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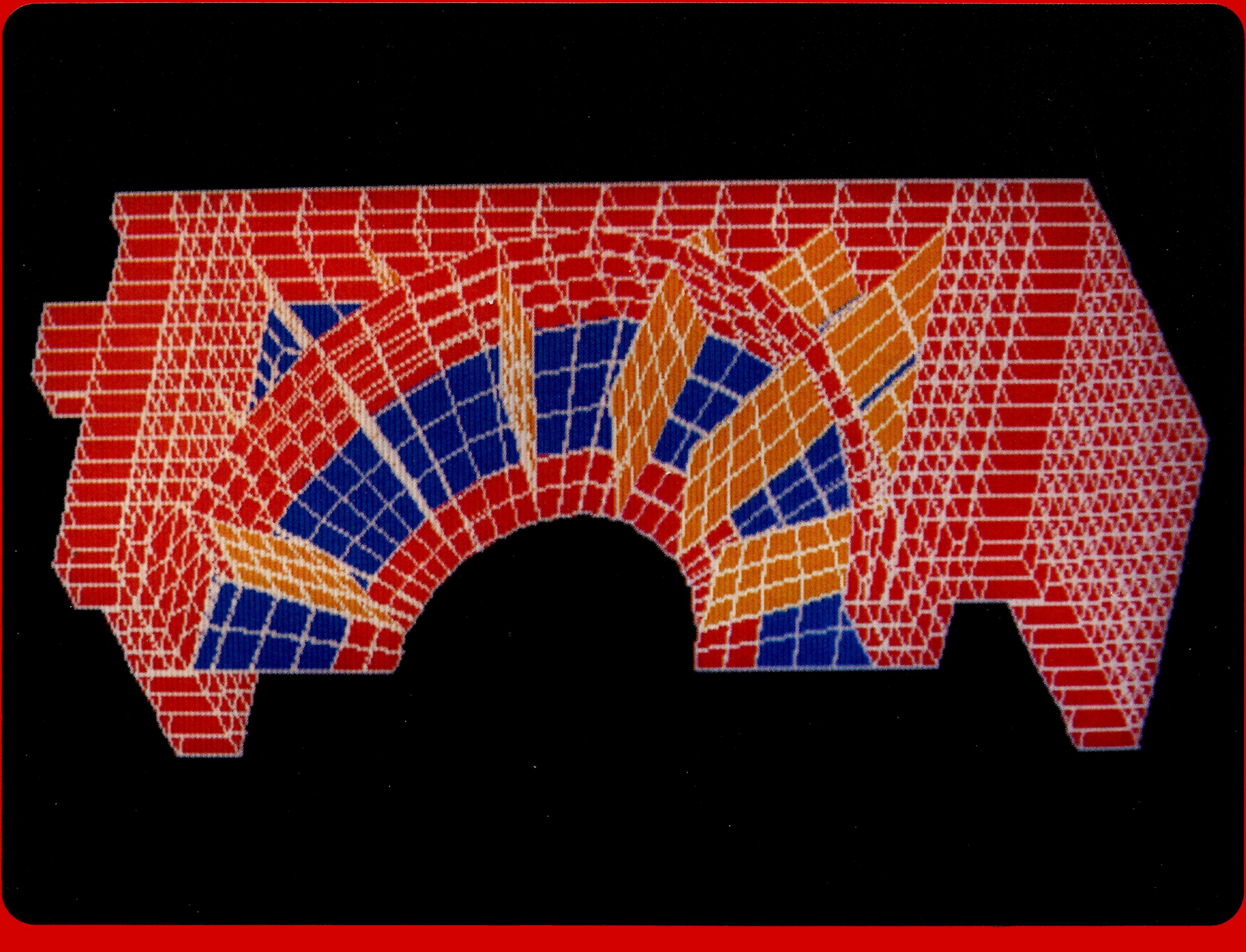

VOLUME 22 6 JULY/AUGUST 1982

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General distribution —
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CERN, 1211 Geneva 23, Switzerland

CERN COURIER is published ten times yearly in English and French editions. The views expressed in the Journal are not necessarily those of the CERN management.

Printed by: Presses Centrales S.A.
1002 Lausanne, Switzerland

Published by:
European Organization for Nuclear Research
CERN, 1211 Geneva 23, Switzerland
Tel. (022) 83 61 11, Telex 23 698
(CERN COURIER only Tel. (022) 83 41 03)
USA: Controlled Circulation
Postage paid at Batavia, Illinois

CERN COURIER

International Journal of the High Energy Physics Community

Editors: Brian Southworth, Gordon Fraser, Henri-Luc Felder (French edition) / Advertisements: Micheline Falciola / Advisory Panel: M. Jacob (Chairman), U. Amaldi, K. Hübner, E. Lillestøl

VOLUME 22 Nº 6 JULY/AUGUST 1982

Cover: Stress analysis model of one quarter of the magnet yoke for the detector at the planned Fermilab proton-antiproton collider. Red elements are the main portions of the yoke. Yellow plates are calorimeter support ribs. Blue plates are stainless steel elements that carry no magnetic flux.

Fifty years ago — nuclear physics at Cambridge

By W. E. Burcham

This year marks the fiftieth anniversary of the discovery of the neutron by Sir James Chadwick at the Cavendish Laboratory, Cambridge. To commemorate this milestone in physics history, an international conference is being held in Cambridge from 13—17 September. Fifty years ago, the Cavendish also saw the first nuclear transformations using artificially accelerated particles, and was soon to provide confirmation of the discovery of the positron. In 1932, the Cavendish Laboratory under the guiding hand of Rutherford was a world focus for research and with these discoveries saw the birth of modern particle physics.

W. E. Burcham is Emeritus Professor of Physics in the University of Birmingham. He began his research career at the Cavendish in 1934, where he collaborated in some of the last experiments with the original Cockcroft-Walton apparatus.

The old Cavendish Laboratory, Free School Lane, Cambridge.

(Photo Cavendish Laboratory)

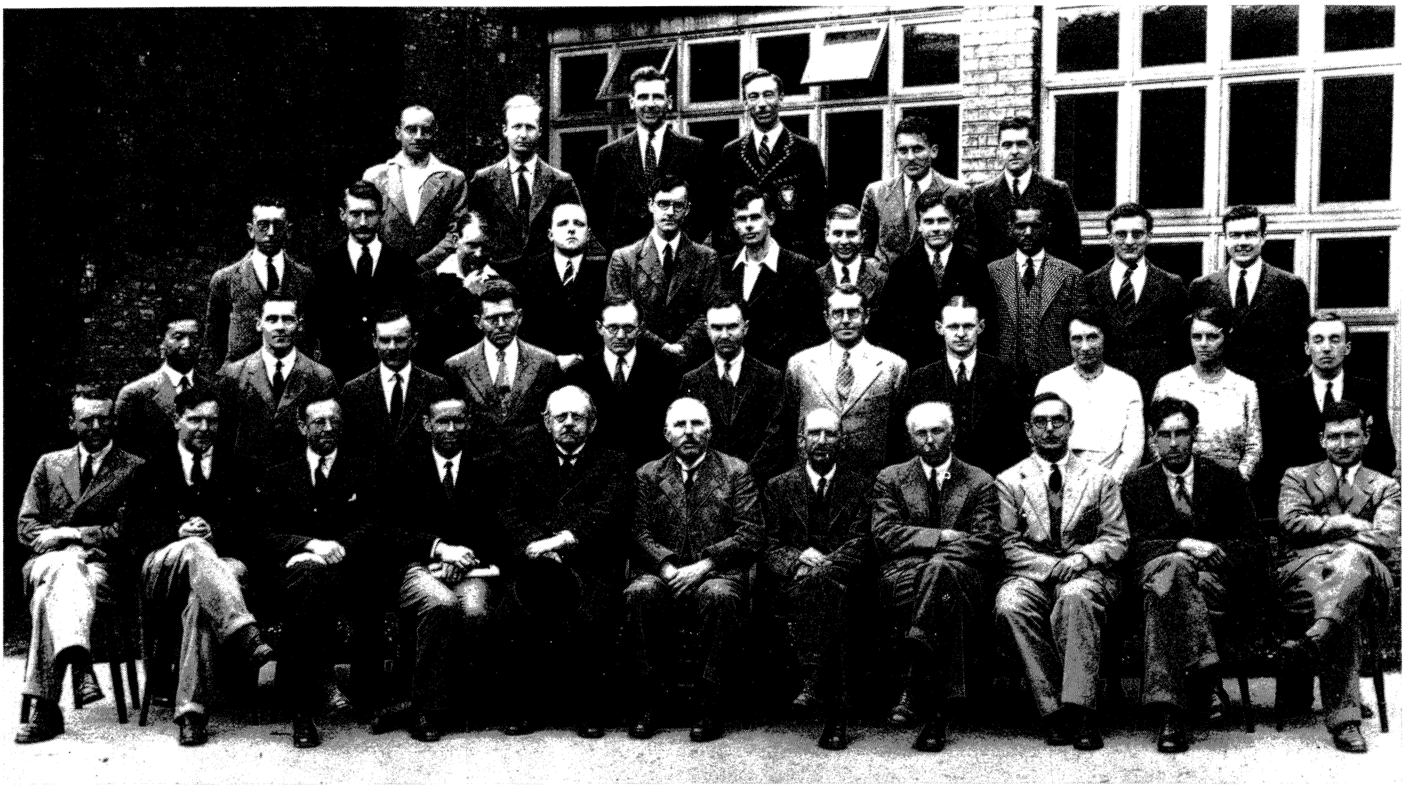
On 16 June 1874, William Cavendish, Duke of Devonshire and Chancellor of the University of Cambridge, unlocked the door of a new laboratory for the teaching of experimental physics and handed the key to the Vice-Chancellor. The building had been paid for by the Chancellor himself and the name finally adopted for the laboratory commemorated not only this benefaction but also the work of the Chancellor's distinguished ancestor Henry Cavendish on the inverse square law of the electric force and on the gravitational constant.

Nearly sixty years later, at the beginning of the 1930s, the Cavendish Laboratory had achieved a distinction in physics that placed it among the great laboratories of Europe and that attracted visitors and workers from all over the world. The first Professor of Experimental Physics, in due course re-named Cavendish Professor, was Clerk Maxwell (1871) and he was followed by Rayleigh (1879), and Thomson (1884). Each of these men contributed fundamentally to physical science and each nurtured the growing research effort of the laboratory, but it was the appointment of Rutherford (1919) and the genius of that great man that carried the Cavendish into the new science of nuclear physics and maintained its leadership in the subject for the greater part of the period between the two World Wars.

The first ten years or so of Ruther-

The historic group photograph taken at the Cavendish Laboratory, Cambridge, in 1932. Back row, left to right, N. S. Alexander, P. Wright, A. G. Hill, J. L. Pawsey, G. Occhialini, H. Miller. Third row, W. E. Duncanson, E. C. Childs, T. G. P. Tarrant, J. McDougall, R. C. Evans, E. S. Shire, E. L. C. White, F. H. Nicholl, R. M. Chaudhri, B. V. Bowden, W. B. Lewis. Second row, P. C. Ho. C. B. Mohr, H. S. W. Massey, M. L. Oliphant, E. T. S. Walton, C. E. Wynn-Williams, J. K. Roberts, N. Feather, Miss Davies, Miss Sparshott, J. P. Gott. Front row, J. A. Ratcliffe, P. Kapitza, J. Chadwick, R. Ladenberg, Prof. Sir J. J. Thomson, Prof. Lord Rutherford, Prof. C.T.R. Wilson, F. W. Aston, C. D. Ellis, P.M.S. Blackett, J. D. Cockcroft. At the time, the group already included four Nobel prizewinners (Thomson, Rutherford, Wilson, Aston), seated together in the middle of the front row. Subsequent Nobel laureates are Walton, Kapitza, Chadwick, Blackett and Cockcroft.

(Photo Cavendish Laboratory)



ford's tenure were a period of consolidation. He had disintegrated the nitrogen nucleus by alpha particle bombardment in Manchester in 1919 and when he moved to Cambridge he brought Chadwick with him to help exploit this discovery as well as to continue work in classical radioactivity. It was the task of most of the Cavendish research students, sometimes registered for the newly-established PhD degree, to contribute to this general attack on the problem of the structure of the nucleus. By 1932 the staff and research students in the Cavendish numbered about 50; the famous annual photograph of the year shows many whose names have an honourable place in the history of physics and not exclusively in nuclear physics, because there was a strong group working on radio and the ionosphere, and Kapitza with the help of Cockcroft was developing high magnetic fields and hydrogen and helium liquefiers. Most of the staff were at the time participating in the undergraduate teaching work of the laboratory or of the Colleges of the University and few had uninterrupted time for research. The laboratory itself was financed primarily by the University and although not lavishly equipped, provided the basic requirements for the research programme.

