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Contents

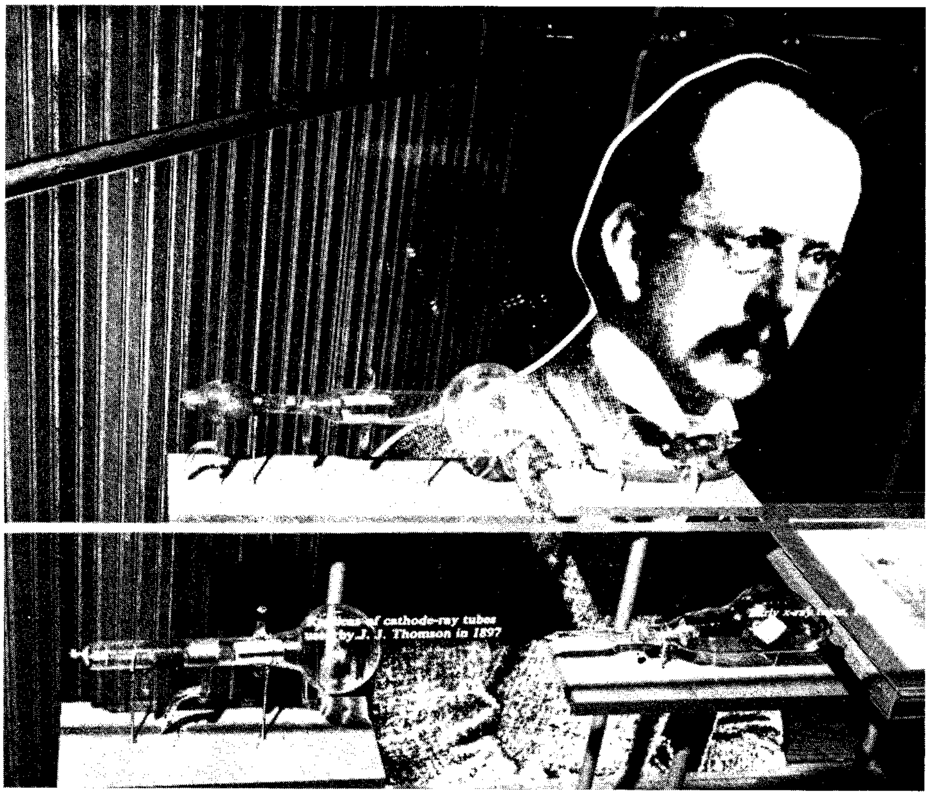
Cover photograph: He has one! The US President's budget message on 23 January announced $275 million for the construction of ISABELLE at Brookhaven and the project will be headed by Jim Sanford. Jim was photographed alongside a placard 'I want an atom smasher' which had been carried by a demonstrator at Batavia during the visit of a team from Atomic Energy Commission prior to the selection of the Fermilab site. The photograph was taken at the opening of the 'Atom Smasher' exhibition at the Smithsonian Institution in Washington — the subject of our first article. (Photo Fermilab)

Atom Smashers... Fifty Years

As reported in our December issue, an exhibition tracing the history and development of particle accelerators and particle detectors has opened at the National Museum of History and Technology of the Smithsonian Institution in Washington. It is probably the most thorough exhibition ever pulled together in one place of the instrumentation used in the study of the nature of matter. By now, of course, we have passed beyond 'atom smashers' to 'nucleus smashers' and 'particle smashers' but the popular name for all accelerators was chosen for the exhibition which has the title 'Atom Smashers... Fifty Years'.

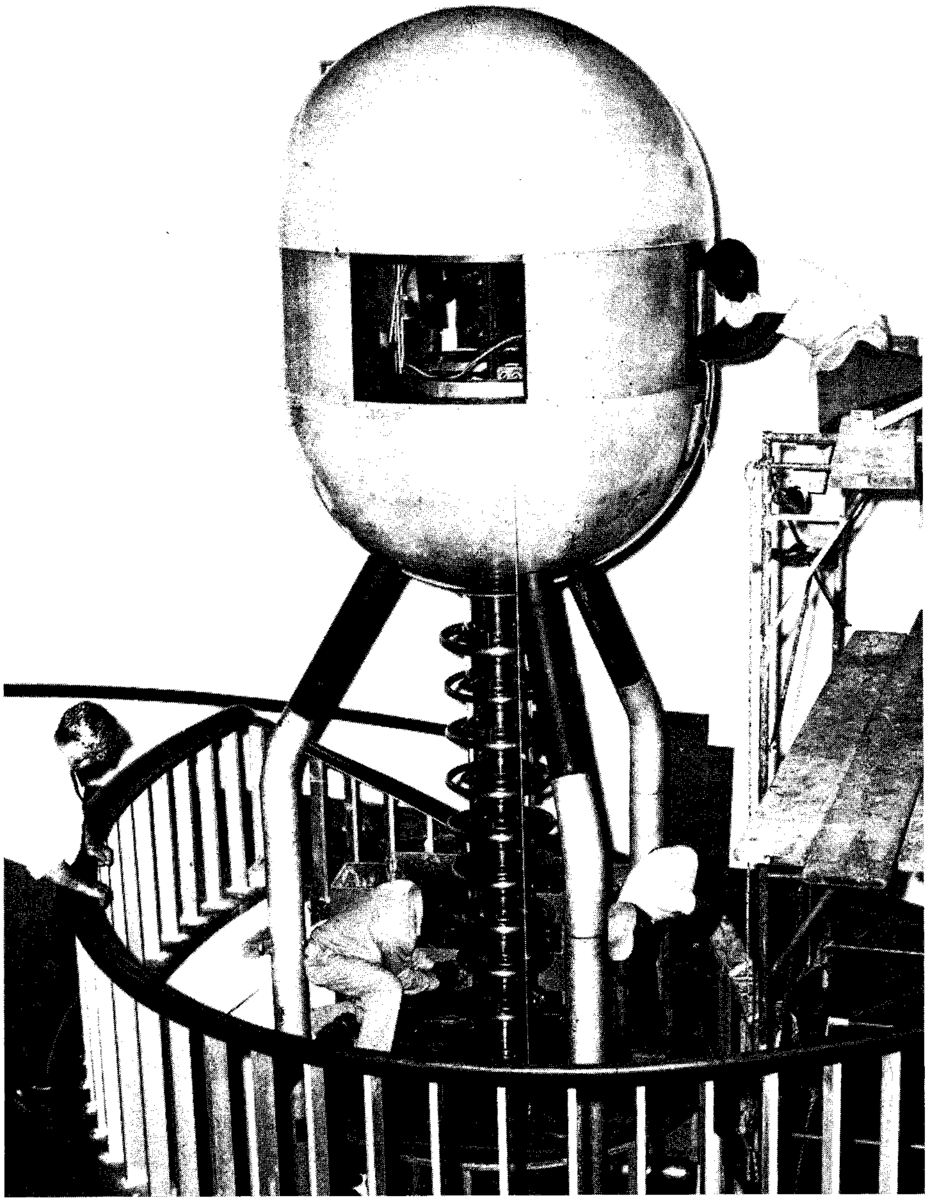
The exhibits open with documents, papers, notebooks and photographs from the years of research into radioactivity and the properties of nuclei and the first ideas on acceleration techniques. These include, for example, the notebooks of Rolf Wideröe from 1923 in which he outlined betatron acceleration and linear resonance acceleration and the 1928 sketches of E.T.S. Walton and Leo Szilard of their linear accelerator ideas.

There is a full size replica of the accelerator tube of the voltage-multiplier system used in England by Walton with John Cockcroft in 1932 in the first



One of the opening displays at the exhibition is a portrait of J.J. Thomson, (the first man to realize, in 1897, that he was smashing atoms) which appears behind replicas of his cathode ray tubes. His explanation of the cathode ray phenomenon concluded, 'atoms are not indivisible for negatively charged particles can be torn from them by the action of electrical forces'.

(Photo Fermilab)



Reassembly at the Smithsonian under the supervision of Louis Brown of the first Van de Graaff accelerator which was built by Merle Tuve, Odd Dahl and Lawrence Hafstad at the Department of Terrestrial Magnetism of the Carnegie Institution in Washington in 1932. These machines were amongst the first to achieve MeV energies sufficient to penetrate the nucleus.

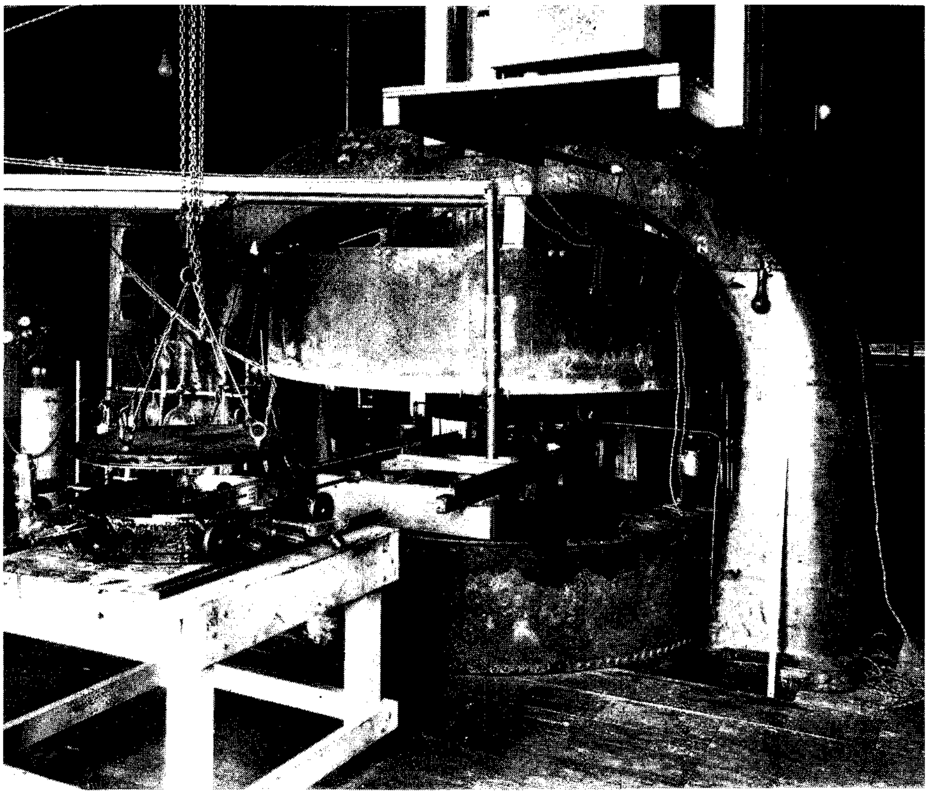
(Photo Smithsonian)

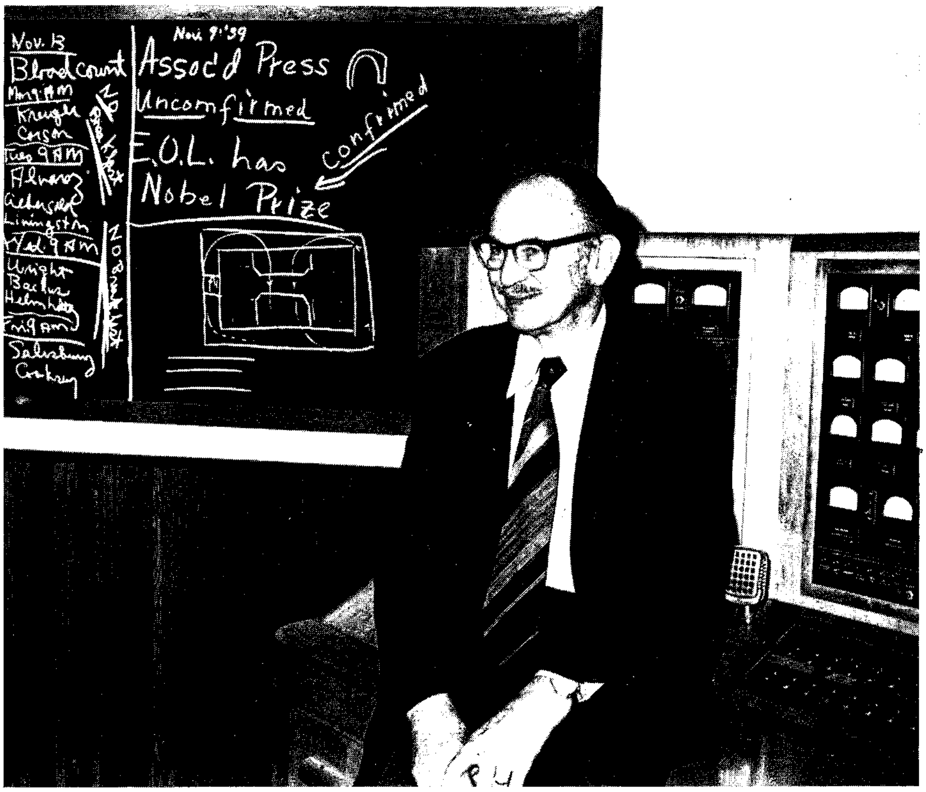
The generation of cyclotrons, initiated by E.O. Lawrence at Berkeley in the 1930s, brought in the crucial idea of using the same accelerating fields repeatedly by circulating particles through them many times. An exhibit including a model of this 27 inch cyclotron with an actual vacuum chamber was prepared for the Smithsonian under the direction of Ed Lofgren. The original magnet now stands outside the Lawrence Hall of Science at Berkeley.

(Photo LBL)

The exhibition has the 1946 control console of the Berkeley 60 inch cyclotron which was completed in 1939. Behind it is a 1939 blackboard announcement of the Nobel Prize award to Lawrence. Photographed at the console is Ed McMillan, former Director of Berkeley, himself Nobel Prize winner and discoverer, with Vladimir Veksler, of the phase stability principle which led to synchro-cyclotrons and synchrotrons.

(Photo Fermilab)





successful atom smasher. Others were hot on their heels — the first Van de Graaff accelerator which operated at the Carnegie Institution in 1932 has been transposed to the Smithsonian. Both these types of machine are limited in peak energy by their operating principle of maintaining a high voltage gradient through which the particles pass once.

The route to still higher atom smasher energy really opened up when E.O. Lawrence emerged with the idea of the cyclotron which, by circulating the particles through the same acceleration system many times, could increase energies in small doses. Notebooks of Lawrence and Stan Livingston cover the time from the first successful operation of the 4 inch cyclotron at Berkeley to the construction of the 27 inch cyclotron in 1936 which achieved proton energies of 6 MeV. A model of the 27 inch machine is exhibited as well as the second control console, built in 1945, of the subsequent 60 inch machine completed in 1939. Lawrence went on to build the 184 inch cyclotron at Berkeley and cyclotrons in modern guise, such as those at SIN in Switzerland and TRIUMF in Canada, are still 'front-line machines. Lawrence was also a fervent promoter of the use of atom smashers in medical applications and would be happy at the present widespread use of cyclotrons in hospitals.

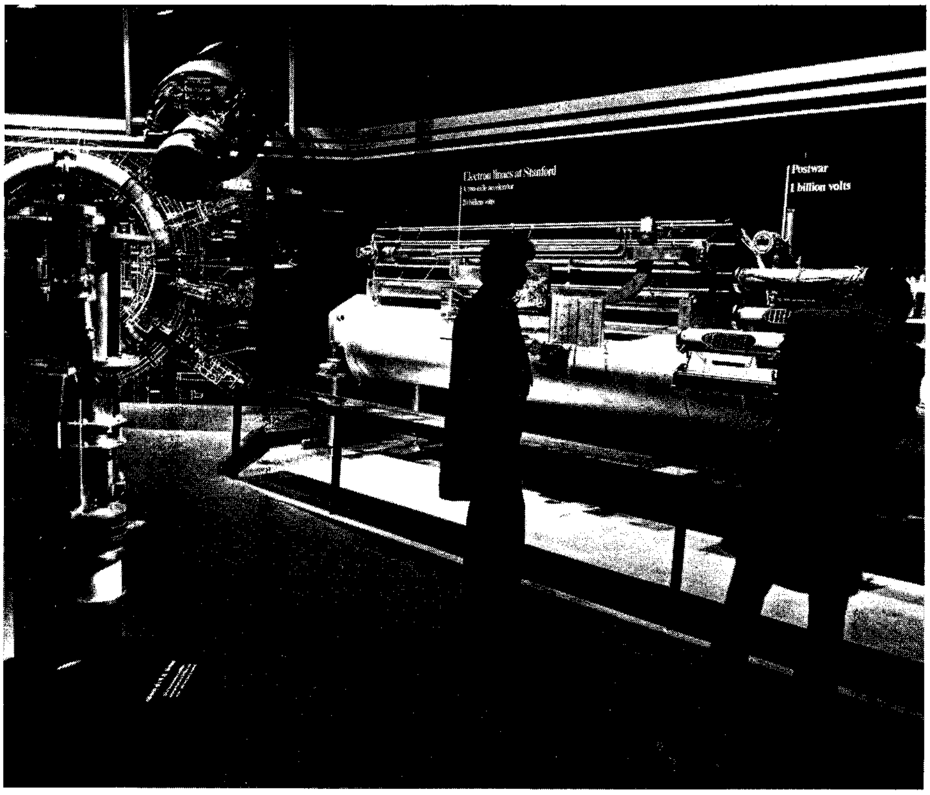
Alongside the cyclotron exhibits is D.W. Kerst's 'magnetic induction accelerator', the first betatron which operated in 1940. Accompanying it is the European equivalent — the betatron built during the War at the Siemens-Reiniger Werke in Erlangen. Betatrons have subsequently gone to the hundreds of MeV region, for example, the 340 MeV machine at the University of Illinois.

Linear accelerators, both for protons and for electrons, came into fashion soon after the war mainly as a consequence of the production of powerful microwave amplifier tubes for radar applications. The exhibition presents the development of both types. There is a section (the first sixth) of the 40 foot proton linac operated at Berkeley in 1947 by Luis Alvarez. It reached 30 MeV and was seen as a step en route to 1 GeV but this was put aside. The present 800 MeV machine at Los Alamos is not far from that first goal.

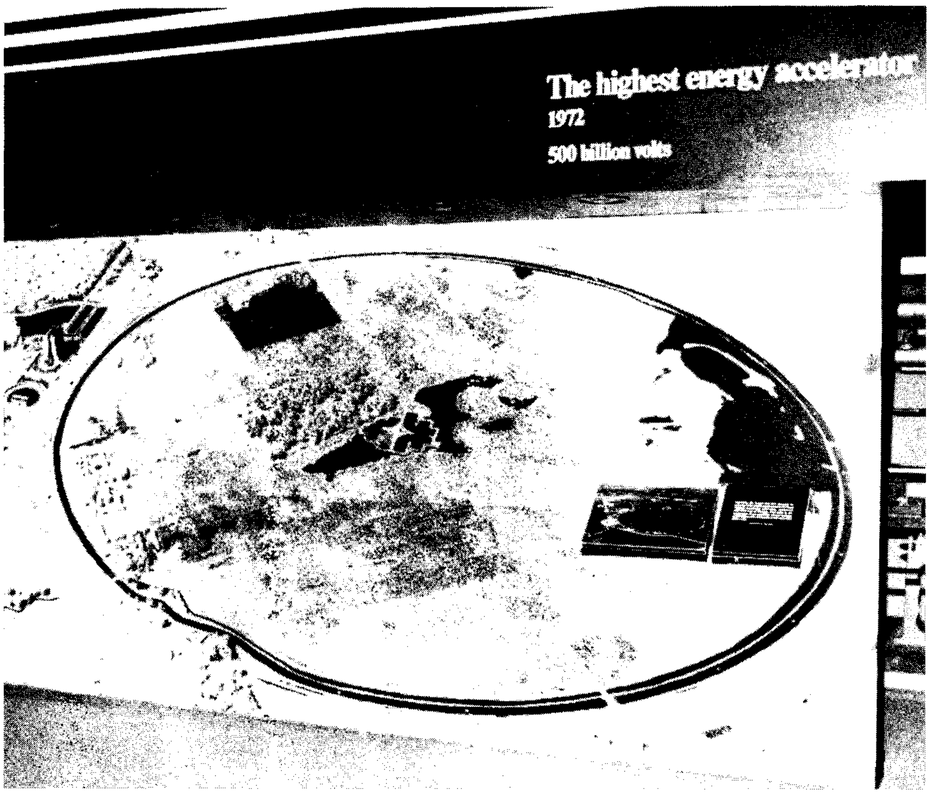
Across the San Francisco Bay, the electron linac was emerging from developments at Stanford University. The way had already been paved by the pre-War work of William Hansen and Russell Varian. Hansen had experimented with electron beams passed through small copper cavities fed with r.f. power. Such a 'rhumbatron' from 1937 is displayed at the exhibition as are Varian's notebooks with the original concept of the klystron power amplifiers.

