradient synchrotrons that would make the Bevatron obsolescent. In the early 1960s the Laboratory's design study for a 200 GeV machine expanded under the patronage of the AEC. However political and regional considerations would ultimately determine the siting of so large and expensive a machine. It was built in the Midwest at what became Fermilab, to serve a previously neglected constituency.

The end of the beginning

Lawrence died on 27 August 1958. As his successor the University chose his long-time associate Edwin McMillan, who served until 1973. Under his direction the Laboratory became a centre for interdisciplinary work in fields as diverse as metallurgy, catalysis and surface science, electron microscopy, theoretical chemistry, photoelectron spectroscopy, earth sciences, hydrology, physical chemistry, cellular biology, oncology and laser chemistry and biology. His successors, Andrew Sessler (1973–80) and David Shirley, have presided over further diversification as the conservation and development of sources of energy became a concern of the Laboratory's patron, the Department of Energy.

While these new opportunities opened, funding of high energy physics levelled off and the 200 GeV accelerator was under construction at Batavia, Illinois. Although, in consequence, high energy physics has declined in relative importance at the Laboratory, substantial contributions to the field continue to come from Berkeley, particularly in collaboration with the nearby Stanford Linear Accelerator Center, SLAC. Among them are participation in the construction and use of the PEP electron-positron storage ring and the construction of a novel large detector known as the Time Projection

The site of the Lawrence Berkeley Laboratory as it is today. The dominant feature is still the circular hall housing the Bevatron.

(Photos LBL)

Chamber, which is just coming into operation.

The Bevatron, long since superseded as an instrument of elementary particle physics, has been incorporated into the last stage of an accelerator complex, called the Bevalac, which can accelerate ions as heavy as uranium. Such ions originate in the 'SuperHilac', an improved version of the Heavy Ion Linear Accelerator (Hilac) that began work at Berkeley in 1957. After acceleration to a maximum energy of 8.5 MeV/nucleon in the SuperHilac, heavy ions may be sent either directly into research areas for nuclear chemistry or shunted into a long pipe for injection into the Bevatron. They emerge from the larger accelerator with a maximum energy of 2.1 GeV/nucleon for applications in nuclear medicine and nuclear physics. The Bevalac and the 88 inch cyclotron, completed in 1961, are the principal tool for heavy ion research in the United States. It is noteworthy that both the cyclotron and the first Hilac incorporated technology developed for the MTA.

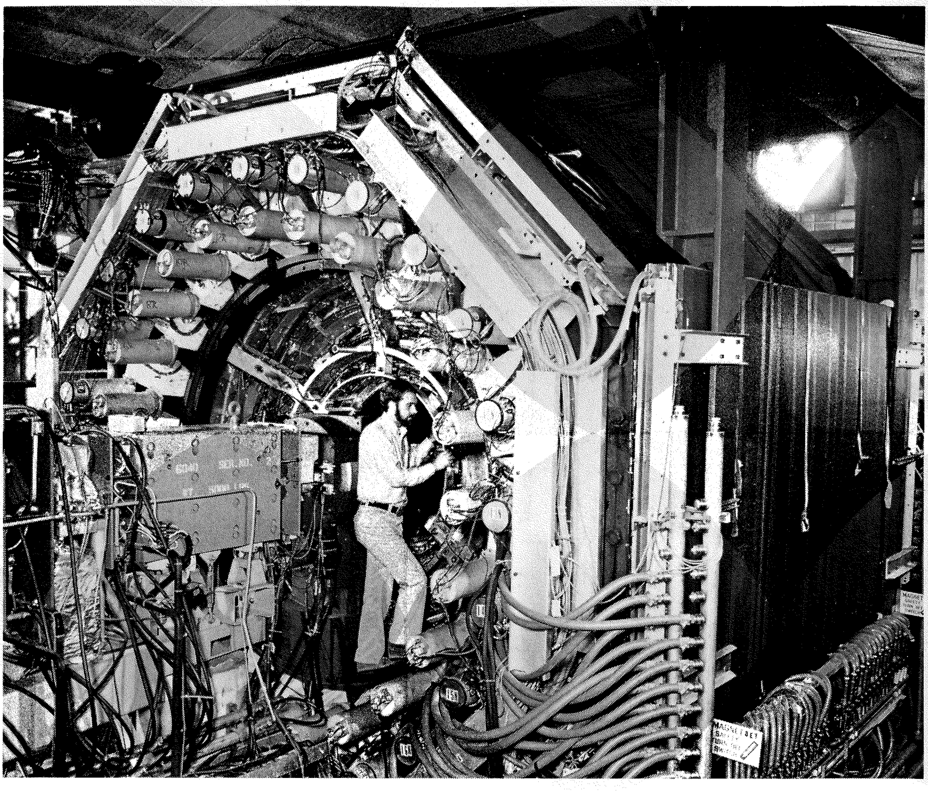
The loss of the 200 GeV accelerator and the subsequent drop in funding for high energy physics brought a sharp decline in the staff number and budget that lasted from 1966 to 1974. Recovery and rapid growth occurred in the late 1970s through promotion of new sources of interdisciplinary research in response to national needs. The Materials and Molecular Research Division (MMRD) assembled and expanded programmes already existing at the Laboratory and on the campus. The origins of the Division may be traced to research on reactor materials begun during the war and continued in connection with high temperature thermodynamics.

Around 1960 the programme became a Division with a mandate to study, among other things, exotic materials for possible application to nuclear and space technologies. In keeping with the Laboratory's tradition, MMRD has developed large specialized instrumentation, for example, a 1.5 MeV electron microscope standing three stories high and costing $1.5 million. With an atomic resolution microscope, scheduled for construction in 1982, MMRD's National Electron Microscope Facility will be the leading microscopy centre in the United States.

When Congress amended the Atomic Energy Act to allow the AEC to support programmes in non-nuclear energy development and environmental conservation in 1970, McMillan formed an Environmental Research Office to promote the new field. Research on water desalination, atmospheric aerosols, disease induced by pollution, and the effects of supersonic transport on the earth's ozone budget were among its early projects. Many others have been added since the Office rose to a Division — becoming the largest in the Laboratory — under Sessler. In 1977 he split it into two, one for Energy and Environment and another for Earth Sciences, which includes research on geothermal energy and on disposal of nuclear wastes. In recent years these two Divisions together have accounted for almost a quarter of the Laboratory's budget.

Overspecialized institutions, like over-specialized organisms, do not long survive major changes in their environments. The Laboratory's main principle of adaptation has been the creation of interdisciplinary teams that dissolve ordinary institutional boundaries in order to develop a machine, a research project, or a research programme. It was on this principle that Lawrence established his Laboratory. To demonstrate the wide promise of his machine and its products to his patrons, he recruited biologists, physicians, and chemists as well as physicists and engineers to work on and around the cyclotron. After the war he reaffirmed the principle by promoting hybrids like Melvin Calvin's bio-organic chemistry. Materials research, the first big interdisciplinary programme initiated after his death, drew on institutional mechanisms already firmly in place. The Divisions of Energy and Environment and Earth Sciences are new variations on the successful principle of growth through diversification into new interdisciplinary research.

If our biological metaphor has any validity—and, perhaps, even if it does not—the Laboratory is well placed to continue the course of high achievement and successful adaptation of its first fifty years into its next half century.



The SLAC/LBL Mark I detector made a remarkable number of discoveries at the SPEAR ring, including the psi family, charmed mesons and the tau lepton.

(Photo SLAC)

Present activities in the Physics Division at Berkeley

The Physics Division (whose official name is the Physics, Computer Science and Mathematics Division) has a long tradition of outstanding research, both experimental and theoretical, in elementary particle physics. But rather than dwelling on past history, we cover some of the major activities which are presently pursued by LBL high energy physicists, in collaboration with scientists from many other universities and Laboratories.

Electron-positron annihilation

Involvement in studies of high energy electron-positron annihilation dates back to the early 1970s and the collaborative effort with SLAC to build and operate a detector at the SPEAR storage ring then under construction at Stanford. The exploitation of this detector, subsequently known as the SLAC/LBL Mark I, produced a remarkable number of discoveries including the psi family, charmed mesons and the tau lepton. It was replaced in 1977 by Mark II, an improved version with drift chambers, a large lead/liquid argon electromagnetic calorimeter, and a more elaborate muon detection system.

Mark II remained at SPEAR until 1979 when, with some upgrading, it moved to PEP. The Mark II results at SPEAR included the quantitative study of many decay modes of the D charmed mesons and the tau, the confirmation of the charmed lambda baryon and of the candidate charmed eta, the first study of exclusive states in radiative decays of psions, and analysis of various exclusive states produced in photon-photon interactions.

At PEP it is being used to study electroweak interference effects, multiple-jet production, properties of gluons, and the tau lifetime. This programme will continue with the addition of a high resolution drift chamber to permit the study of short-lived particles.

New physics often goes hand-in-hand with the development of new experimental tools. A major effort is going into the construction of a sophisticated general purpose detector whose central element is a Time Projection Chamber (TPC). This is being built by a Berkeley / Los Angeles / Johns Hopkins / Riverside / Tokyo / Yale collaboration. It will provide excellent pattern recognition and identification of charged hadrons, simultaneous measurement of the energies and directions of gamma rays in an electromagnetic calorimeter, high purity identification of electrons, and recognition of muons through their penetration in an iron shield. These capabilities will be used to study a large variety of complex final states produced in electron-positron collisions at PEP. There has also been talk of eventually moving the TPC to one of the higher energy machines (LEP, SLC, CESR II) being proposed for the latter half of the 1980s.

Construction progress was described in the June issue (page 203). In June, the high voltage system and two sectors were integrated for the first time and coupled to the electronics. The system was closed on 26 June, pressurized on 29 June, and first cosmic rays were detected on 1 July. The tracks had better resolution than expected at that early stage of operation, and their quality was independent of angle or drift distance. Thus all basic principles of operation have now been tested.

The entire detector (with a conventional rather than a superconducting solenoid — see June issue) will be tested with cosmic rays later this year, before finally moving into PEP. The rebuilt superconducting coil will be installed later.

This description of LBL electron-positron annihilation experiments is completed by mention of the free quark search experiment at PEP carried out by a Berkeley / Frascati / Hawaii / Northwestern / Stanford collaboration. This seeks to identify free quarks with fractional charges through accurate measurements of energy loss in scintillators and of velocity by time-of-flight. A luminosity of about 17 000 inverse nanobarns has been accumulated which will allow quarks of either charge state to be found if their mass is less than 13 GeV and if they occur at more than one per cent of the normal muon pair rate.

Experiments with neutrinos and muons

Berkeley has been involved in high energy neutrino experiments using the 15 foot bubble chamber at Fermilab. Physicists from LBL and Hawaii developed and constructed the External Muon Identifier to identify particles from a neutrino interaction which could penetrate about five hadronic interaction lengths. This has been extensively used in experiments both with and without LBL participation. Evidence for gluon radiation in the hadronic system produced in energetic neutrino interactions and lack of evidence for neutrino oscillations are recent observations from two of the LBL experiments. There is presently no plan for involvement in the Tevatron bubble chamber programme.

There is a strong, continuing involvement in high energy muon physics at Fermilab. Early work by a Cornell / Michigan State / LBL / San Diego collaboration demonstrated a scaling violation in deep inelastic muon scattering. This result, subsequently confirmed by experiments at CERN and Fermilab, gives important evidence in support of the theory of quantum chromodynamics.

More recently, LBL physicists, in collaboration with groups from Fermilab and Princeton, have constructed a Multi-Muon Spectrometer, for studying multimuon final states from muon interactions. This uses a massive target to achieve high luminosity. The spectrometer magnet is integral with the target to maintain high acceptance over the full target length and in the forward direction with no 'blind' beam hole.

The detector was completed in 1977, and data accumulated in 1978 with 209 GeV muons have led to a number of interesting results. These include new limits on the existence of neutral heavy leptons, extensive data on charm production based on observations of dimuon final states, and measurements of J/psi elastic and inelastic production. In the future, the experiment will be upgraded and moved to the new Fermilab muon beam in which measurements with muons of energies up to 800 GeV can be made.

Proton-antiproton colliding beams

LBL is participating in design work for the Fermilab 2 TeV proton-antiproton collider. Teams from two Berkeley Divisions are involved, one concentrating on the design of a general purpose detector, and the other on stochastic cooling techniques for accumulating antiprotons.

In collaboration with groups from Fermilab, Argonne, Wisconsin and Novosibirsk, a team from the Accelerator and Fusion Research Division is working on the source design. A new type of pick-up electrode has been developed for sensing beam position fluctuations. Earlier this year, 200 MeV protons were successfully controlled using this technique.

A Berkeley physics group is participating in the design of the large 'Collider Detector Facility' (CDF) for Fermilab. This features fine-grained hadronic and electromagnetic calorimetry over most of the solid angle. The calorimeters will have a very high degree of spatial segmentation to cope with the expected large multiplicities and jet-like structure at 2 TeV. In addition, a superconducting solenoid with a 1.5 T field and a drift chamber central tracker will provide momentum analysis and charge sign determination for particles produced in the central region. Tube chambers outside the calorimeter will label penetrating particles as muons in the central region and large instrumented iron toroids will extend the muon coverage to small angles on one end.

The LBL group is concentrating on the design of the hadron calorimeter for the end plug region. This is populated typically by hadrons of high energy and spatial density, and calls for a detector with especially fine segmentation. These requirements are met by instrumenting the calorimeter with gas-multiplication wire planes. The wire planes use cathode pad readout with the pads arranged in depth to form projective 'towers' that point back to the interaction region.

Prototype and computer simulation studies have been under way for several months. The final design should be fixed within a year so that construction can begin in time for the initial collisions scheduled for late 1984 or early 1985.

Search for right-handed muon decay

All present experimental observations in weak interactions can be understood in terms of purely left-handed weak currents. The absence of right-handed currents may arise from an intrinsically left-right symmetric world in which the particle which mediates right-handed currents is much more massive than that which mediates the left-handed currents. If so, one may be able to observe right-handed currents with an experiment of high sensitivity.

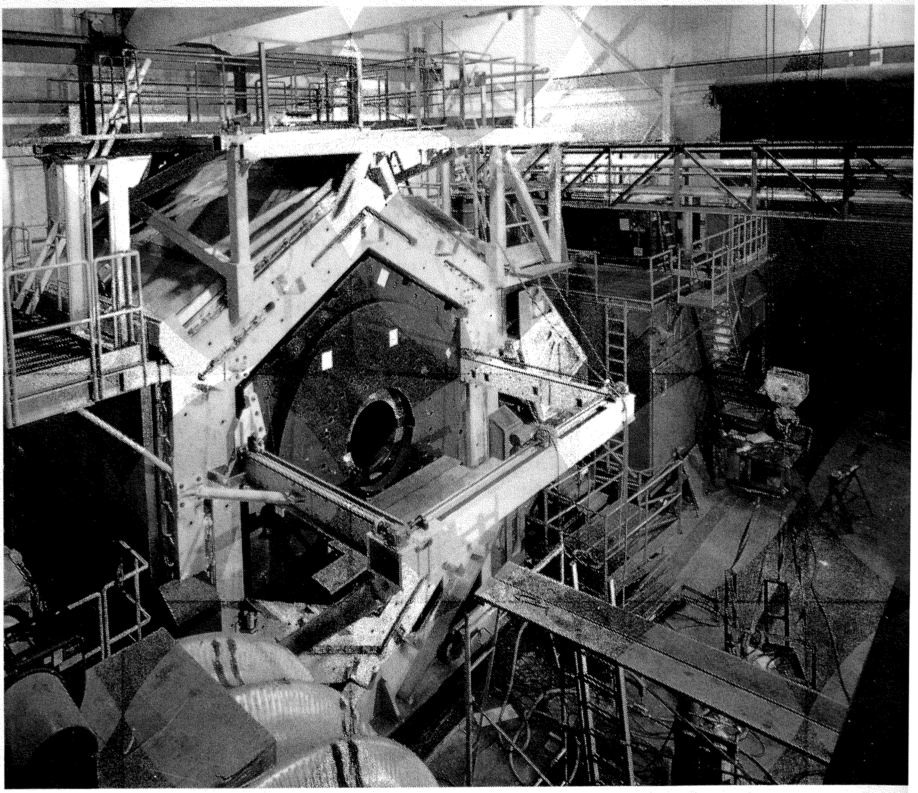
A particularly sensitive such experiment is a high precision study of the decays of completely polarized muons. In the absence of right-handed currents, the decay of a fully polarized positive muon into a maximum energy positron moving in the same direction as that of the muon (relative to its parent pion) is forbidden. Physicists from LBL in collaboration with British Columbia and Northwestern are preparing to measure the positron rate near this endpoint.