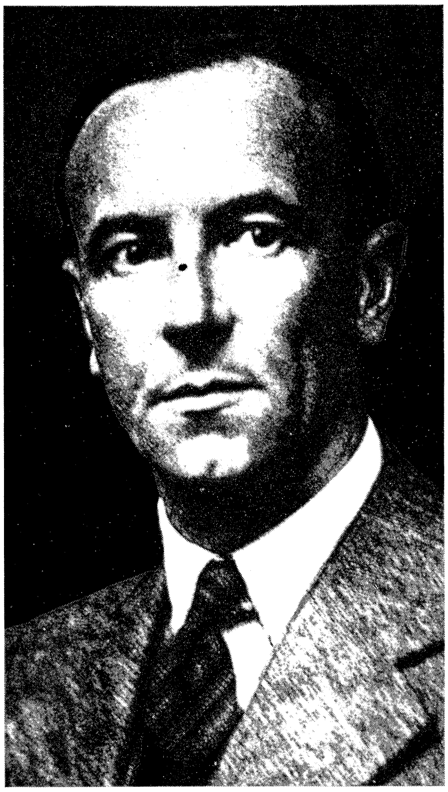
Fortunately in the nuclear physics of the time, many of the experiments were of a pioneer nature and could be approached in a simple and direct way without too much concern for competition from elsewhere. Perhaps this gave rise to the persistent tradition that the Cavendish always used the 'string and sealing wax' method. Often of course it did, but only when such techniques were adequate for the problem in hand, as they were in the work leading to the discovery of the neutron. The nuclear techniques used in the Cavendish in the years immediately preceding 1932 derived directly from Rutherford's classical work in radioactivity. Heavy charged particles were for many years detected individually mainly by scintillations of a zinc sulphide screen and beta and gamma radiation by the gold-leaf electroscope or the photographic plate. Energy measurements were made by the absorption method. Curiously enough, despite Rutherford's early use with Geiger of the proportional counter, neither this type of detector nor the point (Geiger-Müller) counter was used much in reaction studies. On the other hand the cloud chamber, brought into operation by Wilson in 1911, was used extensively and definitively to give visual confirmation of particle behaviour and in particular to study the kinematics of individual processes.

By 1932 however, technical developments were taking place. The scintillation detector was being replaced for single particle detection by the ionization chamber with amplifier and electromechanical register or oscillograph recording. And soon these recorders were supplemented by the first versions of the scale-of-two counter invented by Wynn-Williams and improved by Lewis. None of the nuclear physicists at that time had a cathode ray oscilloscope and the possibility of electronic pulse-height analysis must have seemed remote, improbable and perhaps indeed unnecessary. Magnetic analysis of course was quite another matter, since it had been much used in beta particle work from the early days of radioactivity and it stood only in need of refinement and of application to heavy particle spectra. Following the work of Briggs in Cambridge and of Rosenblum in Paris, Rutherford insisted on high resolution magnetic analysis of alpha particle groups and Cockcroft designed a low cost annular magnet of excellent performance for the purpose. This was a large instrument by the standards of the laboratory at the time but its diameter was only 0.8 m and for its maximum field of 1.8 tesla a power of only 2.2 kW was required. A further development of considerable importance was the application of Geiger counter control to the cloud chamber by Blackett and Occhialini.

The achievements of the years 1919–32 were substantial and worthwhile but not dramatic. What might be discovered was perhaps clearer to Rutherford than to anyone else and the best known of his predictions occurs in his Bakerian lecture to the Royal Society in 1920. He there explicitly postulated the existence of a tightly bound hydrogen nucleus and electron forming a neutral system which 'would be able to move freely through matter'. Staff and students were encouraged to look for this object in ways whose diversity, and lack of success, recall the quark searches of today. But such unfruitful activities did not hinder the general development of nuclear spectroscopy and the 1920s in the Cavendish saw not only a general survey of the production of protons by alpha particles incident on light elements, using natural sources of alpha particles, but also a quantitative understanding of the complexities of the beta and gamma ray emissions of the heavy elements. The alpha particle work was clearly limited by the strength of the available sources and Rutherford's thoughts often turned to the possibility of using artificially accelerated particles although the technical difficulty of generating the necessary high voltages was formidable. Fortunately news of Gamow's theory of the penetration of potential barriers by charged particles reached the Cavendish towards the end of 1928 and Cockcroft at once saw that this would bring the proton energy needed for the transmutation of light elements down below 1 MeV and make a laboratory apparatus feasible. He immediately began to assemble the necessary equipment, but many problems had to be solved and several years passed before success was achieved. Fortuitously this happened almost simultaneously with the discovery of the neutron, for which matters moved very rapidly towards the end, so that 1982 sees the fiftieth anniversary of both major events. The letters to 'Nature' announcing the discoveries were dated 17 February and 16 April 1932 respectively. Blackett and Occhialini's verification of Anderson's discovery of the positron and their demonstration with Chadwick of pair production by gamma radiation, thus confirming Dirac's theory of the electron, were published in 1933 and 1934.

Sir James Chadwick (1891–1974), discoverer of the neutron in 1932.

(Photo Royal Society)



The neutron

The neutron story is now part of most elementary courses in nuclear physics and has been authoritatively told by Chadwick himself. While studying alpha particle reactions he had not been, in his own words, 'unmindful of the possibility of the emission of neutrons, especially from those elements which did not emit protons'. One of these was beryllium which was found by Bothe and Becker in Berlin and by Webster in Cambridge to emit a neutral, penetrating radiation under alpha particle bombardment. Webster showed that the radiation was most penetrating in the direction of the incident alpha particles and Chadwick, reasoning that this might be explained if the radiation consisted of neutral particles, with possibly a magnetic moment, sought in 1931 for lightly-ionized tracks of such particles in the cloud chamber. Nothing of the sort was seen and the situation remained obscure. A few months went by and then came two startling announcements from Paris. Irene Curie had first found the beryllium radiation to be much more penetrating than originally reported and then, with her husband Frederick Joliot, had shown that it could eject protons from a thin absorber of paraffin wax placed in its path. The authors thought that the effect might be due to a Compton interaction of high energy photons with hydrogen. This conclusion was received (January 1932) with incredulity in the Cavendish by Chadwick, by Feather and more remotely by Rutherford himself, because the energies did not seem consistent with the picture of nuclear structure that was slowly building up.

Fortunately the matter could be put to an immediate test because Feather had brought from the USA a number of old radon tubes from which Chadwick himself prepared a suitably strong polonium alpha particle source. He used this source to repeat and confirm the Curie-Joliot experiments and quickly added to them the observation that not only hydrogen nuclei could be projected forward by the radiation but also the nuclei of other atoms, for instance nitrogen. Quantitatively the velocities were those expected if the primary radiation was a stream of neutral particles with a mass about equal to that of the proton. To clinch the matter, he returned to the cloud chamber and this time, with Feather's help, short heavily ionized tracks were seen; the letter to 'Nature' was sent off on the following day with the proposal that the beryllium radiation was due to the reaction $^{9}Be(\alpha,n)^{12}C$.

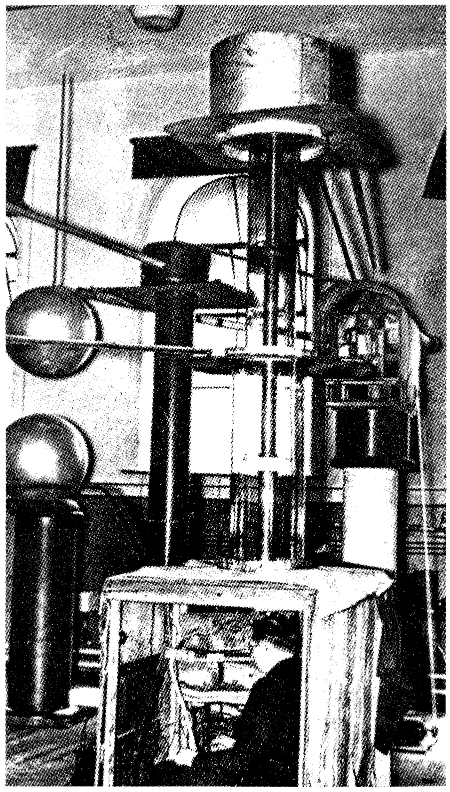
There followed a period of excitement at Cambridge while the Cavendish thought about its new particle, but it was a period of hard work as well and when Chadwick's full paper appeared later in 1932 it was accompanied by accounts of Feather's expansion chamber study of the elastic and inelastic collisions of neutrons with nuclei and of Dee's highly important cloud chamber search for the neutron-electron interaction. In the space of a few months not only the existence of the neutron but some of its important properties had been established.

Transmutations by protons

There is some connection between the discovery of the neutron and the parallel work of Cockcroft and Walton on proton acceleration, because Chadwick had at one time believed that Rutherford's neutron might be produced in an electrical discharge in hydrogen at a voltage of something like 200 kV. Direct voltages up to 280 kV were in fact applied by Cockcroft and Walton, following earlier work by Allibone, to a continuously evacuated glass bulb containing an accelerating gap and part of their motivation was the possibility of stimulating 'a nuclear radiation of the type discovered by Bothe and Becker'. In first tests, using proton beams of about 10 microamps, radiation from targets of beryllium and lead was sought using a gold leaf electroscope, but yields were low and no nuclear effect was established. Encouraged by Gamow's calculations and by Rutherford's intuition (and the modest financial support that he extracted from the University), Cockcroft and Walton set about extending their accelerating voltage to 800 kV in a high room suitable for the purpose. Their

The original Cockcroft-Walton apparatus.

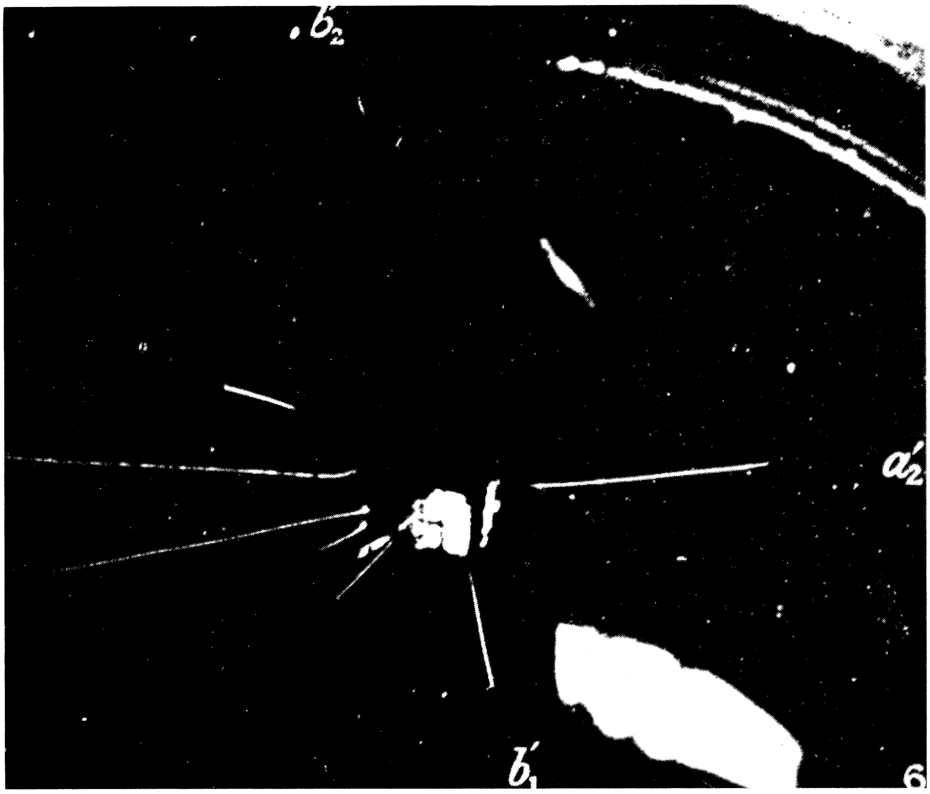
(Photo Cavendish Laboratory)



improved apparatus employed the voltage doubler principle with a transformer, rectifiers and condensers. The central component was a tall, continuously pumped rectifier tower whose glass sections were sealed to electrode plates using a plasticene-like compound. The two-section accelerating tube was also continuously pumped using an oil diffusion pump of generous dimensions (for the time) capable of handling the input of hydrogen gas from the discharge tube ion source. The accelerated protons in this apparatus were allowed to pass out into air through a mica window but no mention of nuclear effects was made in a paper on the technique that was submitted to the Royal Society on 23 February 1932. It seems that Cockcroft and Walton's first concern was to measure the range of their protons in air but then, in Cockcroft's own words, 'after wasting a certain amount of time in this way, until prodded by Chadwick and Rutherford, we directed it on to a lithium target and at once observed, with a zinc sulphide screen, the bright scintillations which were obviously due to particle emission from the lithium'. This detection of the $^7Li(p,\alpha)^4He$ reaction was a delight to Rutherford, especially as the products were his beloved alpha particles, and as they had been observed with his favourite detector, the scintillation screen, although the ionization chamber, amplifier and oscillograph were also used. Although there was little doubt, the final proof was left to the cloud chamber, and the beautiful pictures obtained by Dee and Walton confirmed the transmutation scheme in kinematic detail. For Dee's work a track chamber and accelerating tube were set up in and above a hut in Cockcroft's laboratory known as Newnham Cottage, after Rutherford's residence.