Sections of the Mark I (1.5 MeV) and Mark III (200 MeV) electron linear accelerators, operated at Stanford University in 1947 and 1952 respectively, are shown. The rebuilt Mark III eventually reached 1.2 GeV in 1964. The crowning glory of electron linacs is displayed as a 3 metre section of the SLAC machine which now reaches energies in excess of 20 GeV. To complete the linac section of the exhibit, there is a 6 MeV electron linac used in medical applications in the early 1950s at Stanford — the first of a long series used in cancer research and therapy.

The next major advance towards increasing atom smasher energies was the phase stability principle (advanced independently by Ed McMillan and Vladimir Veksler in the mid 1940s) which keeps the accelerating fields in step with the increasing particle momentum. They opened the door to synchrotrons and McMillan built a 330 MeV electron synchrotron at Berkeley in 1949. This machine is the most elaborately reconstructed of the whole



An exhibit on the historical development of linear electron accelerators was prepared by SLAC. It includes a prewar 'rhumbatron', sections of the Mark I (1947) and Mark III (1952) linacs, and a 3 metre section of the SLAC accelerator. On the left stands a SLAC klystron, cut away to show electron gun and cavities. Suspended overhead is the first of the medical linacs completed in 1955 for the Stanford University Medical Center.



Modern proton synchrotrons are represented particularly by the Fermilab 500 GeV machine of which there is this large aerial photograph and a 30 metre complete section of the main ring tunnel with back lit transparencies across the ends giving the impression of its continuation around the 6 km circumference.

(Photos Fermilab)

1. At the opening of the exhibition in December, the exhibits are toured by S. Dillon Ripley (Secretary of the Smithsonian Institution) and his wife.

2. Bill Wallenmeyer (left) from DOE conveys his historical perspective to C.N. Yang during the opening cocktail. James Kane, Director of the Division of Physical Research of DOE, is in the background on the left.

3. Paul Forman (right) organizer of this exhibition stands with Bruce Strauss (Fermilab) before a layout drawing of the CERN Intersecting Storage Rings which are the major exhibit in the 'current developments' section.

(Photos Fermilab)

exhibition and was put together under the direction of Rudin Johnson who had operated it for many years.

Cyclotrons also benefited from the new phase stability principle and in their synchro-cyclotron versions they have been taken since 1967 as high as 1 GeV peak proton energy at the Gatchina Laboratory near Leningrad.

Atom smasher energies were taken into the GeVs in 1952 with the 3 GeV proton synchrotron, the Cosmotron, at Brookhaven of which there is a big C-shaped magnet block on display. 10 GeV was then breached at Dubna in the Soviet Union while the next great idea had arrived to climb higher still. Nicolas Christofilos and, independently, Ernest Courant, Stan Livingston and H. Snyder developed the concept of alternating gradient focusing which allowed higher energies and higher accelerated beam intensities. Documents from their work are shown.

Electron synchrotrons were the first to fasten onto the alternating gradient idea and there are stacks of the specially shaped pole-piece laminations used in the 1.2 GeV machine built by Bob Wilson at Cornell in 1952. In Europe, Bonn University had a 500 MeV machine in operation in 1958. Cornell has since taken electron synchrotron energies highest with their 12 GeV machine.

Big proton synchrotrons using the alternating gradient focusing technique were led by the operation of the 28 GeV proton synchrotron built under John Adams at CERN in 1959 (symbol of the great European revival in this field), closely followed by the 33 GeV AGS built under Ken Green at Brookhaven. The high energy crown now belongs to the 500 GeV machine brought into operation under Bob Wilson at Fermilab in 1972. A 10 metre section of the Fermilab tunnel is one of the main attractions at the exhibition.

Dramatic further increases by orders of magnitude in atom smasher energy cannot be expected with the present technology though superconductivity will have an impact. It is via colliding beams in storage rings that the study of higher energy phenomena looks most promising. Superconductivity and storage rings are featured in a 'current developments' section at the exhibition which has a strong European flavour.

There is a presentation of the vacuum chamber of the first electron storage ring, AdA, of Frascati and Orsay accompanied by Bruno Touschek's notes. This work opened the route to the PETRA machine at DESY, the PEP machine at SLAC and the LEP project in Europe. There is a large display on the CERN proton 'Intersecting Storage Rings', built under Kjell Johnsen, up to now a unique machine which will see a higher energy version, ISABELLE, at Brookhaven.

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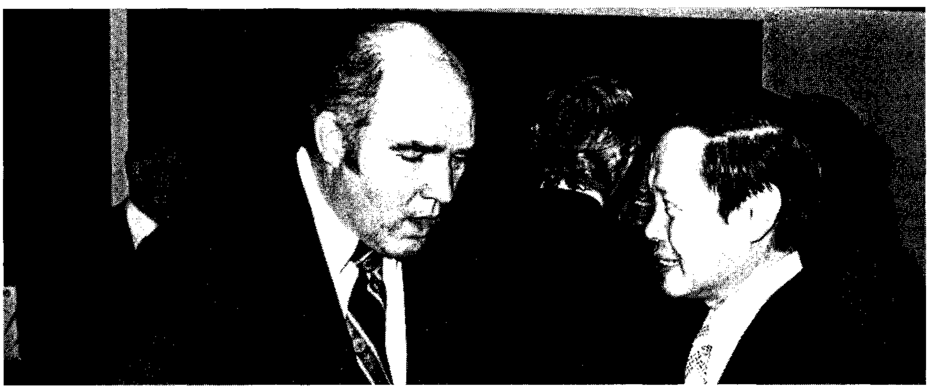

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From Franck and Hertz to Partons and Quarks

The final part of the exhibition is given to the development of particle detection techniques with Geiger-Muller tubes, R. Hofstadter's first sodium iodide scintillator, spark chambers, multiwire proportional chambers, a replica of Wilson's first cloud chamber, nuclear emulsions, Glaser's first bubble chambers through to the 80 inch hydrogen chamber from Brookhaven, 'Franckenstein' bubble chamber film measuring equipment, etc.

The exhibition was organized by Paul Forman, curator of Modern Physics at the Museum of History and Technology, assisted by Claudine Klose and Michael Meo. John Schmid was exhibit designer and Richard Virgo coordinator. Bill Hermannsfeldt, supported by Bill Wallenmeyer and Sam Lindenbaum, initiated the exhibition while in Washington with ERDA, and his successor, Dave Sutter, helped keep it moving. It was prepared in collaboration between the Smithsonian Institute and the US Department of Energy.

It is an exhibition not to miss, if the opportunity arises, for anyone involved in high energy physics, or indeed anyone interested in the progress of science and of the technology that it requires.

Throughout the history of particle physics, scattering experiments using electron beams have helped physicists to gain new insights into the structure of matter. The classic experiments of J. Franck and G. Hertz in 1914 with electrons and mercury atoms were some of the first examples of scattering. Besides providing direct evidence for the existence of discrete energy levels in atoms, these experiments showed ionisation effects in which constituents were ejected from the mercury atoms in violent collisions.

Subsequent experiments at the Cavendish Laboratory, Cambridge, extended this study of atomic structure using electron beams. The spectra which were obtained typically showed a peak of elastically scattered electrons which had lost energy only through giving energy to the recoiling atom, while secondary peaks were seen, each corresponding to a particular energy loss through giving discrete quantities of energy for an atomic transition. Finally a broad peak was obtained corresponding to ionisation processes where the incident electrons knocked bound electrons out of the atomic system.

The next generation of electron scattering experiments was carried out by R. Hofstadter and his collaborators at Stanford in the 1950s. With energies millions of times greater than those of Franck and Hertz, the Stanford electrons were able to probe inside atomic nuclei. Here, the energy losses reflected nuclear transitions and gave valuable information on nuclear energy levels. In addition, nuclei like helium with restricted stable energy levels showed nuclear 'ionisation' effects where component nucleons were knocked out by the incoming electrons.

Most recently, the electron scattering experiments with GeV energies at SLAC in the late 1960s have added a further chapter. These electrons were able to pierce the nucleons themselves and showed for the first time that tiny constituent particles, baptised 'partons' by R. Feynman, were lurking inside the nucleons. Thus in the space of sixty years, electron experiments have helped peel back three layers of the structure of matter, showing in each case, that there is a further level of corpuscular effects hidden beneath.

However, there are signs that, with the discovery of partons, the limit of corpuscularity has been reached, or at least that the constituents of the nucleons behave very differently to the constituents of the atoms and of the nucleus. While atomic and nuclear experiments show ionisation effects where constituent particles are set free by energetic enough collisions, the nucleon does not 'ionise' and, up to the higher energies yet achieved, no convincing sign of free partons has been seen.

The main features of atomic and nuclear interactions can be described without using relativity, but at the parton level, the energies involved mean that only a fully relativistic picture can be used. As well as including these kinematical effects, the parton dynamics may also be totally different to anything else, so that well known effects like ionisation need not carry over in an easily recognised way. Even so, the absence of recognisable nucleon ionisation in high energy electron scattering has significant implications.

If the constituents always remain firmly locked inside nucleons, how can they be recognised and how can their properties be studied?

The parton picture

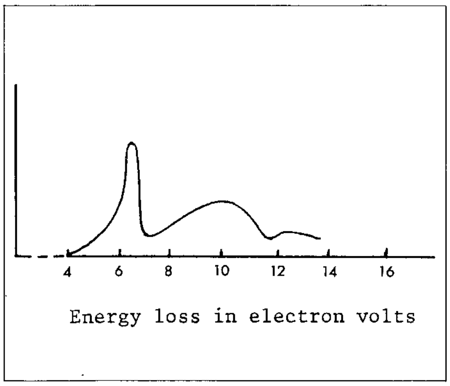
The basic idea of the parton picture is very simple. At high energy, the incident electrons (or other point-like projectiles, such as neutrinos or muons) scatter from the partons within the target nucleons. In each scattering process, one parton interacts with the

Inelastic electron scattering over the years:

1. Scattering of low energy electrons on mercury vapour recorded at the Cavendish Laboratory in the 1930s. The large signal from elastically scattered electrons is not shown. The peak at an energy loss of 6.3 electron-volts is caused by transitions involving an outer electron energy level in the mercury atoms. The broad peak at higher energy losses comes from scatterings on inner electrons.

2. Scattering of 400 MeV electrons on helium nuclei at Stanford in the 1950s. The sharp peak due to elastic scattering is followed by a broad enhancement due to scattering from component nucleons.

3. Scattering of 4.9 GeV electrons on hydrogen at SLAC in the 1960s. The elastic peak (much reduced in scale to fit into the diagram) and excitation effects are followed by a broad signal, this time due to scattering from component partons within the proton.



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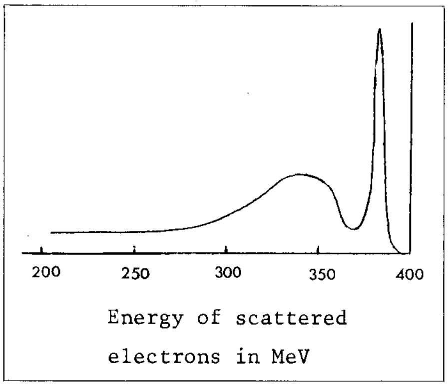

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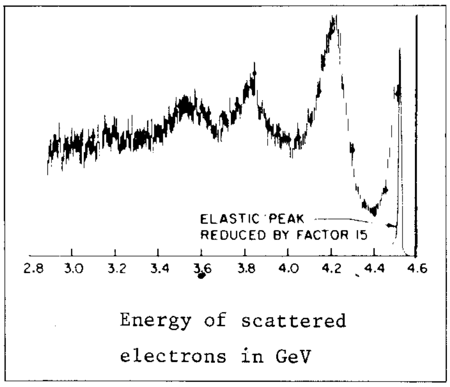


3.

incoming particle, while the other partons behave as 'spectators'.

During each interaction, the parton is considered to behave as a free particle. Since free partons have never been seen, this assumption seems puzzling. However, if the interaction times are short enough, it is possible that in the collisions, the partons do not get a chance to 'feel' the forces which bind them together in the nucleons. Under this assumption, we obtain a description of the overall nucleon behaviour by adding up the individual interactions of its free component partons.

When a large amount of momentum is transferred from the incident particle to the nucleon, this implies that the incident particle probes deep inside the target and interacts violently. In these cases, the results given by the parton model can be simplified to obtain a description of the scattering which depends only on kinematical variables and on the parton distributions within the nucleon. These distributions describe the relative probability of finding a parton inside the nucleon and are therefore dimensionless.

Thus the high energy behaviour for large momentum transfers reduces to a form which depends for its magnitude only on the kinematical conditions of the experiments (energy, momentum transfer, and so on) and is independent of any dimensioned characteristics like the masses of the participating particles, an effective 'size' of the interaction region, etc. As a consequence, we can predict particle behaviour once we have observed behaviour under one set of kinematical conditions by simply 'scaling' according to the new kinematics of the experiment.

The result, known as 'Bjorken scaling' since it originated with J.D. Bjorken, is not at all obvious, and is certainly not observed in most scattering processes, the behaviour of which depends on the nature of the participating particles.

The first results of electron-proton scattering at the 20 GeV electron linear accelerator at Stanford seemed to show, that for large momentum transfers, Bjorken scaling apparently was exact. Excitement rose that here, indeed, was proof that the proton itself had a grainy structure.

Partons and quarks

This was not the first time that the idea of constituents within the nucleon and other hadrons had proved successful. For many years before the verification of the parton picture, theorists realized that the observed proliferation of particles and their classification into families could be accounted for by the existence of a small number of building blocks, termed 'quarks', from which all hadrons were presumed to be composed.

These quark ideas were able to explain with astonishing success the static properties of hadrons, such as electric charge, strangeness and spin and their grouping together into families. However free quarks had never been seen, and despite its triumphant successes for particle classification, the quark model had very little to say about the dynamical behaviour of hadrons and the spectra seen in scattering experiments.

The scaling behaviour seen at Stanford was the first dynamical evidence for the existence of constituents within hadrons, and it was tempting to identify partons with quarks and so tie together two important developments in theory. However more proof was required before this jump could be made.

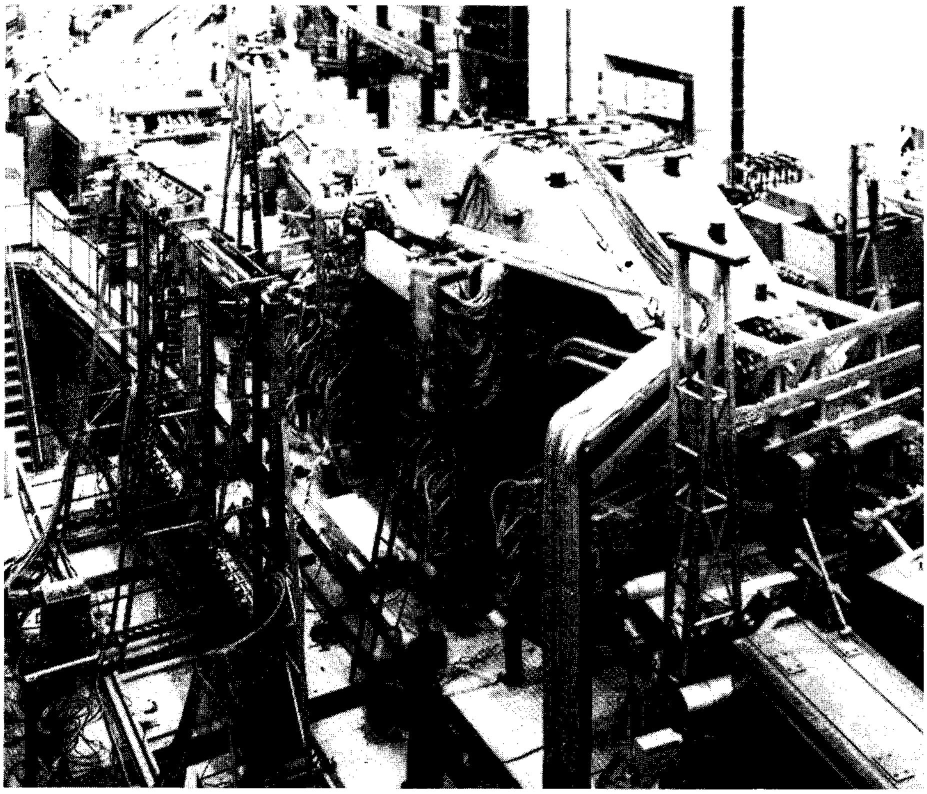
Important evidence which helped to clinch this unification of the quark and parton ideas came from neutrino experiments at CERN using the Gargamelle bubble chamber. The results from these experiments showed that there were three basic components inside the nucleon, each with spin one-half. The quark and parton became one and the same thing.

Scale breaking

All good things have to come to an end. The Bjorken scaling 'law' in electron-nucleon scattering is only an approximation valid at very large momentum transfers. While the momentum transfers in the SLAC ex-

The Split Field Magnet at the CERN Intersecting Storage Rings, scene of the investigation of the production of 'jets' in violent proton-proton collisions. These jets could be the hadronic equivalent of ionisation processes in atomic and nuclear physics.

(Photo CERN 12.9.75)



periments were large, they were not large enough to justify the approximations used in the analysis, and the scaling should at best be only roughly correct. Subsequent experiments at Stanford and Fermilab showed that this indeed was the case.

However the observed scaling effects, even though only approximate, are still relevant and provide an important window on the underlying quark/parton structure of the hadrons. At the same time, the deviations from scaling (scale breaking) can provide clues to the lepton-parton interaction which contributes toward the observed behaviour.

In the simplest treatment of the quark/parton model, the individual lepton-parton interactions are described by the easiest mechanisms to write down — single photon exchange for electromagnetic scattering and heavy boson exchange for weak interactions. Although these mechanisms do contribute significantly to the observed behaviour, and give scaling, there is a dressing of additional effects which can still be important, even at very large momentum transfers.

In a relativistic field theory, such as that required to describe the behaviour of the quark/partons, interactions between the particles and the field itself have to be included. Also, the continual production and annihilation of particle-antiparticle pairs has to be taken into account, so that even a 'vacuum' has residual particle properties.

In the mainly non-relativistic world of atomic and nuclear structure, such correction terms, due to the interaction of a charged particle with field photons and the spontaneous creation of electron-positron pairs are almost unheard of. However, in the world of relativistic electrodynamics these effects become important and produce measurable effects like the Lamb shift between adjacent atomic spectral lines.

For the quark/parton too, the interaction with the field has to be taken into account. Likewise, the continual formation of quark-antiquark pairs means that, for example, nucleons behave as though they contained a small proportion of antiquarks in addition to their main quark constituents. Quark field theory, also known as quantum chromodynamics, attempts to describe the interactions between quark/partons as the result of the exchange of massless 'gluons' in the same way that quantum electrodynamics uses massless photons to describe successfully electromagnetic phenomena. (Some of the ideas behind quantum chromodynamics were described in the November issue, 1977, page 380).

Using these ideas, relativistic effects involving virtual quark-antiquark pairs and interactions with the gluon field can be calculated. They imply systematic deviations from the scaling predicted by the simple quark/parton picture and seem to be in agreement with the latest data from electron, muon and neutrino scattering experiments over a wide range of scaling variables.

Hadron — hadron interactions

While lepton-nucleon scattering experiments provide a good testing ground for quark/parton ideas, they cannot be used to investigate the high energy interactions of the quark/partons with each other. For this, the physicists have to turn to purely hadronic experiments.

It was in 1972 that experiments at the CERN Intersecting Storage Rings first showed that the production of hadrons at wide angles to the incoming beams (i.e. large momentum transfers) was much greater than would be expected by extrapolating the behaviour seen closer to the beam direction. This indicated that some new mechanism must be at work in the proton-proton scattering which could perhaps be related to the parton phenomena seen in lepton-nucleon scattering.

These experiments were analogous to the classic investigations of Rutherford which demonstrated that there was a tiny hard nucleus hidden deep inside the atom which, when struck, caused particles to be scattered at wide angles.

Whether the hard scattering centres encountered in proton-proton collisions are in fact quark/partons is not yet clear. The results obtained so far certainly do not rule out this logical conclusion. In these hadronic experiments, scaling effects are seen and provide an important means of monitoring the behaviour of the hadron constituents.

Free quarks are still not seen but the high energy proton-proton collisions do produce 'jets' of secondary particles which emerge with rather well-defined directions. These jets have now been extensively studied (see June issue 1977, page 196) and could perhaps be the hadronic equivalent of ionisation as experienced earlier for atoms and nuclei.

The corpuscular structure of the nucleon has now been demonstrated in a wide variety of experiments. However, unlike the other corpuscular systems known in Nature, the nucleon does not break up into its constituents, preferring instead to lose excess energy by creating more particles.

This is more remarkable when models, which assume the proton constituents to behave largely as free particles, come out with results which agree, within broad limits, with the observed behaviour.

It is almost as though the quark/partons are 'tied' inside the nucleon by a thick string which is normally slack. Only in very violent collisions does this thick string tighten up — the tighter the string, the stronger the constraining force between the quark/partons. Moreover, as this string tightens, it 'vibrates' and radiates mesons.