This experiment is being performed at the Canadian TRIUMF cyclotron, using intense positive muon beams with high polarization derived from positive pion decay at rest near the surface of the target. The muon polarimeter (scheduled for installation in January 1982) will stop the 4 MeV muon beam in a liquid helium target immersed in a 1.2 T field to preserve its polarization. Decay positrons will be focused by a solenoid through a 90° spectrometer with light drift chambers at the foci. The heart of the spectrometer will be the same 40 ton dipole magnet used at LBL's 184 inch cyclotron in muon decay studies than a quarter of a century ago.

In addition, LBL's physics effort covers subjects as new as quantum chromodynamics, and as old as the extinction of the dinosaurs 65 million years ago. Other interdisciplinary research includes astrophysics and radioisotope detection and dating.

Berkeley has put considerable effort into the development of the Time Projection Chamber detector for use at PEP.

(Photo LBL)



A message from gauge theories

At the UK Royal Society conference on gauge theories earlier this year, Abdus Salam spoke of the implications of these theoretical ideas for the future of physics.

The successes of the electroweak theory now make the prospect of its extension to a 'grand' electronuclear picture very attractive. Not content with this dramatic venture to simplify our description of Nature, ambitious theorists take a further gigantic step forward into the unknown and propose 'superunifications' to bring in gravity as well.

However Salam points out that these unifications, if justified, carry an important message for the future direction of experimental particle physics. In particular, the tradition of relying on bigger machines to provide higher and higher energies might just run out of steam.

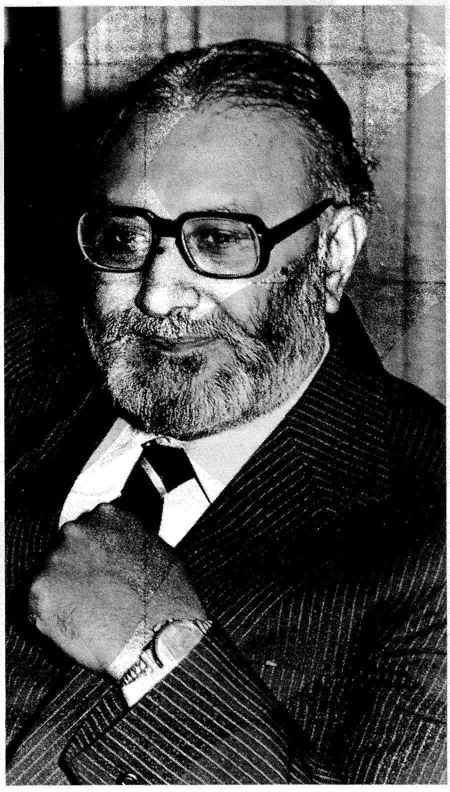
'Particle physics, as we know it today, began some ninety years ago with J. J. Thomson's discovery of the electron and Lorentz's bold extrapolation of Maxwell's electrodynamics down to the distances of the electron's 'classical' radius. Assuming that the 'family' concept currently employed to classify particles is correct, the companions of the electron, essentially constituting the first family, took around forty years of experimentation to identify, as did the strong and the weak nuclear forces governing their mutual interactions. The second family began with the cosmic ray discovery of the muon and required yet another forty years for its completion.

Contrast this relatively slow development, ranging over more than eighty years, with the revolutionary changes registered by the subject during the last decade. Not only was the second family completed and a third nearly so, but more important: the experimental work during the decade, made possible by the availability of new detection devices and higher accelerator energies, gave us confidence in the essential correctness of gauge ideas for describing elementary forces. The first result of this has been the pushing up of the energy frontier, over which it now appears possible to ask meaningful questions, from a few GeV to 'Planck' energies of the order of 10^{19} GeV — with a corresponding pushing back of the time frontier from 10^{-7} seconds to 10^{-44} seconds, within the context of a big bang model of the early Universe. A second result has been the possible obliteration of the traditional distinction between electromagnetic, nuclear and gravitational forces.

Using gauge ideas, the basic questions — what are the elementary constituents of matter and what are the elementary forces among them? — become interrelated through the concept of elementary charges. Describing elementary particles as the basic carriers of certain elementary charges — gravitational, electrical and nuclear — one finds that the gauge forces turn out (at the first approximation) to be proportional to these charges. A postulated symmetry among the charges then leads directly to a possible unification of the elementary forces.

While this is important, the implication of gauge theories goes even deeper. The elementary charges — and the field-theoretic currents associated with them — are rooted, according to our present ideas, within the symmetries of space and time and the symmetries of mysterious manifolds describing the internal structure of elementary particles. By focusing on these symmetries, gauge theories provide us with windows on the topological (and other) structure of space and time as well as of the internal manifolds and appear to suggest an intimate synthesis between them.

Abdus Salam: painting a bleak picture for the experimental prospects of particle physics.



A part of the package of these symmetry ideas is the study of the observed patterns of symmetry-breaking, in particular the breaking of symmetries spontaneously. This has the character of a transition phenomenon, with the possibility of symmetry restoration, revealed in suitable environments of temperature, space-time curvature, topology, or external electric and magnetic fields. An important part of our study relates to the energies — the mass scales — where such transitions occur.

Particle physics has thus been transformed during the last decade through the twin studies of gauge symmetries and their spontaneous breaking. But despite these advances, we are still very far from the elucidation of what the nature of the elementary charges is or of the problems posed by the mass scales.

I wish to add a remark on the experimental outlook for testing these ideas. And one must confess that it is bleak.

There are four types of experiments which are presently yielding data on particle physics: accelerator experiments; cosmic ray experiments; non-accelerator experiments and cosmological data.

For accelerator experiments, let us assume the CERN $p\bar{p}$ collider, the Tevatron, ISABELLE and LEP are available for experimentation during at least part of this decade. We shall then be well off in the TeV range of energies. In the next decade, one may envisage the possible installation of a $p\bar{p}$ collider in the LEP tunnel and the construction of a supertevatron. With superconducting technology these might optimistically reach 10 TeV in the centre of mass. But what will happen to the subject twenty-five years from now?

For definiteness, consider reaching 100 TeV — the presently accepted inverse radius of the muon. With present accelerator technology we shall have reached a saturation in the CERN and Fermilab sites, in available funds, and, most crucially, in ideas for further machine design. We should gratefully recall that our present design ideas were created by far-seeing men 25 years ago.

We desperately need, on a 25-year perspective, new ideas on accelerator design. To emphasize this point, let us remember that present designs are limited by the gradients of accelerating fields. These presently attain values around 1.2 MV/metre and will improve to around 5 MV/metre with superconducting magnets. If a credible design using lasers, for example, could be made available, gradients of the order of GV/metre could be envisaged. (Collective ion effects could give field gradients of the order of 3 GV/metre; estimates of 2 GV/metre are given by ideas using surface effects of a grating; this figure rising to 20 GV/metre if gratings were permitted to be destroyed at each pulse.)

One must not underestimate the difficulties involved (laser wavelengths, for example, are in the micron region), but if such designs could become reality, a 100 TeV accelerator need be no longer than about 30 km, perhaps even as compact as 5 km.

What I am trying to emphasize is that, in twenty-five years, accelerators may become extinct as dinosaurs, unless our Community takes heed now and invests effort on new design.

Turning to cosmic ray experiments, the highest possible cosmic ray energies on earth unfortunately do not exceed 100 TeV in the centre

According to Salam, experiments away from accelerators are likely to provide some eagerly awaited physics information. Seen here are preparations for the Irvine/Michigan/Brookhaven underground experiment near Cleveland, Ohio. In routine tests, instrumentation is submerged for two days in a 21 m-tall tank built in an unused elevator shaft.

(Photo Michigan)

of mass. The global cosmic ray detection effort produces no more than 300 events per year at this energy and no more than 2000 events per year at 10 TeV in the centre of mass. These numbers would increase tenfold if there was a 100 km^2 coverage with detection devices — certainly worthwhile until a 100 TeV accelerator becomes available, but no substitute for investment in new accelerators and their design.

Non-accelerator experiments, including searches for proton decay, searches for neutron oscillations, neutrino mass and oscillation experiments at reactors, and searches for neutrino-less double beta-decay, are likely to provide some of the most eagerly awaited information on new mass scales. For example, each different type of proton decay mode would be associated with its own mass scale. While decays producing one lepton would require a mass of 10^{14} GeV, other decays can be proposed, producing additional leptons, and the masses involved become lighter by many orders of magnitude. All these decay modes could coexist though some of them might be relatively rare. Thus proton decay experiments will have a long lifespan, with the vast information that they and they alone can provide. There is a good case for buying real estate under Mont-Blanc for long occupancy.

Notwithstanding Landau's famous admonition: 'Cosmologists are often wrong, but seldom in doubt' — cosmology, while also exploring other intermediate mass scales, provides our only window on masses beyond 10^{14} GeV.

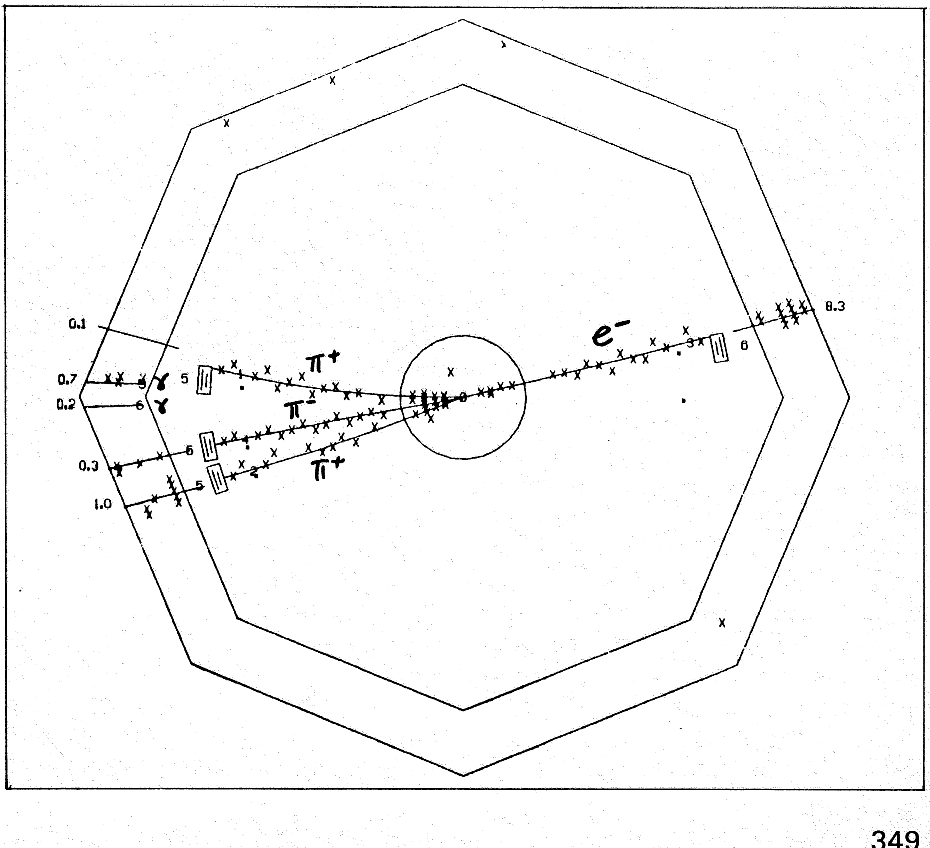
But, even after painting this bleak picture for the experimental prospects of particle physics, I am continually and forever being amazed how relatively rapidly our experimental colleagues succeed in demolishing (or sometimes demonstrating) the seemingly inaccessible and often outrageous of our theoretical speculations. This continual interplay back and forth is the glory of all science, including our own.'

Physics monitor

More results from electrons and positrons

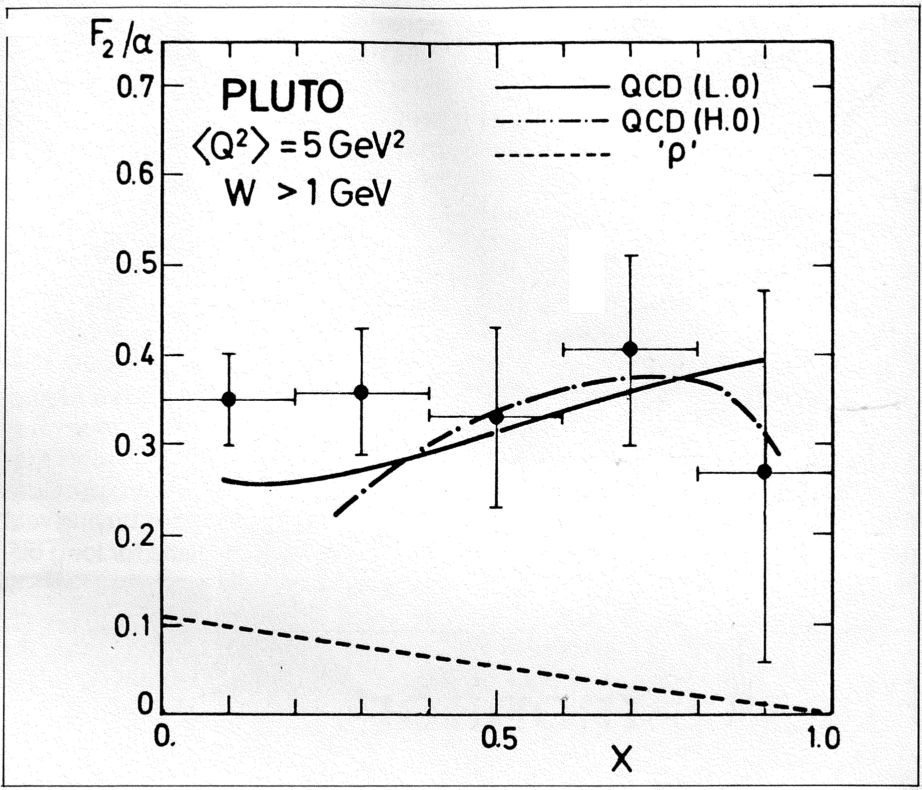
With the first crop of results now coming from the PEP electron-positron ring at SLAC and with a surge of new data from the PETRA ring at DESY, electron-positron physics is back in the limelight. This was especially noticeable at the recent Lepton/Photon Symposium in Bonn at the end of August.

At PETRA, the installation of new focusing quadrupoles ('mini beta' sections) to compress the stored beams has meant that the experi-



Annihilation of an electron and a positron into two tau leptons and their subsequent decay, as seen by the Mark II detector at PEP. One tau produces the electron on the right plus two invisible neutrinos, while the other gives the three charged pions on the left plus a neutral pion decaying in turn into the two gamma rays seen in the outer ring of shower counters.

The photon structure function as measured by the PLUTO detector at PETRA in those photon-photon interactions where a photon is probed deeply. The data points are incompatible with old ideas of vector meson dominance (dashed line). The two curves are the results of theoretical calculations. As these interactions involve free, rather than bound quarks, the theory is in good shape.



ments have been able to log data much faster than before (see July/August issue, page 237), and the physics dividends are now being reaped.

The PEP ring went into action last year, and first results are now emerging. In addition to confirming behaviour seen earlier at PETRA, PEP researchers have some new physics to report.

One goal of high energy electron-positron experiments is to look for the delicate interference effects between electromagnetic and weak interactions. Electrons and positrons can interact either electromagnetically through an intermediate photon, or through a weak boson. Although the electromagnetic process dominates, the standard theory says that the weak interaction increases with energy and in the PETRA/PEP energy range interference between the two processes should produce a small forward-backward asymmetry in the angular distribution of emergent muon pairs.

An average of the results from the JADE, Mark-J, PLUTO and TASSO experiments now gives the predicted asymmetry level (the errors are now down to about five per cent, except at PLUTO). At CELLO, the newcomer to the PETRA ring, the statistics do not yet permit any definite asymmetry to be seen. PEP measurements are also at the five per cent error level. The total asymmetry results amassed so far do not contradict the prediction of the standard model, and can now be usefully compared to the fixed target neutrino — electron data.

Another electron-positron speciality is photon-photon physics — the mutual interactions between photons accompanying the 'colliding' electrons and positrons. This provides a new window on the high energy behaviour of the photon, traditionally thought to be associated with virtual vector mesons (like the rho). Results from PLUTO show that the photon, when probed deeply, includes a distinct 'harder' component due to virtual unbound quark-antiquark pairs (not bound as mesons).

These photon-photon interactions are ideal for quantum chromodynamics (QCD) calculations because the contributing interactions involve free quarks and can be calculated by perturbative methods. This contrasts with the analysis of deep inelastic scattering on nucleons where the nucleon structure functions have to be taken from experiment and QCD effects can only be gauged from small correction terms.

A preliminary analysis of this PLUTO data was presented last year at the Madison Conference. Although the shape of the photon structure function has apparently changed, it is still incompatible with the old idea of vector meson dominance.