... and afterwards

The neutron discovery has rightly attracted wider anniversary recognition than the Cockcroft-Walton experiment because of the particle's special role in both theory and application. The work of Cockcroft and Walton however had the more profound effect on the Cavendish and other nuclear laboratories because it inaugurated the age of nuclear machines, of which the apotheosis may be seen in CERN today. At Cambridge new accelerators were built (or procured when funds became available) and Rutherford himself used a low voltage transmutation equipment constructed by Oliphant for the first study of the deuteron-deuteron reactions. With the availability of deuterium, the important photodisintegration reaction was observed by Chadwick and Goldhaber and the neutron mass was confirmed to be greater than that of the proton, contrary to the Rutherford proposal of 1920. Rutherford died in 1937 and thereafter the influence of the Cavendish Laboratory on nuclear physics inevitably declined, although the decline had indeed started earlier with the migration of Blackett, Chadwick, Ellis, Mott and Oliphant to chairs elsewhere, partly at least because of misgivings about the likely future level of resources for nuclear physics in Cambridge. The dispersion of talent was good for nuclear science in the United Kingdom as a whole, and those remaining in Cambridge were not short of ideas, but the best times for nuclear physics were past and as the clouds of war gathered it was clear that the Cavendish was to be a radically different place in the future. That has indeed happened but nothing has taken place to deny to the laboratory the special honour in nuclear history that it gained some fifty years ago.



1933 cloud chamber picture by Dee and Walton of a reaction using artificially accelerated protons.

Physics monitor

Monopole sighting?

Earlier this year, a young Stanford University physicist saw Something in the response of his superconducting magnetometer. The signal appears to correspond to what would happen if a magnetic monopole had passed through the apparatus, although more mundane (and less interesting) explanations cannot yet be ruled out.

The absence of free magnetic poles has long intrigued physicists, as the equations of electromagnetism appear to be symmetric with respect to electric and magnetic charge. Paul Dirac revived the idea of magnetic monopoles and predicted that the magnetic charge should be simply related to other physical constants.

Recently the search for free magnetic poles has been given additional impetus by the predictions of grand unified theories which attempt to bring together electroweak and strong interactions (see May 1980 issue, page 114).

Superconductors make natural magnetic charge detectors. In the Stanford experiment, a four turn 20 cm^2 horizontal loop is connected to the superconducting input coil of a SQUID (Superconducting Quantum Interference Device) magnetometer. Both the loop and the SQUID are enclosed in a magnetic shield with an ambient field of 5×10^{-8} gauss. The signal from the detector is continuously monitored and during some 150 days of operation showed no disturbances other than those caused by periodic transfers of liquid nitrogen and liquid helium.

But on 14 February the apparatus hiccupped. A single event was recorded which is consistent with a stray magnetic monopole with Dirac charge passing through the loop.

In such a sensitive experiment, care was taken to minimize effects which could also produce such a signal. The apparatus is continuing to take data and larger detectors are also being built.

Blas Cabrera in his laboratory at Stanford University where his apparatus recently gave a signal compatible with the passage of a free magnetic monopole.

(Photo Stanford University News and Publications Service)

Computing the hadron spectrum

One of the basic problems in the theory of strongly interacting particles is whether the gauge theory of gluons and quarks (quantum chromodynamics — QCD) can indeed account for the observed properties of hadrons. To do this, the theory must explain both the quasi-free behaviour of quarks when probed at small distances and their apparent confinement inside hadrons at relatively large separations. The behaviour at small distances (i.e. high energies) can be theoretically studied by perturbative techniques, since it can be shown that the strength of the interaction then becomes sufficiently weak (a condition known as asymptotic freedom). The domain of low energy phenomena, including the problems of hadron spectroscopy, lie outside the reach of perturbation theory, and until recently looked difficult to attack.

A special way of regularizing quantum chromodynamics, with the continuum of space-time replaced by the points of a discrete lattice, has opened the way towards powerful new non-perturbative techniques. The correct method of defining gauge theories on the lattice has been given by Ken Wilson of Cornell. He was the first to propose the application of different non-perturbative methods, like strong coupling expansions, variational methods and Monte Carlo techniques, to high energy systems.

The first spectacular results on the confining force between quarks obtained by Mike Creutz at Brookhaven using Monte Carlo methods were followed by a burst of quantitative results from theorists at a number of different centres. These studies led to rather conclusive evidence for quark confinement, a determination of the value of the 'string tension' (the parameter characterizing the force between quarks) and predictions on the glueball spectrum. The initial temperature when the hadron matter goes over to non-confined gluon (and quark) constituents has also been determined. Recently a numerical determination of the masses in the spectrum of hadrons has been attempted.

The Monte Carlo method, sometimes combined with other techniques, seems to be the most effective way for studying lattice gauge theories. Monte Carlo simulations have been used for several years in the analysis of thermodynamical systems. Thermal averages are expressed as sums over configurations weighted by the Boltzmann factor (the quantity exp $(-E/kT)$, where E, T and k are respectively the internal energy, temperature and the Boltzmann constant). Although the number of terms in these sums is enormous, it is a crucial property of thermodynamical systems that effectively only a subset of all possible configurations contribute to the averages. Monte Carlo simulations work by sampling this set. An algorithm is devised to produce a (pseudo) stochastic sequence of configurations such that the probability of encountering any definite configuration in the sequence is proportional to the Boltzmann factor. Averages are then computed as averages over the configurations occurring in the sequence. The current values of all dynamical variables are stored in the memory of the computer. The basic step in going from one configuration to the next consists of altering the value of one of the dynamical variables. If the change lowers the energy it is accepted and the new configuration replaces the old one. If the energy is increased, then the change is accepted with a conditional probability. This process simulates the thermal fluctuations.

In quantum field theories, the average (observed) values of quantities are also expressed as averages over all configurations, the weighting factor being $\exp(-iS/h)$, where S is the action of the configuration and h is Planck constant. The trick of rotating to imaginary time converts this factor into the better defined measure $\exp(-S/h)$ — time is extrapolated back to real time at the end of the calculations. Using lattice regularization, the formulae giving the average quantum expectation values take precisely the same form as those for the thermal averages: the replacement of E/kT with S/h and the fact of working in four dimensions being the only reminder that a quantum field is being handled.

Of course, the lattice is only a computational tool. At the end of the calculation the lattice distance should be extrapolated to zero and a continuous field theory recovered. The available evidence seems to confirm that this indeed can be done. In the perturbative regime, lattice quantum chromodynamics is equivalent to the usual continuum formulation, and a link can be established between the perturbative results obtained earlier in continuum QCD and the new lattice results. For the non-perturbative lattice calculations, renormalization group arguments dictate a very definite behaviour in the continuum limit. Confronting the Monte Carlo data with this expected behaviour helps to decide whether the correct continuum limit is obtained, assuring that the measured quantities are free of lattice artefacts. It is surprising that on a lattice with some 10^4 lattice points only, this continuous behaviour can be simulated rather consistently.

Realistic models for strong interaction must take account of fermion (namely quark) degrees of freedom. Many of the most recent developments in Monte Carlo simulations have concentrated on incorporating the effects of fermionic fields into the algorithm. Several schemes have been devised: basically the quarks are studied in the presence of a fixed gauge field background and expectation values of fermionic observables are computed. These expectation values are then further averaged over a large set of configurations of the gauge field.

The probability distribution of these configurations is only partly determined by the pure gauge field dynamics: vacuum fluctuations may modify the gauge field distribution. Methods to deal with this dynamical feedback from the fermions have been proposed by several authors and tested on lower dimensional models with a reasonable degree of success. Arguments can be given to support the idea that a good approximation may be obtained by neglecting this effort and letting the distribution of the gauge fields be governed by its own action. This approximation has been applied to obtain estimates for the hadronic mass spectrum first in SU(2) and then in SU(3).

Hadronic masses are determined by measuring the correlation between one two-quark quantity, which creates a meson at zero time, and another which annihilates it at time t. In Euclidean space-time the lowest rate of decay of the correlation is expected to be given by exp(—mt), where m is the mass of the state. By making t sufficiently large, such a behaviour can be isolated and a value for m derived. In both SU(2) and SU(3), the mass of a pseudoscalar state goes to zero when the quark mass is set to zero, in agreement with the notion of spontaneous symmetry breaking. For the SU(2) case, the 'experiment' has been performed by E. Marinari, G. Parisi and C. Rebbi.

Using the pion mass to fix the quark mass and the independently derived value of the string tension, one obtains 800 ± 80 MeV for the mass of the rho meson, 950 ± 100 MeV for the mass of the scalar delta meson and 150 ± 10 MeV for the pion decay constant. Similar estimates have been obtained by Don Weingarten of the University of Indiana. Applying the same approximation to the SU(3) gauge theory, which also covers baryons, Herbert Hamber of the Brookhaven Solid State Theory Group and G. Parisi have derived rather encouraging results.

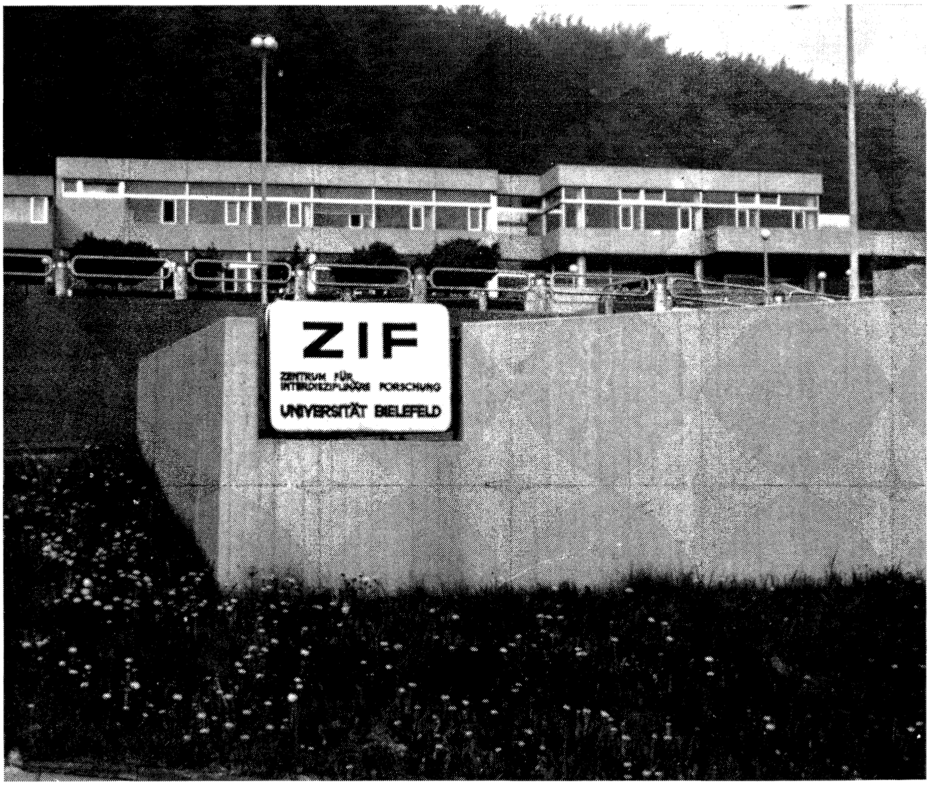
Recently the experiment has been repeated at CERN by a CERN / Rome group with better statistics and a more accurate analysis of the errors. Although the errors are rather large, the general pattern tends to reproduce the experimental data. The statistical fluctuations are particularly strong for baryons: analogous difficulties arise in this case within a different approach, based on a semi-analytic method recently discussed by a CERN group. The results for the meson spectrum obtained in the latter approach are of the same quality as Monte Carlo results. The general trend of the predictions is rather encouraging, mainly if one considers that a rather poor spatial resolution, of the order of 0.2 fermi, has been used in the computation.

Given the approximation involved, this body of results gives very strong support to the validity of quantum chromodynamics as the theory of hadronic interactions and leaves us with some optimism that we may arrive at a complete understanding of hadrons in the not too distant future.

(We are grateful to Claudio Rebbi, Peter Hasenfratz and Roberto Petronzio for their assistance in preparing this article.)

The Centre for Interdisciplinary Research at the University of Bielefeld, scene of the recent meeting on physics with heavy ion collisions.

(Photo D. Penke, Bielefeld)



In search of quark matter

There is a growing belief that matter at very high densities and temperatures could exhibit new properties. From 10—14 May, the Centre for Interdisciplinary Research of the University of Bielefeld, Germany, was host to a meeting which brought together over one hundred physicists sharing a strong common interest in the quest for such new physics in heavy ion collisions.

The quark densities considered are several times those found in nuclei and the temperatures talked about are of the order of 200 MeV. According to quantum chromodynamics (QCD) a new phase of matter, consisting of a quark-gluon plasma, will appear under such conditions (see December 1981 issue, page 455).

Uranium in Bevalac

On 11 May, the Bevalac at the Lawrence Berkeley Laboratory successfully accelerated its first beams of uranium ions. The Berkeley Bevatron and its linac injector, the Super HILAC, have both undergone improvement programmes to enable such heavy ions to be handled. The new ABEL ion source was commissioned late last year. The recent success follows installation of a new Bevatron vacuum system. Many experiments are lined up to use the new heavy ion beams, including the 'Plastic Ball' and the HISS heavy ion spectrometer system (see November 1981 issue, page 393).

As the density and/or temperature eventually fall, the plasma condenses into hadrons through a phase transition which theorists are trying to understand through non-perturbative QCD calculations on a lattice (see previous article).

It is reasonable to think that such conditions could be achieved in heavy ion collisions with ion beams of incident energy of the order of 100 GeV/nucleon. This is two orders of magnitude above what is presently considered as 'high energy' heavy ion research (Bevalac, Saturne II, Dubna...) but could be envisaged, in a not too distant future, from ions accelerated in larger machines, such as those at CERN.