Whether the string is strong enough to withstand even higher tensions and stop free quark/partons from ever appearing, only time and higher energy experiments will tell.

Around the Laboratories

BROOKHAVEN ISABELLE gets 'go ahead'

In his budget message on 23 January President Carter announced that a sum of $ 275 million will be assigned to the construction of 400 GeV proton-proton storage rings at the Brookhaven National Laboratory. This project, known as ISABELLE, has been under discussion for many years and will add significantly to the armoury of high energy physics research facilities in the USA.

The scheduled construction time has been extended from five to seven years by the Department of Energy involving a cost increase from the $ 238 million requested by Brookhaven. The first instalment of $ 23 million is expected for Fiscal Year 1979 which begins on 1 October 1978. All these monies have, of course, still to pass through Congress but no problems are anticipated.

There has been some internal reorganisation within the Laboratory to confront the construction of ISABELLE. Jim Sanford will be Chairman of the Accelerator Department, with Lyle Smith as Deputy, and will also head the ISABELLE project assisted by Harald Hahn and Julie Spiro.

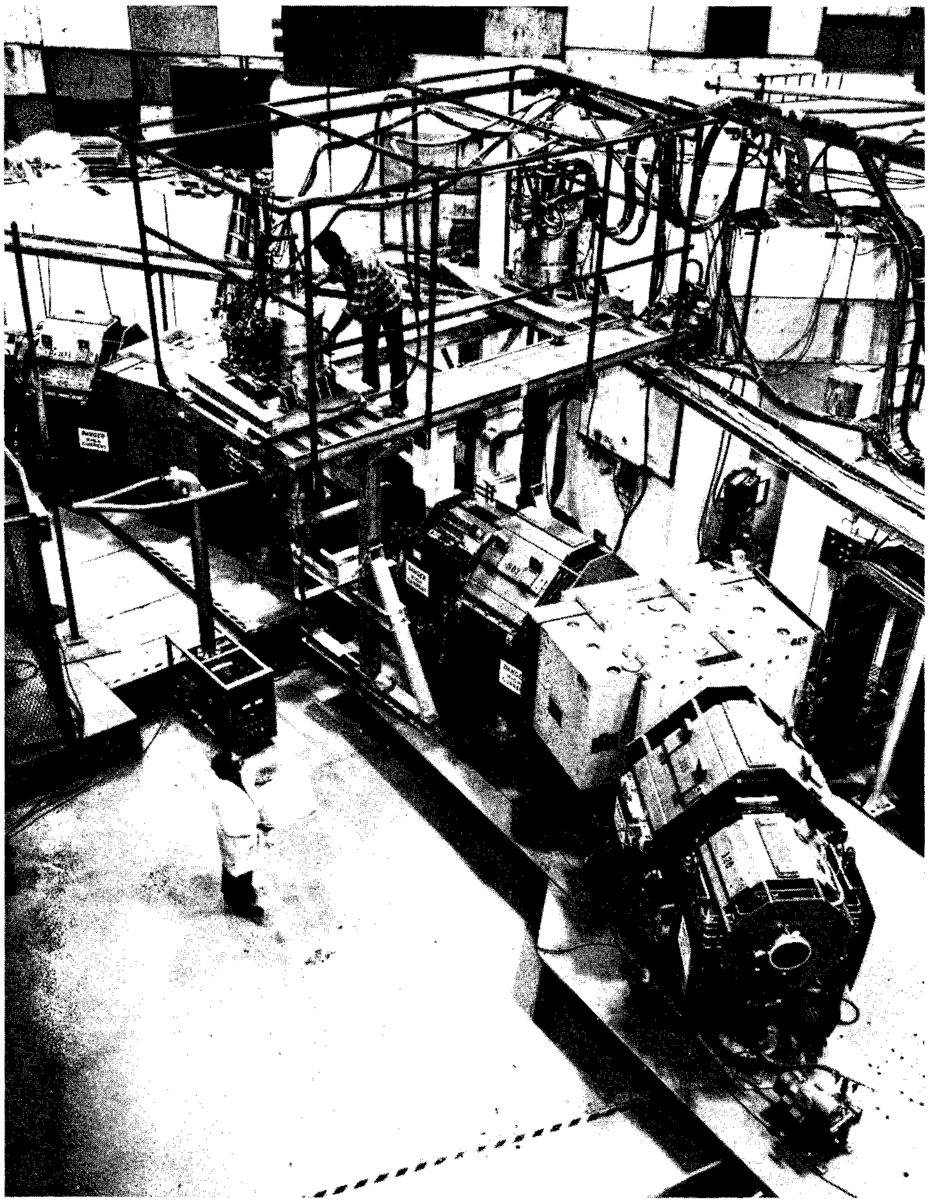
Mark Barton, former Chairman of the Department, had asked to be relieved of some of his administrative duties and will lead one of five Divisions set up for the ISABELLE project — the Accelerator Division which will be responsible for the design and construction of the storage ring components. An Experimental Areas Division will be headed by Hywel White (on leave of absence from Cornell), a Detectors Division will be headed by Bill Willis, an Administration Division will be headed by Harvey McChesney and the head of a Construction Division remains to be appointed.

The 'go ahead' for ISABELLE is good news for the high energy physics world. We wish Jim Sanford and his colleagues every success in their challenging project.

The hypernuclear spectrometer in a low energy separated beam at the Brookhaven AGS. The spectrometer uses the missing mass technique to detect hypernuclei when a negative kaon interacts to give a nucleus containing a lambda and emits a negative pion. The resolution is about 200 keV.

(Photo BNL)

AGS experimental programme



The New Year seems a good time for a brief summary of the research programme at the Brookhaven 33 GeV Alternating Gradient Synchrotron. The current experiments are directed toward subjects which range from the most current topics in particle physics (charm, neutrino oscillations, axions, baryonium...) to precision measurements of parameters important for understanding pre-charm physics.

In the year which began October 1977, the AGS is to run ten weeks for the neutrino experiments, which use the fast extracted beam, and twenty weeks for experiments which use the slow extracted beam (SEB). These programmes are run separately because each needs the 10^{13} protons accelerated by the AGS. This arrangement also lowers power consumption and allows the neutrino area to run with a 1.5 s pulse rate.

The neutrino area has started its ten week run with the 7 foot bubble chamber filled with a 70% neon, 30% hydrogen mixture for a Columbia / Rutgers/Stevens collaboration which hopes to obtain 700 thousand pictures with neutrino narrow-band and neutrino and antineutrino wide-band beams. So far 157 thousand pictures have been taken. In 1977, the chamber took a total of 910 thousand pictures.

Two counter spark chamber experiments are set up behind the bubble chamber. A Columbia / Illinois / Brookhaven collaboration is studying neutral current neutrino-proton elastic scattering and single pion production. The apparatus uses aluminium plate optical spark chambers, scintillators and both air gap and iron toroid analyzing magnets. The first data were taken last April. The second experiment has liquid scintillator-drift chamber apparatus for a Harvard / Pennsylvania / Wisconsin / Brookhaven collaboration taking data on neutrino-proton and antineutrino-proton elastic scattering. Last fall, the same group completed a ten day search for neutrino oscillations, with the AGS accelerating protons to 1.5 GeV/c (see December issue, page 417). All three experiments are now checking the feasibility of running a beam dump experiment to search for axions and other new particles.

Eleven experiments are likely to be in action during the SEB which is scheduled for March through June. The Multiparticle Spectrometer Facility (MPS) will use the High Energy Unseparated Beam (HEUB). Presently, the MPS is set up with an electron trigger which uses lithium-foil transition radiation detectors and a lead-scintillator shower hodoscope. A Brookhaven / Stony Brook / Brandeis / Syracuse / Penn collaboration is searching for charm production and plans to measure the spectrum of electron-positron pairs at low invariant mass. This experiment took test data last fall.

A Brookhaven / Brandeis / CCNY / U. Mass. group will perform the next experiment in the MPS. A random access memory (RAM) with about 6×10^6 bits will be used to trigger on one or two fast forward protons or a positive kaon and a slow recoil proton to search for charmed particles and baryonium. A third experiment will be set up in the MPS at the end of the SEB period. The MPS change-over for these experiments takes one to two weeks and during the two change-over periods a Yale / Brookhaven group will take preliminary data in the other branch of the HEUB searching for CP violation by measuring transverse muon polarization in the decay of the long-lived kaon into a muon, pion and neutrino.

At the B target station, a Princeton / Brookhaven group, which is searching for D meson production in negative pion-nucleon interactions, will resume data taking with their two arm spectrometer. Most recently this extremely versatile spectrometer has been used to search for H production and in a feasibility test for a baryonium search. The spectrometer used by a University of Massachusetts group to study the beta decay of the lambda in the neutral beam derived from the B target station is still set up and a U. Mass. / Brookhaven collaboration has proposed to use it to measure the polarization of lambdas produced in hydrogen and deuterium targets. Also, the Rutgers/Brookhaven cylindrical spark chamber spectrometer, which is set up in the medium energy separated beam may take additional $\bar{p}p \rightarrow V^oV^o$ data.

The C target station will produce two low energy separated beams. Two experiments will be set up in the existing beam, LESB I. A hypernuclear spectrometer of a Brookhaven / Princeton / MIT / Houston / Vassar collaboration, took test data last fall and plans a substantial run in spring. A Berkeley / Mt. Holylake / Brookhaven group is setting up a high statistics measurement of backward kaon-proton elastic scattering and negative kaon-proton producing a sigma and a pion at zero degrees, with incident momenta 500 to 1070 MeV/c.

A new, more intense beam, LESB II, will be commissioned in spring. One branch will be used by a University of California, Irvine/New Mexico/Los Alamos/Temple collaboration to search for baryonium states. The apparatus will be equipped to identify nucleons, pions and photons. The other branch will be used for another baryonium search by a Syracuse / Michigan State / Brookhaven / Brown collaboration and will have a pair spectrometer to measure the photon spectrum.

CERN
Entering the ICE age

One of the most exciting advances in the experimental facilities envisaged on the existing CERN accelerators for the coming years is the possibility of colliding protons and antiprotons in the 400 GeV synchrotron, the SPS. To achieve such collisions at a rate which will make experiments feasible requires much higher intensity antiproton beams than have been available up to now. It is the technique of 'beam cooling' which has opened the way to such higher intensities.

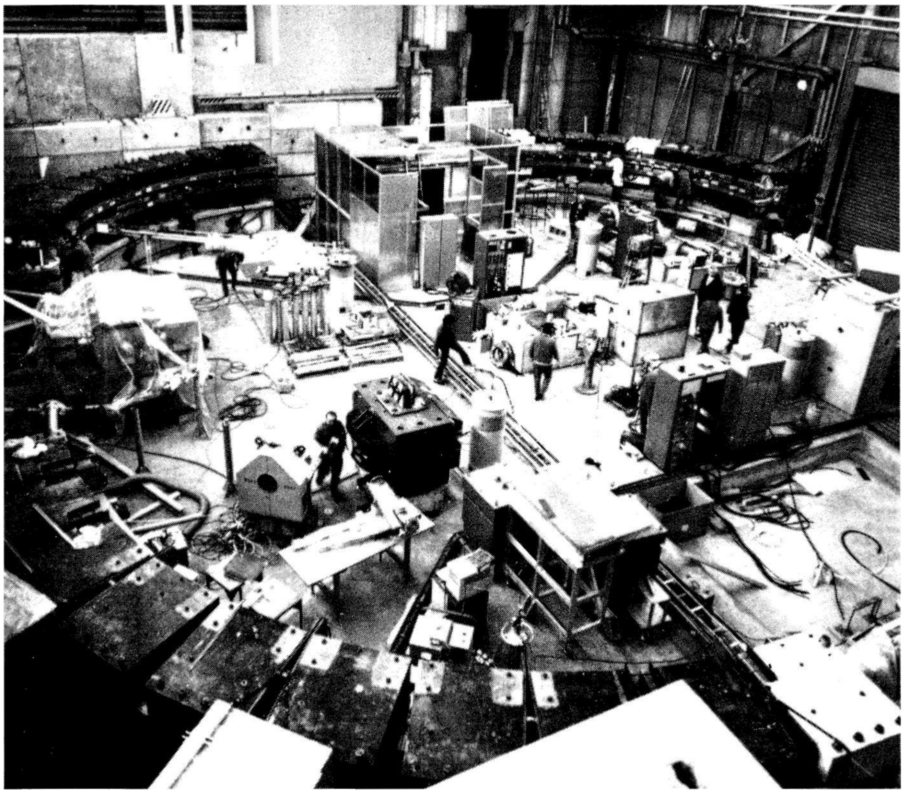
The essential feature is that, if it is possible to accept antiprotons of a wide momentum and angular spread (increasing the number drawn from a target) and to 'cool' them quickly to reduce this spread, intense antiproton beams can be built up in an acceptable time. Two techniques have emerged in recent years — electron cooling (following work at Novosibirsk) and stochastic cooling (following work on the Intersecting Storage Rings at CERN). As a preliminary to the proton-antiproton project at CERN these techniques are to be tested in an Initial Cooling Experiment, ICE.

ICE has a magnet ring (rebuilt from the muon storage ring of the famous g-2 experiment) with magnet arcs 7 m radius and four long straight sections. Fields of up to 1 T in the magnets hold protons of momentum up to 2.1 GeV/c. The ring is located in the hall which housed Gargamelle shielding and beams prior to its move to the SPS. It is fed with protons from the PS. There are stochastic cooling systems and a panoply of beam control and beam monitoring devices. One of the straight sections will be fitted with an electron cooling system (providing 60 keV electrons to cool 110 MeV protons).

During the week before the shutdown of the CERN accelerators before Christmas, injection and cooling tests were carried out. The protons were fed in at 1.73 GeV/c and it was quickly shown that the beam control systems using pole-face windings and back-leg windings, are adequate to store the beam in stable conditions (half life up to 300 s). A momentum spread of over 0.2 % could be accepted.

Stochastic cooling was then tried. The system was far from optimized but cooling was achieved — both momentum and vertical betatron cooling (reducing the dimensions of a proton bunch both in the longitudinal and vertical directions). This was a very good start.

When the PS comes back into action in February stochastic cooling will be pursued again with the aim of demonstrating cooling times of a few seconds. A few months later electron cooling will also be tried but with less urgency since it is probable that only stochastic cooling will be used in the antiproton system for the SPS.



The rebuilding of the muon storage ring of the famous g-2 experiment for ICE — Initial Cooling Experiment. It is here that beam cooling techniques are to be checked en route to high intensity antiproton beams. Successful stochastic cooling tests took place in December.

(Photo CERN 282.11.77)

At the SPS itself there have been further tests to make ready for proton-antiproton colliding beams. The main achievements have been the storage of 200 GeV proton beams for times in excess of 15 hours, the acceleration of single bunches (5 ns long and 10^{11} protons per bunch) to 200 GeV with about 30% efficiency so far, and injection of protons at 3.5 GeV which is the intended energy for antiproton injection. Even at these low levels the magnet fields look good enough to hold the beams. Also, a design for a low beta insertion in long straight section LSS 5, has been developed and is such that it could be switched on at the desired collision energy.

There is still a long way to go and many difficult problems of beam physics and technology to overcome before proton-antiproton physics is achieved but these preliminary tests with the ICE set-up have been very encouraging.

Superconducting separator in action

A superconducting radio-frequency particle separator, developed in collaboration with KfK Karlsruhe, was operated in December for the first time in the SPS beam feeding the Omega spectrometer in the West Hall. The project started in the Institut für Kernphysik under A. Citron in 1971 and H. Lengeler moved from CERN to Karlsruhe for the construction period as project leader.

Separators are used to help select a particular type of particle from among the many which pour out of a target struck by the high energy beam from the accelerator. Magnetic fields will bend particles of a fixed momentum (mass x velocity) into a beam-line. Separators then sift out particles of a particular mass by only allowing through those of a particular velocity. This is done on a 'traffic light' principle. A first unit gives the green light to the particles and, further down the beam-line, a second unit gives another green light only to those which have traversed the intervening distance at a certain velocity. Unwanted particles are ploughed into a beam stop while wanted particles experience a deflecting field at right angles to the beam direction which bends them around the stop towards the experiment.

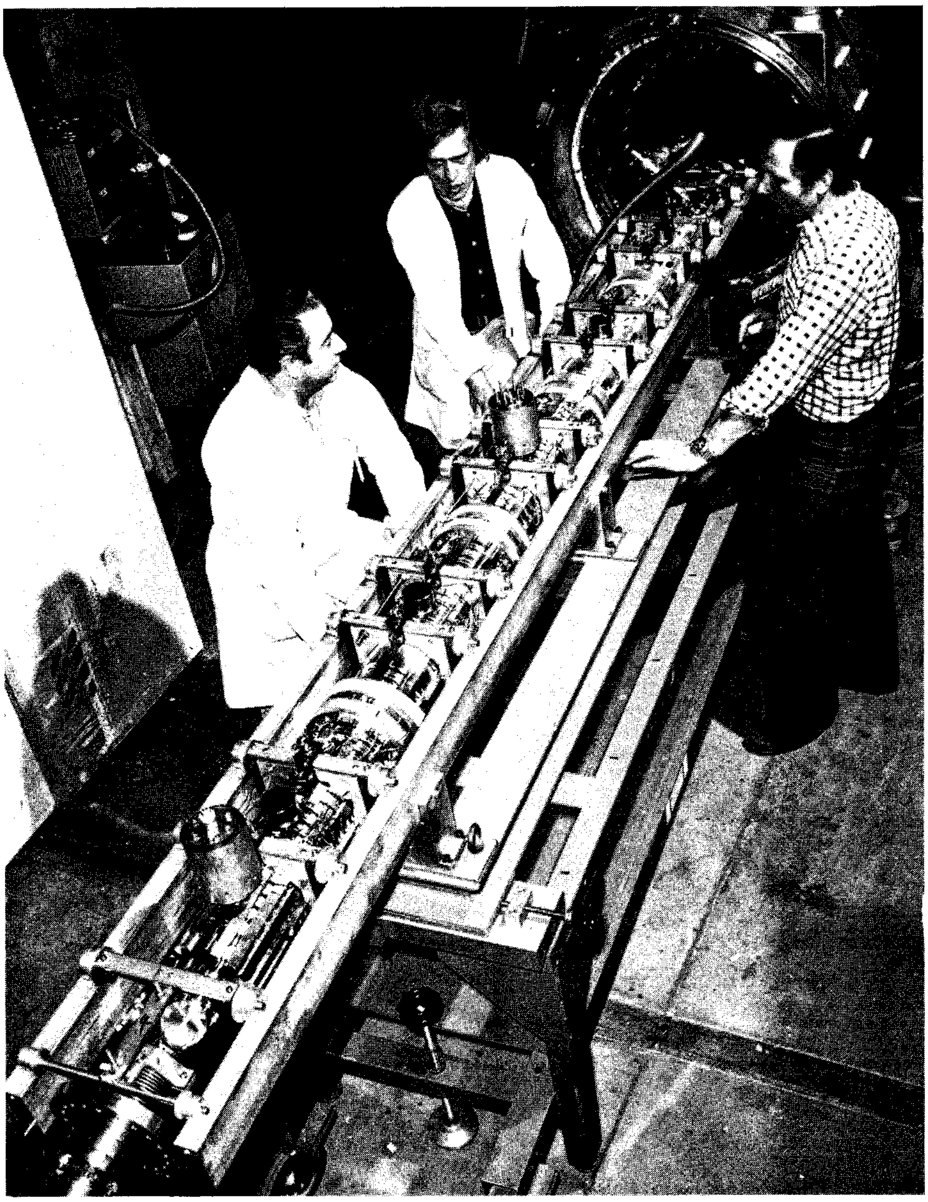
The deflecting fields can be provided in radio-frequency cavities but such r.f. systems have, up to now, only been usable in beams to bubble chambers which are happy to receive very short pulses of particles. The cavities have been built of copper and operated at room temperature with an r.f. frequency of 3-6 GHz. They required a large amount of power (some 10-20 MW) half of which was absorbed in the copper walls. This limited their operation to pulses of less than 10 μs which is far too short for counter detection systems, such as the Omega spectrometer, which like pulses of 100 ms or longer. Only by going to superconducting r.f. cavities could the power requirements be brought down to acceptable levels for a beam to counter detectors.

The superconducting separator built at Karlsruhe uses disk-loaded cylindrical wave-guides, familiar from linear accelerators, providing deflecting fields perpendicular to their axis. The two deflectors are made of high purity niobium which becomes superconducting at temperatures below 9.2 K. Each deflector is 3 m long and is built of five sections with 104 'cells' in total. Each cell was turned from solid niobium at Siemens and they were assembled by electron beam welding around their circumference.

Several technological problems had to be overcome. The most difficult was to achieve surfaces of adequate quality

One of the superconducting deflectors built at Karlsruhe during assembly in its cryostat in the beam-line to the Omega spectrometer at CERN. The r.f. superconducting separator operated successfully in December.