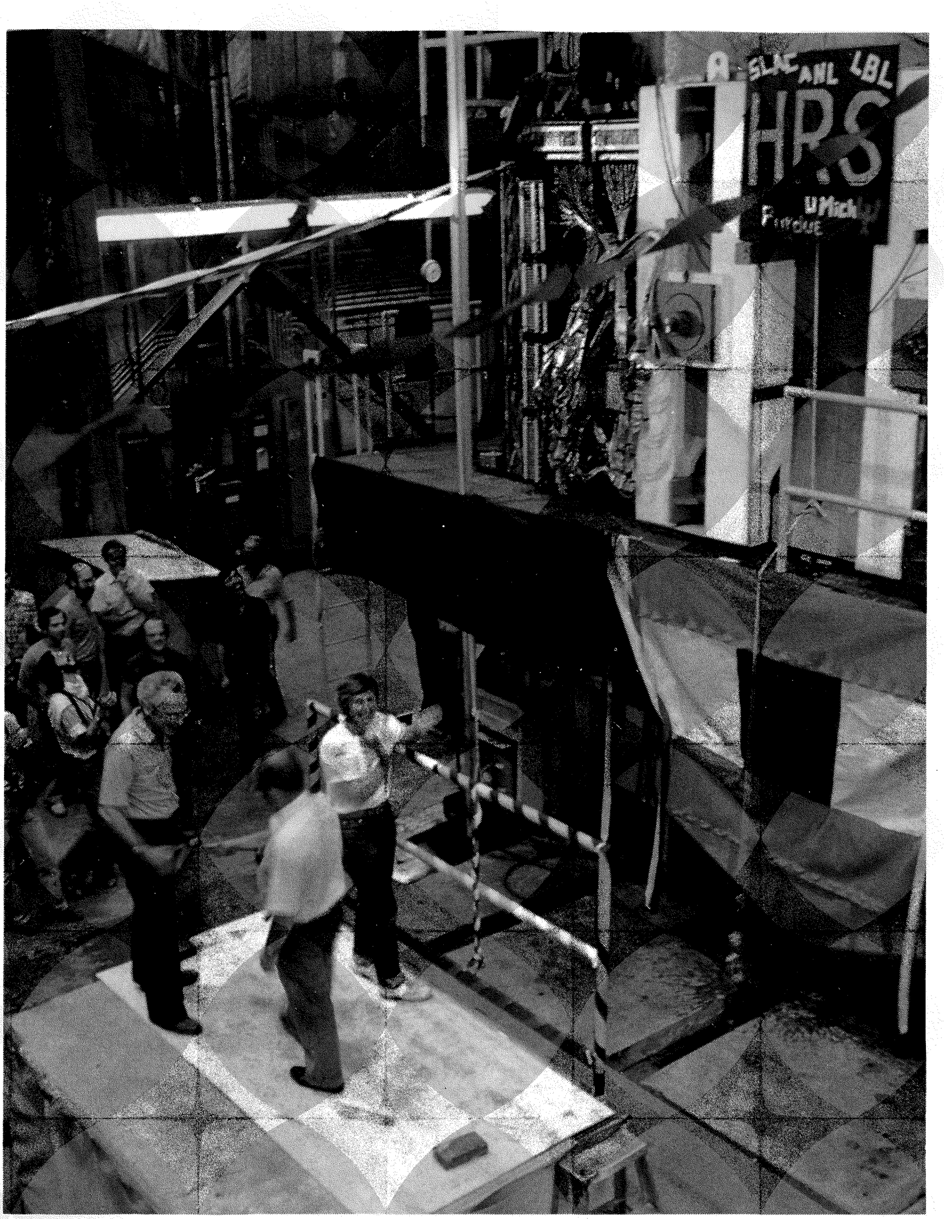
Also on the photon-photon front, TASSO has found eight examples of the production of proton-antiproton pairs. These eight events required two and a half years of data taking! Photon-photon studies also provide a new way of looking for resonances whose quantum numbers make them difficult to isolate otherwise.

Production of single gluons along with quark-antiquark pairs in electron-positron annihilation gives events with a three-jet structure. Comparison of the jet properties could reveal differences between the behaviour of quarks and gluons. CELLO finds the behaviour of neutral particles similar to that seen earlier for charged particles.

In contrast to some results from PETRA, the LENA detector at the lower energy DORIS ring at DESY finds no difference between the properties of quark and gluon jets. In

Celebrations as the High Resolution Spectrometer moves into intersection 6 of the PEP ring at SLAC. On the platform, Don Meyer of Michigan (left) is congratulated by Pief Panofsky while Adele Panofsky applauds enthusiastically.

(Photo Joe Faust)



what is probably a pointer to some future physics, LENA has also reported its first upsilon radiative decay. These decays could reveal more of the spectroscopy of hidden beauty particles.

Results from PEP are broadly in line with those of PETRA, but even at this early stage SLAC has some notable 'firsts'. The Mark II detector already had its first taste of tau leptons at the SPEAR ring, and together with the MAC detector, has gone on to make further tau studies at PEP. In particular, some high resolution data from Mark II using comprehensive event selection and analysis to measure the tiny tau decay path (about a millimetre) gives a value for the lifetime of the tau as $4.9 \pm 1.8 \times 10^{-13}$s, as compared with the theoretical estimate of 2.8×10^{-13}. Thanks to the high resolution provided by the drift chambers inside the Mark II magnet, this is the first time that a definite value for the tau lifetime has been obtained.

Analysis of the hadron jets seen at PEP takes a different approach which uses quantities which are both directly measurable and calculable. The results agree with quantum chromodynamics predictions. Mark II finds that the behaviour of the lowest energy jet (which has the highest probability of being the gluon jet) is very similar to the low energy jets seen at SPEAR.

Because of the wide kinematic range covered, comparison of charged particle production seen in the Mark II detector earlier at SPEAR ahd now at PEP gives interesting results, and the scaling violations observed now begin to look like those seen in fixed target experiments.

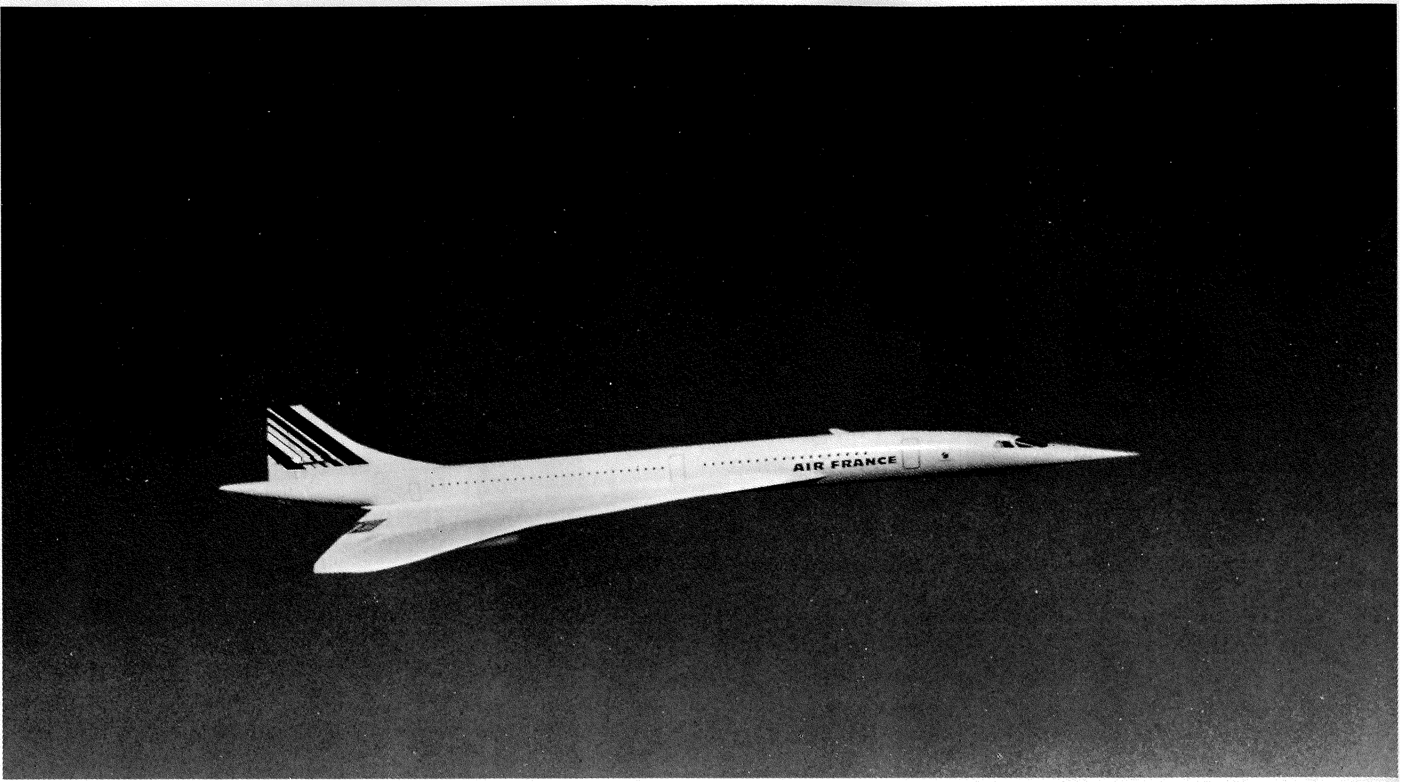
As at PETRA, experiments at PEP find unexpectedly high levels of baryon production. These effects invite explanation. It was initially suggested that the fragmentation of quarks into hadrons can pull not only quark-antiquark pairs but also a diquark-antidiquark system out of the vacuum. However the correlations between jet structure and baryon production seen at PEP suggest that even more exotic mechanisms might be required.

The Crystal Ball detector at the SPEAR ring continues to fill up the charmonium spectrum. After playing a prominent role in discovering the lightest spin zero charmonium particle, the eta-c (see March issue, page 68), Crystal Ball has now seen a heavier companion particle at about 3.6 GeV, and analysis of J/psi radiative decays gives evidence of new states, possibly 'glueballs'.

The prolific production of upsilons at DORIS and at the CESR ring at Cornell provides a good laboratory for studying the properties of gluons. Certainly a gluon of spin zero can

Concorde — adding to the repertoire of cosmic ray experiments.

(Photo Air France)



now be excluded. CESR has really capitalized on its ability to cover the full upsilon region, however DORIS is soon to be rebuilt as a single ring, reaching energies of up to 5.6 GeV per beam.

High flying physics

Cosmic ray physicists have always had to aim high. In the constant search for interactions produced as close as possible to the immensely high primary particles entering the earth's atmosphere from outer space, they have installed experiments on high mountain peaks and flown detectors aloft in balloons.

In these studies, there have been periodic sightings of remarkable configurations of secondary particles. These events, many of which bear exotic names like Centauro, Andromeda, Texas Lone Star, etc., frequently defy explanation in terms of conventional physics ideas and give a glimpse of what may lie beyond the behaviour seen so far under laboratory conditions.

The 540 GeV collisions at the CERN proton-antiproton collider (equivalent to a 155 TeV proton beam hitting a stationary target) will for the first time provide man-made energies which approach the region where these exotic events might turn up. This search is perhaps second only on the experimental agenda to the quest for the intermediate weak interaction bosons.

But cosmic ray studies continue to produce interesting results. In 1978, the ECHOS experiment began by a France/Japan collaboration using emulsion chambers mounted in the baggage compartment of an Air France Concorde supersonic airliner. This has too produced its exotic event, tamely referred to as JF1af1.

Two emulsion chambers were packed in the Concorde baggage hold, one being specifically designed for the detailed observation of high energy events. This 35 kg JF1a chamber contained three sections, an upper one with different types of nuclear emulsion plates to enable charge determinations to be made, a central target layer, and an emulsion calorimeter at the bottom. The second Concorde detector was more concerned with measuring particle fluxes.

The exposure was planned to cover 200 hours of level flight some 16 km above sea level, requiring a total of some two months in the aircraft. Because of the high altitude and relatively long exposure, a good crop of high energy interactions was obtained. In particular, the very first flight produced the JF1af1 event, estimated as containing about 150 gamma rays and a total radiated energy of 260 TeV. As well as its large energy and high multiplicity, the event is remarkably well collimated. The presence of a certain level of hadrons implies that the event was due to a nuclear interaction and analysis suggests that it occurred somewhere on or inside the Concorde, rather than in the outer atmosphere. Its closest counterpart so far observed is the Texas Lone Star interaction picked up by balloon-borne emulsion stacks.

Around the Laboratories

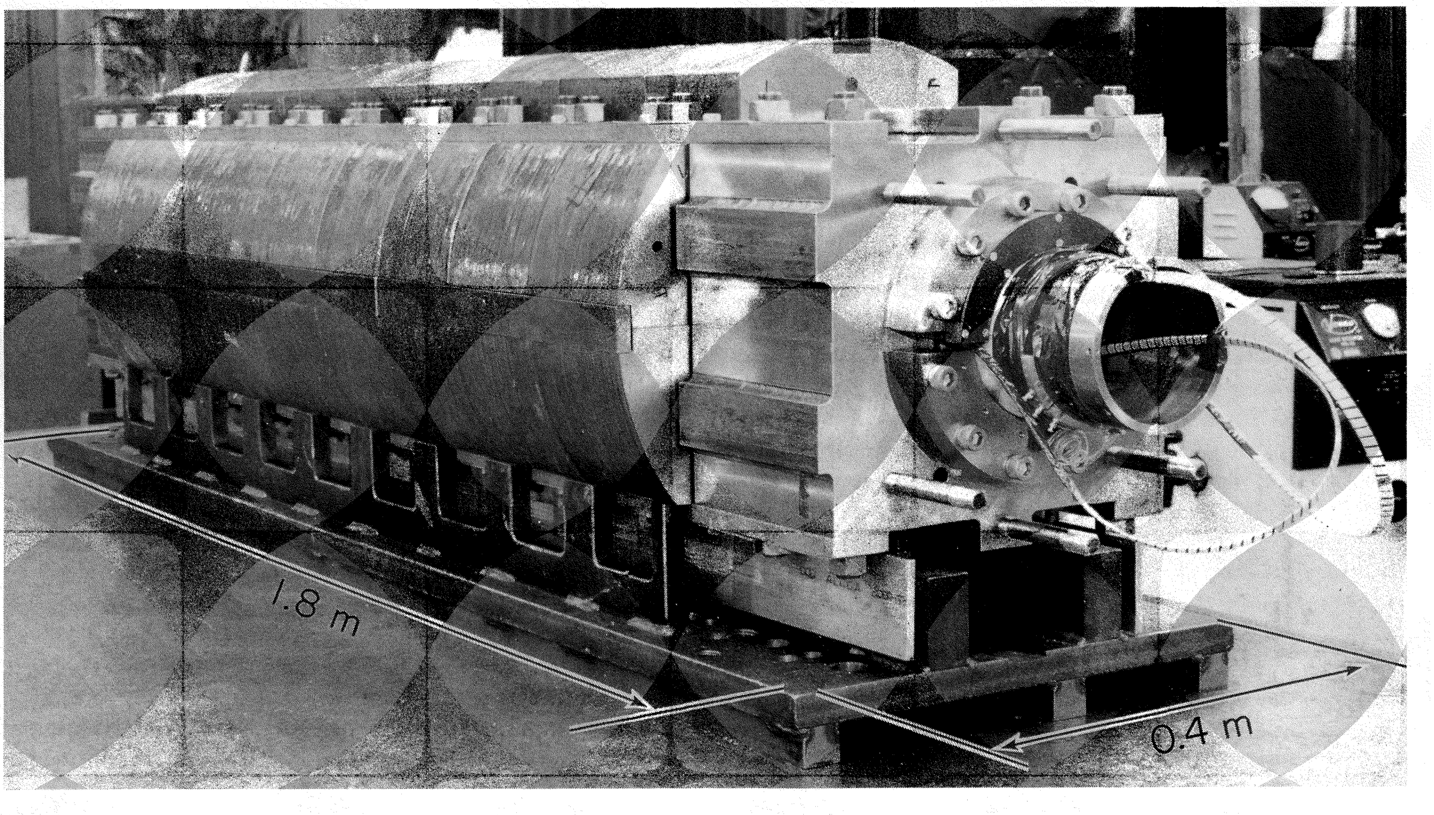
*** Late news: It has been decided to adopt the two-layer cable magnet (see below) for the ISABELLE project, retaining full aperture, energy and luminosity. All effort on the braid magnet shifts to the cable magnet. However the possibility of using Fermilab magnets will be retained as an emergency backup. The ISABELLE project is expected to be completed in 1987.**

BROOKHAVEN ISABELLE magnet breakthrough

As reported briefly in our September edition (page 298), tests on a new type of superconducting magnet for the ISABELLE proton storage ring promise well.