Theoretical progress recently achieved, new knowledge gained from the wealth of data already accumulated at the Bevalac, and the possibility of using existing proton machines for this research at a limited cost, called for a meeting to survey the present state of knowledge and to provide a forum for discussion.

The Bielefeld meeting brought together an unusual even mix of experimentalists and theorists from particle and nuclear physics. A highly congenial and cooperative atmosphere, conducive to very fruitful work, prevailed throughout. The morning sessions were organized around plenary talks aimed at all participants. This information was part of the input for the afternoon sessions involving seven different specialized working groups.

The last day of the Workshop was given over to a general status report, organized as an open conference which actually filled the auditorium. S. Nagamiya (Tokyo) reviewed present energy heavy ion physics at the Bevalac. Machine prospects were surveyed by H. Pugh (Berkeley). H. Gutbrod (Darmstadt) talked about the 'medium' energy proposal to use oxygen 16 ions at the CERN PS. M. Albrow (Rutherford) presented the very large amount of work which the various experimental groups had done with some very concrete proposals very much in line with current theoretical ideas. L. Van Hove (CERN) concluded the meeting with a review of the theoretical situation.

Heavy ion collisions as discussed in Bielefeld could well be the way to reproduce conditions which could have prevailed in our very early Universe, less than 10^{-4} s after the initial 'Big Bang'. After that the vacuum as we know it was created as the expanding and cooling quark-gluon plasma condensed into hadrons.

The thinking behind the use of heavy ion collisions to investigate these new frontiers was eloquently described by Bill Willis in the article published in our January/February issue, page 17.

(We are grateful to Maurice Jacob for the report of the recent Bielefeld meeting.)

Fly's Eye

First results are being produced from the University of Utah's 'Fly's Eye' cosmic ray detector, designed to study extensive air showers in the energy range 10^{17} to 10^{21} eV. The idea is to detect and measure the atmospheric fluorescence produced by these extreme energy particles. Although the atmosphere is in fact a poor scintillation medium, this is compensated by the enormous numbers of secondary charged particles produced. The experimenters compare it to tracking a five-watt blue light bulb travelling through the sky at the speed of light.

There are two detecting stations, separated by a distance of 3.3 km. The first station (Fly's Eye 1) consists of 67 62-inch mirrors together with 880 associated photomultipliers and light collectors arranged in clusters in the focal plane of each mirror. This detector is able to image the entire night sky and pick up the extensive air showers produced by the incoming primary cosmic particles. The other detector is smaller and contains eight mirrors and photomultiplier clusters.

As a check on the tracking and measuring procedures, a flash tube has been installed at Fly's Eye II and is periodically fired over the main detector (this flash tube is soon to be replaced by a nitrogen laser). This is also able to extend knowledge of how the atmosphere attenuates and scatters light.

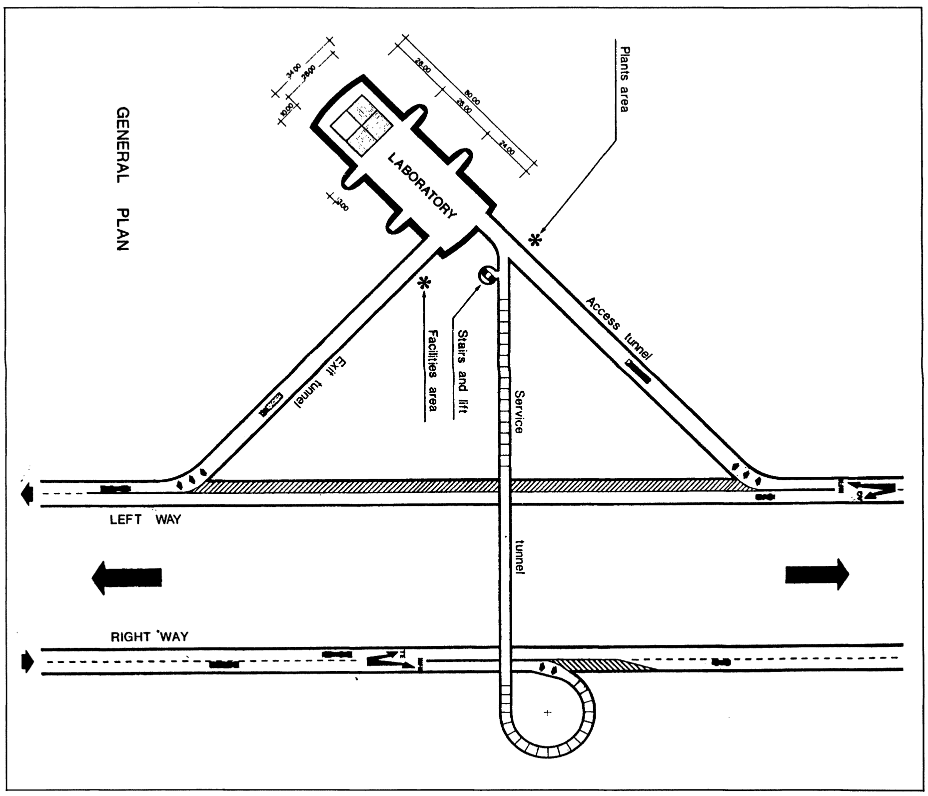
The experimental group hopes to be able to answer questions in both particle physics and astrophysics, and to disentangle particle physics and astrophysics effects.

The low luminosities provided by Nature limit the detector to the study of processes with relatively high reaction rates. Potential topics for study include total cross-sections, secondary multiplicities, searches for unusual events, and a study of the composition and the spectrum of cosmic rays.

A sample of 1500 events gives a high energy cosmic ray spectrum which is consistent with measurements from other experiments. Interesting indications are found as to the direction of arrival of extreme energy primary cosmic ray particles. The attenuation of cosmic ray showers gives a clue to the proton-proton cross-section at these energies. A proton-proton total cross-section of 120 millibarns is estimated, but more precise results could be obtained from a larger data sample.

Another possibility is the study of extragalactic neutrinos. At large angles, the earth's atmosphere is so thick that protons cannot generate showers near enough the detector to be picked up. This large angle sector provides a good place to search for neutrino events. Their absence in the initial data sample gives a limit on the cosmic ray neutrino flux.

Plan of the Italian Gran Sasso underground laboratory, showing the access and service tunnels leading off the main 10 km-long road tunnel.



Underground tremors

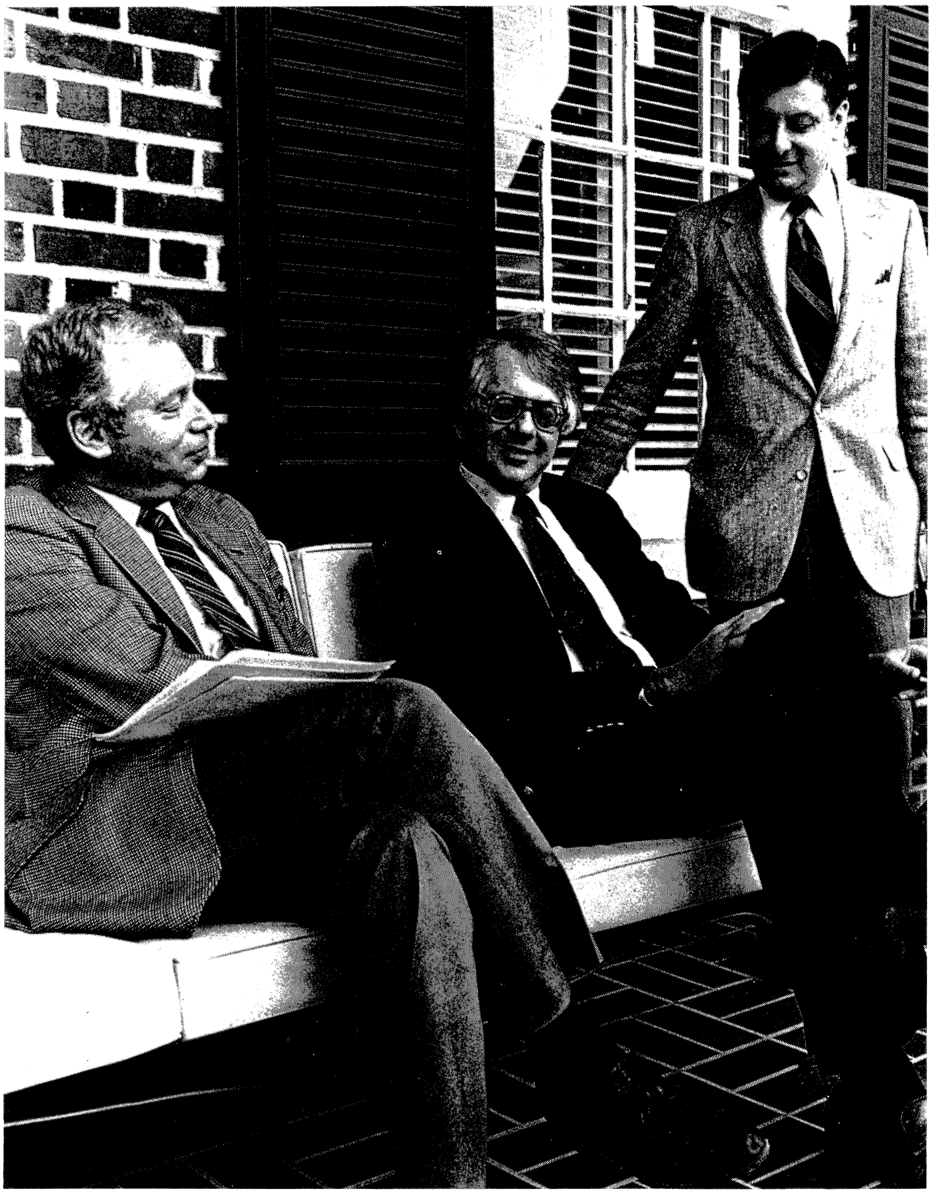
The prediction of the unstable proton continues to lure physicists away from their habitual working environments at high energy physics laboratories to new 'passive' experiments, under way or under construction deep underground to shield off cosmic ray background.

The 'grand unified' theories which attempt to synthesize electroweak and strong forces into a single conceptual framework predict that the proton should live for some 10^{32} years, the exact exponent depending on the theoretical input. To catch such rare decays needs big detectors.

Broadly, the experimental projects can be divided into two classes, those using Cherenkov radiation produced in a large volume of water, and those using slabs of heavy detector interspersed with electronics.

Examples of the water Cherenkov type are at the Morton Salt Mine in Ohio (Brookhaven / Irvine / Michigan), the Silver King Mine in Utah (Harvard / Purdue / Wisconsin), the Homestake Gold Mine in South Dakota (Brookhaven / Pennsylvania) and the Japanese Kamioka project (KEK / Tokyo / Tsukuba).

Two electronics experiments are already operational, at the Kolar Gold Fields in South India (Bombay / Osaka / Tokyo) and at the Soudan Iron Mine in Minnesota (Argonne/Minnesota / Oxford). The Kolar Gold Fields search produced its first proton decay candidates last year (see



Nobel prizewinners Steve Weinberg (left) and Sheldon Glashow with Paul Frampton (standing), organizer of the recent Workshop on Grand Unification held at the University of North Carolina, Chapel Hill. Following the prediction of an unstable proton by theories which attempt to unify strong and electroweak interactions, such meetings are now a regular feature of the current particle physics scene.

(Photo Will Owens)

July/August 1981 issue, page 253).

In Europe, work is under way for additional electronics experiments in the Mont Blanc tunnel (CERN / Frascati / Milan / Turin) and in the Frejus tunnel (Ecole Polytechnique / Orsay / Saclay / Wuppertal). These will soon be joined by the new Italian project in the Gran Sasso tunnel (Frascati / Milan / Rome / Turin).

The Italian Gran Sasso project is one of the newer arrivals on the scene, and the bill for its construction has been approved by the Italian authorities in record time. It votes 2×10^{10} Italian lire (about 15 million dollars) for the construction of the new underground laboratory 1400 m below ground off the 10 km-long Gran Sasso road tunnel near Rome.

Unlike other underground laboratories using existing road tunnels, the Gran Sasso project can get under way before the road tunnel comes into regular operation. Special access and service tunnels for the laboratory are planned, so avoiding some of the problems with other underground projects.

As well as the underground laboratory itself, big enough to house a 10 000 ton detector, additional accommodation near the entrance to the tunnel would include offices, library, guest rooms, workshop and lecture hall. The laboratory would be open to all. A modular detector is envisaged, so as to encourage participation by smaller groups.

Unexpected results with polarized hyperons

Although the Argonne ZGS machine ceased operation some three years ago, interesting results are still emerging from the mass of collected data. Whenever spin physics is discussed, the unexplained effects found with polarized protons at the AGS (see October 1978 issue, page 347) still figure prominently, and underline the need for polarized proton studies at higher energies (see June issue, page 180). Now another interesting Argonne ZGS result has appeared in the analysis of the beta (semileptonic) decay of polarized hyperons.

An Argonne / Chicago / Ohio team studied the decays of polarized negative sigma particles, produced in negative kaon-proton reactions tuned to the neutral Y* (1520) resonance. The experiment measured the up-down asymmetry (parity violation) of the emitted electrons with respect to the spin direction of the parent sigmas.