(Photo CERN 94.11.77)



since r.f. superconductivity is a surface phenomenon (the fields penetrate only about 50 nm into the niobium). The performance of the cavities is limited by the magnetic field levels which can be supported at the surfaces without causing the superconductor to go 'normal'. The mechanisms behind this are not fully understood but it has become obvious that extremely clean, smooth and homogeneous surfaces are essential for good performance.

The deflectors have many square metres of superconductor surface of complicated geometry. Surface treatment techniques were developed at Karlsruhe including a large ultra high vacuum furnace operating at 1850°C. All these treatments are done under dust free conditions such as those used in microelectronics or pharmacological production lines.

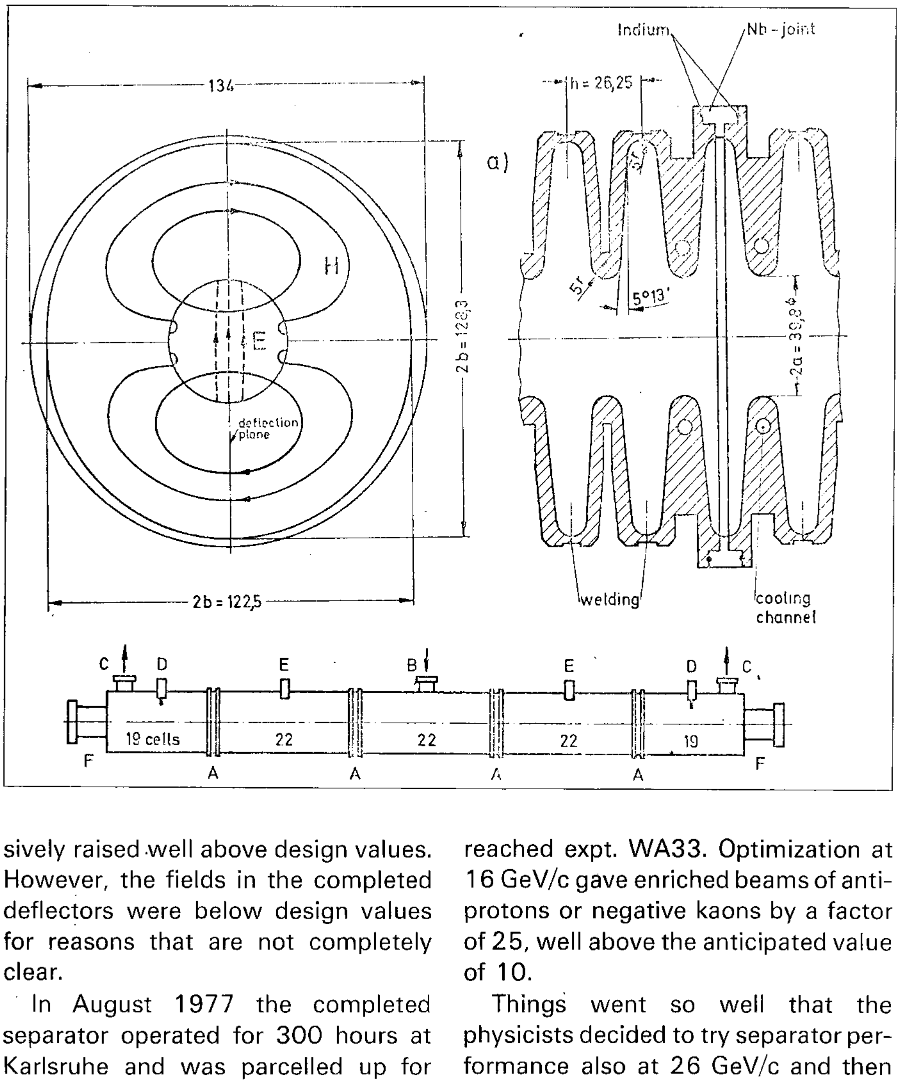
Superconducting deflectors have Q values of 10^9 or above, which corresponds to a bandwidth of a few Hz at 3 GHz. This required special measurement methods. Each connection to the cavity from the outside world (r.f. coupling, probes, frequency tuners) needed new technical solutions so as not to limit fields or Q values.

To have sufficiently low r.f. losses, the niobium deflectors are operated at 1.8 K well below their 9.2 K transition temperature. The resistance of the walls decreases with temperature for r.f. fields (unlike for d.c. fields where the resistance drops virtually to zero below the transition temperature). To achieve 1.8 K implies the use of helium in its superfluid state which needs more stringent precautions against leaks. The deflectors sit in a bath of helium within their cryostat and there are over 50 connections to vacuum which have to be helium-tight.

The refrigerators used at Karlsruhe and CERN to supply the helium are the first large-scale installations of their type. They include a large pumping system to keep the helium bath at a pressure of 16 mbar corresponding to 1.8 K. Under c.w. operation each deflector absorbs about 7 W of r.f. power, at maximum field levels, which has to be cooled by the 1.8 K system. This can only be achieved with about 0.05 % efficiency — for every watt absorbed at 1.8 K, 2 kW are produced at room temperature. Nevertheless this is much smaller than the 10-20 MW of r.f. power which would be needed for an equivalent room temperature separator.

The design values for each deflector of 104 cells were — Q value of 0.5 × 10^9 and deflecting field of 2 MW/m. A test section of four cells gave a Q of 2.5 × 10^9 and field of 5.5 MV/m. The ten sections tested individually gave Qs from 1.2 to 3.6 × 10^9 and fields of 1.6 to 2.6 MV/m. The two assembled deflectors gave Qs of 1.8 and 2.2 × 10^9 and fields of 1.2 and 1.4 MV/m. As the surface treatment techniques improved, the Q-values were progres-

At the top is a drawing of the geometry of the field lines in an r.f. cavity (on the left) with the cavity structure (on the right) showing how the superconducting niobium cells are joined. Below is the layout of a full deflector assembled from five sections, two of 19 cells and three of 22 cells. The positions marked A are r.f. joints, B is the r.f. input, C the r.f. probes, D and E the frequency tuners and F the beam tube.



sively raised well above design values. However, the fields in the completed deflectors were below design values for reasons that are not completely clear.

In August 1977 the completed separator operated for 300 hours at Karlsruhe and was parcelled up for transport to CERN. The beam-line to Omega was modified under the supervision of D. Plane to its separated version at 16 GeV/c and the refrigerator was brought into action by G. Winkler. On 13 December, the separator was cooled to 1.8 K and reached its Karlsruhe operating figures. During the tests of the next two days, performance was remarkably successful.

Three hours after the beam was switched on, deflection of particles by the separators was detected showing that, happily, Maxwell's equations remain valid at 1.8 K. A few hours later the r.f. control systems were properly synchronized and separated particles reached expt. WA33. Optimization at 16 GeV/c gave enriched beams of antiprotons or negative kaons by a factor of 25, well above the anticipated value of 10.

Things went so well that the physicists decided to try separator performance also at 26 GeV/c and then 37 GeV/c using the excellent computer control and beam diagnostics of the beam-line. All this was accomplished in a few hours with good results and the start of physics with the separated beams could begin at the end of the present SPS shutdown.

Bringing the separator to this stage has not been easy and the technology of superconducting r.f. still has some troublesome problems. Nevertheless, it is a great advance to have mastered the production of adequate surface quality in complex structures and to have mastered the r.f. and cryogenic systems. This bodes well for the further stages which could contribute so much to the r.f. accelerating systems of the next generation of electron-positron storage rings.

Upsilons at CERN

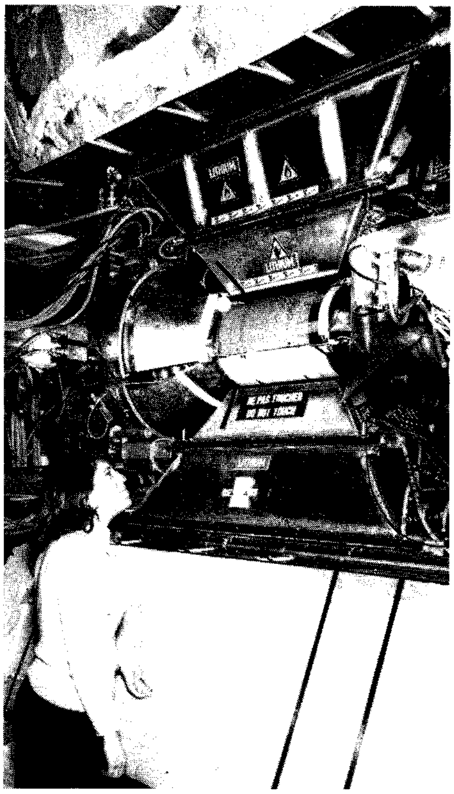
Just in time to catch the December issue of the COURIER as it went to press, came news of the sighting of Upsilon particles at the CERN Intersecting Storage Rings by an Athens / Brookhaven / CERN / Syracuse / Yale collaboration. First reported from Fermilab earlier last year (see July/August issue, page 223), Upsilons seem to be similar to J/psi particles but about three times heavier. Just as the J/psi heralded the discovery of charm, so the Upsilon could mean that there are more quark flavours waiting to be discovered and explained.

The CERN group sees a relatively strong signal in the spectrum of electron-positron pairs produced in high energy proton-proton collisions at the Intersecting Storage Rings with centre of mass energies ranging up to 62 GeV. At these high energies, the production of electron-positron pairs falls off sharply above the J/psi mass, so that very little is seen in the electron-positron spectrum above about 7.5 GeV/c^2. However in the mass range 8.7 - 10.3 GeV/c^2, the CERN experiment sees a handful of events which seem to stand on zero background and these are attributed to the production of Upsilon-type enhancements.

Less than a dozen such heavy electron-positron pairs have been seen but the very low pair production level from other sources makes the effect stand out vividly. In the Fermilab experiment looking at muon pairs which first reported Upsilons, the pair production attributable to other sources is subtracted to reveal the true nature of the Upsilon spectrum. The thousands of Upsilon events collected

The heavy Upsilon enhancements have been seen in electron pairs by a Brookhaven / CERN / Syracuse / Yale collaboration at the ISR using some new detection techniques. Radiating outwards from the cylindrical wire chambers surrounding the vacuum chamber can be seen successive layers of lithium foil transition radiation detectors and scintillation counters. Top and bottom are liquid argon-lead plate total absorption calorimeters.

(Photo CERN 172.3.76)



at Fermilab represent almost all the world statistics on these new particles.

The ISR collaboration had seen a few heavy electron-positron pairs sticking out from zero background in a preliminary run using a temporary experimental configuration in 1976. But given the preliminary nature of the system and the tentative confidence at that time in novel detectors, the events were never announced.

The ISR experiment uses two novel types of detector — liquid argon calorimeters and lithium foil transition radiation detectors to measure and identify the produced electrons. The collaboration was the first to build a liquid argon calorimeter and use it in an experiment and provided a valuable demonstration of the abilities of transition radiation detectors. So novel are these detection techniques that the chances of them both performing well was not, initially, rated high. For a long time the system carried the title 'Test' rather than the fully authorized 'Experiment'.

Liquid argon calorimeters are now lined up for several PETRA experiments and for the Mark II detector to be used at PEP after preliminary work at SPEAR, while transition radiation detectors are coming into use at CERN and Brookhaven after many years of limited success.

Having blazed a trail for the use of liquid argon calorimeters and transition radiation techniques and providing a useful independent confirmation of the Upsilon, the Athens / Brookhaven / CERN / Syracuse / Yale collaboration will have its run extended with an altered configuration of the experimental equipment. It will then give way to investigation of high transverse momentum phenomena.

Meanwhile, first indications of enhancements in the Upsilon region have been heard from two other experiments at the ISR — one a CERN / Columbia/Oxford/Rockefeller collaboration looking at the production of electron pairs, and the other a Frascati/ Genoa / Harvard / MIT / Naples / Pisa collaboration studying muon pairs.

Crash programme

The last SPS run in 1977 saw intense activity in neutrino 'beam dump' experiments, with some hadronic work being put aside while the BEBC and Gargamelle bubble chambers and the CERN / Dortmund / Heidelberg / Saclay counter set-up all searched for unusual neutrino happenings.

Neutrino experiments at Fermilab and CERN have amassed relatively large numbers of events with two, three and even more muons emerging. (The Harvard / Wisconsin / Pennsylvania / Fermilab / Rutgers experiment at Fermilab also has evidence for a four muon event; we reported a four muon event from CERN in December.) The origin of all these events is not clear and the major aim of the crash programme of beam dump experiments at CERN was to see if multimuon events could be attributed to some previously unknown component in conventional neutrino beams.

The usual primary target was taken away and the SPS beam was deposited into a 2 m long copper block — hence the 'beam dump' title. In such a mass of metal, secondary pions and kaons are quickly absorbed close to their formation vertices and have little chance of decaying weakly to produce neutrinos. In this way, the flux of conventional neutrinos was reduced by a factor of about a thousand. However, the yield of some directly produced new type of penetrating particle or of neutrinos from the decay of very short-lived hadron parents would not be affected.

To maximise its chances of spotting neutrinos, BEBC was filled with a heavy neon-hydrogen mixture. Some 70000 photographs were taken and an event due to a high energy neutral incoming particle was seen roughly once in every thousand exposures. During the same run, the Gargamelle heavy liquid chamber took about 80000 photographs resulting in some fifty events of interest. The counter experiment recorded details of about a thousand muon events.

Preliminary results can be understood without the need for a new kind of neutrino. The evidence so far seems to point to multimuon events being due to the production of muon pairs in the hadron showers emerging from charged current neutrino interactions.

However, the bubble chambers see a relatively large number of events with electrons or positrons emerging. The electron neutrinos responsible for these interactions could come from very short-lived parent particles which manage to decay in the beam dump.

Recently there has been speculation that new types of particles, such as 'axions', could reveal themselves in beam dump experiments.

Some figures from the CERN Experimental Programme at the end of 1977

	Super Proton Synchrotron	Intersecting Storage Rings	Proton Synchrotron	Synchro-cyclotron
Number of active experiments	38	9	5	15 (+ ISOLDE)
Number of physicists	1064	196	66	111 (+ 102 at ISOLDE)
Average number of physicists per experiment	28.0	21.8	13.2	7.4
Average number of CERN physicists per experiment	3.1	4.6	2.6	1.1
Average number of Institutes per experiment	5.0	4.1	3.0	'2.4

Total number of physicists: 1539

New trends in CERN research

Addressing the CERN Council Meeting in December, Research Director General Leon Van Hove described the significant achievements of CERN research in 1977, using a selection of results from some thirty experiments to illustrate the major areas of progress made during the year. Many of these results have been described in CERN COURIER.

At the end of the first year of operation of the 400 GeV proton synchrotron (SPS) for physics, Professor Van Hove drew attention to the changed profile of research at CERN now that this big machine is in use. Already there are about the same number of active experiments at the SPS as there are at the ISR, PS and SC combined, while about twice as many physicists work on the SPS as on the other machines (even taking into account the large ISOLDE contingent). More physicists tend to be involved in an SPS experiment than is the case with the other machines but relatively less of these SPS physicists are from CERN, the increased numbers being made up by the scientists from outside research centres.

Because of this high level of participation by visiting scientists in the research at CERN, an Advisory Committee of CERN Users is being set up. Its job will be to look after the interests of visiting scientists using the research facilities, particularly concerning working conditions and technical support. The Committee will not concern itself with the scientific programme as such.

CERN users come in all shapes and sizes, and the Committee membership will reflect this, including scientists working at their home institutes and travelling only occasionally to CERN and physicists based at CERN.

SERPUKHOV/CERN Charmonium news

New analysis of data from an experiment carried out at the 76 GeV proton synchroton at Serpukhov, under the auspices of the CERN-Serpukhov agreement, has come up with further evidence for the hidden charm X(2.8) meson which was first seen by the DASP collaboration at DESY.

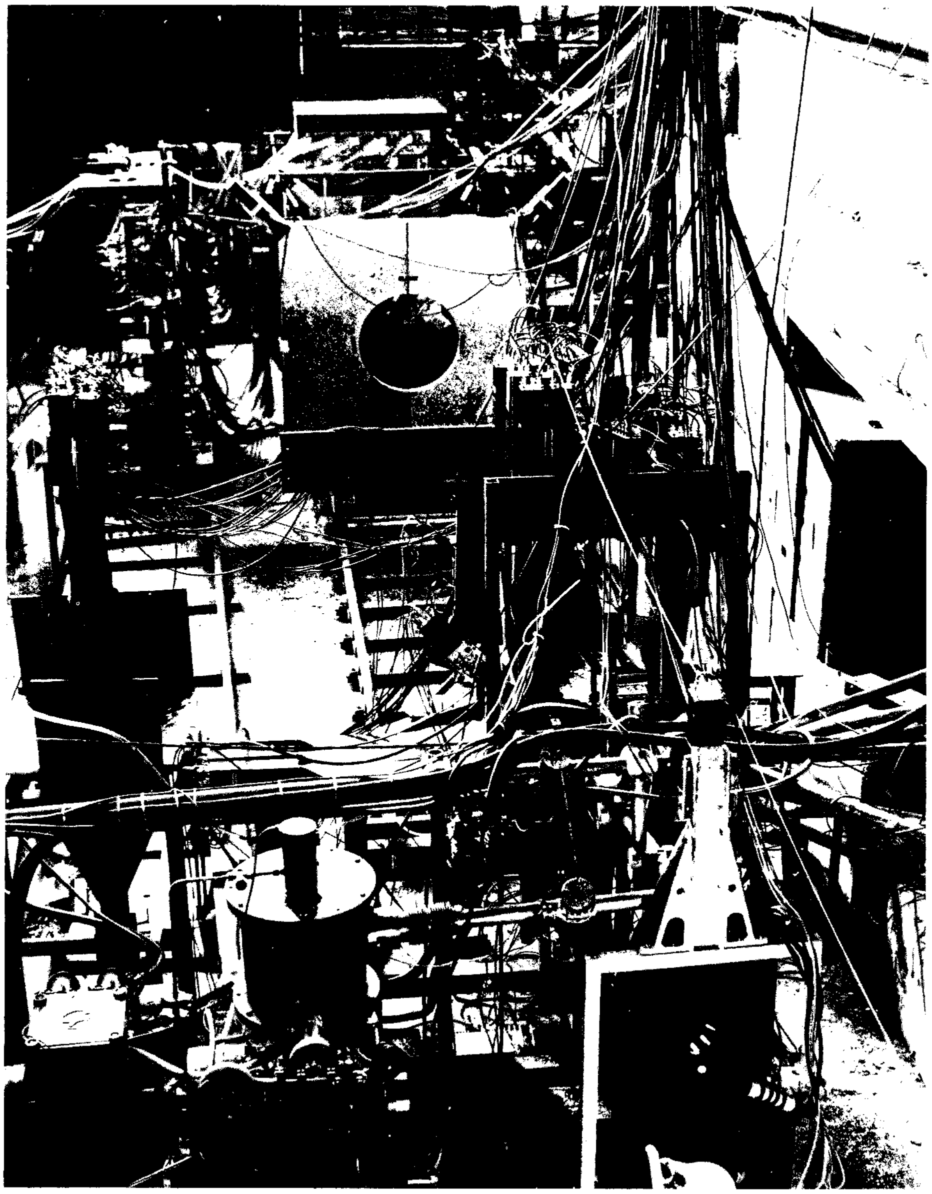
The Karlsruhe / Pisa / Serpukhov / Vienna collaboration made an extensive study of pion-proton charge exchange reactions using a 40 GeV/c negative pion beam. Results from this experiment have already been published but, using improved pattern recognition software, the data has been further analysed to uncover hitherto unseen effects due to energetic photon pairs produced by the decay of heavy neutral mesons. The new photon pair spectrum shows an enhancement at 2.85 GeV, interpreted as the hidden charm X(2.8) meson seen at DESY among the decays of the J/psi.

The production levels of this meson measured in the Serpukhov experiment are in broad agreement with the prediction of quark-gluon models which describe the production of hidden charm states from conventional quark matter.

Hidden charm mesons (sometimes called charmonium) consist of a charmed quark and a charmed antiquark in a bound state. These quarks can bind together in different spin states but selection rules dictate that only the spin one states, like the J/psi, can come directly from a single photon. As a result, these states are seen more often in electron-positron colliding beam experiments such as those on DORIS at DESY and SPEAR at Stanford.

The spin zero charmonium states cannot come from a single photon and

The detection system of the Karlsruhe / Pisa / Serpukhov / Vienna collaboration at the 76 GeV Serpukhov accelerator. In the foreground, surrounded by counters and cables, is the hydrogen target which is bombarded by a negative pion beam. At the rear is the on-line photon detector. Further analysis of data from this experiment has produced important new evidence for the X (2.8), the lightest charmonium state.



are more reluctant to show themselves. They show up only in the decays of spin one charmonium (mainly the J/psi). The X(2.8) is the lightest charmonium state yet seen and has previously only been sighted at DORIS in the decay of the J/psi into three photons. An additional sighting of this state is therefore particularly welcome.