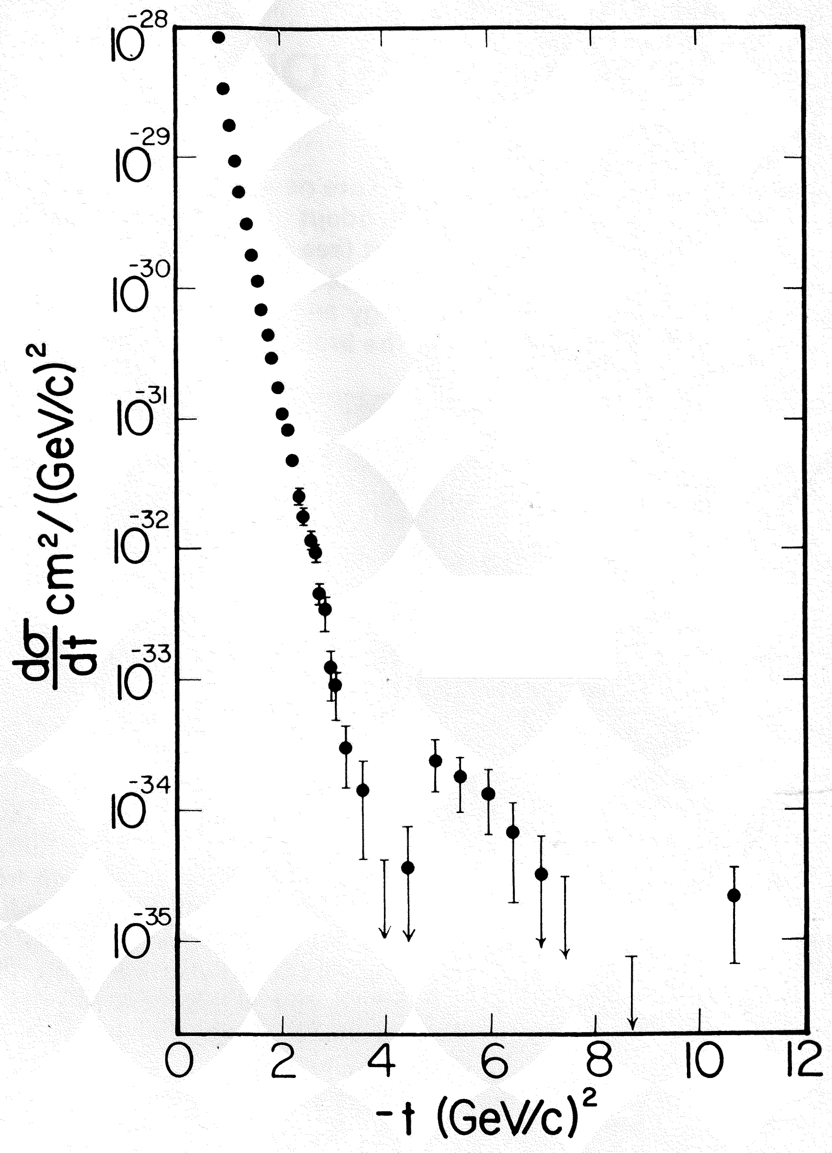
About a year ago, R.B. Palmer suggested building a magnet with ISABELLE design specifications but replacing the braid superconductor used until now with twisted Rutherford cable. This would benefit from the cable technology successfully used in hundreds of superconducting magnets at Fermilab and build on the experience already gained for the standard ISABELLE magnets.

In December 1980, a 1.8 m dipole one-third of the standard length was authorized and design began in earnest in January. A stock of surplus cable about four years old was located at Fermilab which, by happy coincidence, had just the right dimensions for a two-layer magnet inside the volume allocated for the standard magnets, and with the same aperture. In designing the magnet careful attention was paid to engineering details to incorporate lessons from previous magnets. Slip planes were introduced between the coil layers to prevent friction. The iron core was split along the median plane. By careful shimming and bolting, the amount of stress on both inner and outer layers could be controlled. The iron core was also divided longitudinally into blocks held together by stainless steel rails to match the thermal coefficient of expansion of the core with that of the coils. To reduce the field enhancement effects, the ends of the magnet were kept outside the iron core and held in place by stainless steel blocks



The first ISABELLE-style magnet built at Brookhaven using Rutherford-type cable rather than braid superconductor. Its performance (which was repeated in a second magnet of the same type) has raised hopes that the problems which have been dogging the project are being overcome.

(Photo Brookhaven)



Diffraction-like dip in seen 200 GeV negative pion on proton interactions at Fermilab by an Arizona/Cornell/Fermilab/San Diego collaboration. This is the first time that such an effect has been seen in pion elastic scattering. The result was announced at the recent Lisbon conference (see September issue, page 287).

and end restraints to prevent longitudinal motion.

The first magnet was built and tested in six and a half months and its performance exceeded the most optimistic expectations. At 4.5 K it reached 5.35 T on the first quench and stayed at that value on all subsequent quenches (showing no 'training'). It could be ramped at 120 A/s without any noticeable effects; in particular, there was no measurable degradation of field quality due to eddy currents. When cooled to 3.8 K (the operating temperature for ISABELLE), all quenches occurred at 5.85 T, while at 4.8 K the corresponding maximum was 5.1 T. This is a strong indication that the magnet has reached the short sample limit and, in fact, the values agree well with prediction within errors. The magnet was able to absorb its own energy without damage and calculations based on its performance indicate that even a magnet three times as long should be self-protecting.

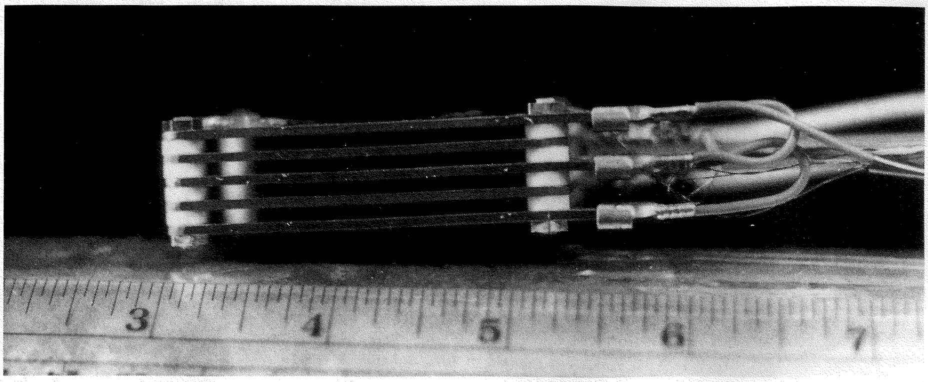
A second magnet was ready for testing four weeks later and behaved almost as spectacularly as the first. It reached 5.08 T on the first quench at 4.5 K and all subsequent ones were at 5.35 T. In all other respects its performance matched that of the first magnet. However, the second magnet contained a sextupole trim coil which was operated at twice its design current (70 per cent of short sample) with no quenches and with negligible effect on the dipole coil quench current. It will thus be able to correct saturation-induced effects at high fields. Destructive testing will be done soon to determine the maximum amount of energy it is able to absorb.

The field quality of these magnets does not yet meet ISABELLE specifications but is close. The multipole moments were predicted from the amount of shimming needed to achieve the right prestress and matched the field measurements. The thickness of the cable was not well controlled during manufacture (it varied by as much as 2 per cent), while in the present Fermilab magnets it is kept constant within 0.2 per cent. It is therefore expected that with good cable the field quality required for ISABELLE will be easily met. An additional bonus is that this cable has a higher current carrying capacity and the expected maximum field at 3.8 K is 6.3 T.

These new magnets are a substantial step forward. A magnet capable of meeting the ISABELLE goals of 400 GeV on 400 GeV protons with high luminosity seems to be within reach. By December the first full-length magnet will be tested and, barring unforeseen difficulties, six more full length magnets and a pre-production magnet will have been tested by March of next year. If the remarkable performance is repeated in the longer magnets as expected, it is fair to say that the major technical difficulties plaguing the ISABELLE project will have been overcome.

FERMILAB
Transatlantic cooperation on cold detectors

A recent series of tests in the M5 beam at Fermilab has shown that solid neon, frozen from a mixture of neon and hydrogen, can act as a particle detector. This is a further step in the development of an 'electromagnetic calorimeter' which could be mounted inside the liquid of the 15 foot bubble chamber at Fermilab or the BEBC bubble chamber at CERN. Such a calorimeter would be a multilayer sandwich of thin lead plates and thin layers of frozen neon or



A view of the chamber used in the recent tests at Fermilab of a solid neon ion chamber working from neon-helium mixtures.
(The scale is in inches.)

(Photo Fermilab)

argon. A photon or electron produces a shower of electrons which ionize the solid giving a measurable pulse of charge on the high voltage electrodes.

Similar calorimeters using liquid argon were pioneered by a Brookhaven/CERN collaboration and have been used extensively in the past ten years. The problem is that argon freezes at bubble chamber temperatures and that electrons do not move freely in liquid neon. A series of tests has been going on for some years with physicists from University College London, CERN and Ecole Polytechnique working first at CERN and then at Saclay. These tests showed that solid argon and solid neon give identical pulse height spectra to liquid argon in small test cells.

Bubble chamber engineers prefer the idea of a solid neon calorimeter to a solid argon calorimeter because it would be easier to fill and to freeze. But neon is much more expensive than argon, unless the large existing stocks of neon-hydrogen mixtures could be used. Both Fermilab and CERN have ample neon-hydrogen mixture to fill their bubble chambers (a great deal more than would be needed for a calorimeter). A small cell was built at Fermilab to test gas mixtures (five plates 2 mm apart, 6 cm x 5 cm with two high voltage and three ground electrodes). It was mounted in a stainless steel box and fitted with coils through which liquid helium was passed to condense and freeze the argon or neon-hydrogen. Mixtures of 3.1 per cent hydrogen in neon and 7.3 per cent hydrogen in neon were used. In both cases the solid gave clear pulses with a pulse height spectrum closely comparable to that seen last year at Saclay.

Another interesting result from the tests came when a filling of liquid argon proved to be insensitive. This is a frequent problem with liquid argon calorimeters and is usually caused by contamination by a few parts per million of oxygen. When the same filling was frozen, however, clear pulses were seen. At first sight this suggests that liquid argon calorimeters would be better if they were frozen.

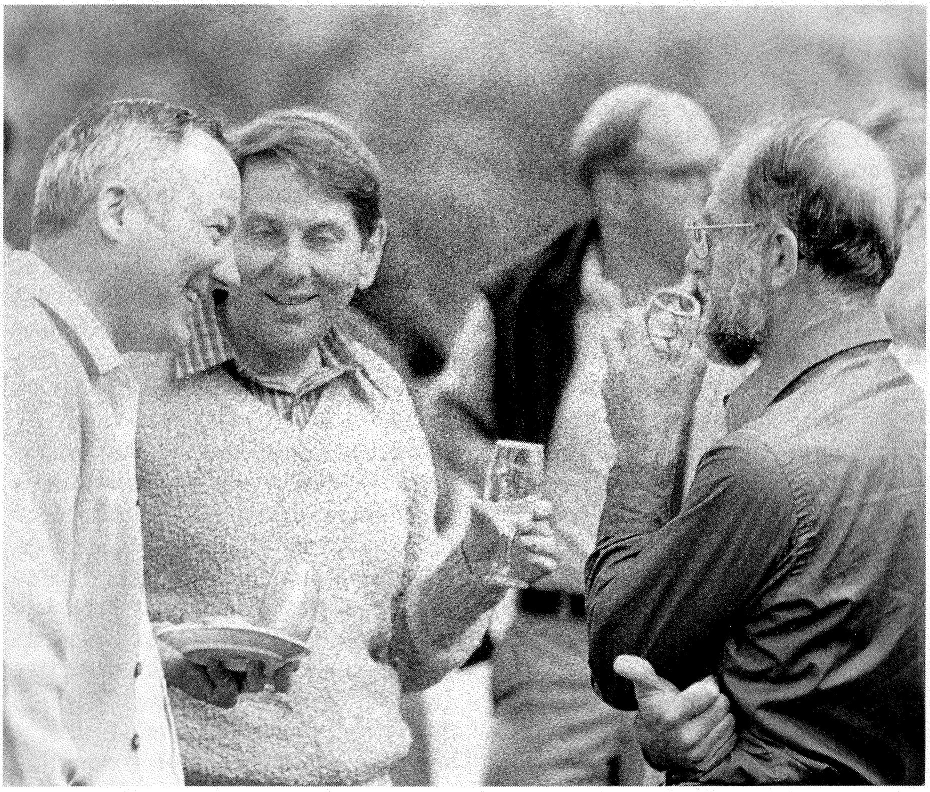
However, the 1980 tests showed that this could only be true if the particle flux is less than a few hundred per square centimeter per second. Some existing calorimeters sit in much richer beams than this but many do not and it only needs a little extra flow of liquid nitrogen to freeze argon. Perhaps someone will try it?

The next tests will be back at CERN in the near future. A prototype calorimeter is being built rather than a small test cell and the BEBC group of University College London /Brussels / Bari / Tufts / Illinois Institute of Technology will be collaborators with CERN to study its performance.

Since the 15-foot chamber at Fermilab will probably be run next at Tevatron energies it seems likely that the first use of a solid neon or argon calorimeter would be in BEBC, assuming that the tests this autumn are successful and that any subsequent physics proposals are approved.

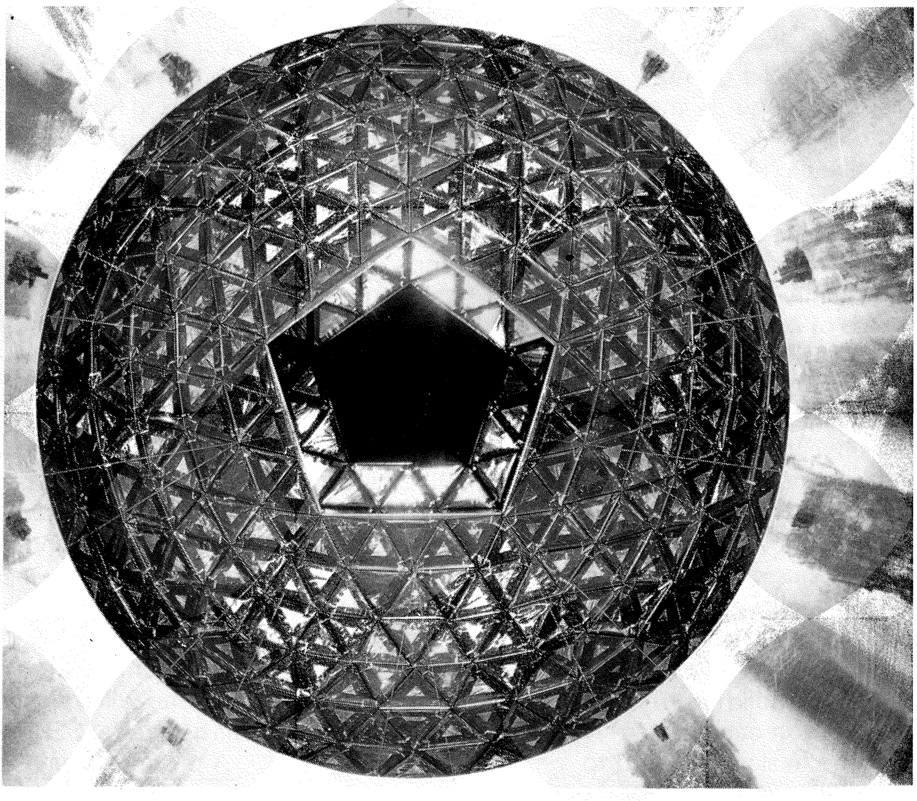
Accelerator Summer School

Fermilab was host to a new kind of summer school on high energy particle accelerators from 13-24 July. Its main purpose was to attract young scientists to become knowledgeable



At one of the more relaxed events during the Summer School on accelerators held at Fermilab — left are School organizers Russ Huson (extreme left) and Mel Month. Right is former Berkeley Director Andy Sessler.

(Photo Fermilab)



Unusual view of the 'Plastic Ball' — a new detector in operation at the Berkeley Bevala to study nuclear reactions.

(Photo LBL)

in accelerator physics and to be ready to work in the field.

This purpose emerged partly in response to the recommendations of the subpanel of the High Energy Physics Advisory Panel (HEPAP), chaired by Maury Tigner, which examined the present state of research and development in accelerator physics in the US (see July/August 1980 issue, page 203). The restraints of money and manpower in recent years have led to a reduction of research and development to what is regarded as a critical level. The same is recognized to be true in Europe. Unfortunately this is happening at a time when theory is calling for experimental verifications at still higher energies and when current accelerator 'know-how' is hitting technical and financial limits. New ideas must be pursued to extend knowledge of the behaviour of matter.

The School had lectures ranging from the basic concepts of accelerator physics to the present frontiers, with topics such as laser acceleration and collective field acceleration. Over 150 scientists attended and it is hoped that the spreading of education in accelerator physics will help in the quest for new ideas and in the pursuit of existing ones.

BERKELEY Heavy Ion Study

More than 160 scientists from the United States, Europe and Japan attended the 5th High Energy Heavy Ion Study at the Lawrence Berkeley Laboratory on 18-22 May. Enthusiasm for this relatively new field of research kept interest high throughout the lengthy programme of talks.