One of the notable physics successes of the early 1960s was the development by Nicola Cabibbo and others of a simple formalism which explains why certain decay channels are favoured and others suppressed in the weak decays of particles. The idea was to assign SU(3) symmetry properties to the weak currents. It has become a cornerstone of particle theory and has since been extended to cover charmed particles.

In beta decays, the 'handedness' of the emitted particles provides essential clues to the nature of the underlying weak force mechanisms. It was through precision studies of the asymmetries of particles emitted in nuclear beta decay that the very special characteristics of the weak force were discovered.

Not only is the new observed asymmetry in polarized sigma decays different to that predicted by the Cabibbo theory, it is also in the wrong direction! However radiative corrections have yet to be made and momentum dependence applied, which could affect the result.

The Cabibbo picture is only supposed to be approximate, but the emergence of a result so drastically different to the predicted value is puzzling.

Spin-related hyperon measurements have a habit of giving unexpected results from time to time. Hyperons produced in unpolarized hadron collisions tend to be polarized. Some of the observed hyperon magnetic moments do not fit otherwise successful theoretical models.

Anomalons

Evidence continues to accumulate for 'anomalons' — some interesting and as yet unexplained behaviour observed in nuclear collisions. A number of experiments have found extremely reactive secondary nuclear fragments close to the collision point. The lifetime of these states is of the order of 10^{-11} seconds, certainly stable against strong nuclear decays and long-lived by any nuclear standards.

Anomalons (the name arose after a mistyping of the word anomalous) are an order of magnitude more reactive than ordinary nuclear matter of the same mass. Nuclear excitations which could produce such behaviour typically live for 10^{-23} to 10^{-16} seconds. The 10^{-11} second anomalon lifetimes defy comprehension.

Hints of such behaviour had been seen in cosmic ray events some thirty years ago. Now it has been observed by a number of teams using heavy ion beams with energies around 2 GeV/nucleon at the Berkeley Bevalac. A Berkeley/Ottawa collaboration has evidence from the interactions of iron and oxygen ions in emulsion targets, and a Buffalo (New York) group has examples from iron and argon beams. This team reports no anomalons with iron beams at half the energy, and has made a special search for anomalon alpha particles, without success. More anomalon evidence comes from a Minnesota cosmic ray group using samples flown from balloons.

There is no shortage of theoretical candidate mechanisms. Many of these involve unusual quark configurations, such as a 'demon' deuteron involving three quark pairs instead of the conventional deuteron of two nucleons, each containing three quarks.

Counting neutrinos

A new experiment by Los Alamos researchers could go on to provide new clues in the study of the neutrinos emitted by the sun.

An appreciable flux of neutrinos should be produced by the intense thermonuclear reactions deep in the sun's interior which attain the enormous temperatures able to resist the huge gravitational compression. The flux of these neutrinos, which should be measurable on earth, provides in principle a useful thermometer to measure the temperature of the sun's interior.

For many years, a Brookhaven experiment led by Ray Davis has been using a neutrino detector 5000 feet below ground in a South Dakota lead mine to intercept these solar particles. But this study has only intercepted a fraction of the expected neutrino level.

The Brookhaven experiment looks for neutrino-induced reactions more or less as they occur. However the Los Alamos study plans to look for signs of neutrino interactions in fossil ores in which the products of millions of years of exposure to solar neutrinos would be stored.

Residues from molybdenum ore mined a mile below the earth's surface in Colorado's Red Mountain will be brought back to the Laboratory and examined for the presence of three isotopes of technetium, including two that result directly from the interaction of neutrinos with molybdenum. These isotopes, with half-lives ranging from 200 000 to four million years, should provide a record of neutrino abundances over the millenia.

As well as finding any 'missing' neutrinos emitted by the sun, such a study could reveal systematic variations in the sun's activity.

Another possibility now receiving attention is the construction of directionally sensitive neutrino detectors containing large amounts of material with polarized nuclear spins.

Muonium in a vacuum

Muonium is an atomic state consisting of a positive muon and an 'orbital' electron. For atomic and chemical purposes it is aptly described as a light isotope of hydrogen with about one ninth of the hydrogen mass. Because it is composed of (supposedly) pointlike particles with no strong interactions, it is a potentially useful way of testing exact predictions.

Muonium is usually formed by slowing down beams of positively charged muons in matter. The interaction of this muonium with the target material is exploited in the muon spin rotation technique (see, for example, March issue, page 64). However this interaction can be undesirable if precision measurements on muonium itself are required. Recent developments at LAMPF and at TRIUMF have succeeded in producing muonium in a vacuum by passing low energy muon beams through thin foils.

According to relativistic (Dirac) electron theory, certain excited atomic states should have exactly the same energy. However this is not the case, and the tiny energy difference — the Lamb shift — is used as one of the standard tests of modern quantum electrodynamics. Because it avoids the complications of protons, muonium provides a potentially good laboratory for making precise measurements. Preliminary measurements of the Lamb shift in muonium have been made at TRIUMF, and are consistent with theory.

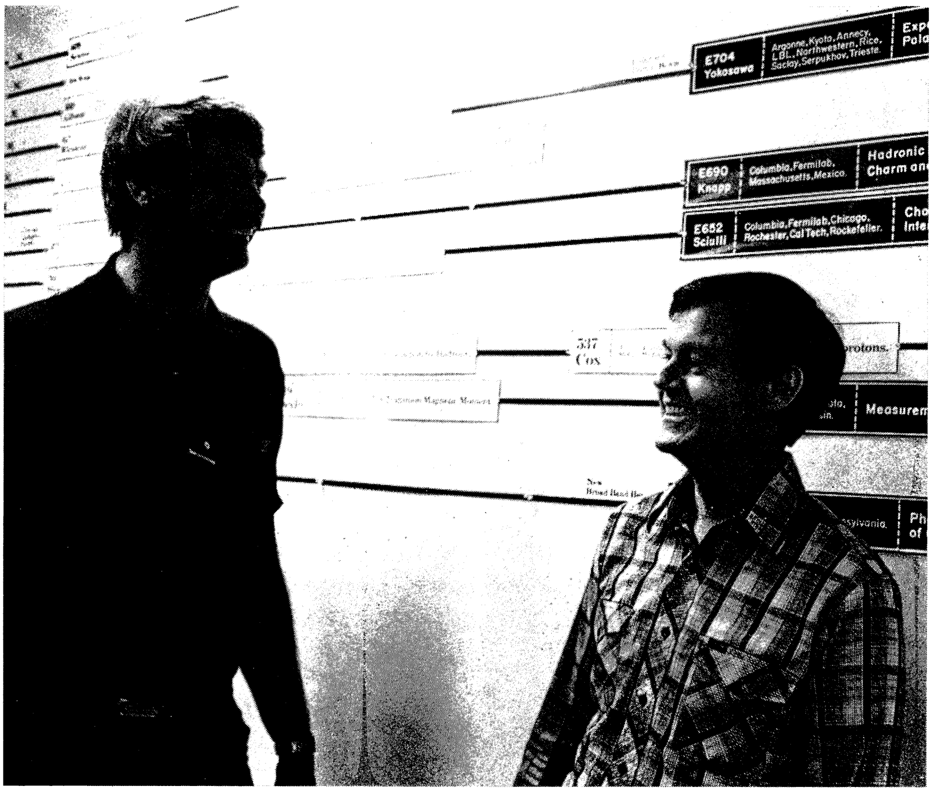
In the most easily accessible example of the Lamb shift, the lower of the two adjacent energy levels cannot decay directly and is thus metastable. This state has been observed at TRIUMF. When a strong electric field is applied, it is partially converted through the Stark effect to an adjacent state, which radiates down to the ground state. The intensity of the emitted radiation depends on the degree of conversion achieved, and gives an indication of the Lamb shift.

Measurements of the muonium flux from a variety of different foils are under way at TRIUMF and methods are being considered for precise measurements of muonium Lamb shifts.

FERMILAB Tevatron II gets under way

This spring Fermilab was given the go-ahead for Tevatron II, the project to upgrade the Laboratory beam switchyard and experimental areas for operation at 1000 GeV (1 TeV). Broad unexplored energy regimes will open for fixed target physics. For example, the gain in the event rate of energetic interactions and the doubled energy of the proposed muon beam will allow expanded measurements of the quark structure functions of the nucleons and sensitive tests of quantum chromodynamics predictions. Careful measurement of high energy neutrino interactions will test the unified description of leptons, including the predicted damping of the total event rates from the anticipated effect of the intermediate vector boson. The production of heavy quarks is greatly enhanced at higher energies. At the same time the combination of higher beam energies and new detector technology will make it possible to study particles with lifetimes as short as 10^{-13} seconds. As a result, it may be possible to study charm and bottom mesons in detail, and to start to look at tau neutrinos.

Tevatron II is one leg of the overall Tevatron triangle. The base is the Energy Saver/Doubler — the construction of a superconducting accelerator ring in the present main ring tunnel. A fair fraction of the installation of the Energy Doubler is complete. The remainder will continue this summer. The second part of the overall project, Tevatron I, is the construction of an antiproton source and other associated facilities to permit proton-antiproton collisions in



Tom Kirk (left), Project Manager of Fermilab's Tevatron II, seen with Deputy Project Manager Roger Dixon.

(Photo Fermilab)

A deliberate night 'quench' of a portion of the Fermilab superconducting ring, showing the effects of cold evaporating gas escaping through a safety valve.

(Photo Fermilab)

the new ring with 2 TeV total energy. The added refrigeration and acceleration systems provided under the Tevatron I project will make it possible to accelerate protons to 1 TeV at a rate close to 100 GeV/s and to provide long beam spills for experiments. The third part is Tevatron II, the fixed target areas energy upgrade.

There will be Tevatron II activities in both the Accelerator and Research Divisions. Personnel from the Accelerator Division will handle the primary beam extraction and modifications in the switchyard while the Research Division will carry out the upgrade on the experimental areas. Tom Kirk, deputy head of the Research Division, is the project Manager of Tevatron II. Roger Dixon of the Accelerator Division is Deputy Project Manager.

A great deal of work has gone into planning the Tevatron II project. A summer study in 1976 developed an initial list of possible physics objectives, desirable new facilities, and modifications to existing ones. In the following years a number of workshops at the Laboratory refined the approach to the various experimental areas. In 1980 a comprehensive design study was developed for the programme. User interest and involvement in these plans have been intense at every stage.

All of the improvements for the current 400 GeV programme in the experimental areas over the last several years have also taken into account future Tevatron operation. Examples include the installation of the superconducting left bend to the Meson Area in 1980 and the installation of iron from the Argonne ZGS in the neutrino muon shield.

The bloodstream of a fixed target laboratory is the switchyard and the associated extraction facilities. The Tevatron II design uses the existing 400 GeV switchyard enclosures to the maximum extent possible. The Tevatron will have both slow resonant extraction and fast resonant extraction with a spill of 1 to 3 ms. One advantage of the superconducting ring is the possibility of an extremely long spill extending over many seconds with a consequent improvement in duty factor of the beam. However this places additional demands on beam extraction.

An important part of the switchyard construction will be a superconducting right bend for the Proton Area. The right bend is a 5° horizontal bend to the east in the primary beam transport to the Proton Area. It will be made with 12 Energy Doubler dipoles running at 40 kG (1000 GeV). This is approximately one half the size of the existing left bend cryogenic system to the Meson Area.

Each of the experimental areas will undergo a major upgrade and will see the addition of new features. In the Proton Area the existing broad-band photon beam will be replaced with a high intensity electron beam. The designers have aimed for a very large momentum acceptance, ± 15 per cent, and a large solid angle of 4 microsteradians. The beam will be able to transport electrons up to 800 GeV. These will be converted to photons in a radiator. The beam will be operated purely as a bremsstrahlung beam with no tagging of the photon energy, permitting high photon fluxes up to 500 GeV. It can also be used as a high energy neutral hadron beam. A splitting station will permit simultaneous and independent operation of this beam with the tagged photon beam. A new detector enclosure will be built in the high intensity electron beam capable of supporting two experiments.

In the Neutrino Area a completely

new 800 GeV muon beam will be added to the east of the existing neutrino line. Stretching more than 8000 feet from the switchyard enclosure to well beyond the existing bubble chamber complex, the beam consists of three parts — a hadron capture section, a FODO quadrupole decay channel, and a muon transport section. The quadrupoles for the decay channel are contained in fifteen small buried enclosures, each spaced 200 feet apart. Conventional quadrupoles will be used rather than superconducting ones because of the wide spacing. The muon transport section follows the same pattern. A new experimental area will be constructed at the end of the line. An active prompt neutrino beam dump will also be constructed. This will be located directly upstream of the existing Neutrino Area experiments. A new high energy dichromatic neutrino train will be available so that the increased energy can be exploited for neutrino physics.

The principal new feature in the Meson Area will be a polarized proton beam that will cover the energy range from 70 to 350 GeV. Argonne National Laboratory will supply the dipole magnets for the project, to be built as a joint Argonne/Fermilab project. The beam is produced by using the polarized protons from the decay of lambda particles. A special array of dipoles called a 'snake' will make it possible to rotate the polarization to any orientation.

The targeting arrangements for the upgraded Meson Area have been a source of intense discussion. A new philosophy has evolved so that the three primary beams are handled separately, permitting more flexible operation and simplifying the switchyard requirements.

The Tevatron II construction project will last until 1985. Improvements will be made first in the primary beams. The secondary beamlines will benefit from the energy increases in the primary beam even when the secondary beams operate at present energy capabilities, since the yields will increase.