It is tempting to identify the X(2.8) with the η_c particle, predicted by the quark model as the ground state of charmonium with spin zero and negative parity, but this can only be confirmed by fixing the spin and parity of the X(2.8). Just as the J/psi and psi prime states are only the bottom two rungs of a whole ladder of spin one charmonium states, so the η_c is the lightest member of another series of states.

Heavier charmonium states show up in other experiments. The Brookhaven / CERN / Syracuse / Yale collaboration at the CERN ISR which sees signs of the Upsilon has also looked at the correlation between J/psis and photons. An enhancement in the electron pair-photon spectrum near 3.5 GeV is attributed to the decay of a heavier charmonium state into a J/psi and a photon and is large enough to indicate that a significant proportion of J/psis come from the decay of heavier charmonium states rather than being formed directly. This could help account for the wide difference between the observed production rates of the J/psi and psi prime.

DESY
Heavy leptons below charm threshold

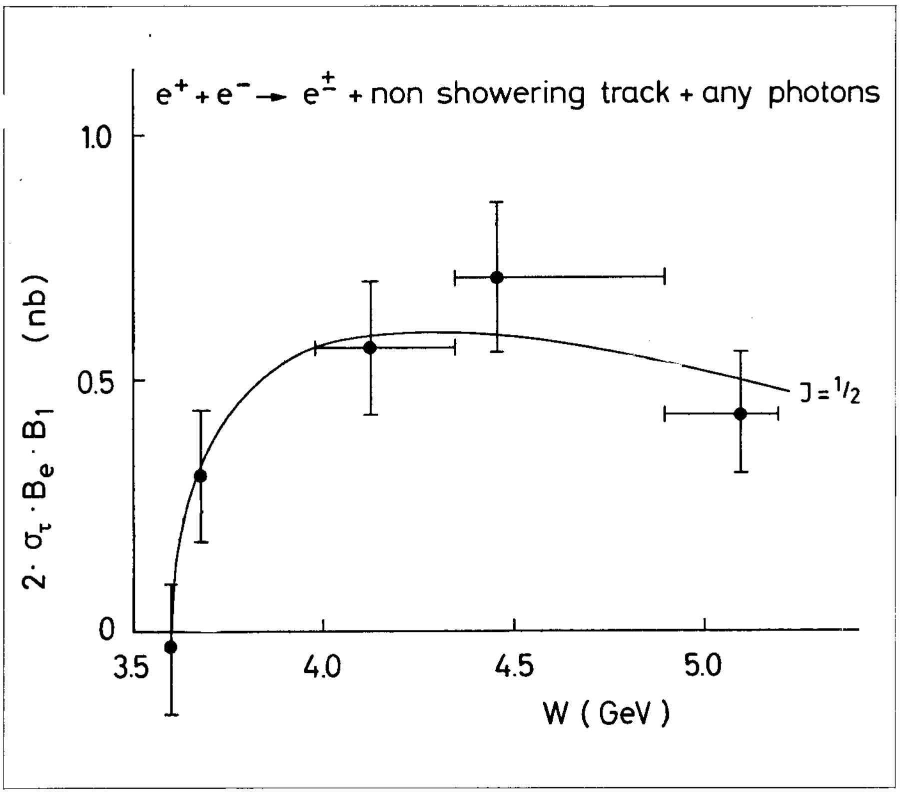
Since the discovery of electron/muon events at SPEAR in 1975, there has been increasing evidence for the production of a heavy lepton in electron-positron interactions. This new particle, named tau by the SLAC / LBL group, is expected to be produced in pairs like electrons or muons. According to theoretical models, about 80 % of the tau decays lead to a single charged particle (lepton or hadron) and additional neutrinos or other neutrals.

A good way to study tau pair production is therefore to look for events with a lepton (electron or muon) plus a single charged particle. The only competing process, charmed particle production followed by semileptonic decay, contributes only a small background. In fact, significantly more 'lepton plus one prong' events have been observed than expected from charm production. Moreover, the lepton momentum spectrum in these events agrees well with the expected tau decay spectrum. In the multiprong events, the leptons have lower momenta and the spectrum fits semileptonic charmed meson decay.

Welcoming the Chinese physicists from the High Energy Physics Institute in Peking, who will collaborate at the PETRA experiment, Mark J; — Drs Tang (seen from back), Deutsch, Schopper, Ma, Tung and Ting.

(Photo DESY)

The spectrum at the foot of the page shows effects due to the heavy tau lepton as measured by the DASP group on the DORIS electron-positron storage rings at DESY. 'Lepton plus one-prong' events are seen below the threshold for charm production (3.73 GeV), and are attributed to the tau. This experiment gives a better value for the tau mass.



New and very conclusive evidence that the events with a lepton plus a single charged particle cannot be explained in terms of charm production comes from a recent measurement with the DASP detector on the DORIS electron-positron storage rings. Events of this type have been observed at the psi prime (3.68) resonance, well below the charm threshold at 3.73 GeV. Since no events were found at 3.6 GeV, the tau mass must lie between 1.80 and 1.84 GeV. The data are well fitted by the cross section for pair production of point-like fermions. From the fit, the tau is determined to be 1.807 ± 0.02 GeV. This is more precise than earlier values because of the data point close to threshold.

In the DASP experiment, the tau was detected through its decay into an electron and neutrinos. Nearly the whole momentum range of the electrons was covered. A very clean particle identification was achieved using Cherenkov, time of flight and shower counters. In the muonic decay mode most of the events would have been lost due to the high cut-off momentum required for muon identification.

Earlier DASP measurements have shown other interesting properties of the tau. Kaons are very rare among the decay products, indicating that the weak current responsible for tau decay has a small coupling to strange quarks like the normal Cabibbo current. Quite different, but also well understood, is the observation that the multiprong events contain (almost) one charged kaon per event, that is (almost) one charged or neutral kaon per charmed meson decay.

The decay into a rho has been observed, giving information on the vector part of the tau weak current. There is still a puzzle in that too few decays into a pion have been found, so there is a problem about the axial vector part of the weak current.

At the end of 1977 electrons and

Bob Wilson, Director of Fermilab, examines a gift to the Laboratory from the Lederman group — the chrome-plated remains of a high current copper magnet shunt. The shunt caused a fire which delayed the Upsilon discovery last year. Leon Lederman pointed out that successes in experiments are duly recorded but failures, which can be even more spectacular, are not properly honoured.

The same group had previously (in 1975) presented Fermilab with a block of leadglass intended for high energy electron detection. An error during heat treatment produced a beautiful pattern of internal fractures. Science's loss was Art's gain.

(Photos Fermilab)

positrons in DORIS reached an energy of 4.2 GeV in each beam — the highest ever achieved in an electron-positron storage ring. During routine experimental shifts the DASP and PLUTO detection system are now taking data at 3.9 GeV with luminosities greater than 10^{30} per cm^2 per s.

FERMILAB
Eight magnet test

A string of eight superconducting magnets for the Fermilab Energy Doubler / Saver has passed a week-long test and provided useful information on monitoring and control questions relating to the Doubler. The test is in the sequence of one, two, and four magnet tests heading toward a full sector test of one-sixth of the ring. Rich Orr, former Laboratory Business Manager, is now in charge of the sector installation.

Preparations for the eight magnet test began in August. Eight superconducting bending magnets were set up in series at the 'awning', a test shed located one sixth of the way clockwise round the ring from the Central Laboratory Building. September and October saw the solution of numerous vacuum and electrical problems. The tests culminated in late October when the eight magnet string was energized. Through the next week, the magnets were ramped about 2000 times with currents of 3.5 kA. The peak current during the test was 4.1 kA.

After the ramp tests, quench experiments were run to test magnet protection circuitry. When a superconducting magnet goes normal, or quenches, the stored energy must be removed quickly to prevent damage to the magnet coils. Investigations are now under way on quench protection schemes using heater wires integrally wound with the superconducting wire. With this approach, when a quench is detected, a heat pulse is spread throughout the magnet to distribute the quench.

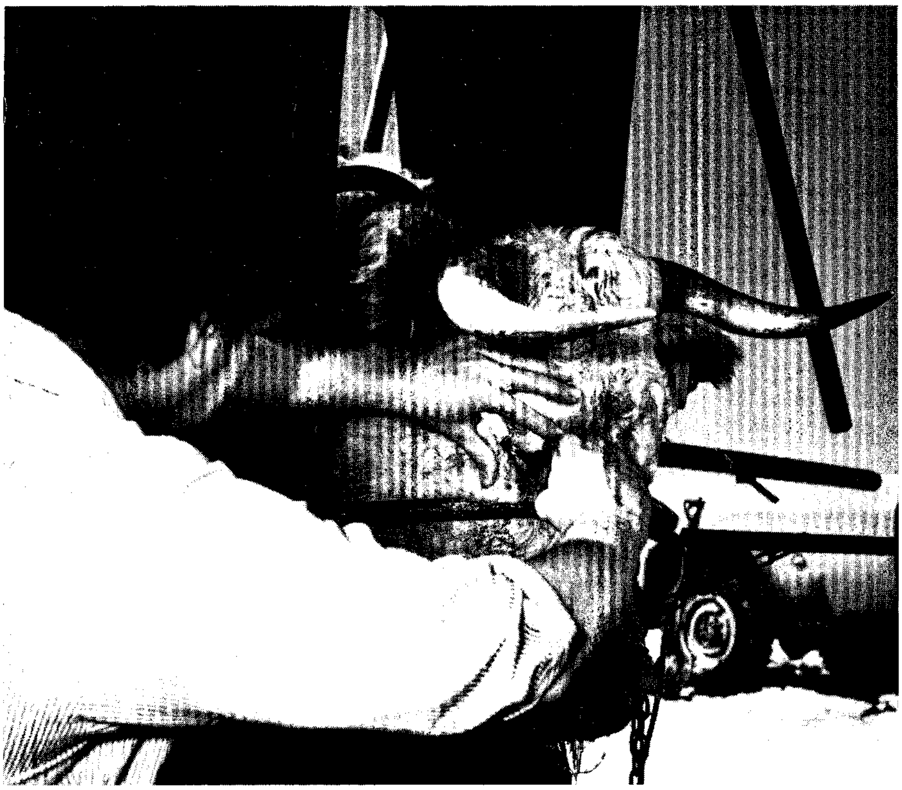
LOS ALAMOS
LAMPF Users' Meeting

Achievement of a 300 μA (average) proton beam, routine use of the negative hydrogen ion beam, completion of the EPICS spectrometer and the start of the experimental programme in the pulsed neutron area (WNR), were among the 1977 developments reported to the 11th LAMPF Users' Group Meeting on 13 - 15 November. LAMPF is one of the world's 'meson factories' using a 800 MeV high intensity proton linac to produce high fluxes of mesons.

Louis Rosen, Director of LAMPF, saw this as an appropriate time to look back with some satisfaction on the research programme. Highlights mentioned by Rosen were results from pion charge exchange, pion total cross sections, neutron and proton distributions in nuclei, high momentum components and clustering effects in nuclei, pion channelling, the pion-pion interaction, identification of new isotopes, radiation damage studies, proton-proton scattering with polarized beam and target, neutron-proton scattering, muonium hyperfine structure, colliding photon excitation of negative hydrogen ions, pion and muon rare decay modes (neutral pion to three gammas, muon to electron and gamma) and neutrino interactions.

Recently highly successful negative pion treatments of deep seated cancer tumours have been reported by the biochemical researchers. These results, in some cases exceeding expectations, have given great satisfaction, especially since these were tumours particularly difficult to treat by conventional means.

Harvey Willard (in the foreground), then Chairman of the LAMPF Users' Group, leads the applause for LAMPF Director, Louis Rosen, at the end of his account of the achievements at the 800 MeV proton linac 'meson factory' in the course of 1977.



Sooner or later, the discussion of the research programme at any large experimental facility must turn to money. Rosen said that the present budget level would allow only 26 weeks of operation in 1978 and expressed the hope that additional operating and improvement funds would be granted. Enloe Ritter, representing the U.S. Department of Energy (DOE) and Doug Bryman from the National Science Foundation (NSF) took up this buck. Their cautious message was that funding, at least to support the present level of operation, could be expected to continue despite the rapid increase of electric power costs.

The Users' Meeting also heard of the programmes and plans at the other 'meson factories' reported by Jack Sample from TRIUMF and John Domingo from SIN. Technical talks were given by William Fowler (Cal. Tech.) on Astrophysics, George Burleson (New Mexico State) on Pion Physics, Ed Knapp (LASL) on WNR, Herb Chen (Irvine) on Neutrino Physics, Mike McNaughton (Case Western) on Polarization Experiments, George Igo (UCLA) on HRS results, and Wilhelm Gauster (Sandia) on Muon Spin Rotation Experiments.

The Board of Directors of the Users' Group for 1978 was elected - Chairman John Allred (Houston); Chairman-elect Isaac Halpern (Washington); Past Chairman Harvey Willard (Case Western); Members - Cliff Hargrove (NRC, Canada), Ralph Minehart (Virginia), Dick Mischke (Los Alamos), Glenn Rebka (MIT).

The LAMPF Program Advisory Committee met mid-January to consider research proposals. They were in-

Use of the hand-held device developed at Los Alamos for treatment of 'cancer eye' in cattle. This r.f. heating technique has had great success in field trials and can be used easily by ranchers themselves.
The device is in commercial production and the technique is being extended to therapy on human cancers.

(Photos Los Alamos)

formed of a successful development run giving a 400 μA beam intensity. Although currents up to 440 μA were held for several hours, the linac appears to be approaching a beam spill limit imposed by emittance. Also in the high intensity experimental area, heating at the targets poses increasing problems as the beam current is raised.

Treatment of 'cancer eye'

A new spin-off from the work on the LAMPF project was also reported to the Users' Meeting; it concerns the use of r.f. heating to destroy cancerous cells. This has been successfully applied in the treatment of 'bovine cancer eye' and therapy trials with tumours in humans are beginning.

'Cancer eye' is one of the most troublesome diseases in cattle involving benign or malignant tumours appearing on the eye or eyelid of cattle. It is a main cause of cattle carcass rejection in slaughterhouses and, in the USA alone, it is estimated that losses from this cause exceed $ 20 million per year.

The conventional treatment is surgical removal of the tumour which is a costly and time consuming progress. The LAMPF Practical Applications Group, together with Dale Holm of the Los Alamos Agriculture Biosciences Group and L.M. Holland of the Mammalian Biology Group, turned their attention to another technique because of their experience with r.f. systems such as were used in the building of the 800 MeV linac.

Some types of cancer respond to heating of the cancerous cells to temperatures above the normal body temperature, since they are more susceptible to damage and thus preferentially destroyed compared to the healthy cells. The Los Alamos team developed a hand-held device operated from a 12 V battery (which can thus be plugged into a car cigarette lighter socket) which feeds r.f. (2 MHz and about 10 W) to electrodes which are applied to the tumours. The resistance of the tissue to the high frequency current causes heating (usually up to about 50 °C after 10 s of application of the electrodes) and cells are destroyed. Using r.f. there is no sensation of electrical shock.

In collaboration with the University of New Mexico Medical School a series of field trials with affected cattle have been carried out. During the later part of this pilot programme cure rates of over 90% seem to have been achieved. The device has now moved into commercial production and will be suitable for field use by veterinary surgeons or by ranchers themselves.

The same technique has also recently been used on carefully selected human patients at the University of New Mexico Cancer Research and Treatment Center. Significant tumour regression has been achieved.

SACLAY
Hail CESAR

The first superconducting dipole of the 'CESAR' project was successfully tested at Saclay in December. The magnet was designed and built by a joint group from Saclay (STIPE) and CERN (superconducting group of the SPS Experimental Areas Groups) in a collaboration since September 1975.

The aim is to build two dipoles with the same features as the conventional MBN-type beam transport magnets which are used in the experimental areas of the SPS. A special feature of these dipoles is their highly uniform field, necessary for their use in spectrometry experiments. They have a bending power of 9 Tm achieved by a field of 4.5 T along a magnetic length of 2 m. The dipoles have warm bore, 100 mm in diameter, in which field precision to two parts in ten thousand must be sustained within a rectangular area measuring 80 mm horizontally and 40 mm vertically.

In the December tests, the nominal characteristics of the magnet were obtained without training at approximately 80 % of the critical field. This is probably a consequence of the high mechanical quality of the magnet since careful attention was given to the mechanical structure. An example of this is the coil, in which the shims between the current carrying conductors are made from copper to minimize differences in contraction and provide a very uniform structure. Another example is the magnetic circuit which forms the collar of the coil, and whose radial and longitudinal contractions are precisely matched to those of the coil.

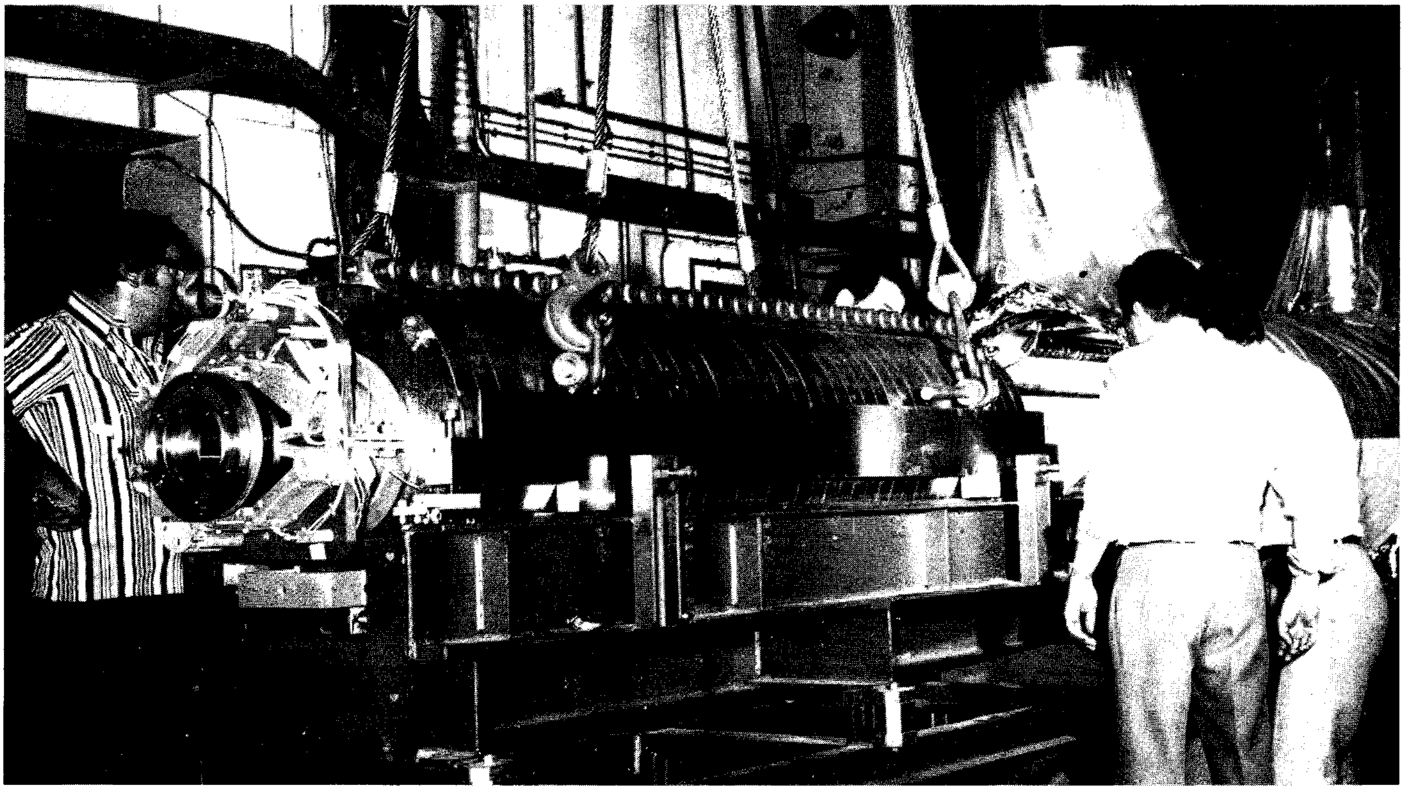
The magnet and its cryostat (completely welded) were tested as a combined unit and functioned smoothly from the first cool-down. This emphasises that magnets of this type are no longer to be considered as laboratory produced units but as units ready for industrial production. The field measurements are in accordance with expectations and anticipated quadrupole corrections will not have to be made. Only sextupole correction will be necessary, using a special coil, because of iron saturation.

The cryogenic system is also highly satisfactory; the consumption is approximately 8 l of helium per hour (with a cryostat volume of about 3 m^3, cold weight 5 tons, warm bore). A nitrogen screen is used, with a consumption of 1.5 l of nitrogen per hour. The cooling time was 130 hours from 300 K to 80 K using a nitrogen exchanger requiring approximately 2000 litres of liquid nitrogen. Cooling from 80 K to 4.2 K required 1000 litres of liquid helium and took 48 hours.