With the exception of the first Ultra-Relativistic Heavy Ion Workshop held in 1979, previous Studies in the series have concentrated on Bevalac energies (1 to 2 GeV/nucleon). Because of the increasing interest in both lower energy heavy ion physics (for example, at the Michigan State superconducting cyclotron in the US and GANIL in France) and higher energy research (for example the recent successful alpha-alpha collisions at the CERN ISR), the energy range for this meeting was broadened from 20 MeV/nucleon to the highest energy cosmic ray collisions.

Discussions of the physics at Bevalac energies demonstrated new experimental and theoretical sophistication. Single particle inclusive spectra, although clearly still valuable as samplers of reaction mechanisms, are giving way to multi-particle studies thanks to devices like the streamer chamber or the GSI/LBL Plastic Ball/Plastic Wall, in which one sees essentially all of the emitted charged fragments. Even at 1 to GeV/nucleon, the multiplicities c particles in a given event can easil exceed a hundred.

On the theoretical side, the role c entropy in such collisions was described by G. Bertsch and H. Stöcke In addition, a comprehensive discussion of the roles of microscopic (cascade calculations, few particle effects) versus macroscopic (fluid dynamics) models was presented by J Knoll and others. It is becoming clea that experimentalists must carefull pick the regions of phase space tha they study to avoid signals tha would otherwise mask the physic of interest.

In a talk on multiparticle observables, R. Stock predicted that th high energy heavy ion communit will be leaning heavily on high energ physics for such analytic concepts a thrust and sphericity to shed furthe light on nucleus-nucleus collisions.

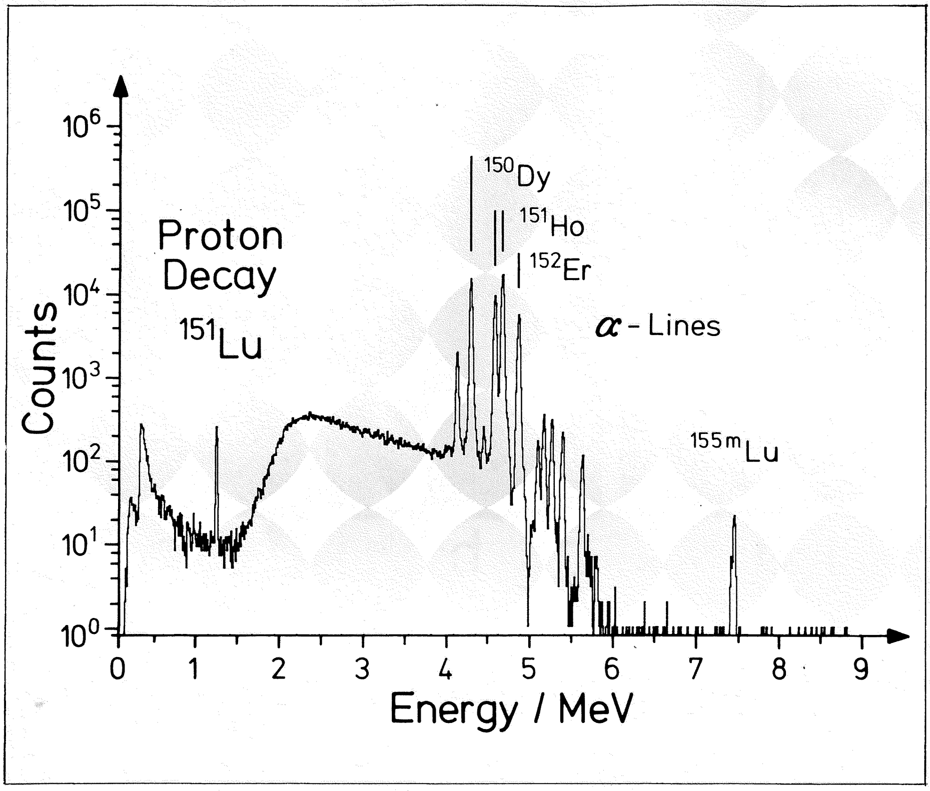
At the higher energies, the exotic physics of the postulated quark-gluon plasma was discussed by W. Willis. M. Faessler reviewed some of the results of the alpha collisions seen in the Split Field Magnet at the ISR, and M. Jacob provided a theoretical overview of the alpha experiments (see May issue, page 163). Although many features appear to follow from nucleon-nucleon results, others suggest that one cannot simply treat alpha interactions as the collision of individual free nucleons.

Theoretical talks by H. Satz, J. Rafelski and L. McLerran emphasized that a transition from nuclear to quark matter could occur and that heavy ions appear to be the only tool available on earth to study this possibility. A recurring theme was the possibility that a signature of this new phase would be a yield of strange particles in nucleus-nucleus collisions larger than anticipated.

DARMSTADT Ground-state proton radioactivity

For the first time since the study of nuclear decay began 85 years ago, proton radioactivity of nuclear ground states has been detected unambiguously. The discovery was made at the UNILAC heavy ion accelerator at GSI Darmstadt.

It was in attempting to establish radioactive decay with emission of protons — at that time called H particles — that Rutherford in 1919 discovered the first nuclear reaction — a nitrogen nucleus bombarded with an alpha particle giving an oxygen nucleus and a proton. Prior to the Darmstadt work, proton emission had been observed only from excited states. Proton emission from a cobalt isomer was found in 1970.



The particle spectrum of decaying nuclei resulting from the reaction of a 163 MeV nickel 58 beam of the Darmstadt UNILAC with a target 98 per cent enriched in rubidium-96. Mass separation of beam and reaction products is made by their velocity. Those product nuclei surviving the passage time through the velocity filter of about 1 microsecond and entering the selected mass/velocity window are implanted in a 300 micron-thick silicon detector. In the spectrum the line at 1.22 MeV is identified as coming from protons emitted by lutetium 151. The proton character was verified by an energy loss measurement. The lutetium 151 can be shown to result from the deexcitation of excited hafnium 154, the fusion product of the initial nuclear reaction.

Searching among so far unexplored extremely neutron-deficient nuclides in the region of the periodic table from gadolinium to bismuth, the velocity filter SHIP (see May edition, page 164) was used for the fast mass separation of reaction products from the UNILAC beam. Proton emission from the new rare earth isotope lutetium 151, resulting from the reaction of nickel 58 and niobium 96 nuclei, and the two-neutron deexcitation channel of hafnium 154 (announced during the International Conference on Nuclei far from Stability at Helsingor in June) was confirmed.

The half-life and proton energy of this new isotope were measured as 85 ± 10 ms and 1217 ± 5 keV. Proton emission from the new isotope thulium 147 with half-life 420 ± 100 ms and proton energy 1040 ± 7 keV was established by an experiment in a following run. Again a beam of nickel 58 ions was accelerated by UNILAC and the analogous reaction with the target nucleus molybdenum 92 was used. Mass separation this time was made using the GSI on-line mass separator.

These results support the belief that more proton emitters can be found with sensitive techniques and that the obtained data can help make confident predictions of new proton emission candidates.

The new isotopes came from the last heavy ion reactions induced at the UNILAC before starting the energy upgrading programme. On 1 August accelerator operation was stopped for four months. During this period two additional Alvarez tanks will be inserted to bring the beam energy from the present 12 to about 20 MeV per nucleon. For this the twenty single gap resonators must be moved by 30 m, and 30 m of additional beam transport system has to be rebuilt.

DUBNA
Self-quenching streamers revisited

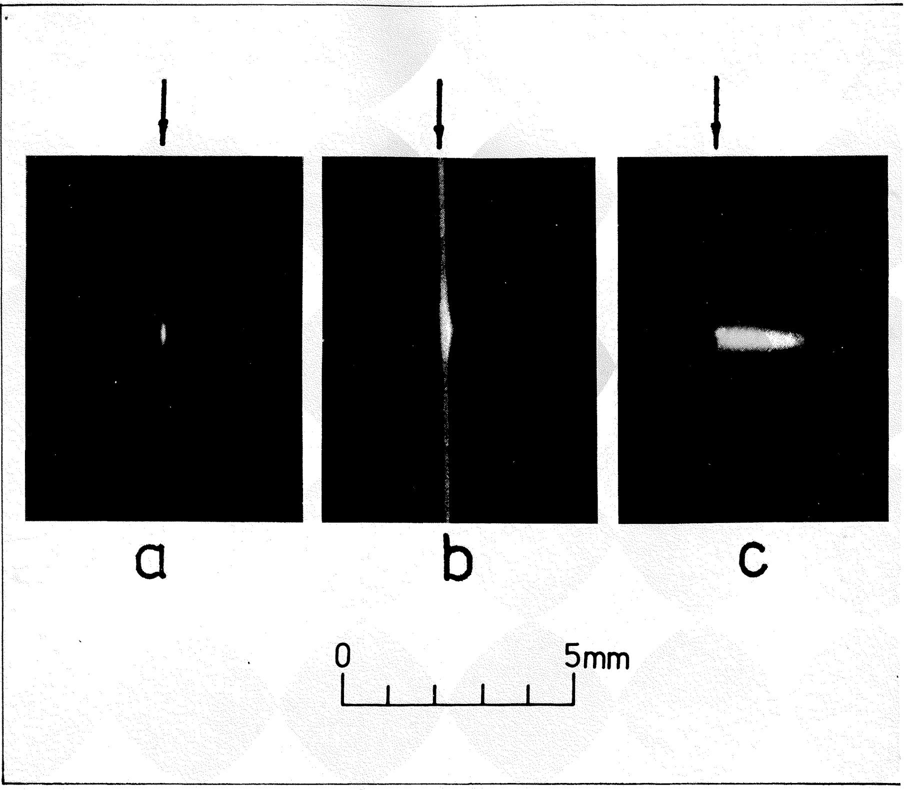
In our May (page 152) and July/August (page 252) issues we carried news of work on self-quenching streamer detectors at Fermilab and Frascati/CERN respectively. While adding this report of the developments at Dubna, we also turn back the clock and underline pioneering work done at CERN and Brookhaven.

In recent years, in addition to the familiar gas discharge detectors with continuous sensitivity (ionization, proportional and Geiger counters), a new type of detector has been developed. It differs fundamentally in its discharge mechanism and has a number of characteristics which make it attractive for practical use. Dubna has been involved in this development, which has led to the construction of large-scale systems of wire chambers and counters working in the 'self-quenching streamer' mode.

In the Nuclear Studies Laboratory of the Joint Institute for Nuclear Research at Dubna, work started in 1976 after Charpak and his colleagues at CERN had demonstrated that in chambers with a thick anode wire it was possible to establish an operating regime which gives an exceptionally high amplitude signal. At that time the conclusion was that this regime had a quasi-Geiger character and could only be used in detectors with very small loads.

The aim of the Dubna group was to achieve a higher load capacity by matching the gas mixture and the geometry of the chamber. The research was successful, and the very first mixture resulted in a ten-fold increase in load capacity. Moreover a very wide plateau in the operating parameters was obtained, which also indicated that it was not a quasi-Geiger regime. It was concluded that this was something fundamentally new which could not be explained by any type of gas discharge in a wire chamber known at that time. The results were published in 1978.

Photographs taken at Dubna showing gas discharges in a) the proportional, b) the Geiger, and c) the self-quenching streamer mode. (The arrows show the direction of the anode wire.) Detectors using the latter technique are gaining in popularity.



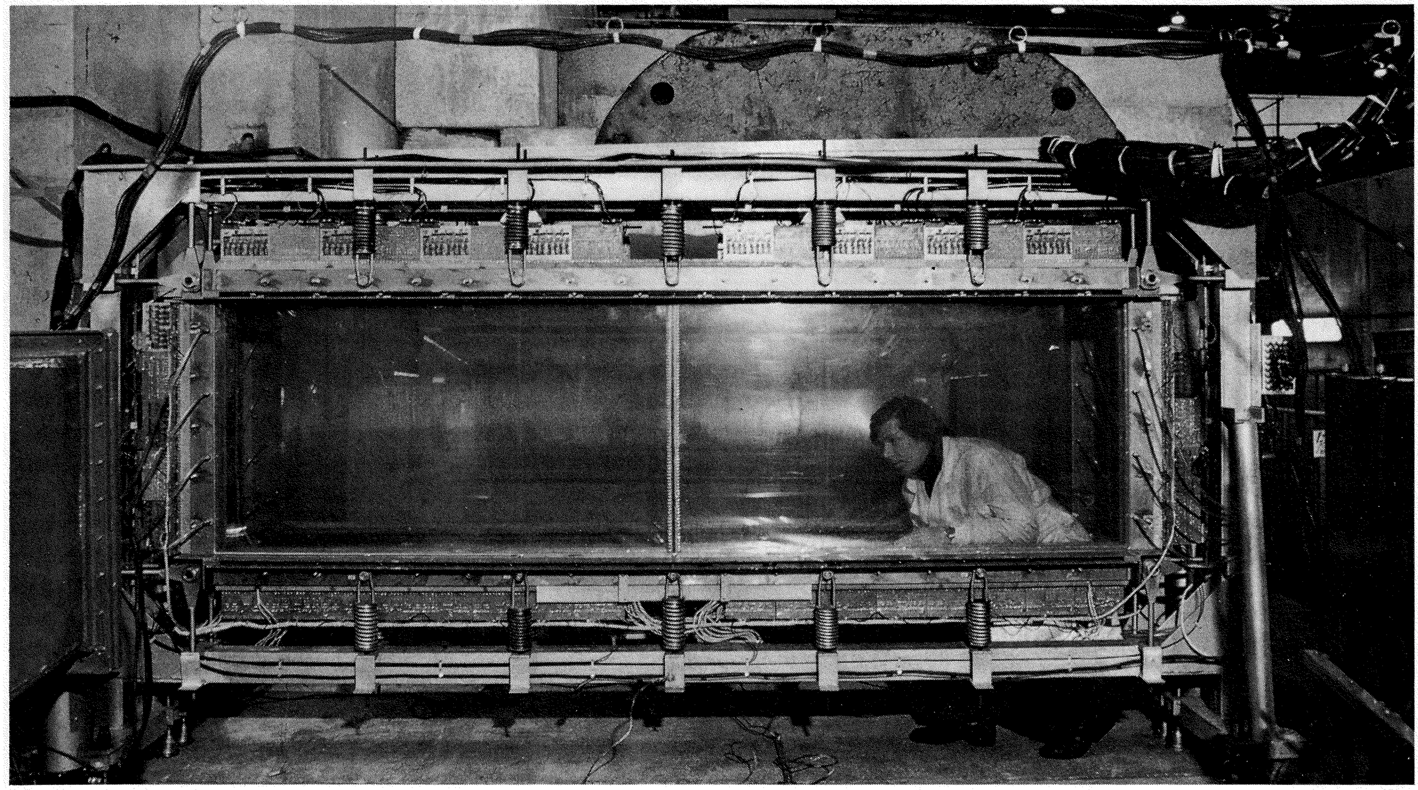
The same paper pointed out the possibilities for practical applications and the superiority over the proportional mode when used in larger chambers. The high amplitude of the signal (about 1 mA) guarantees good suppression of other signals and simplifies the electronics. The use of a thick anode wire (diameter 50 to 200 microns) simplifies manufacture and increases chamber reliability. The local nature of the discharge guarantees the chamber's high load ability, which can (in principle) even exceed the load capacity in a proportional mode in a chamber more than 1 m in size.

(In 1974 self-quenching streamer had been predicted in a theoretic paper by V. Palladino and B. Sadou let. The first relevant experiment work was done by the Charpa group at CERN and the group of A.H Walenta at Brookhaven.)

The Dubna group found an expl nation of the discharge mechanis on the basis of classical studies ca ried out in the Leba Laboratory in th late 1930s, during which the form tion of self-quenching streamers o the peaks of corona discharges wa discovered. Photographs of the di charges in the chamber taken in th Nuclear Studies Laboratory in 197 clearly demonstrate that the stro ger signals emerge as a result of th formation of streamers, startin from the anode wire. They are u usual in that they are self-quenchin until they reach the cathode and giv rise to spark breakdown. Develo ment and quenching of the streame is always stable and this, together with the localized nature of the development of the discharge, gives the very useful characteristics for detector applications.

Systematic research was carried out at Dubna into the influence on the composition of the gas, its pressure and the anode wire diameter. This resulted in a first system of drift chambers (0.5×0.5 m^2) operating in a self-quenching streamer mode. Eighteen chambers, containing 864 read-out channels, have operated at Dubna for three years in a study of the inverse electroproduction of pions.

The chambers are very reliable. They have 99.6 per cent efficiency and an average accuracy of 0.2 mm in locating particle position. (The best accuracy which has been achieved is 0.11 mm.) Another system consisting of twenty 3×0.8 m^2 chambers is being assembled for use in experiments at the Serpukhov 76 GeV accelerator. The chambers work with quite a high background load (about 10^6 particles per m^2 per s) and are characterized by good suppression of unwanted signals. They have a broad operating voltage plateau (up to 800 V), low noise level and an accuracy of about 0.2 mm.