Over the past year the Fermilab Physics Advisory Committee has recommended approval of twelve new experiments for Tevatron running, many based on existing equipment. These would supplement several transition experiments that are now on the floor and would continue operation in an early period of the Tevatron. The programme spans the entire gamut of particle physics. However some potential beam space is still available for particularly important experiments.

Energy Saver/Doubler progress

Installation of the Fermilab superconducting accelerator ring forges ahead. Testing of three 40-magnet cryoloops in A-Sector has continued in parallel with the 400 GeV research programme. The magnet system has reached 4000 A, corresponding to over 900 GeV.

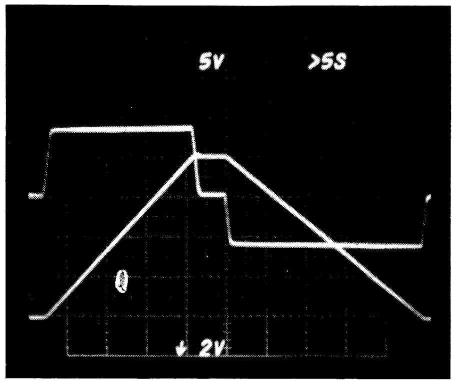
The magnets have been ramping continuously at 4000 A with a 75s cycle since the end of April. Tests of the quench protection system at full current indicate that the installed magnet systems can successfully sustain a full energy quench.

Considerable expertise and controls sophistication have been developed during the running which began in January. This involved not only the three satellite refrigerators on the A-Sector cryoloops, but also the Central Helium Liquifier, and a fourth satellite running the Systems Development Facility at B-12. All of these communicate with the console in the Main Control Room.

Magnet production is at or above levels predicted in an intensive review by the Department of Energy in February. Magnet measuring is running substantially ahead of those projections. As of 10 May, 696 dipoles out of 774 needed for the ring were complete and 631 were measured; 107 quadrupoles out of 216 were complete and 80 were measured; and 147 spoolpieces were complete and measured.

The ring could be commissioned within a year.

A portion of the new Fermilab superconducting magnet system has attained 4000 A, equivalent to acceleration to over 900 GeV. The step-like trace (upper left) is the voltage from the power supply (500 V per scale division). Note the zero voltage during the flat-top. The lower trace shows the current through the superconducting magnets, attaining 4000 A. Repetition rate is 75 seconds.



Annual users meeting

This year's Annual Meeting of the Fermilab Users Organization was particulaly important because 1982 is a year of change for Fermilab, with a new machine in sight. The Users Executive Committee had stressed the need for users attending the meeting.

Dick Gustafson, as head of the Users Executive Committee, chaired the two day meeting; he observed that more than 300 users from around the country and world had responded. They were attracted by an impressive schedule of speakers, coupled with the opportunity to help mould the programme and future direction of the Laboratory.

A broad spectrum of outside user participation from universities and other institutions has been at the heart of Fermilab activities since its inception. This extends well beyond participation in the research programme, including involvement in the Physics Advisory Committee, membership in the Board of Trustees, planning of numerous workshops, the Users Executive Committee and of course the Users Annual Meeting.

High on this year's list of user concerns was the basic science planning process. Dick Gustafson announced a Summer Study in Aspen, Colorado, sponsored by the Division of Particles and Fields of the American Physical Society to look at intermediate and long range needs in particle physics.

Several of the speakers at the meeting helped to shed more light on the science policy process. H. Guyford Stever, addressing the users for the first time as the new URA (Universities Research Association — the governing body of Fermilab) President, reviewed the history of science advice in Washington. Representative Don Fuqua, chairman of the US House of Representatives Committee on Science and Technology, stressed the importance of good science education. He noted that industry seems to be attracting potential graduate students from the engineering and scientific field, commenting that this was 'like eating one's seed corn'. He also judged the Reagan administration as wise in the area of basic research. Hugh Loweth, Deputy Director for Energy and Science of the US Office of Management and Budget (OMB), and Martha Krebs, Staff Director of the US Congress Subcommittee on Energy Development and Application, shed further light on the details of the Washington budget process.

Leon Lederman's briefing to the users ranged as far as the year 2001. He pictured a set of vigorous imperatives: operate the 400 GeV programme, complete the Energy Saver, produce an intense source of antiprotons for colliding beam experiments, construct the fixed target areas for the Tevatron, and still work toward a long range future with advanced research on such projects as high field superconducting magnets. He noted the publication list from the Laboratory for 1981 was long, varied, and included many PhD theses. Still, there has been a problem with available accelerator time. There has been a steady drop over the years due principally to budget strictures. He indicated that the President's budget proposal for 1983 holds promise for the first real relief from this problem in nearly five years.

Taiji Yamanouchi and Norman Gelfand reviewed the present experimental programme and the proposals that have been received. Peter Koehler outlined the extensive programme of improvements that had been carried out in the research areas over the last year. In particular, a large number of construction projects have been under way in the Proton Laboratory. In addition several major new experiments have been installed.

Rich Orr, John Peoples, and Tom Kirk reported on the progress of the large new projects now under way at Fermilab. John Peoples showed the updated plans for the Collider including a striking new triangular debuncher-accumulator 'ring'. He announced that invitations to bid on construction for the experimental area around the collision region went out on 3 May.

An interesting new proposal for an electron-proton collider was aired by a US/Canadian group represented by Nathan Isgur and Steve Holmes. The project would use a 5 GeV electron ring, nearly 500 metres in circumference. It would be tangent to the Saver ring and reach a luminosity of 4×10^{31} cm^{-2} s^{-1}.

John Cumalat, head of the Laboratory Computer Advisory Committee, and Al Brenner, head of the Fermilab Computing Department, discussed the present and future computer situation at the Laboratory. Several roads are available for relieving the present problem with saturation of computing capability but Brenner stressed that a substantial increase in capacity is not budgeted until 1984.

Martin Veltman gave his perspective on the current status of particle physics. He listed some of the exotic particle possibilities that have been suggested but stressed the need for careful, determined programmes to attack the more prosaic problems.

Dick Gustafson, Chairman of the Fermilab Users Organization.

(Photo Fermilab)

SACLAY
Polarized protons

Before it was shut down in 1979, the Argonne ZGS machine successfully pioneered the acceleration of polarized protons into the GeV range. This effort resulted in the discovery of interesting physics spin effects that are still not understood (see November 1979 issue, page 351). This has fuelled the effort to provide more accelerated polarized proton beams (see June issue, page 180). Meanwhile GeV polarized protons have once more been produced, this time at the Saturne machine at Saclay.

The problem in accelerating polarized particles is the crossing of the various depolarizing resonances which occur during the acceleration cycle, without losing the valuable polarization. There are two ways of doing this in a small ring. One is the 'fast crossing' technique, in which the resonance is crossed so rapidly that the particles do not get a good chance to become depolarized. Corrections are then applied to regain any lost polarization. Alternatively, the intrinsic power of the resonance can be exploited to systematically switch all the spins. Though the polarization direction is changed, the beam still emerges in a highly polarized state. This is called 'adiabatic spin reversal'.

The polarized protons in Saturne crossed nine resonances, of both closed orbit and betatron type, during their acceleration to about 2.4 GeV. Weak resonances were negotiated using fast crossing. Stronger resonances required adiabatic spin reversal to maintain the high level of polarization. In some cases the magnetic field conditions responsible for the resonance were manipulated to make the resonance stronger.

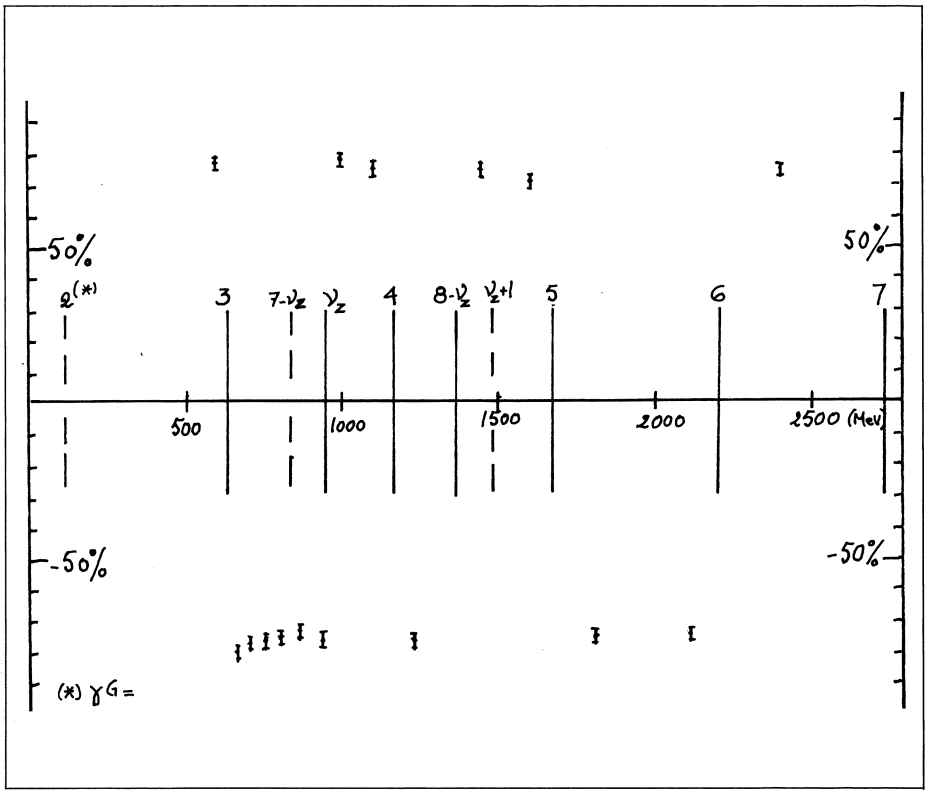
After the appropriate theoretical work had been done several years ago, the Saturne polarization experiments lasted for about a year. A careful choice of extraction energy had to be made in order to study each resonance separately. A control system was developed for the pulsed power supplies of the dipole and quadrupole correctors used to manipulate the magnetic fields.

The polarization measurements were carried out with an external proton polarimeter with four different target positions and four detector arms, two picking up scattered particles and two for recoil particles.

The polarized proton beam has been used in a number of experiments. The nucleon-nucleon interaction is being studied from 600 MeV up to 2.4 GeV to measure the difference in the observed reaction rates for different spin configurations. The formation of deuterons from polarized protons is being studied, and another experiment is now under way using polarized deuterons.

For the future, a small booster (the MIMAS ring) could substantially improve the polarized beam intensities. It would also extend the machine's capabilities for handling heavy ions.

(A report of this work was given at the recent DESY Polarization Workshop, covered in our May issue, page 139. An error crept into our account of the meeting—the vital interest in polarized electrons is of course of potential benefit particularly for electron-proton as well as electron-positron projects.)



Polarized protons have been accelerated to some 2.4 GeV in the Saturne machine at Saclay. The diagram shows how the various depolarizing resonances were negotiated. The weaker resonances were crossed quickly, while the power of the stronger resonances was exploited in 'adiabatic spin reversal' in which the direction of polarization was switched.

Speaking at the recent Heavy Ion Fusion Symposium at GSI Darmstadt, John Lawson of Rutherford suggested that the gulf between concept and reality in this area should be attacked.

(Photo GSI Darmstadt)

DARMSTADT Symposium on Heavy Ion Fusion

One route towards inertial confinement fusion is the use of heavy ion beams for ignition of cryogenic pellets of a few millimeters diameter as deuterium-tritium targets. Beam energies are of the order 10 GeV, the currents in the kiloampere range and the beam pulse duration on the target about 20 ns, resulting in a driver power delivery of 100 to 240 Terawatt. The proposed accelerator concepts are either an induction linac or a linac-storage ring combination.

After four workshops on heavy ion fusion in the past years (Berkeley 1976, Brookhaven 1977, Argonne 1978, and again Berkeley 1979) about 85 participants from 9 countries of the comparatively young HIF community met at GSI Darmstadt from 29 March to 2 April. The aim was to review the progress and the actual status of work, together with ideas and proposals for future developments. A second issue was a thorough review of a particular linac/storage ring heavy ion fusion scenario, proposed by a collaboration of German research centres and the University of Wisconsin, to which was given the acronym HIBALL (Heavy Ion Beams and Lithium Lead). Although the symposium mainly covered developments in accelerator physics and engineering, the participation of the target experts stimulated some useful exchanges.

Surveys of the national programmes (US, UK, Japan, Germany) of actual heavy ion fusion research were followed by specialized talks and informal working group sessions covering linacs, storage rings, beam transport, final focussing and target studies. Lastly there was a review of plans for beam experiments in storage rings, considered to be of major importance. These could be realized in the next years at TARN (Test Accumulator Ring for Numatron) already in operation at INS (Tokyo) as well as with the SNS synchrotron under construction at the Rutherford Laboratory.

Only a few possibilities are foreseen in the near future for experimental studies of beam-target interactions with heavy ions. To explore the predicted beam-plasma interaction effects, even the next generation of heavy ion accelerators will not deliver the necessary energy density to produce high enough temperatures. The only possible exception could be a programme proposed in the US to build an induction linac capable of delivering in about 35 ns 2.8 kJ of 100 MeV sodium ions to a plane target. This so-called High Temperature Experiment should lead to a solid density plasma of 50—100 eV temperature.