This first dipole, built with Vacuum-Schmelze conductor, was delivered to CERN in January. The second dipole, made from M.C.A. conductor, is now being tested at Saclay.

The superconducting dipole, CESAR, built at Saclay shown being inserted into its cryostat. Two dipoles will be used in a North Area beam of the CERN SPS in July.

(Photo Saclay)



Monochromatic photon beam

An intermediate energy quasi-monochromatic photon beam produced by positron annihilation in flight is now available at the 600 MeV electron linac accelerator, ALS, at Saclay. The photon energy can be varied from 150 to 450 MeV and the number of photons is 5×10^7 per second at 300 MeV with a 1 % energy resolution. Obtaining such an intense monochromatic photon beam from double conversion (electron-positron annihilation followed by the decay of the positron to give a photon) depended on high current and high linac duty cycle which are characteristics of the ALS.

The main photon source used up to now in this energy region was the Bremsstrahlung; because it gives a continuous spectrum of energies, the kinetic relations of reactions cannot be established in most cases and the cross sections have to be 'extracted' from yield curves. This was a serious limitation in nuclear studies with Bremsstrahlung beams.

The ALS electron beam of about 80 MeV and 80 μA average current (20 mA, 8 μs, 500 Hz) hits a fixed gold converter (about one radiation length thick) located about a third of the way down the linac. The positrons are further accelerated to a final energy variable between 150 and 450 MeV. At the entrance to the experimental room after the beam transport system, the ratio between the positron current (after a 1 % momentum analyzing slit) and the electron current on the converter, is 0.5×10^{-3} at 200 MeV and 10^{-3} at 450 MeV.

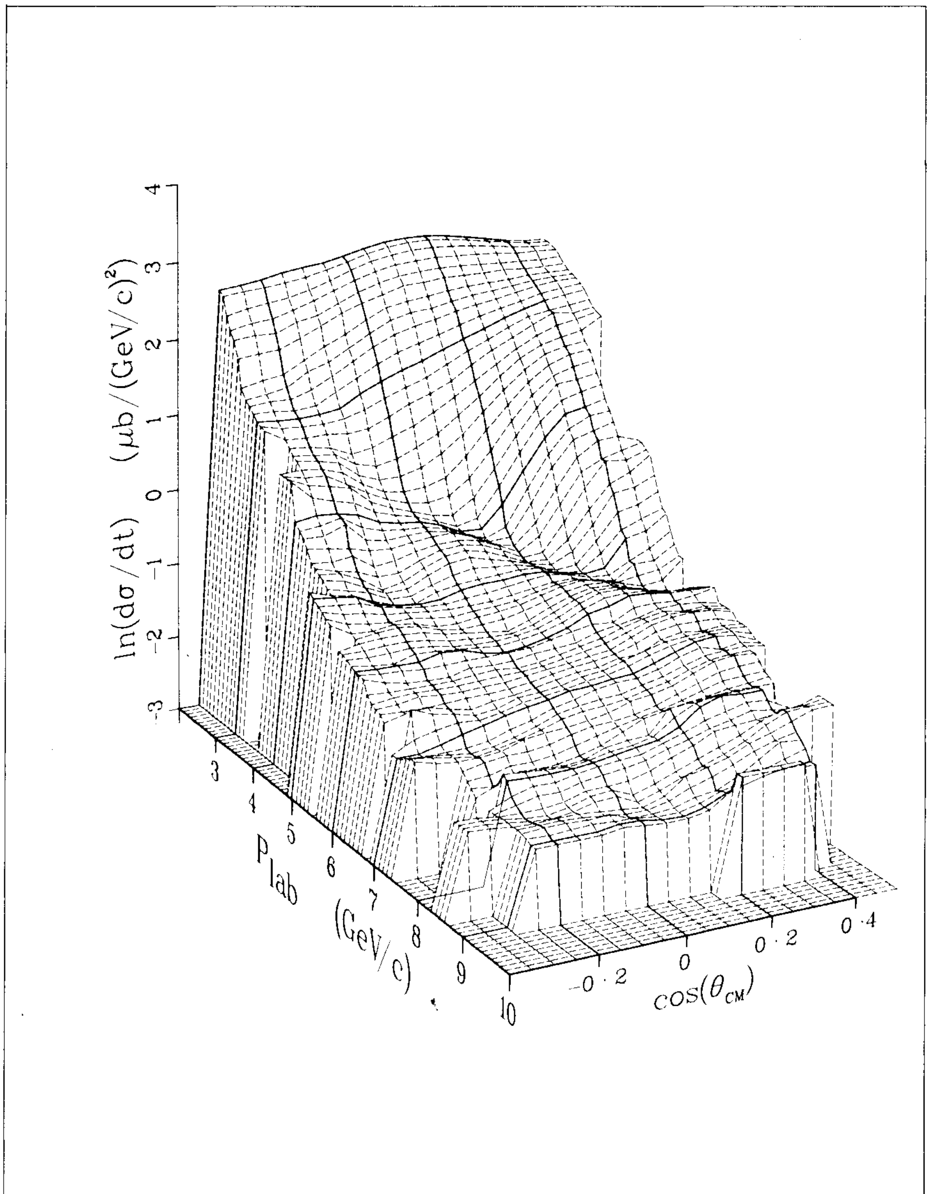
At present the main limitation to increasing photon flux is the limit of thermal destruction of the electron-positron converter. With the fixed converter, the limit is about a third of the maximum average current which can be delivered by the linac.

The 'monochromator' positron to photon converter consists of a lithium annihilation target about a hundredth of a radiation length thick, followed by a 30° sweeping magnet and a Faraday cup all buried in iron and lead shielding. The photon source is very close (3.5 m) to the experimental target to ensure the maximum of photons in the solid angle determined by a 3 cm spot on the target.

The Bremsstrahlung of positrons can be corrected for by using the fact that two converters of same radiation length, but of different atomic number, give the same number of Bremsstrahlung photons, but a number of annihilation photons which is inversely proportional to the atomic number. The quasi-monochromatic photon flux can be obtained by subtracting two measurements using a lithium and a copper converter.

The elastic differential cross section for the negative pion-proton interaction, as a function of momentum angle measured in an experiment at the Argonne Zero Gradient Synchrotron. The structure looks more complicated than expected. Statistical errors range from 3 % for the lowest energy points to 30 % at the highest energy.

ARGONNE Pion-proton scattering structure



An experiment at the Argonne ZGS has shown that large angle pion-proton elastic scattering is more complicated than had been previously known. The experiment by a Minnesota/Columbia/Argonne collaboration fills large gaps in the data on the elastic differential cross sections.

A two arm non-magnetic spectrometer was used to give a smooth and large (20%) acceptance over the centre of mass angular range up to cos θ about 0.3. Data were obtained in 0.5% incident momentum intervals from 2 to 9 GeV/c for negative pion-proton and proton-proton elastic scattering and from 2 to 6 GeV/c positive pion-proton. The proton-proton reaction, which has been extensively measured in previous experiments, provides a useful check on the normalization and analysis.

The negative pion-proton cross sections fall from 10^3 μb/(GeV/c)^2 to 10^{-2} μb/(GeV/c)^2 in the range of this measurement and, as the figure illustrates, it is not a slope for beginners. The dominant feature is the well-known minimum at 3(GeV/c)^2. In addition, there are many other statistically significant structures in the data. A qualitative analysis reveals that these structures cannot be explained by features which are constant in other kinematical variables. They have widths of the order of 100-200 MeV and exist in both negative and positive pion data. The proton-proton data, on the other hand, show no statistically significant fluctuations and are consistent with previous experiments.

These results are not totally unexpected. S. Frautschi suggested in 1972 that if there were many overlapping resonant states in the pion-proton system at energies above 2-3 GeV, this could result in sizable fluctuations in the large angle cross sections. Such fluctuations have been known for many years in nuclear reaction cross sections and have been used to extract information about the average width and density of resonant states.

In an experiment at CERN, it was found that large angle positive pion-proton cross sections near 5 GeV/c changed by as much as a factor of three between two momenta separated by only 20 MeV and that result was interpreted as support for Frautschi's model. A quantitative analysis of the data from the ZGS experiment is being attempted to determine whether the details of the fluctuation model can be confirmed.

Physics monitor

STANFORD
On-line polarization measurement

Polarization experiments using high energy electron beams provide a useful way of comparing the effects of weak and electromagnetic interactions and could give a handle on the elusive parity-violating component of the weak neutral current.

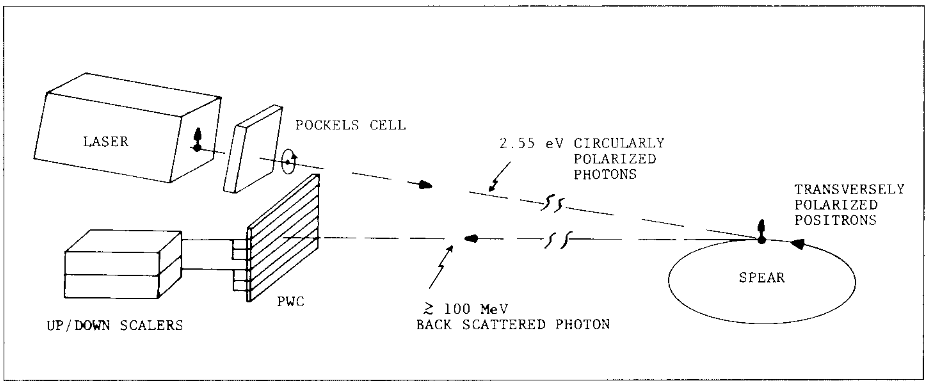
The usefulness of polarized electron beams for physics increases at higher energies but, unfortunately, depolarizing effects due to spin resonances, vertical betatron motion, etc., come into play and it had been believed that it would be difficult to hold polarized beams in storage rings up to high energies.

However, many physicists are now confident that these depolarizing effects can be controlled so that sophisticated polarization experiments will be possible even with very high energy machines like PETRA and PEP (see June issue 1977, page 186). To check the effectiveness of techniques for optimizing beam polarization, some form of polarimeter is needed to give fast, accurate measurements of the beam.

A collaboration of physicists from Wisconsin and SLAC has developed a polarimeter for the SPEAR electron-positron storage ring which is able to measure beam polarization accurately within a minute and is now being used to explore the variation of beam polarization with energy and storage ring tuning.

In the polarimeter, linearly polarized photons are produced by a laser operating at the SPEAR bunch frequency of 1.3 MHz. These photons are then passed through a Pockels cell (an electrically controlled quarter-wave plate) to become circularly polarized and a photon detector measures the resultant back scattering from the SPEAR beam particles (in this case the positrons). The observed asymmetry in the photon distribution depends on the level of transverse polarization in the positron beam. The system is functioning well.

Schematic drawing of the polarimeter now in operation on the SPEAR electron-positron storage ring at Stanford. Polarized laser photons are back scattered from polarized positrons in the storage ring giving an asymmetry in the scattered photons. The laser and detector are in fact quite small units ('table top') located some 13 m from SPEAR.



Muon puzzle continues

The mu-meson, or muon, is a perplexing particle. Even its name is inappropriate. The word meson, for intermediate mass particle, was originally coined to label particles which have a mass heavier than the electron but lighter than the proton and the muon obviously fitted that requirement. However, 'meson' now describes a boson (particle of integer spin) which takes part in strong interactions and consists of a quark-antiquark combination.

The muon certainly does not fit that requirement — it takes no part in strong interactions and is not interpreted as a quark-antiquark combination. It no longer has any right to the term 'meson' in modern terminology. However the name has stuck.

Not only did it get baptized with the wrong name, but also everyone wished it hadn't been born. The muon was discovered in cosmic ray experiments in the 1930s, when physicists were eagerly looking for the Yukawa meson (the pi-meson or pion), postulated as the field quantum responsible for the forces inside nuclei. At first mistakenly identified as the Yukawa meson, the muon was subsequently found to have properties very different from those of a particle closely involved with the mechanisms of the strong nuclear force.

The muon in fact interacts very little with nuclear matter, as vividly demonstrated by its ability to travel through the whole thickness of the earth's atmosphere, and even to considerable depths below ground, before being transformed in some interaction with another particle. Taking no direct part in strong nuclear interactions, the muon belongs with the electron and the neutrinos, to which we should now add the new tau particle (seen at SLAC and DESY), in the small group of particles called leptons.

Although the muon is some two hundred times heavier than the electron, and is unstable with a mean lifetime of 2.2 μs, all its other properties appear to be similar to those of its stable relative. The muon and the electron both appear to be 'point-like' particles whose interactions can be precisely calculated by the methods of quantum electrodynamics.

The uncanny duality between the electron and the muon has been a great mystery in particle physics and is still not understood. Nothing has yet been found to 'explain' the existence of the muon and to account for its being so much heavier than the electron. However, to the best of our knowledge the muon and the electron, although similar in so many ways, are not interchangeable. There is some mysterious 'muonness' which, like electric charge, has to be preserved in particle interactions and prevents the muon from changing directly into an electron while shedding its excess mass.

Much effort has been spent in looking for violations, no matter how small, of this rule which strictly distinguishes muons and electrons. These investigations have been given additional stimulus in recent years with the availability of the so-called 'meson factories' — LAMPF at Los Alamos, SIN near Zurich and TRIUMF in Vancouver — where muons can be poured out in abundance.

Experiments were mounted to look for examples of muons turning into electrons or of muonic matter being transformed into electronic matter, but without success. Before the meson factories began operation, the experimental accuracy implied that if there were any such reactions which violated conservation of muonness, then they were at least 10^8 rarer than conventional processes. The limit has now been carried much further.

Gauge theories

At the same time as new experiments at TRIUMF and SIN were searching for hints of muon-electron conversion, developments in gauge theory enabled the weak and electromagnetic interactions of particles like the electron and the muon to be considered together. The theories provided a framework to describe and to calculate any muon-electron affinity.

In such a theoretical picture, all matter can be seen as consisting of spin one half fermions — that is, particles which obey the Pauli Exclusion Principle. The fermions are either quarks (making up hadronic matter) or leptons (like the electron, muon and neutrinos). One problem is that nobody yet knows how many quarks or how many leptons should be included in the theory.

The standard model which embodies this synthesis between quarks and leptons uses four quarks (up, down, strange and charm) and four leptons (electron, muon and their respective neutrinos). In this model, which seems to describe, for example, many aspects of the behaviour seen in neutrino experiments, the zero mass attributed to the two neutrinos rules out the possibility of muon-electron conversion.

Now it looks likely that at least one extra lepton (the tau particle) has to be incorporated into this model and such an additional lepton should, according to the rules, bring with it its own neutrino. The two additional leptons would imply extra quarks to keep them company and these may well have been presaged by the new heavy Upsilon enhancements discovered at Fermilab.

Any such enlargement of the fundamental set of quarks and leptons used in the gauge theory picture opens the door to muon-electron conversion, but in a way which depends on the basic set of particles used and on the form of the mechanism proposed to 'drive' the conversion. Although allowed in these enlarged models, muon-electron conversion is suppressed to a low level by the ratios of particle masses, etc.

Experimental results

Searches for anomalous muon decays have recently been carried out by TRIUMF and SIN collaborations and a Bern group has searched for muon-electron conversion in nuclei at SIN. No examples have been seen and the accuracy of these experiments means that the upper limit on the possible fraction of processes showing anomalous muon decay is down at the 10^{-9} level, while the corresponding limit for muon-electron conversion in nuclei is estimated by the Bern group to be in the 10^{-10} region.

While absorbing these figures, it is worth recalling that the fraction of events violating charge-parity conservation in the decay of the neutral kaons is about 10^{-3} and even that is considered a small effect. With limits now down near 10^{-10}, any kind of muon-electron conversion would be a minuscule effect and very difficult to detect.

If these new limits imply that the muon and electron always retain their individual identity then physicists still need a reason for the muon's existence. Forty years after its discovery, the muon remains a perplexing particle.

People and things

Bernard Gregory

We learned with shock that Bernard Gregory died from a heart attack during the night of 24-25 December. Only days before, he had been elected President of the CERN Council and the European high energy physics community was looking forward to his devoted and experienced leadership in the coming years.

Bernard Gregory was born in Bergerac, France, in 1919. His reputation in our field of research grew in the 1950s when he worked with Louis Leprince-Ringuet at the Ecole Polytechnique participating in important cosmic ray physics and then becoming a specialist in the exploitation of the new technique of bubble chambers. His qualities were seen to be so outstanding that he was elected Member of the CERN Scientific Policy Committee in 1960 — an honour assigned only on the basis of scientific ability. Around that time he was involved in the early research with bubble chambers, directing the work on the 81 cm hydrogen chamber built at Saclay and brought to the CERN PS.

In 1964 he joined CERN as Directorate Member for Research and in 1966 became Director General. He led the Laboratory through those difficult years (1966-1970) of the debate on the construction of the 300 GeV machine. He poured enormous energy and talent into keeping this debate alive and was one of the three people (with Edoardo Amaldi and John Adams) cited, when construction authorization was finally achieved in 1971, as someone whose contribution to the decision had been outstanding. It was during his period of office as Director General also that that unique instrument, the Intersecting Storage Rings, was constructed and that the collaborations with our colleagues in the Soviet Union flourished.

Bernard Gregory returned to France and became a very influential figure in national science policy. He led the Centre national de la Recherche scientifique (CNRS) from 1973 to 1976 and was then appointed Délégué général à la Recherche scientifique et technique (DGRST).

At the December 1977 CERN Council session he was elected President. He had the respect of the whole European science community and of the political bodies which determine science policy. His broad experience, his commitment to the field of high energy physics, his great talent for analysis and the formulation of acceptable compromises, were just the qualities which will be needed in the coming years as Europe looks to the future again. His death has created a deep sense of loss.

Meetings

The 4th General Conference of the European Physical Society will be held at York in England from 25-29 September 1978 under the title 'Trends in Physics'. In the high energy physics field there will be a plenary session on 'New developments in elementary particle physics' and symposia on quarks and on synchrotron radiation. Further information from EPS4, The Meetings Office, The Institute of Physics, 47 Belgrave Square, London SW1X 8QX.

A Workshop on Channelling at High Energies sponsored by the State University of New York at Albany and Fermilab will be held at Fermilab on 7-8 April. For further information, contact R.A. Carrigan at Fermilab, P.O. Box 500, Batavia, Illinois 60510.

The next SLAC Users' Meeting, followed by Workshops on the future of Linac and SPEAR physics, will be held on 30-31 March (possibly extending to 1 April) at the Stanford Linear Accelerator Center.

The Fourth Summer Study on High Energy Nuclear Collisions will be held at Berkeley from 24-28 July. It will consist of a relaxed schedule of discussion and talks covering experimental and theoretical accomplishments of the last two years and perspectives for the future for heavy ion physics in the approximate range 20 MeV/nucleon to a few GeV/nucleon. Further information can be obtained from the ARC Office, Building 51, Lawrence Berkeley Laboratory, Berkeley, California 94720.

APS/AAPT in San Francisco

The 1978 Annual Joint Meeting of the American Physical Society (APS) and the American Association of Physics Teachers (AAPT) was held in San Francisco from 23-26 January. Among the highlights was a session on DUMAND, the Deep Underseas Muon and Neutrino Detection project which hopes to open an era of neutrino astronomy (see May issue, 1977, page 154). Sid Drell from Stanford gave the 1978 Richtmeyer Lecture with the title 'When is a Particle?'. Norman Ramsey, Higgins Professor of Physics at Harvard University, prominent on the scientific and political scene in USA high energy physics for many years, has taken over this year as President of the APS.

Principles of Ignorance

The 'Encyclopaedia of Ignorance', recently published by Pergamon Press, is an attempt to put between two covers the present limits of scientific knowledge and to indicate those areas where our understanding is a bit thin. The book contains contributions from a number of distinguished cosmologists such as Herman Bondi, J.A. Wheeler, W. McCrea. Only Abdus Salam writes on the underlying structure of matter. Does this mean that in particle physics we are less ignorant than in cosmology or does it mean we are less ready to admit it?

On People

Laura Fermi, author of several books on the world of atomic physics and physicists and wife of Enrico Fermi, the Italian physicist who built the first nuclear reactor in Chicago, died on 26 December at the age of 70. Laura Fermi remained a lively and active personality right up to her death. She was a main speaker at the dedication ceremony in 1974 of the National Accelerator Laboratory which was named the Fermi National Accelerator Laboratory (Fermilab) in honour of her husband.

Kurt Mellentin, Head of the DESY library, died on 28 December at the age of 54. Dr. Mellentin went to DESY in 1962 to organize the library and built up an information and documentation system, including preprints which were not covered by other systems. In the High Energy Physics (HEP) Index, now in its 16th volume, compiled at DESY and published by ZAED, new publications and preprints are included within four weeks. The Index is on tape and DESY provides a SDI service and retrospective searches (one of the first services of this kind). The tapes are used by other information services as part of their data base (for example SPIRES at SLAC and HEPPI at CERN). Those who knew Kurt Mellentin closely had a high respect for his broad knowledge in science and the liberal arts.