This assembly of self-quenching streamer chambers, built at the Joint Laboratory for Nuclear Research, Dubna, is being used in an experiment at Serpukhov.

People and things

On people

George Vineyard has announced his wish to return to full-time research and resign as Director of Brookhaven National Laboratory. He has led the Laboratory since 1973. The Board of Associated Universities•Inc. intends to appoint a new Director to take up office at the end of this year.

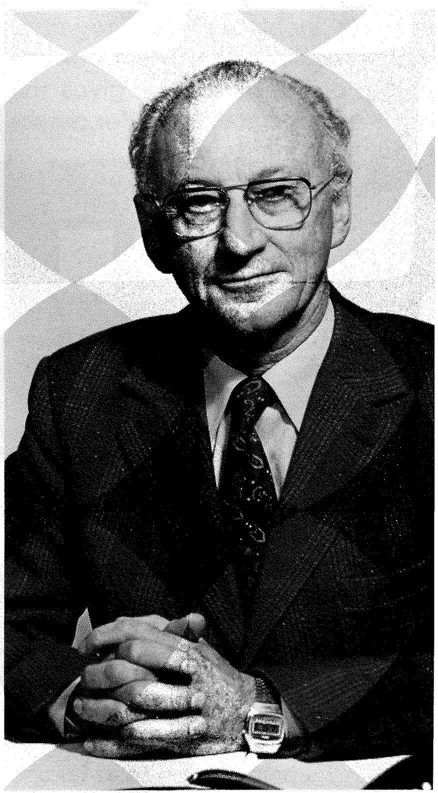
Change of Director at Rutherford

On 30 September Dr. Godfrey Stafford retired as Director-General of the Rutherford and Appleton Laboratories to devote more time to his work as Master of St. Cross postgraduate college in Oxford. He has been associated with the Rutherford Laboratory since its early days, doing research on the Proton Linear Accelerator and lead-

ing the High Energy Physics Division during the start of operations at the 7 GeV Nimrod proton synchrotron. In 1971 he succeeded Gerry Pickavance as Director of the Laboratory. In the subsequent years presided over its transformation from a high energy physics to a multi-disciplinary research centre, including the recent merger with the Appleton Laboratory for research in astronomy. During this time, Godfrey Stafford has also been closely associated with CERN and was for several years Chairman of the Scientific Policy Committee, on which he continues to serve.

Dr. Geoffrey Manning will succeed him at Rutherford, and will have the title of Director, with Professor J. T. Houghton, formerly Director of the Appleton Laboratory, as Deputy Director. The Laboratory itself is renamed the Rutherford Appleton Laboratory. Geoff Manning has also been at Rutherford since its early days. He was prominent in the research programme at Nimrod and was Head of High Energy Physics Division before going on to become Deputy Director.

The Board of the High Energy and Particle Physics Division of the European Physical Society has appointed John Charap of Queen Mary College, London, as its new Chairman. Günter Wolf of DESY is Secretary.



Directors new and old at Rutherford: Geoff Manning (left) and Godfrey Stafford (right).

More proton-antiproton collisions

After the first successes at storing antiprotons in the CERN SPS (see September issue, page 289), another antiproton test took place in the third week of August. Intensities were about the same as the first run, with a maximum of a few times 10^9 270 GeV antiprotons circulating against 5×10^{10} protons.

The full UA1 calorimeter was in place, and data from about 4000 proton-antiproton collisions were recorded. The next antiproton test run is scheduled for October, when it is hoped that much higher intensities will be achieved.

Solid-State Detector Workshop

A Workshop is planned on the use of silicon detectors in high energy physics experiments. It will be held at Fermilab on 15-16 October. People wishing to attend, or who have measurements to report, should contact Tom Ferbel, Physics Department, University of Rochester, Rochester, New York 14627.

TRISTAN Physics Workshop

The second TRISTAN Physics Workshop is to be held at the KEK Laboratory, Tsukuba, Japan, from 6-11 November. Main subject of discussion will be the physics of electron-positron collisions in the 60 GeV total energy range and the corresponding instrumentation requirements. A call for experimen tal proposals for TRISTAN will be made at the same time. Further details from the scientific secretary, Y. Unno, Physics Division, KEK Oho-machi, Tsukuba-gun, Ibaraki-ken, 300-32, Japan.

Linking computer networks

A project for high speed data com munication via satellite, initiated at the Rutherford Laboratory, is under way in the UK. Known as UNIVERSE (UNIVersities Expande

In June, CERN Director General Herwig Schopper visited the Academy of Finland and was awarded the Medal of the Academy in recognition of the support CERN has given to Finnish particle physics. Finland is not a CERN Member State, but Finnish particle physicists hope to develop further their contacts with and contributions to CERN.

(Photo A. Lappi)

Ring and Satellite Experiment), it will study and demonstrate the linking of local area computer networks, such as the Cambridge ring, by means of the OTS satellite. It is hoped that the first transmissions will start early next year. The earth stations and other equipment are similar to those already in use in the STELLA European satellite transmission project initiated at CERN (see January/February 1980 issue, page 444).

STELLA is now operational between CERN, Rutherford and Pisa. The contents of some two hundred magnetic tapes already exchanged between these centres involve not only raw physics data but also Data Summary Tapes from the analysis of earlier experiments. Further stations at DESY, Frascati, Dublin, Graz and ISPRA are expected to become operational in the coming months.

Improvements to STELLA now being implemented will allow other Laboratories to have high speed links to the CERNET network at CERN, permitting more rapid and flexible communications between machines and experiments at CERN and elsewhere.

CERN-JINR Summer School

The 1981 CERN-JINR School of Physics took place from 6-19 June at Hanko, Finland. The School was the seventh in the series organized by CERN in collaboration with Dubna, and was held for the second time in Finland (the first being in 1970 at Loma-Koli). The seventy participants were young experimental physicists mainly from the Member States of the two Laboratories. The lectures in the successful school covered theoretical and experimental aspects of gauge theories, grand unification, and particle and nuclear scattering at large transverse momentum.

1000th neutron therapy patient

Fermilab's Neutron Therapy Facility (NTF) recently received its 1000th patient after being in operation for some five years. The NTF is only the second centre in the world to have registered so many patients, the other being London's Hammersmith Hospital, which has been treating patients with neutrons for twelve years.

The Fermilab centre operates simultaneously with the high energy physics programme, using the linac to create neutrons between injector pulses to the main accelerator. NTF Director Frank Hendrickson says that five years of experience have shown clearly that patients can be treated effectively and safely. Some selected rare tumours and some of the common tumours respond better to treatment with neutrons than to more conventional treatments. Research is still under way to establish how well neutrons will eradicate dangerous tumours or at least bring them under control. It is too early to make a precise evaluation, but many experts are encouraged and even excited by these findings.

Many medical innovations have been exploited, including the use of fast neutrons with chemical sensitizers. The NTF was the first to use an isocentric treatment system in which the patient rather than the source of radiation is rotated around the centre of the target volume. New shielding and targetting techniques have also been developed.

The Fermilab NTF is funded by a grant from the US National Cancer Institute.

Doubler/Saver progress

Installation work for the Fermilab Energy Doubler/Saver is gathering momentum. The accelerator was shut down in June to start the major installation work on the superconducting magnets. The 100th magnet was installed on 4 August, and by mid-August 160 dipoles were in place and the installation was proceeding at the rate of ten a day.

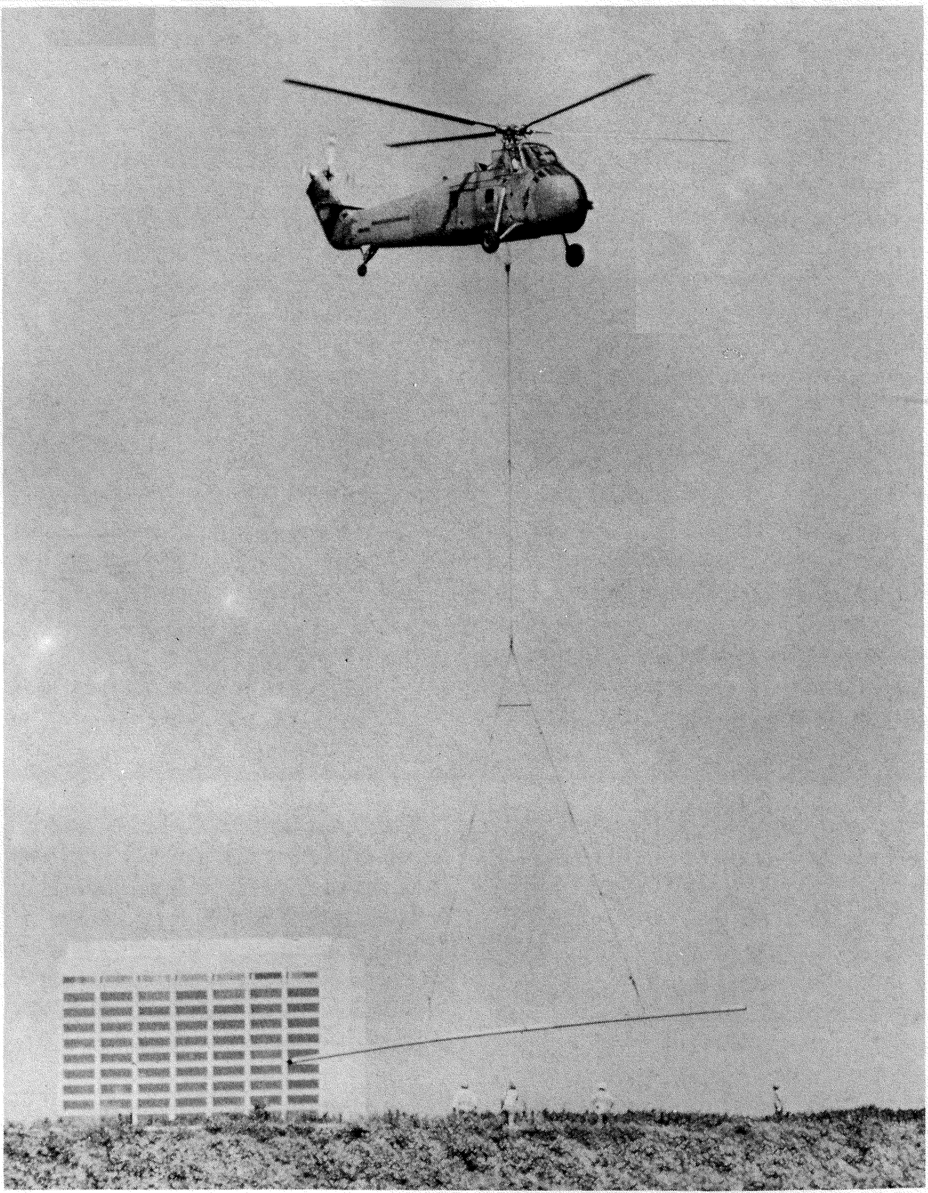
The current shutdown, scheduled partly during the summer to lessen expensive power needs, will extend into the fall. There will be a second installation period next summer and fall.

One dramatic event has been the placement of the helium transfer line by helicopter. Over a two-day period, the helicopter positioned one hundred and eighty segments of the transfer line, each eighty feet long, around the ring. The transfer line is complete from the Central Helium Liquifier. A full scale test of a cryoloop, including power tests, was scheduled for September.

One of the most encouraging developments has been the successful operation of the refrigerator controls. The algorithms for refrigerator operation have been devised and successfully incorporated into the microprocessor system. The control links to the Main Control Room have been established and A-Sector refrigerator control and monitoring is now delegated to the normal Accelerator Operations crews.

Tevatron I, the antiproton storage ring project, has been reorganized in view of the common interests of the Antiproton Source Project, the Colliding Detector Facility of the Research Division, and the new Accelerator Division (which combines the old Energy Saver and Accelerator Divisions). The storage ring project aims for the achievement of proton-antiproton collisions near 2 TeV in 1984 at a luminosity equal to or in excess of 10^{30} cm^{-2} sec^{-1}.

The reorganization will pool the talents of the Colliding Detector Facility headed by Alvin Tollestrup and Roy Schwitters and the antiproton source group with strong input and liaison from the new Accelerator Division. John Peoples is the head of the Tevatron I Project and the Antiproton Source Project. Don Young is Deputy Head and Fred Mills Associate Head.



A helicopter positions an 80-foot length of helium transfer line on top of the main ring berm as installation proceeds for the Energy Doubler/Saver.

(Photo Fermilab)

STANFORD LINEAR ACCELERATOR CENTER
OF
STANFORD UNIVERSITY
announces an opening for the position of

ASSOCIATE DIRECTOR, RESEARCH DIVISION

The Stanford Linear Accelerator Center (SLAC) is a major high energy physics research laboratory operated by Stanford University under contract with the U.S. Department of Energy. SLAC's Research Division consists of experimental and theoretical physics groups and supporting staff; a large computation center; and groups concerned with the operation and development of certain major experimental facilities and with instrumentation research. The Associate Director, Research Division, has primary responsibility for coordinating and administering this program under the general direction of the Laboratory Director.

Candidates for the position of Associate Director, Research Division, must have had extensive and widely recognized experience as practicing scientists in the field of elementary-particle physics. The laboratory is seeking a person who is willing to play a strong leadership role in the years ahead.

The tentative starting date for this position is 1 July 1982; the actual date can be a matter of negotiation. Applicants should submit a curriculum vitae, together with the names of at least three references, to:

Professor Burton Richter, Chairman
Associate Director Search Committee
Bin 95, SLAC, Stanford University
P.O. Box 4349
Stanford, California 94305

STANFORD LINEAR ACCELERATOR CENTER
OF
STANFORD UNIVERSITY
announces an opening for the position of

ASSOCIATE DIRECTOR, TECHNICAL DIVISION

The Stanford Linear Accelerator Center (SLAC) is a major high energy physics research laboratory operated by Stanford University under contract with the U.S. Department of Energy. SLAC's Technical Division consists of groups that are responsible for operating and maintaining the large electron accelerator and major experimental research facilities; for advanced research and development in the fields of accelerator physics and engineering; and for the general provision of technical services to the rest of the laboratory. The Associate Director, Technical Division, has primary responsibility for the leadership and management of this program under the general direction of the Laboratory Director.

Candidates for the position of Associate Director, Technical Division, must have had extensive and widely recognized experience as practicing scientists in the field of accelerator physics. The laboratory is seeking a person who is willing to play a strong leadership role in the years ahead.

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UNIVERSITÄT ZÜRICH

High/intermediate Energy Physics

A postdoctoral position is open at the experimental particle physics group of the University of Zurich, starting October 1, 1981. The group is involved in antiproton-proton experiments at LEAR/CERN and intermediate energy experiments (rare decays, pion and muon capture) at SIN. The appointment will be for one to three years, depending on the choice of the candidate and can also be adapted to visiting faculty members on sabbatical leave.