The meeting resulted in an increased confidence within the HIF community that the accelerator part of a linac/storage ring Heavy Ion Fusion power station can be built. Reasons for this confidence are:

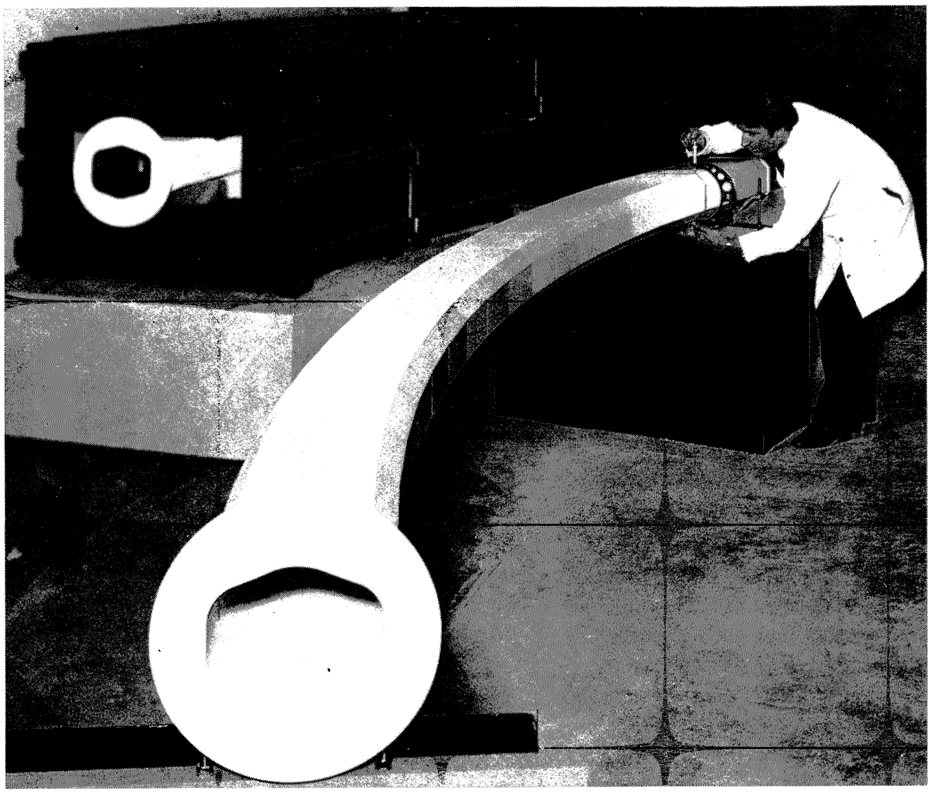
- the elimination of some fundamental weaknesses in proposed storage ring designs
- an increased confidence that the linac and high energy beam transport seem to grounded on a technologically mastered terrain
- establishment of a consensus view on how the values in parameter space can be newly adjusted in a more optimized scheme, and in a rapidly converging design
- the focus of attention on the experimental opportunities which could be explored without too much effort and cost in facilities either under construction or up for approval
- the promotion of international collaboration—particularly in view of restricted funding.

RUTHERFORD Progress with neutron source

It is some time since we reported the progress of construction of the Spallation Neutron Source, SNS, at the Rutherford Laboratory. We begin therefore with a brief recap of the major aims and machine features.

To achieve the higher intensities needed for present-day research with neutron beams it has been necessary to move away from the traditional use of nuclear reactors to neutron sources based on accelerators. Such beams are used by physicists, chemists, materials scientists, biologists, etc., to investigate the

A prototype SNS ceramic vacuum chamber section, 5 m long with a bending radius of 7 m. A model bending magnet can be seen in the background.



structure and properties of a wide range of materials including alloys, defect solids, liquid crystals, ferroelectrics, amorphous polymers, organic molecules and membranes and macromolecules such as proteins and viruses.

The Rutherford Laboratory has had considerable experience in support of these research fields since it has been the UK focus of participation in the research programme at the reactor of the Institute Laue-Langevin at Grenoble. With the demise of the UK's nationally-based high energy programme and the closing down of the Nimrod proton synchrotron at Rutherford and the Nina electron synchrotron at Daresbury, resources became available for the construction of a high repetition-rate high intensity machine for neutron production.

The main design parameters of the SNS are — proton energy of 800 MeV, 2.5×10^{13} protons per pulse at a repetition rate of 53 Hz (1.3×10^{15} protons per second). Fired into a heavy metal target, some thirty fast neutrons are generated by spallation from each proton. The neutrons are slowed down to appropriate energies for atomic studies in a moderator surrounding the target. With these parameters the SNS will be the most intense spallation neutron source in the world — a factor of ten up on existing facilities.

The main SNS component is a rapid cycling proton synchrotron built in the hall of the Nimrod machine at Rutherford. It will use negative hydrogen ion injection to achieve high intensities from a 70 MeV linac originally foreseen as a new injector for Nimrod. The synchrotron magnet system has ten magnet superperiods. The magnets are powered from the former Nina power supply. The vacuum will be sustained between 10^{-6} and 10^{-7} torr. Six r.f. accelerating cavities will operate at frequencies from 1.3 MHz at injection to 3.1 MHz at 800 MeV ejection after an acceleration time of 10 ms.

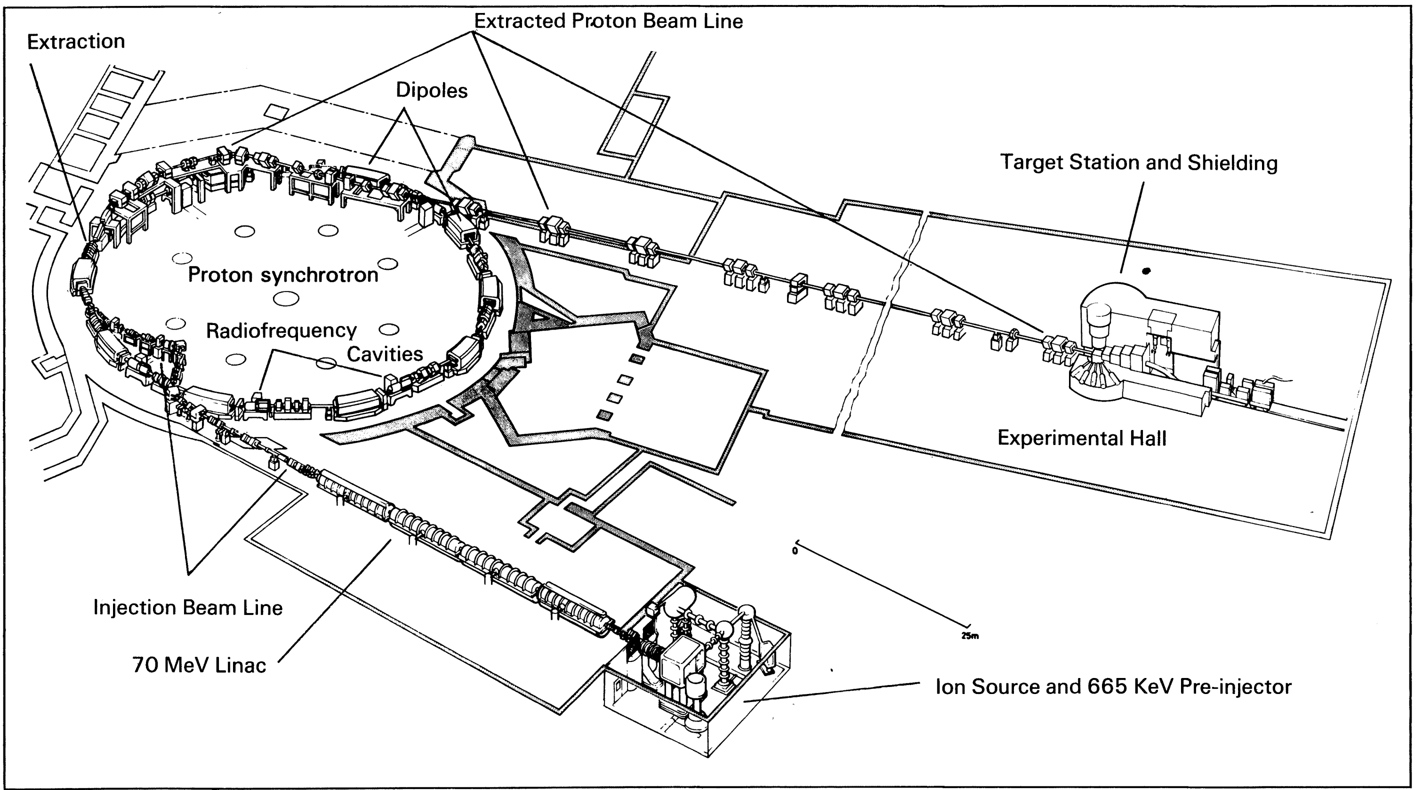
Up to now the ion source has provided 30 mA of ions compared to the design aim of 40 mA. The 665 keV preinjector has operated at full voltage and accelerated the negative hydrogen ion beam. The first tank of the four tank linac has operated at full power. Large aluminium oxide stripping foils (12×3 cm^2, 0.25 micron thick) to convert the ions into protons have been made and are ready for tests with beam to ensure that they can withstand an operating temperature around 800 C.

Some problems were encountered in the manufacture of the synchrotron bending magnets but now seem to be solved. Quadrupole focusing magnets have been delivered and tested. Novel ceramic vacuum chamber sections 30 cm long have been received from the manufacturers and stacked and heated to 1100 C to form the ten 3 m-long chambers for the quadrupole sections. Prototype chambers for the quadrupole singlet sections and the 5 m bending magnet sections have also been built successfully. The bending magnet sections are particularly tricky, involving a double stacking and heating process on units which span a 36 degree angle with a 7 m radius of curvature.

A complete prototype r.f. system has been built and is being tested. Beam extraction units have been designed and an extraction kicker magnet has achieved design field in 0.22 μs. Work continues on the crucial design of the target station.

Preparations for the experimental programme have reached the stage where the first detection systems are being tested. During April, tests were carried out on the first of two

Layout of the Spallation Neutron Source, SNS, being built at the Rutherford Laboratory. A 70 MeV linac feeds negative hydrogen ions to an 800 MeV rapid cycling proton synchrotron, to provide high neutron fluxes by spallation in a target.



systems, scheduled for the SNS, to be installed on the 136 MeV electron linac pulsed neutron source at the neighbouring Harwell Laboratory. It is a 'Liquid and Amorphous Materials Diffractometer' (LAD) which will move to SNS in 1984 as a total scattering spectrometer. Some useful research will be done on the linac, beginning a programme of measurements on the structure factors of liquids and amorphous materials.

GRENOBLE
First beams at SARA

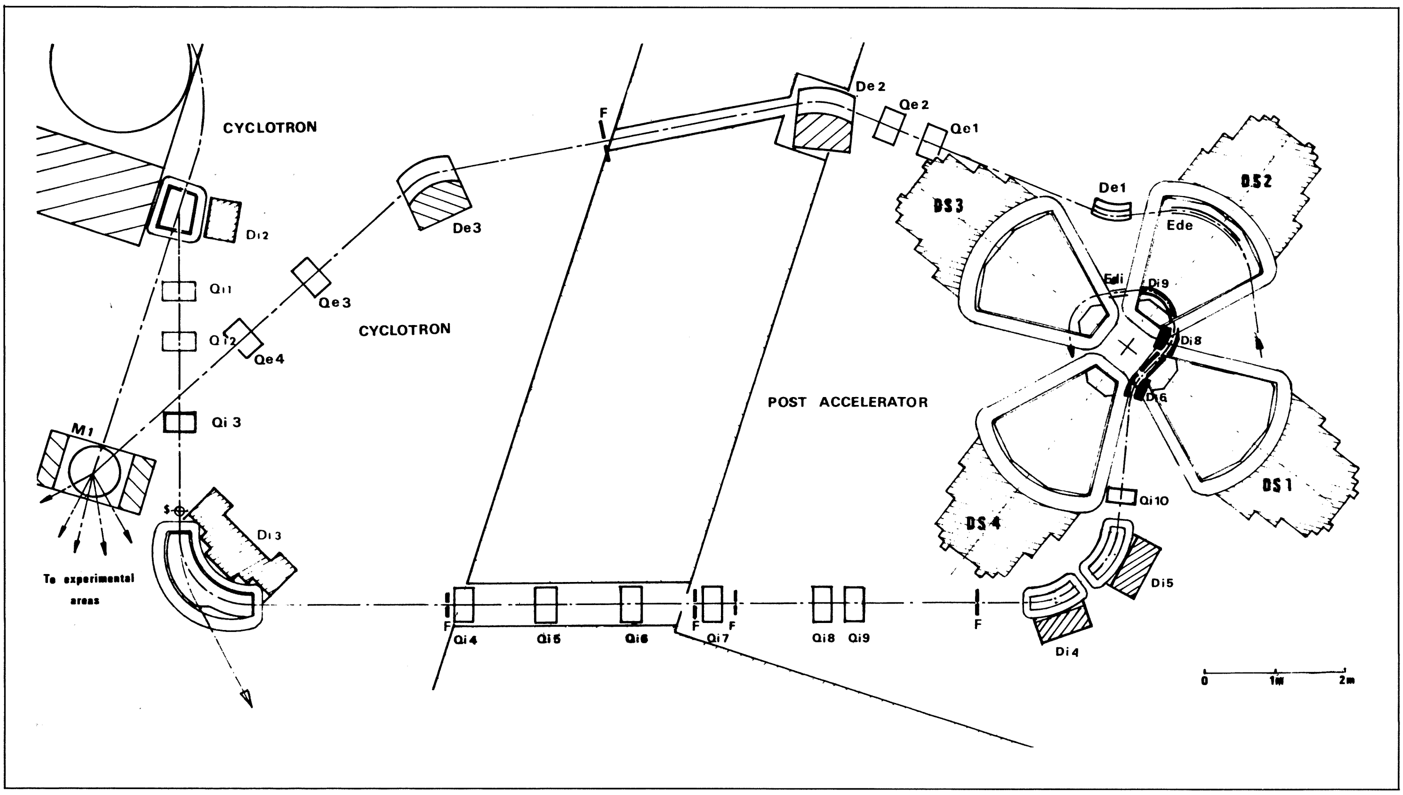
One of the priority items in French nuclear research is heavy ion physics. A distinction can be made between three ranges in this physics, depending on the energy of the incident ions: up to 10 MeV per nucleon is the low energy range in which a great deal of research has already been done; from 10 to 100 MeV per nucleon is the transition range; and above 100 MeV per nucleon is the range of relativistic heavy ions. The transition range is potentially very rich since it is here that the limit may be found to some nuclear concepts such as nuclear potential, the fusion process and the extremes of physical values like angular momentum. It also covers the Fermi threshold which defines the movement of the nucleons in the nucleus; it may be possible to see here extreme states of nuclear density, temperature and interaction time before the physical aspects of the particles themselves become dominant.