On 22 November, Samuel Goudsmit, for 26 years until 1974 a scientist at Brookhaven, received the National Medal of Science (the USA's highest national award for scientific or engineering achievement) from President Carter. The citation read, 'for the discovery of the electron spin as the source of a new quantum number' and commemorates the work carried out in 1925 in collaboration with George Uhlenbeck who also received the Medal.

Gerald Smith has been appointed to succeed Tom Fields as Associate Laboratory Director for High Energy Physics at Argonne. Dr. Smith, from Michigan State University, joined Argonne on 16 January as Head of the Accelerator Research Facilities and High Energy Physics Divisions. Tom Fields is returning to full time research and spending a sabbatical year at CERN.

Giorgio Bellettini has become Director of the National Laboratories of Frascati in Italy. Among his other duties prior to his appointment, Professor Bellettini was Leader of the Pisa University group in the Frascati / Genova / Harvard / MIT / Naples / Pisa collaboration at the CERN Intersecting Storage Rings and was joint spokesman of the collaboration with Sam Ting. P.L. Braccini has now taken over as joint spokesman.

At the December CERN Council Session there were tributes to P. Levaux the retiring President for the very efficient way in which he had guided Council affairs during his years in office and to W. Paul for his leadership of the Scientific Policy Committee for the past three years.

The following elections and appointments were made at the CERN Council Session in December: Vice-Presidents of Council - P. Levaux, A.C. Pappas; G. Stafford succeeds W. Paul as Chairman of the Scientific Policy Committee and N. Cabbibo, W. Paul, H. Schopper and V.L. Telegdi are elected SPC members for three years; M. Gigliarelli Fiumi was re-elected Chairman of the Finance Committee with J. Beattie as Vice-

1. Laura Fermi at the Fermilab Dedication ceremony in 1974.
2. Hans-Otto Wüster, newly appointed Head of the JET fusion project.
3. P. Levaux, retiring President of CERN Council.

Chairman; E. Lohrmann will continue as Member of the CERN Directorate for Experimental Physics until the end of 1978 and will be succeeded by I. Mannelli.

From 1 January E. Gabathuler has succeeded E. Picasso as Leader of the Experimental Physics Division (as decided at the June 1977 Council Session). Emilio Picasso earned much praise for his work as Division Leader and for the engaging style with which he carried out his work.

Joining the Jet Set

Hans-Otto Wüster, Directorate Member at CERN, has been appointed to lead the JET project at the Culham Laboratory in the UK. JET (Joint European Torus) is Europe's next step in the attempt to master thermonuclear fusion by the toroidal plasma confinement technique which usually goes under the name of 'Tokamak', selected by its originator the late Lev Artsimovitch from the Soviet Union. The project is under the auspices of Euratom (European Atomic Energy Community).

Hans-Otto Wüster has had a distinguished career in high energy physics Laboratories. At DESY he was also a Member of the Directorate and had much to do with the bringing into operation of the successful electron synchrotron. He came to CERN in 1971 as Deputy to John Adams during the construction of the SPS with special responsibilities in budgetary and personnel matters. These managerial responsibilities were extended to the whole of CERN in the reorganization at the beginning of 1976. They have been conducted in ebullient style backed by a very keen mind and a thorough understanding of what he was managing.

It is perhaps not a coincidence that the USA equivalent of JET (TFTR, the Tokamak Fusion Test Reactor being built at Princeton) is also headed by an ex-accelerator physicist — Paul Reardon, who was a leading personality in the construction of the Fermilab machine. Their appointments are a measure of the strength of expertise and leadership which exist in high energy physics Laboratories.

CERN will miss Hans-Otto Wüster's abilities and personality very much. We wish him well in his new appointment.

New Division at Los Alamos

A new Accelerator Technology Division has been formed at Los Alamos Scientific Laboratory, under Ed Knapp as Division Leader and Bob Jameson as Alternate. It will bring together activities from several existing Divisions. One of the core projects will be the PIGMI linac design

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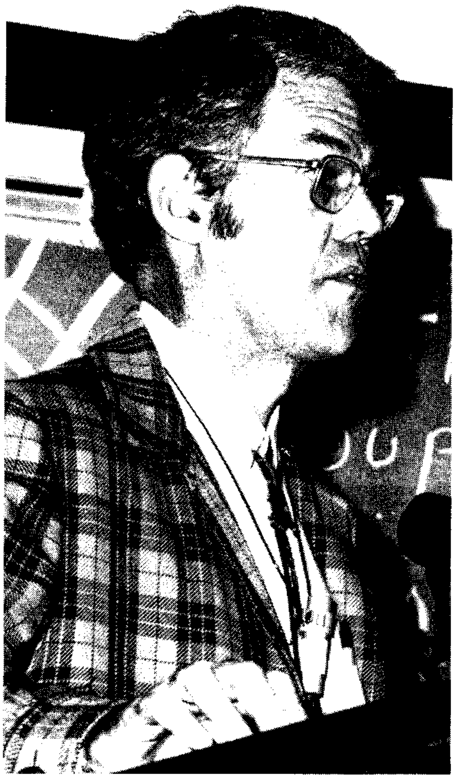

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for medical applications under Don Swenson (see September issue, 1976). A new study on accelerators for fertile to fissile nuclear fuel conversion will be shared between the Energy Division and the Accelerator Technology Division. Work on gyrocon r.f. power generation as promoted at Novosibirsk (see August issue, 1977) and high-brightness negative hydrogen ion sources will also move to the new Division together with the design and construction of a proton storage ring for the LAMPF Pulsed Neutron Source, now under active consideration for funding by the US Department of Energy.

Reorganization of colliding beams research at Fermilab

The colliding beams effort at Fermilab has now been split into three separate groups. In the Research Division, a Colliding Detector Facility (CDF) Department is responsible for organizing the design, construction and implementation of a facility to study proton-proton and proton-antiproton collisions. The existence of such a facility is not meant to preclude other more modest experiments, but there is no need to organize such experiments at this early time. Instead they might be planned and proposed when colliding beams are closer to operation at the Laboratory. Alvin Tollestrup will Head the CDF Department, with Jim Walker as Deputy Head and Peter McIntyre as Assistant Head.

In the Accelerator Division two new groups have been formed. One, the Colliding Beam (CB) Group, will be responsible for research on such topics as beam lifetimes, experimental backgrounds, low beta insertions, and similar other topics. The group is also responsible for the design and construction of the experimental area in which the CDF is to be housed. Stan Ecklund is heading this new group. A second group, the Antiproton Cooling (AC) Group, is responsible for the construction and use of the new cooling ring, of the reverse injection line between Booster and the Main Ring, and of the antiproton target to be located in that line. Don Young is Group Leader and Fred Mills is the Associate Group Leader.

J.H. Bannier / W. Gentner

The CERN Council bade good-bye to two of its most distinguished, long-standing members during the December session. J.H. Bannier left the Council as delegate from the Netherlands. W. Gentner left the Council as delegate from the Federal Republic of Germany. Both were amongst the small group, who, 25 years ago, brought CERN from the realm of ambition to reality. Both have played important roles in the intervening years to ensure the Organization's growth and success.

1. Ed Knapp, Leader of the new Accelerator Technology Division at Los Alamos.
2. J.H. Bannier, retiring CERN Council delegate from the Netherlands.
3. W. Gentner, retiring CERN Council delegate from the Federal Republic of Germany.

Dr. Bannier served as Chairman of the Finance Committee from 1958-1960 and he was the architect of the financial planning system, the 'Bannier procedure', which helps the Governments of the Member States and the CERN management in their long-term planning, by preparing budget figures for four years ahead. He was President of the Council from 1964-1966 when the improvement programme for the existing facilities took shape and when the construction of the Intersecting Storage Rings was authorized.

Professor Gentner was one of the early leaders at CERN itself heading the team which built the first accelerator — the 600 MeV synchrocyclotron. He played an important role in the development of the experimental programmes as Director of Research. He has long contributed to the work of the Scientific Policy Committee and was President of the Council from 1972-1974.

To both of these devoted friends of CERN we express our gratitude and our best wishes for many full and happy years to come.

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Model No.	Package	No of Channels	Updating	Threshold (mV)	Output Width (nsec)	No. of Outputs (complementary)	No. of Outputs (normal)	Veto	Max. Rate (MHz)	Summing Output	Burst Guard	Hi Z Bridged Input Option	Required Voltages
161L	NIM	2	Yes	−100	3-150	4	2	Yes	150	No	Yes	Yes	±12; ±24
620BL	NIM	8	No	−30 to −1000 (common)	5-20	3	0	No	100	Yes	No	No	±6; ±12; −24
620CL	NIM	8	No	−30 to −1000 (common)	5-20	3	0	Yes	100	No	No	No	±6; ±12; −24
623	NIM	8	Yes	−30 to −1000	6-150	3	0	No	100	No	No	Yes*	±6; ±12; −24
621BL	NIM	4	Yes	−30 to −1000	5-1000	5	1	No	100	No	Yes	Yes*	±6; ±12; −24
2623	CAMAC	8	Yes	−30 to −1000	6-150	3	0	No	100	No	No	Yes*	±6; ±12; −24
821	NIM	4	Yes	−30 to −1000	5-1000	5	1	Yes	100	No	Yes	Yes*	±6; ±12; −24
826	NIM	6	No	Dual level for low slewing	4-50	3	0	Yes	100	No	No	No	±6; ±12;

*Hi-impedance bridged inputs are available at the expense of one normal output.

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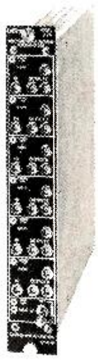

- 6 channels in #1 NIM module
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- Variable threshold from −10mV
- Low slewing — minimizes risetime effects
- Convenient Veto Input

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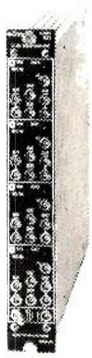

- 4 inputs, each with 4 normal and 2 complementary outputs
- 100 MHz maximum rate
- Variable threshold from −30 mV
- NEW—*Rate Lites*™ for visual verification of phototube and discriminator operation
- NEW—Veto Input

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RRA I, AB Bates

La meilleure amélioration jamais faite sur le NORD-10

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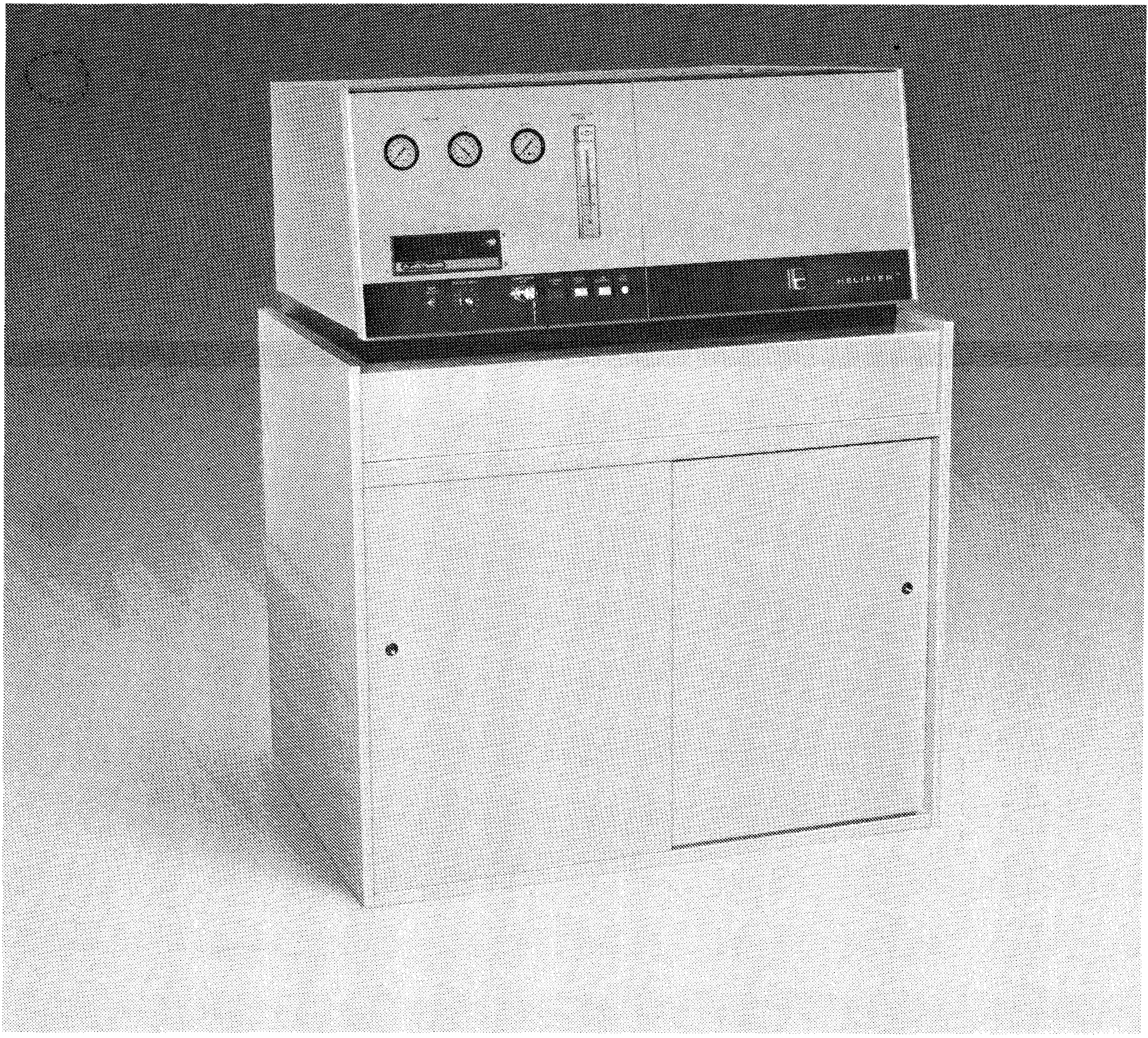
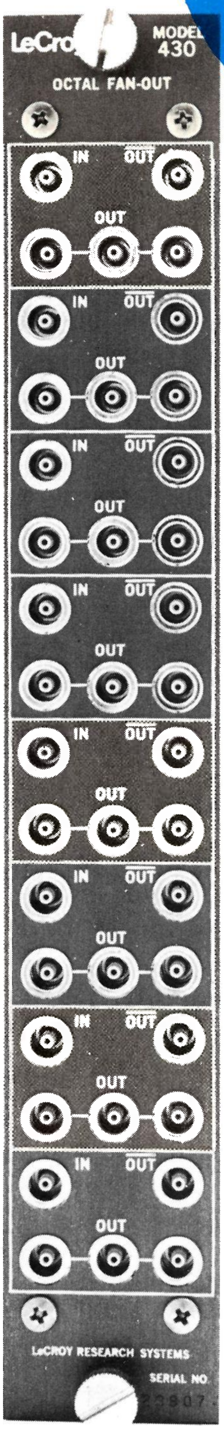


NEW in NIM



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- 2.5 nsec stage delays, minimizing logic propagation time and the requirement for compensating cables.
- Accurate restandardization of input signals; output durations are equal to input durations.
- High packaging density, allowing up to 96 channels (384 outputs) to be powered from one NIM bin.

For complete technical data and pricing information on the Model 430, call or write your local LeCroy Sales Office.

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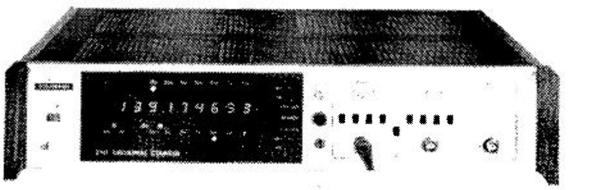

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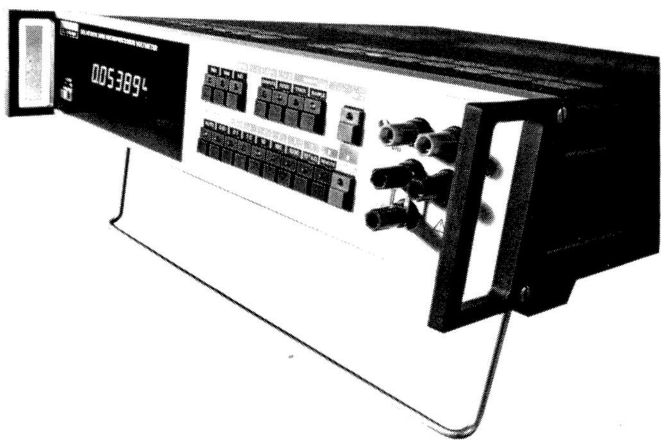

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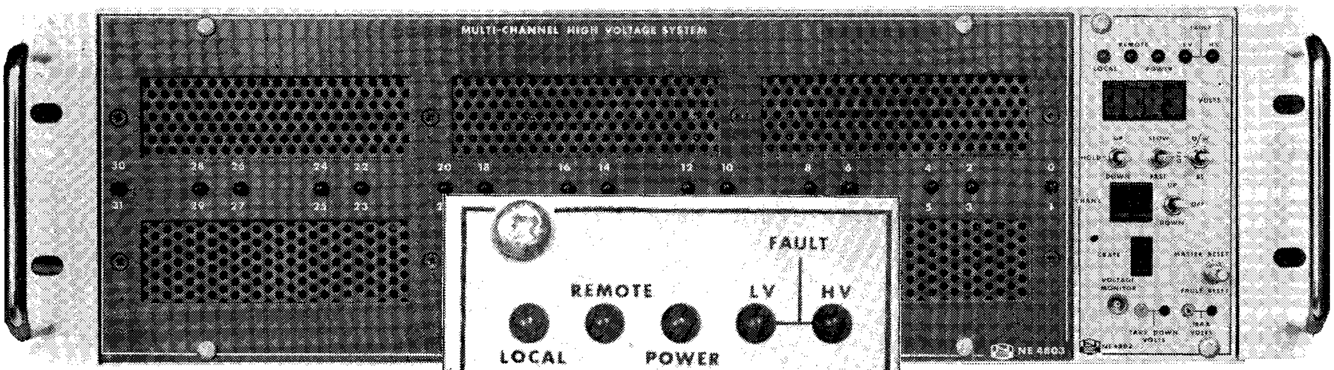

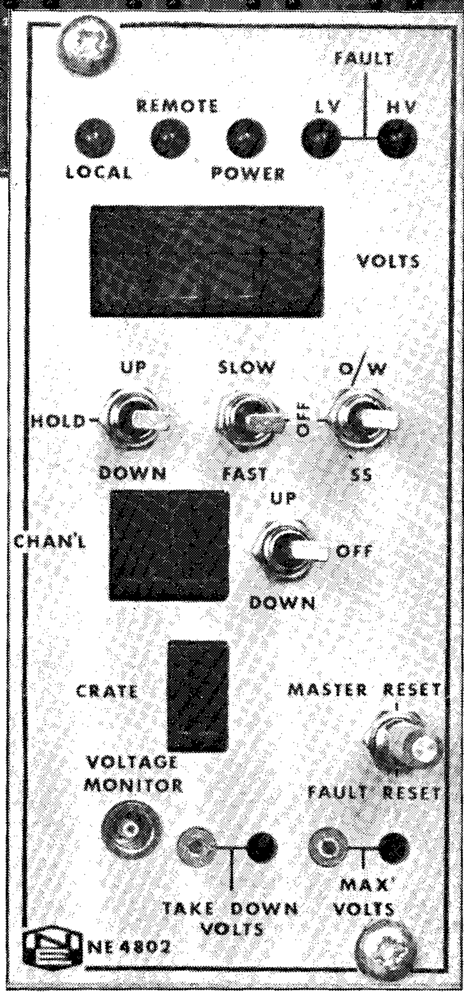

NE 4803 PHOTOMULTIPLIER HV

Outputs Up to 32 per crate
Voltage 300V to 3kV negative (positive optional)
Current 0 to 2mA average per channel, 3mA max
Stability 0.1% for line and temperature, range 0°C to +50°C
Ripple ⩽0.5V peak to peak at 2mA
Protection Protected against short circuits on output
Overload Common overload line activated when any channel is overloaded
HV Monitoring From rear panel connector on common analogue line. Ratio 1V/1kV
Packaging 3'u' high rack containing 16 cards each with 2 individual outputs

NE 4802 HV CONTROL MODULE

Common to PM and wire chamber systems. Allows local control of any of the HV channels in the associated crate.
Control Range 0 to 6999V
Resolution ±0.5V
Up/Down 3 toggle controls provide voltage increment/decrement from single step to 200V/s.
Monitor 1V/kV trimmable to 0.05% at a specific voltage
Take Down Range 0 to 2500V set by front panel control (common to all channels)
Maximum Voltage Range 1kV to 7kV set by front panel control (common to all channels)
Data Bus Serial duplex, 20mA current loops. The control signals are based on the ASC11 code allowing remote control of any channel (256 per remote controller output) using either a remote Camac controller or a Teletypewriter (or similar) terminal.