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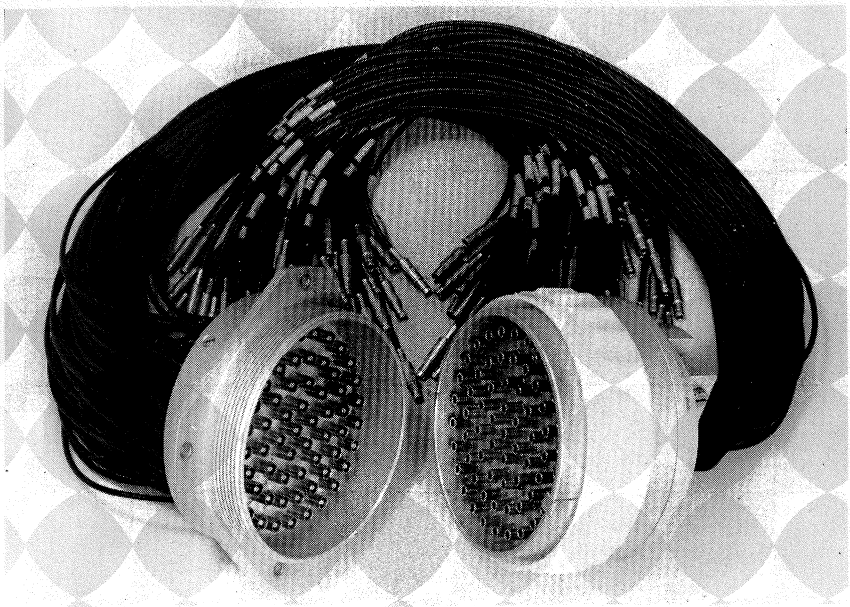

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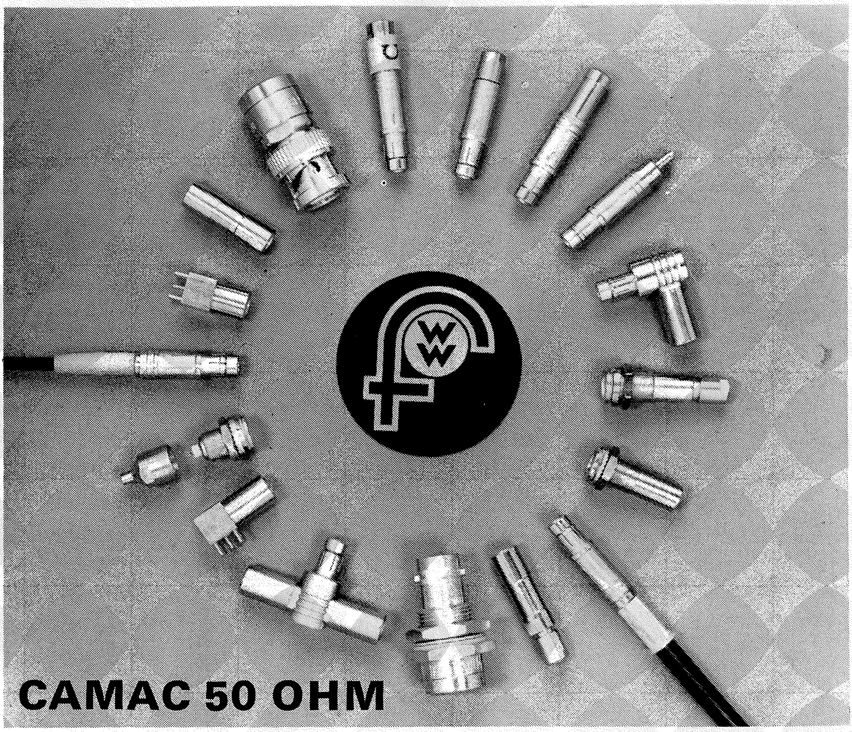

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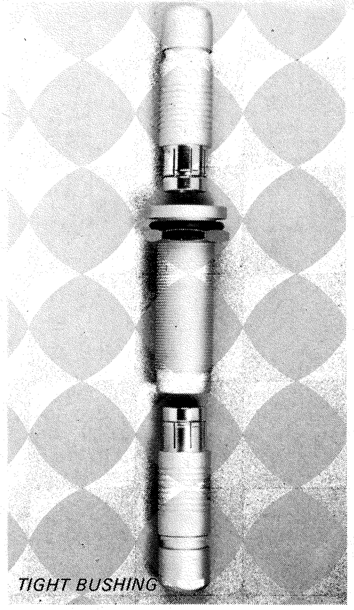

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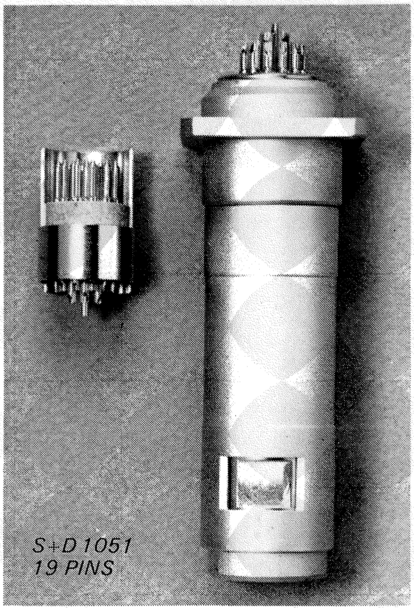

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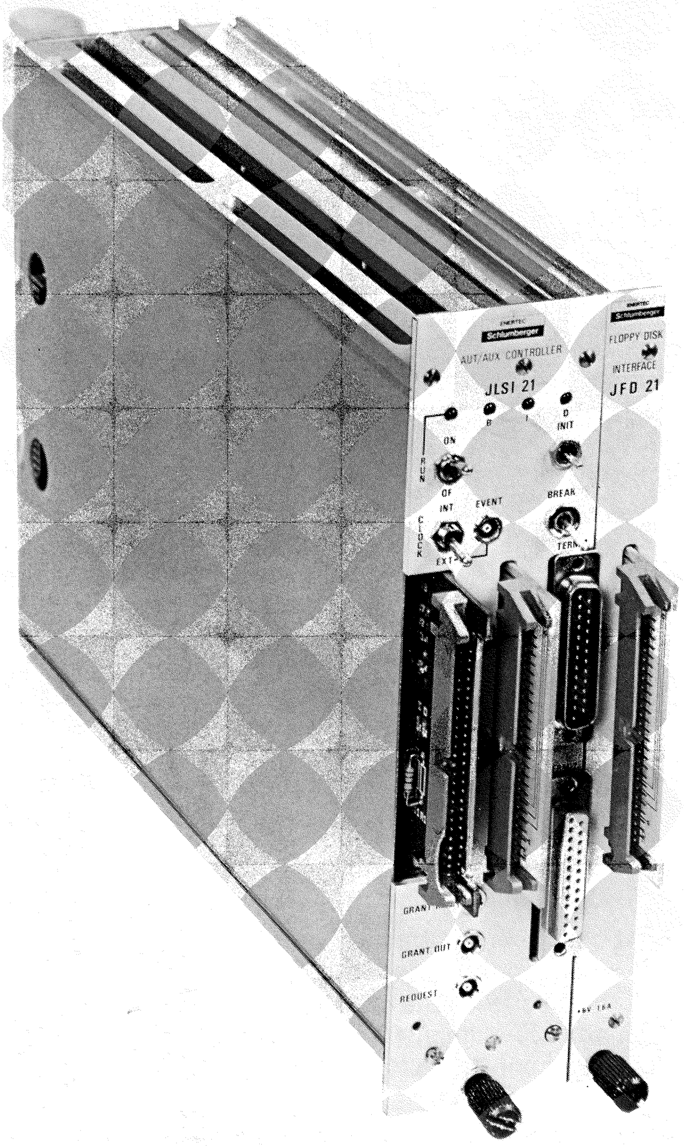
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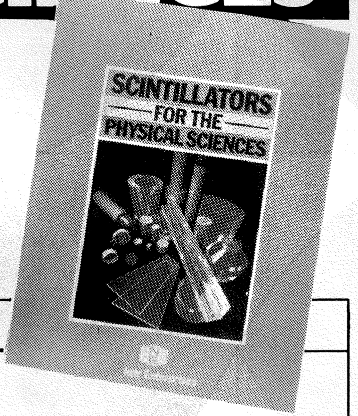
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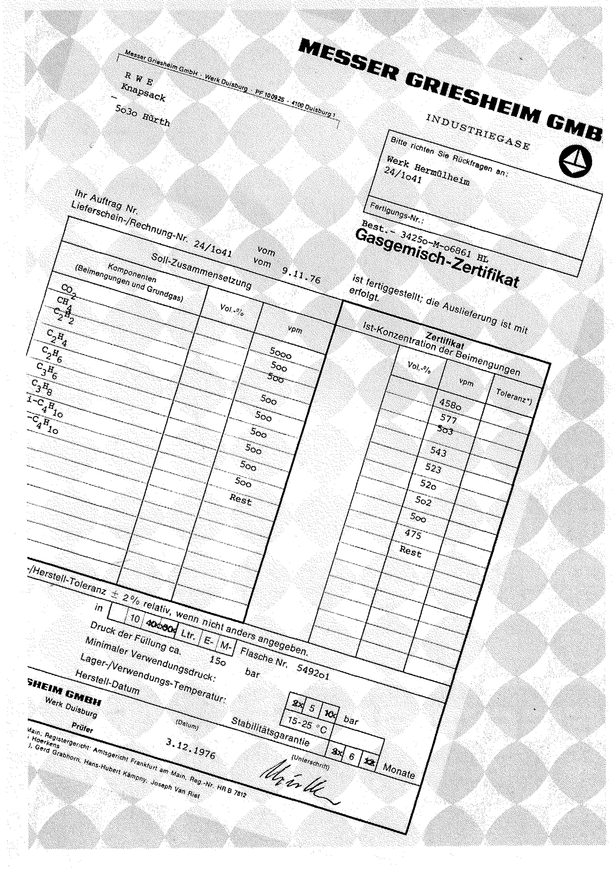

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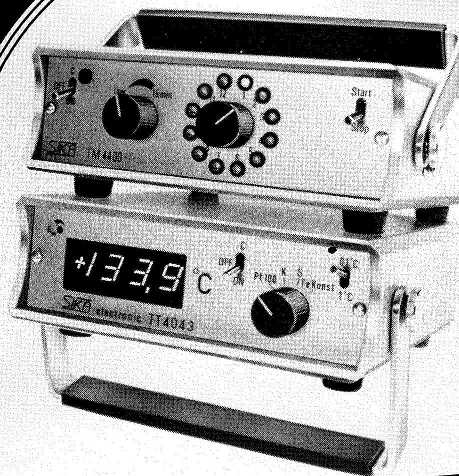

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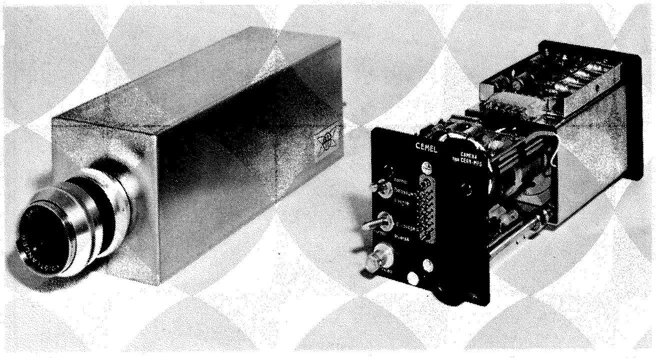

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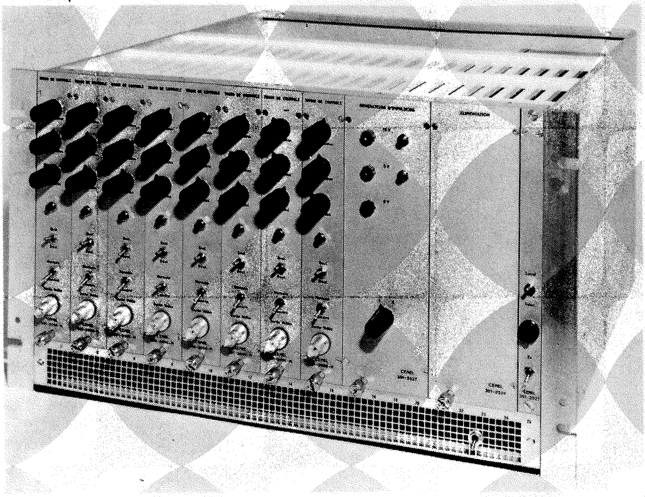

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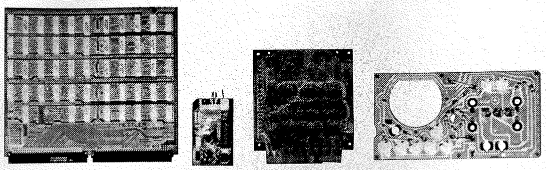

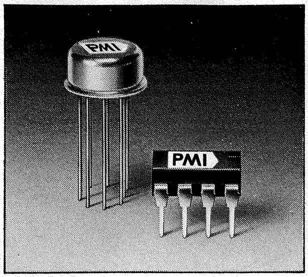

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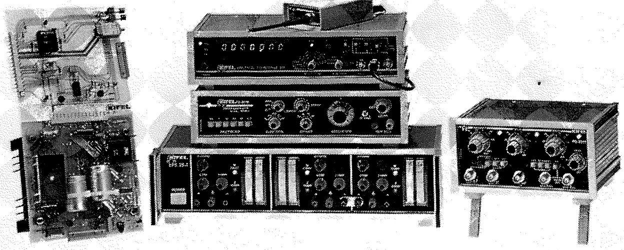


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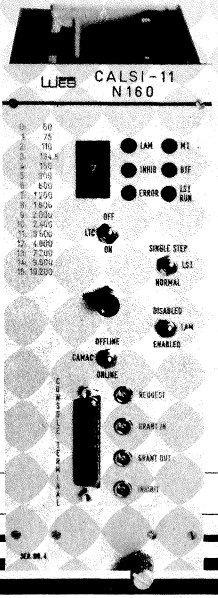
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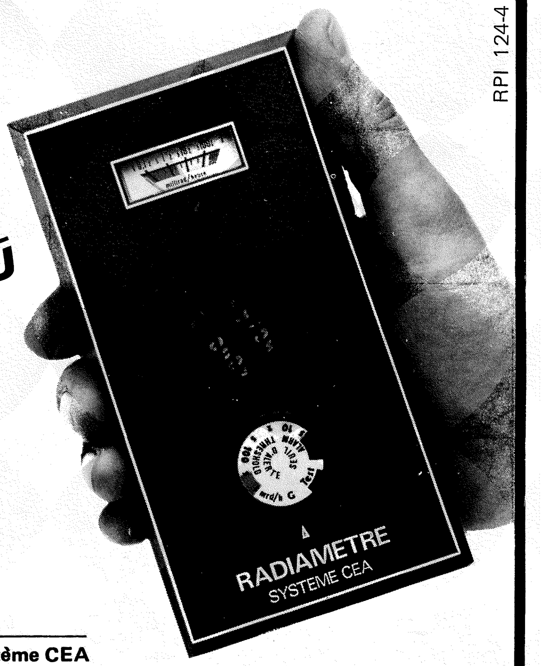

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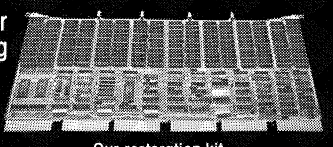

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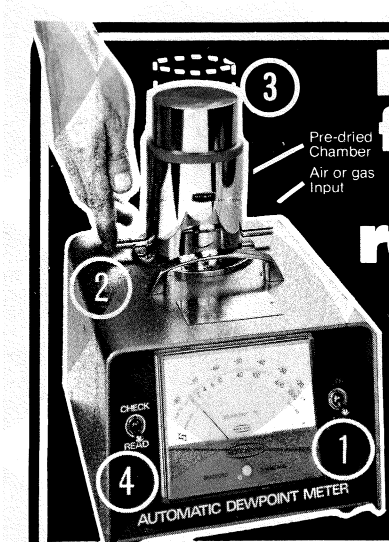
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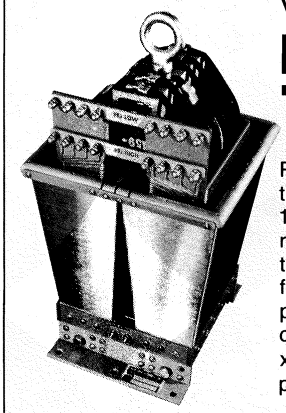

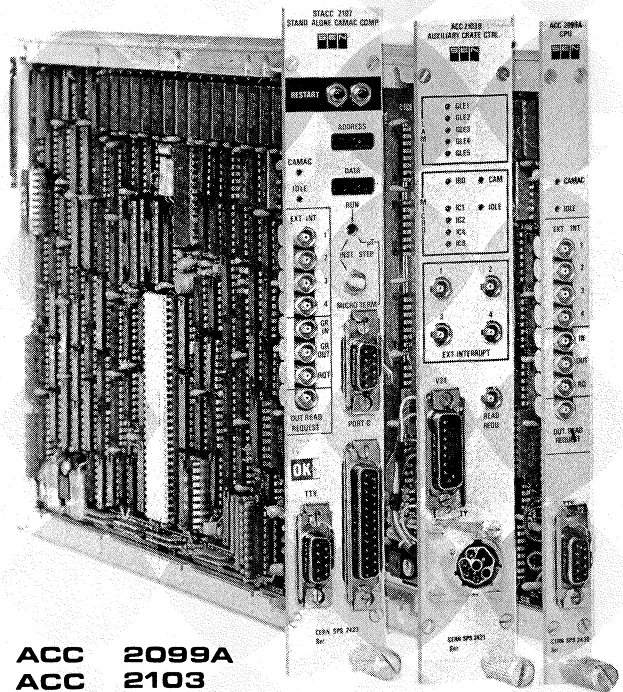

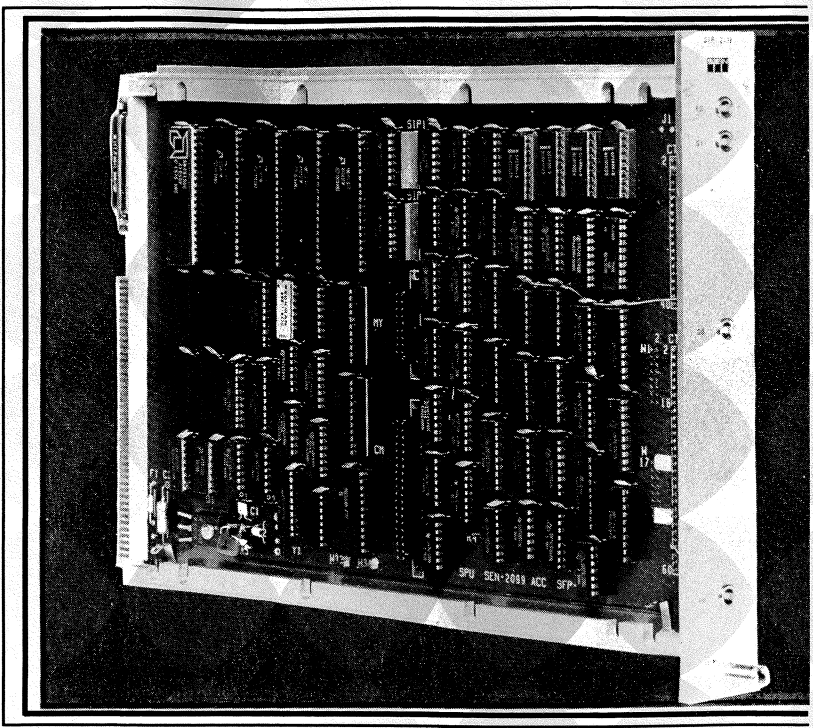
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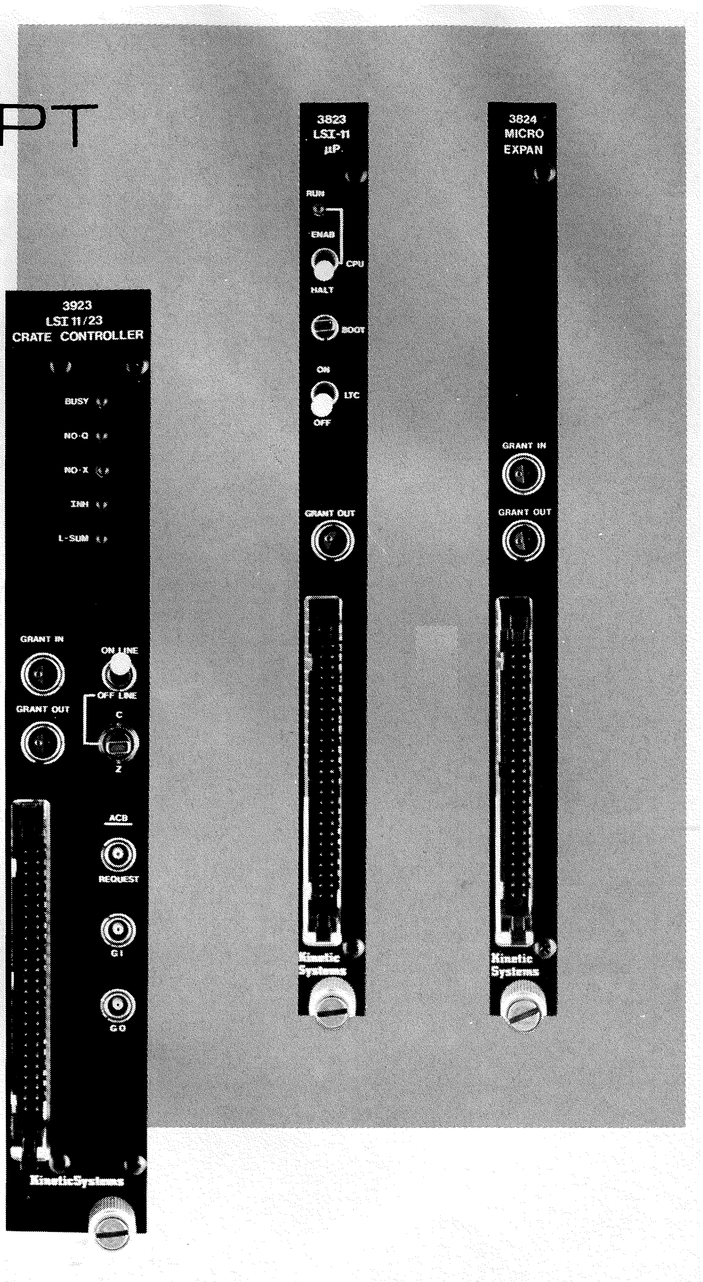

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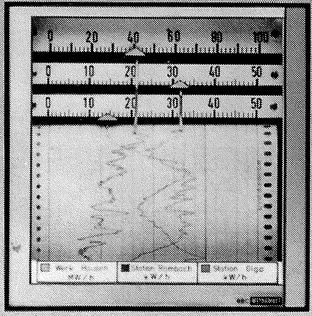

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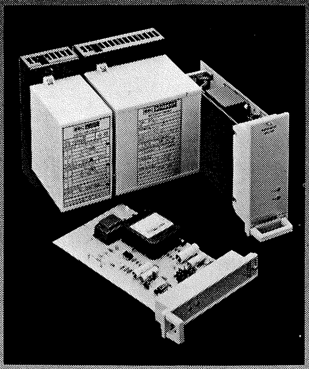

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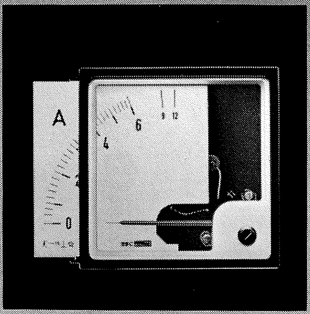

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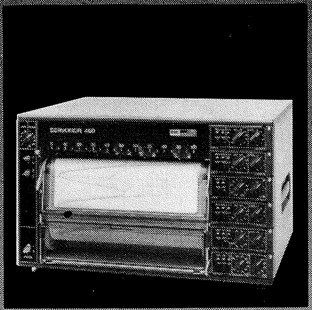

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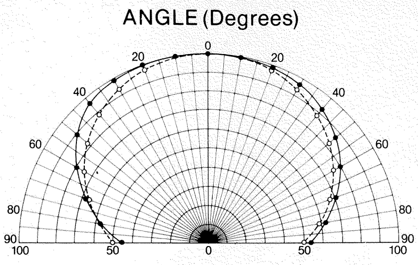

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The new R1391X 5″ hemispherical photomultiplier tube provides excellent sensitivity over the full 180°.

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XP2020	12	$2\text{x}10^7$	2500	1,5	2,4	250
XP2230B	12	$2\text{x}10^7$	2500	1,6	2,7	250
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t_r = anode pulse rise time for a delta light pulse

t_w = anode pulse duration FWHM for a delta light pulse

* SIN = Schweizerisches Institut für Nuklearforschung

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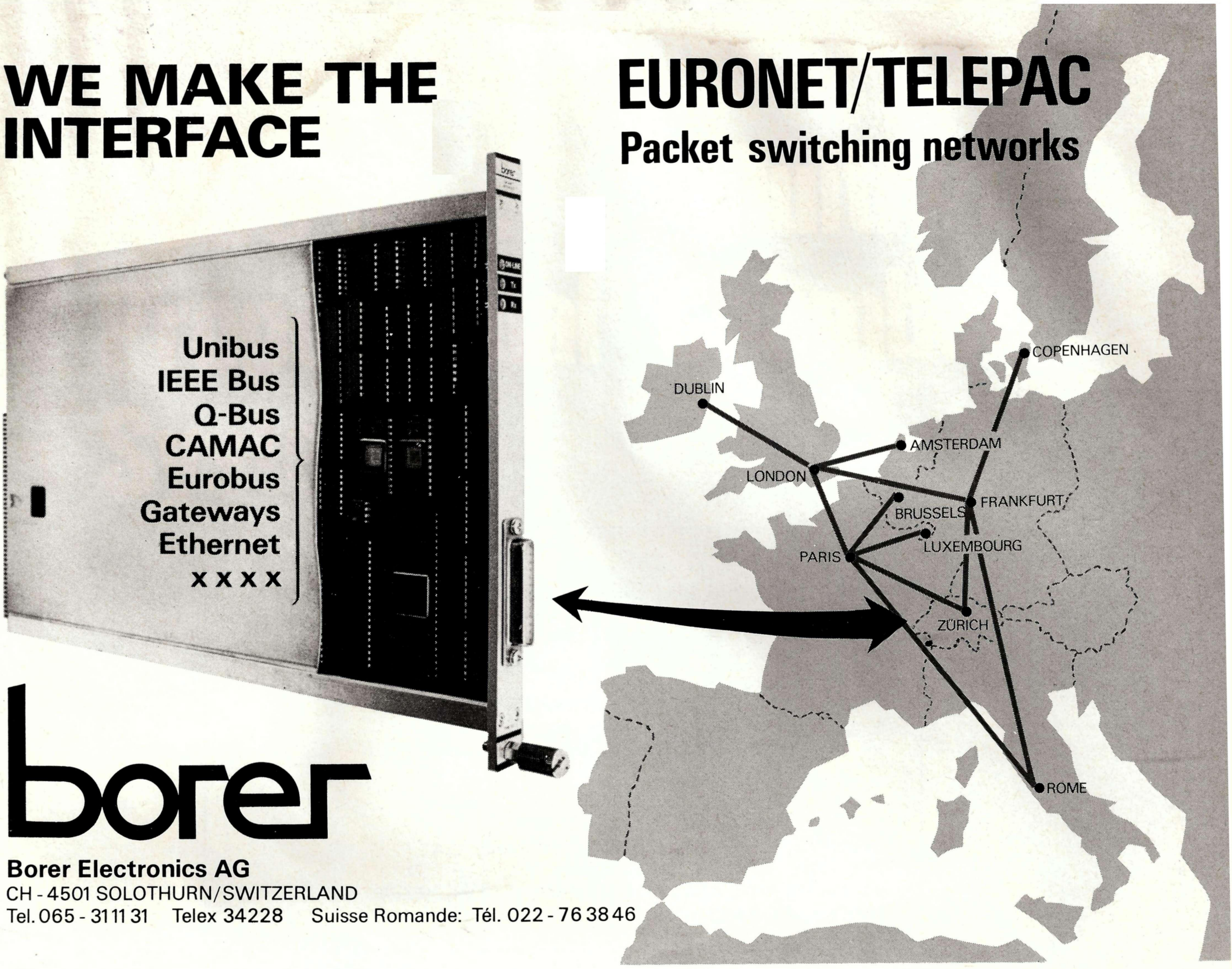

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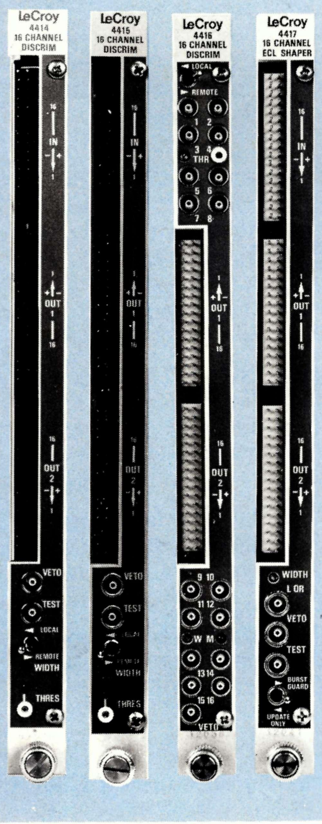
LeCroy's ECLine Standard provides a wide variety of discriminators for a wide range of applications



Four different CAMAC-Standard Discriminators are now available in the LeCroy ECLine standard. They offer new concepts in pulse height discrimination—like convenient cabling, programmability of threshold and masking patterns, very low thresholds, and complementary ECL outputs...features that not only represent better specs, but also facilitate complete, dynamic system testing.

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Features	Model 4414	Model 4415	Model 4416	Model 4417
Number of Channels per Module	16	16	16	16
Maximum Rate (MHz)	35	50	200	200
Threshold Range (mV)	1-3	30-600	15-1000	30
Programmable Threshold	Yes*	Yes*	Yes	No
Input Connectors	ECL	ECL	LEMO	ECL
Single-ended Inputs	Yes	Yes	Yes	Yes
Complementary Inputs	Yes	Yes	No	Yes
DC Coupling	No	No	Yes	Yes
Burst Guard Mode	No	No	Yes	Yes
Programmable Channel Masking	Yes	Yes	Yes	No
Test Input	Yes	Yes	Yes	Yes
Fast Common Veto	Yes	Yes	Yes	Yes

*with external control

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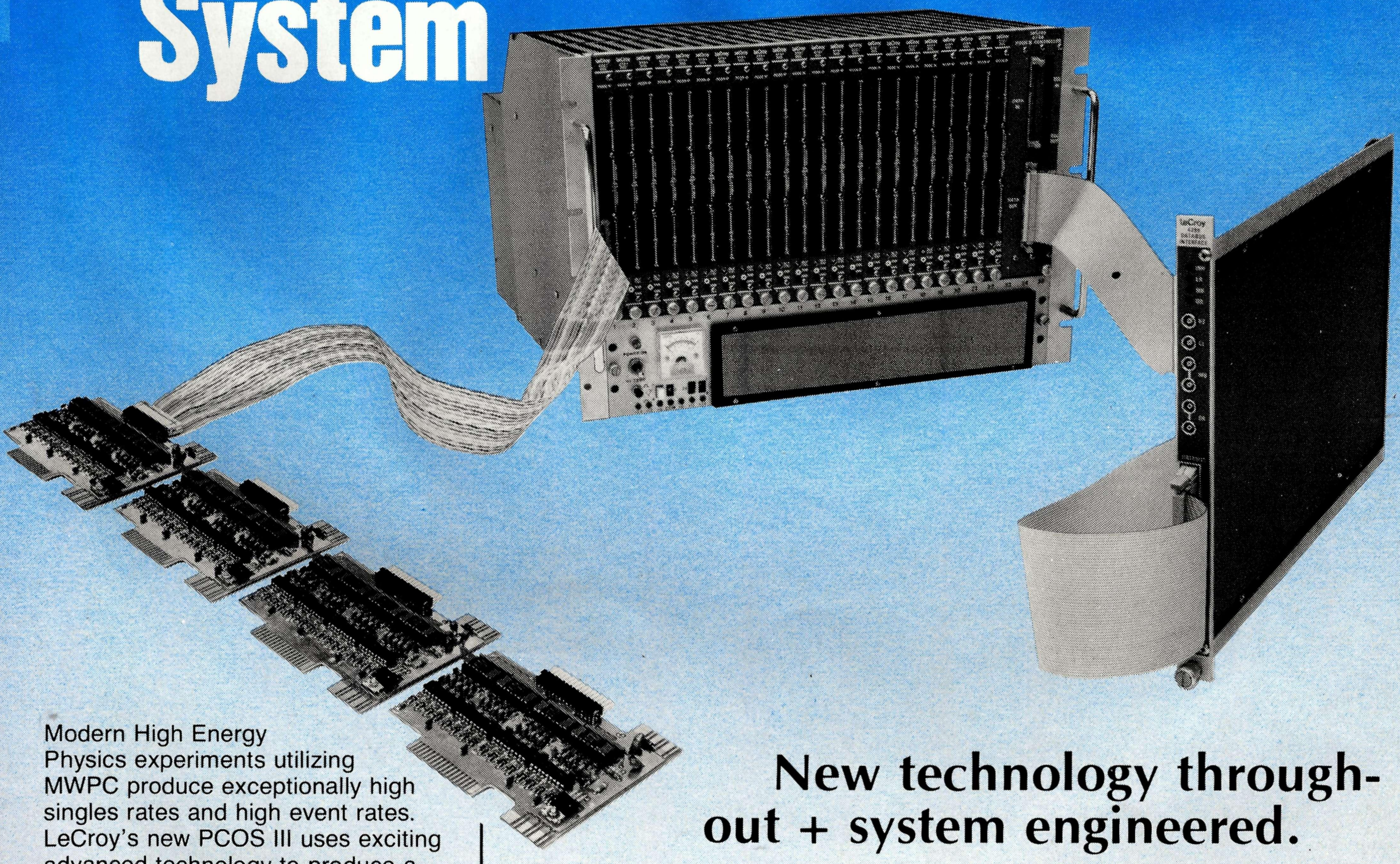

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PCOS III consists of exceptionally compact 16-channel chamber cards, remote 32-channel delay/latch modules and priority encoders to scan and encode at high speed. Readout is performed via LeCroy's CAMAC DATABUS system.

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Programmable Threshold
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CAMAC programmable with 1.5 nsec resolution (300-682.5 nsec) with the double pulse resolution of cable but without the bulk, waste, or cost.

Prompt wire and latched outputs are supplied. Provision for 2-fold to 16-fold in any combination. Compatible with LeCroy's ECLine family of logic modules.

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Use of distributed intelligence results in a total encoding time for typical events of 1-2 μsec.

Cluster Compacting
Built-in logic allows automatic on-line calculation of the cluster centroid and width.

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PCOS III integrates into virtually any modern experiment. Options include user-assignable logical wire addresses, programmable delay and threshold, user assignable fast outputs, cluster-compacting control and many more. PCOS III is available now. Contact LeCroy for details.

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