NE 4804 WIRE CHAMBER HV

Outputs 16 per crate
Voltage 2.5kV to 7kV negative (positive optional)
Current 0 to 0.7mA
Stability 0.1% for line and temperature, range 0°C to +50°C
Ripple ⩽1V peak to peak at 0.5mA
Overshoot ⩽50V
Protection Protected against short circuit on output
Current limit Presettable for each channel 10μA to 700μA
Overload alarm Common overload line activated when any one channel goes into current limit
HV Current Monitoring From rear panel connector on common analogue line. Ratio 1V/1kV or 1V/100μA
Meter Indication Meter indicates voltage or current for each channel

Typical system: NE 4801 Crate and Low Voltage, NE 4802 Control, NE 4803 PM cards X16 = 32 channels, or NE 4804 wire chamber cards X16 = 16 channels

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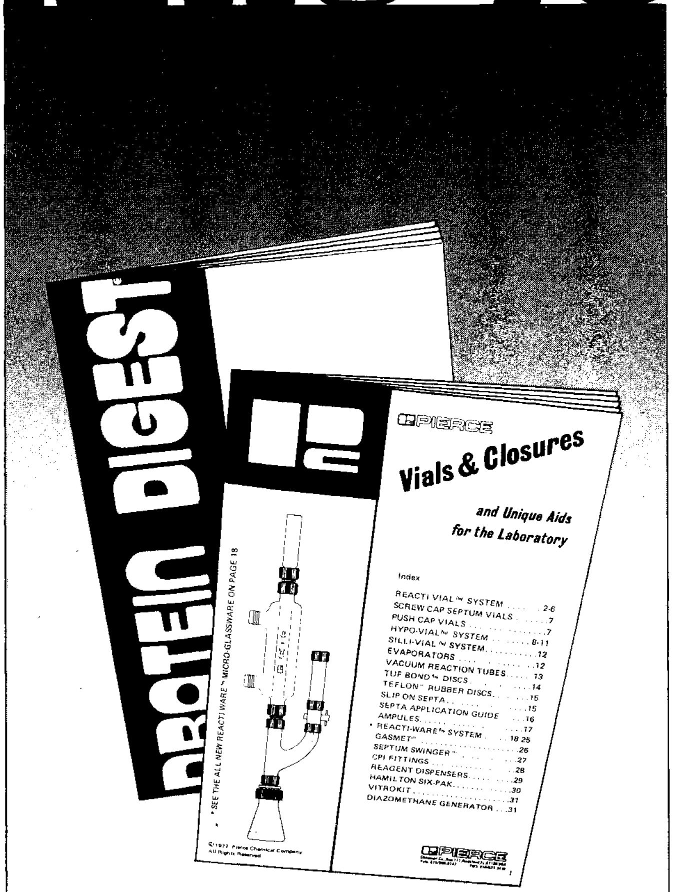

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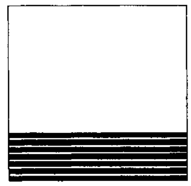
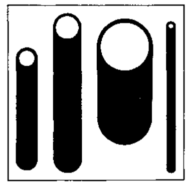
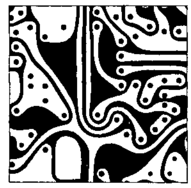
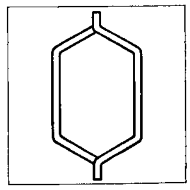
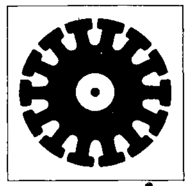
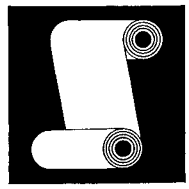

Stratifié pressé


Tubes en matériau Hp et Hgw


Matériel de base pour circuits imprimés


Isolant flexible


Matériel isolant pour encoche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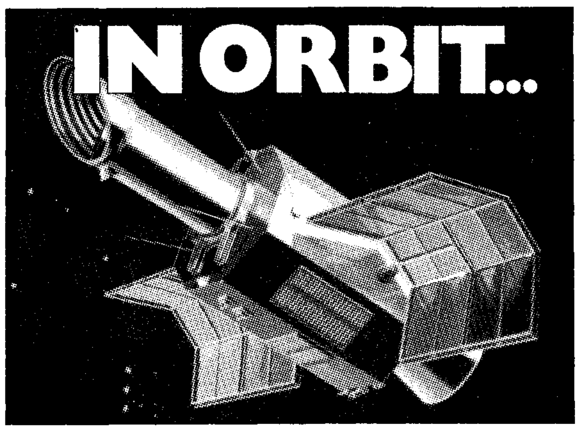

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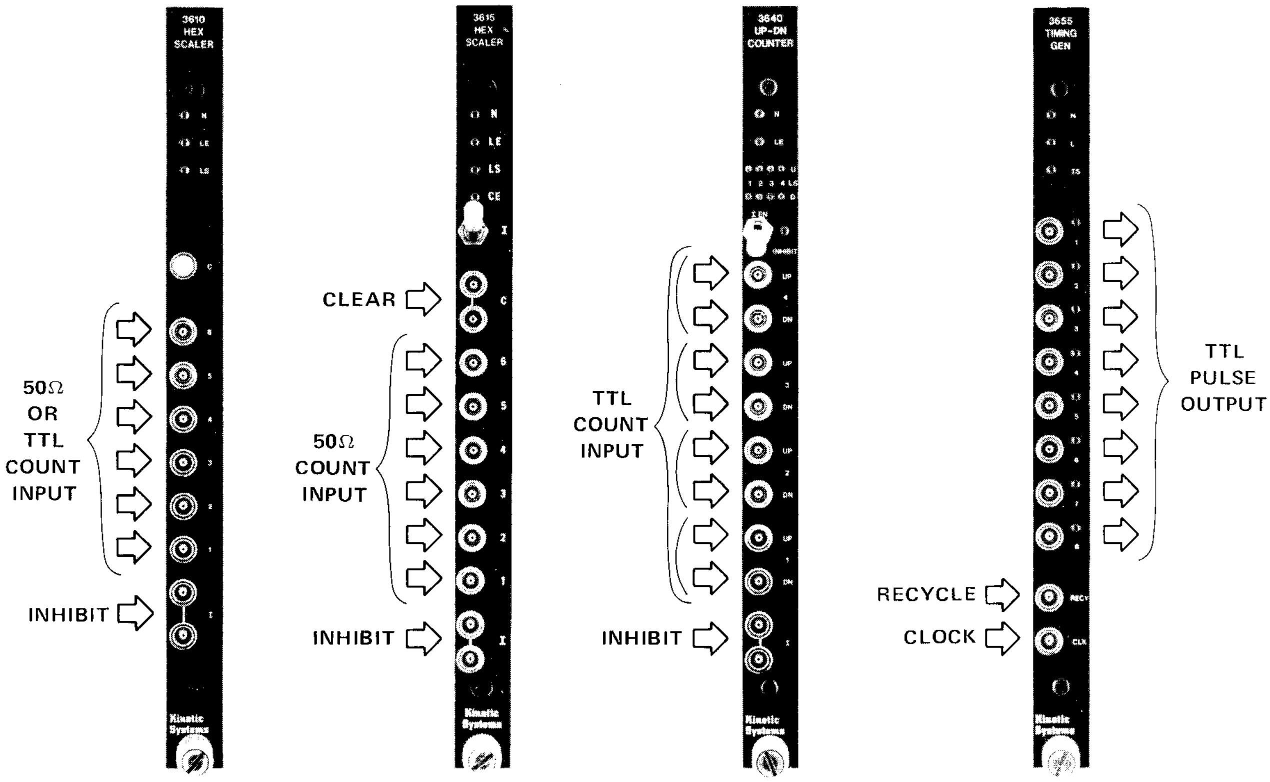

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6-Channel, 50 MHz Counter

- Six independent 24-bit counters
- Counter inputs are 50 ohm terminated or TTL (strap selected)
- Input pulse rate from DC to 50 MHz
- Independent clear by command for each counter
- LAM status bits set on overflow

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- Counter inputs are 50 ohm terminated
- Input pulse rate from DC to 100 MHz
- Independent clear by command for each counter
- LAM status bits set on overflow

3640
4-Channel, Up-Down Presettable Counter

- Four independent 16-bit up-down counters
- Separate up/down inputs for each channel
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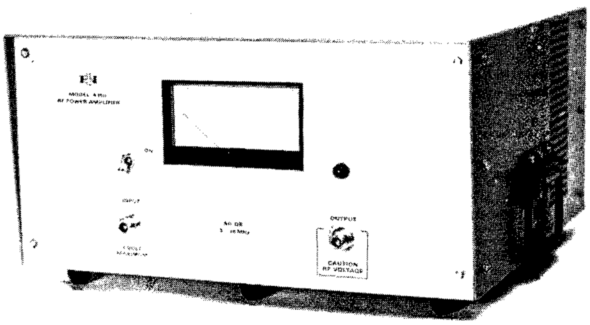

PULSE HANDLING SYSTEM

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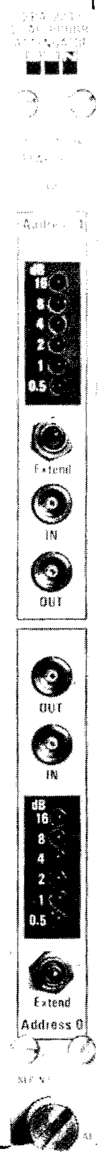


NUMBER OF CHANNELS 2

INPUT
50 Ω, LEMO OO connectors.

REFLECTION
≤6% with tr=1ns.

RANGE
0db to 31.5db in increments of 0.5db + 0.5db of internal attenuation

SWITCHING TIME 3.5ms

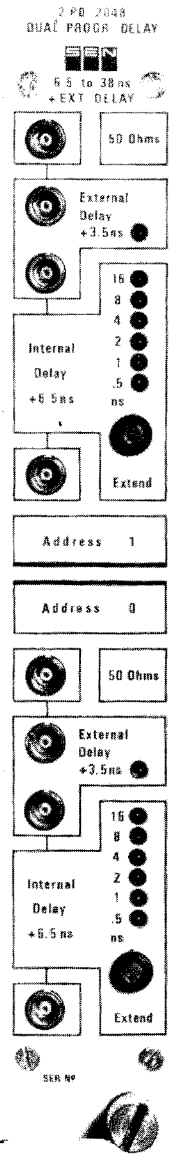
DELAY ≤6.5ns

SETTING
front panel increment switch with automatic timer or dataway command

CAMAC FUNCTIONS per channel:
Read, Write, Busy/Done checking
LAM testing, disabling and clearing

POWER +6V 500mA
+24V 0-240mA

DUAL PROGRAMMABLE DELAY UNIT 2PD 2048



NUMBER OF CHANNELS 2

INPUT
50 Ω, LEMO OO connectors.

REFLECTION
≤6% with tr=1ns.

RANGE
0 to 31.5ns in increments of 0.5ns + 6.5ns of internal delay and external delay.

SWITCHING TIME 3.5ms

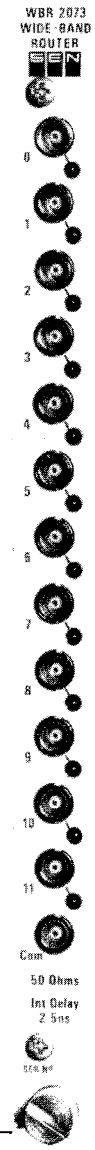
ATTENUATION <10%

SETTING
front panel increment switch with automatic timer or dataway command

CAMAC FUNCTIONS per channel:
Read, Write, Busy/Done checking
LAM testing, disabling and clearing

POWER +6V 500mA
+24V 0-240mA

WIDE-BAND ROUTER WBR 2073



NUMBER OF CHANNELS 12

INPUT
50 Ω, LEMO OO connectors

REFLECTION
≤5% with tr=1ns

SWITCHING TIME 3.5ms

ATTENUATION <7%

DELAY 2.5ns

CHANNEL SELECTION MODE
- single channel addressing
- automatic scanning
- automatic skip of unused channels

CAMAC FUNCTIONS
select a channel, Busy Done checking, LAM testing and clearing, scanning matrix loading, auto-scanning, clearing

POWER +6V 700mA
+24V 80mA

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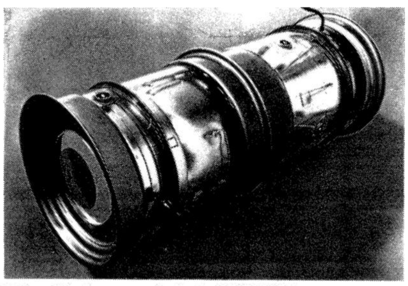

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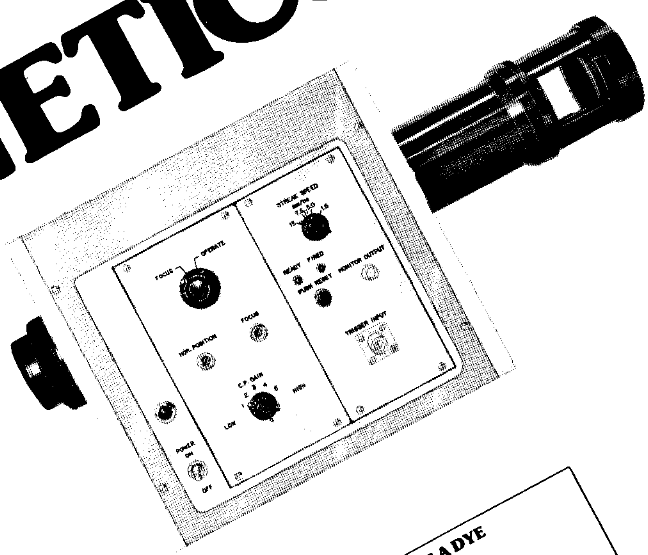

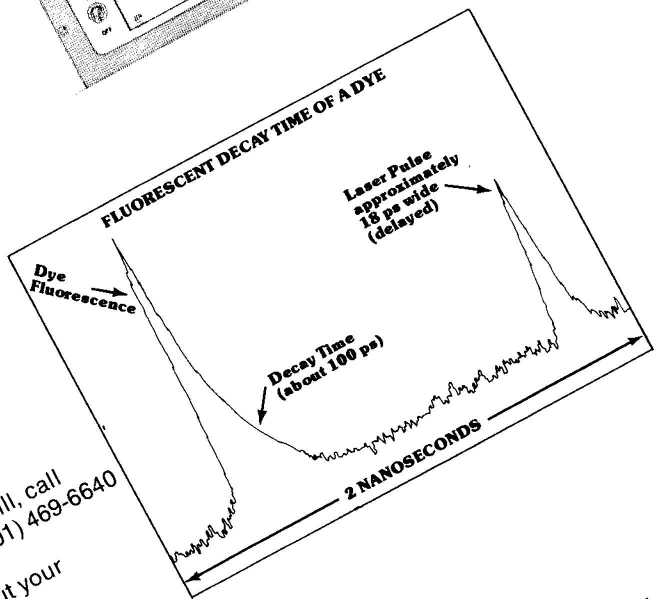

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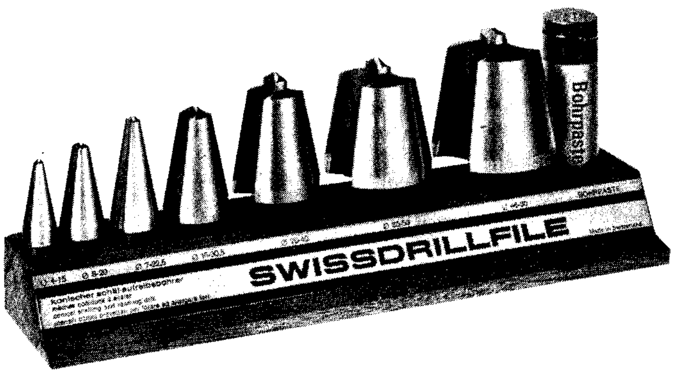

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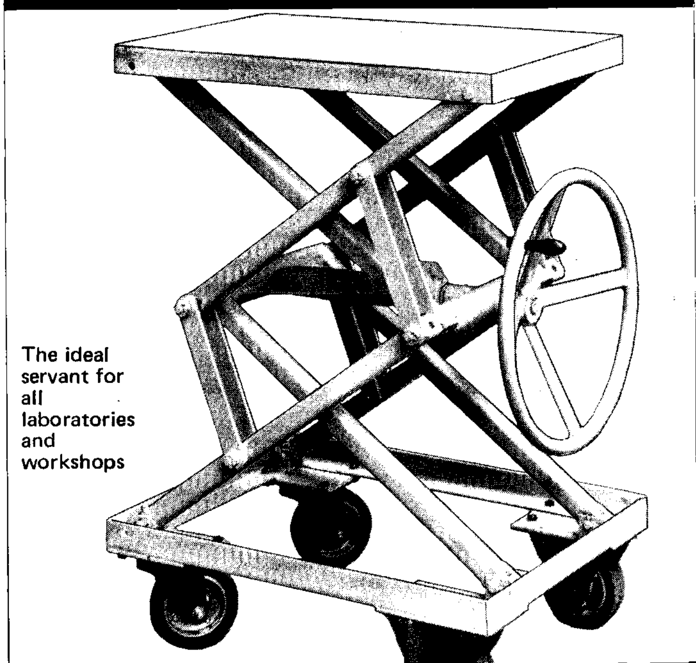

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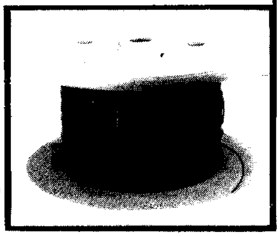


Specifications :

• Material	: Silica
• Attenuation	: 5 to 10 dB/km
• Numerical aperture	: 18 to 20°
• Passband	: 300 MHz/km
• Outer fiber dia.	: 120 μ ± 5 μ
• Cable O.D.	: 0.9 mm ± 0.1 – 0
• Max. available length	: 1500 mm

Optical cable with 3, 7 19 silica fibers TIS LD

Optical cable with 7 silica fibers TIS ZMO7 and TIS PZO7

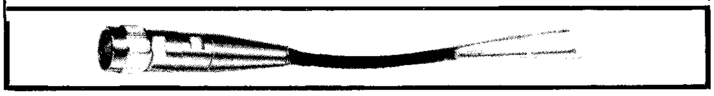
Specifications :

• Material	: Silica
• Attenuation	: 15 to 50 dB/km
• Numerical aperture	: 32°
• Passband	: > 150 MHz/500 m n
• Outer fiber dia.	: 400 μ ± 10 μ
• Cable O.D.	: 6 mm
• Max. available length	: 500 mm
• Tensile strength	: 25 kg
• Radius of curvature	: 80 mm

Optical cable with 19 glass fibers TIS-MD 19

Specifications :

• Material	: Glass
• Attenuation	: < 100 dN/km
• Numerical aperture	: 57°
• Passband	: > 100 MHz/100 m n
• Outer fiber dia.	: 105 μ ± 5 μ
• Cable O.D.	: 6 mm
• Max. available length	: 250 m
• Tensile strength	: 25 kg
• Radius of curvature	: 80 mm



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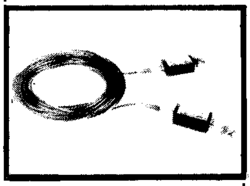

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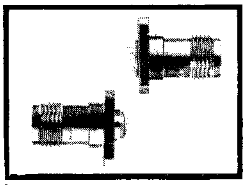

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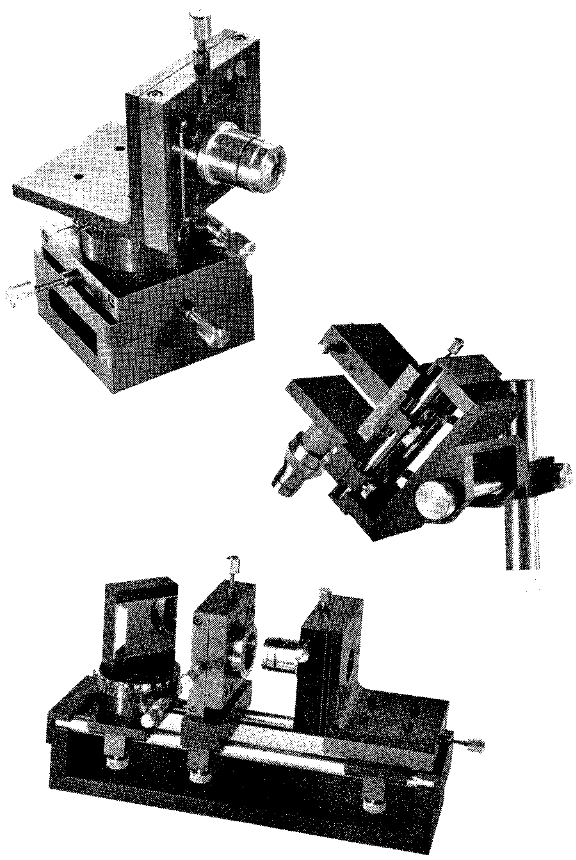

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