The GANIL accelerator, construction of which is nearing completion at Caen, was designed for the overall study of this transition range. However it is in the energy range around 30 MeV per nucleon that the greatest changes in the behaviour of nuclear material are expected and this range is the most promising for the appearance of new phenomena. SARA (Système Accélérateur Rhône—Alpes), now coming into action at Grenoble, accelerates 'light heavy' ions up to 40 MeV per nucleon, providing exactly the right conditions and, for a year, it will be the only machine providing beams in this energy range. It will subsequently supplement GANIL, which will handle heavier or higher energy ions.

SARA is a heavy ion accelerator system consisting of two cyclotrons. The first is of compact type, rated at 90 MeV which has been operating since 1968. It has a PIG internal source and an axial injection system also with a PIG source which will be replaced in 1983 by an ECR source.

The second cyclotron is of the

Plan of the SARA twin-cyclotron heavy ion accelerator complex at Grenoble.



'separate sector' type, rated at 160 MeV. The ions accelerated in the first cyclotron are stripped and further accelerated in the second. The plans for this second cyclotron were put forward in 1976 and the decision to build was taken a year later. It is a joint project of two regional laboratories—the Nuclear Physics Institute of Lyon and the Institute for Nuclear Sciences of Grenoble, which managed the project. It was built under the supervision of a Scientific Project Committee representing both laboratories, while the construction itself was completed by a group of about forty technicians and engineers from the two Institutes. The project has cost 9 million francs (at 1976 prices).

The first SARA cyclotron accelerates a beam of heavy ions to energies of between 2 and 7.4 MeV per nucleon. The beam is stripped in a carbon foil and is then guided from the first cyclotron to the centre of the second accelerator, where it is injected into the first acceleration orbit by means of magnets and an electrostatic kicker. After acceleration, the beam is extracted and taken to the various experimental stations via the existing beam transport system.

The second cyclotron acts as an energy amplifier, giving a gain of almost 5.4. The frequency of its accelerating system must be properly synchronized for the machine to be able to accelerate all the beam bunches provided by the first cyclotron. The frequency of the second cyclotron is double that of the first and the harmonic used is also double that of the first.

With the PIG source, the acceleration limit in the first cyclotron makes it impossible to accelerate ions with mass over 50. When the ECR source is installed, the performance will be extended both in terms of energy and of the range of ions which can be accelerated (up to atomic masses of 100 and perhaps even 130).

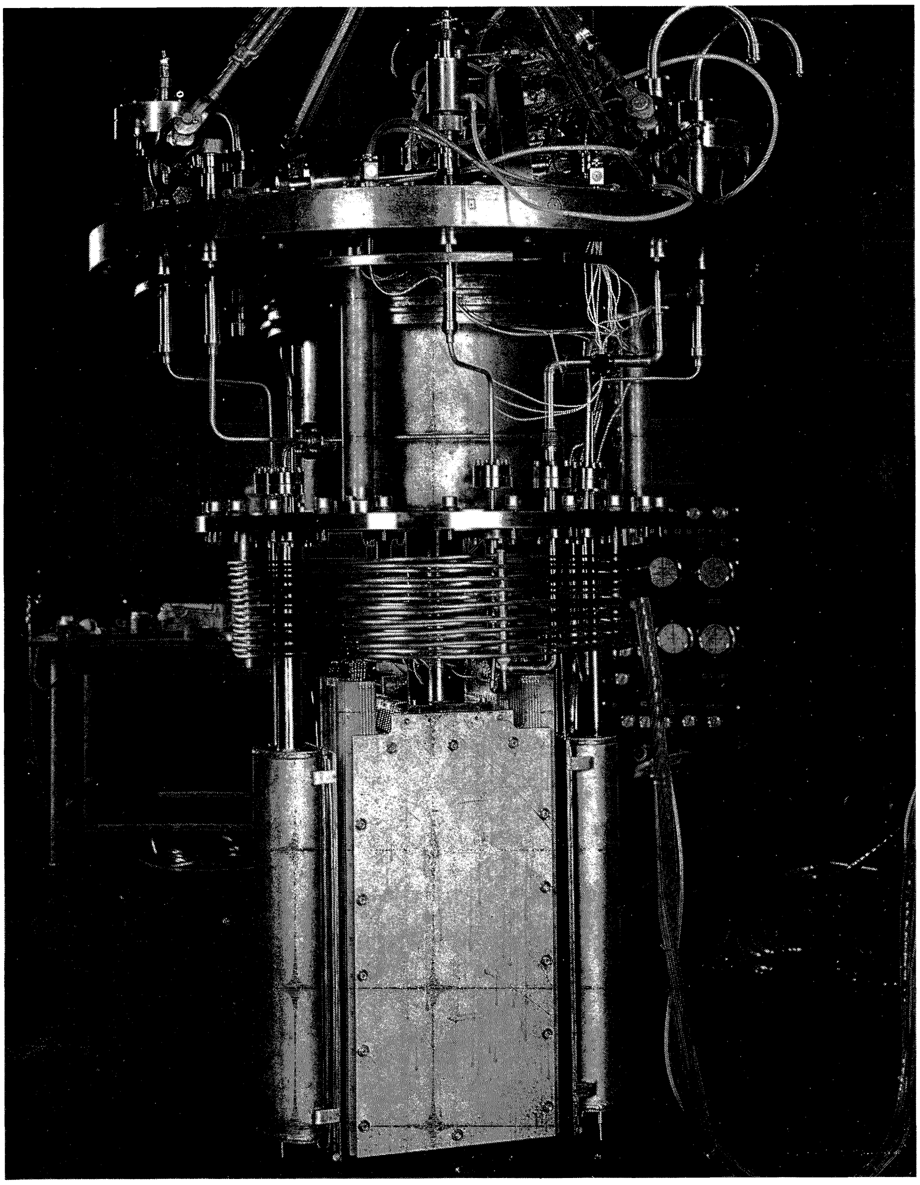
Internal beam was obtained in the second cyclotron in March during the first trial injection. The beam was extracted with an energy of 30 MeV per nucleon on 6 April and 38 MeV per nucleon was attained two days later. Preliminary experiments are under way, and full use of the machine is scheduled to start in September.

ECOLE POLYTECHNIQUE
Frozen detectors

Light bubble chamber liquids, such as hydrogen and deuterium, provide the simplest conditions for the analysis of particle interactions. On the other hand, heavier target materials

Prototype solid argon or neon calorimeter built at the Ecole Polytechnique. Visible at the bottom are the alternate layers of lead and printed circuit boards, and the heat exchangers for cooling the rare gas in the surrounding vessel in which the apparatus is eventually mounted.

(Photo Ecole Polytechnique)



provide a more efficient means of catching the products of the interactions. The problem is to get the best of both worlds.

One solution is the track sensitive target technique in which a transparent box of liquid hydrogen or deuterium is immersed in a bubble chamber containing a heavier liquid. The box acts as the primary target for the beam while the surrounding heavy liquid serves to intercept the produced particles.

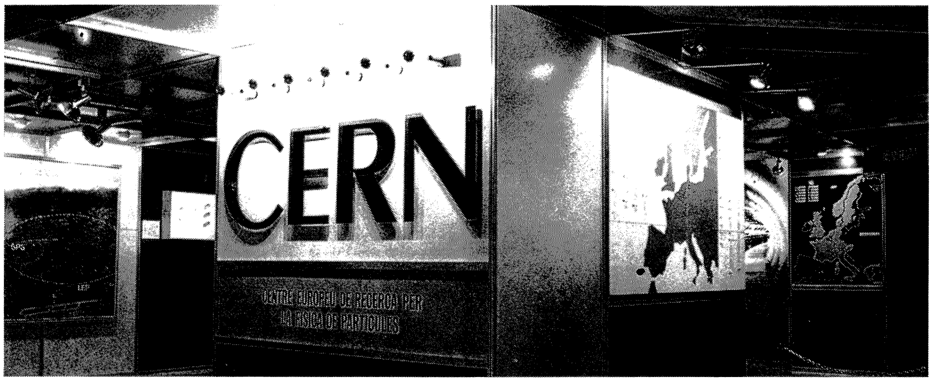
Another possibility is to put a 'liquid argon' type calorimeter inside the cryogenic bubble chamber, to provide additional identification of produced electrons and photons. However liquid argon freezes at the operating temperatures of big cryogenic bubble chambers, and the behaviour of these solid detecting media had to be investigated.

Tests with detectors made of a multilayer sandwich of lead plates and solid argon or neon were carried out both at CERN and using a beam at Saclay. These trials demonstrated comparable results to those obtained with liquid argon. Further tests with a small neon-hydrogen or argon-filled assembly at Fermilab were satisfactory. In particular they showed how solid argon detectors avoided some of the troubles encountered with liquid argon detectors (see October 1981 issue, page 354).

After these trials with small scale detectors, it remained to test a large calorimeter. A 60-litre unit, comprising 15 lead plates and intermediate ionization chambers to cope with electromagnetic showers of up to 5 GeV, has now been tested at CERN. The tests were carried out by a Bari / Brussels / Ecole Polytechnique/Illinois Institute of Technology/Tufts/University College London collaboration with the CERN BEBC team.

Not all the test data has yet been analysed, but already it is clear that solid neon or argon behaves similarly to liquid argon. There is a linear response to the incident electron energy, and the assembly is stable even in much higher particle fluxes than would normally be encountered in bubble chambers. Unlike liquid argon, the purity of the sample has little effect. These tests are encouraging and the installation of internal frozen calorimeters in cryogenic bubble chambers thus becomes one step nearer.

People and things

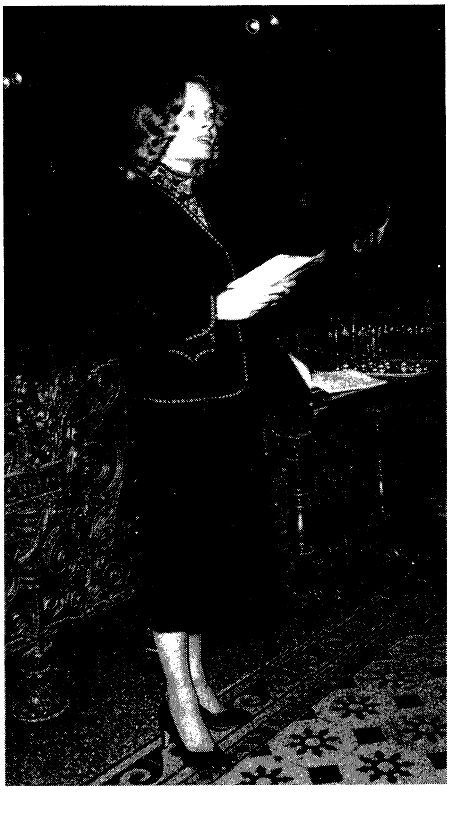


CERN on show. Continuing its journey round Europe, the CERN exhibition was recently at the Museu de la Ciència in Barcelona. The title under the CERN logo is in the Catalan language.

(Photo CERN 181.3.82)

New upsilon

The CUSB detector at Cornell's CESR electron-positron ring has seen evidence for a new upsilon-like state in the decays of the third (3S) upsilon. As with charmonium, only certain types of quark-antiquark states can be formed directly in electron-positron annihilations. The others have to be sought in the subsequent decay processes. The new state seen at CESR appears to correspond to one unit of rotational angular momentum in the heavy quark-antiquark system. The standard upsilons have no rotational angular momentum between the component quarks. This new enlargement of upsilon spectroscopy will be of particular interest to theorists looking at inter-quark forces. More details on the new upsilon in our next issue.



Finnish Minister of Science and Cultural Affairs Kaarina Suonio inaugurated a physics exhibition at Helsinki on 19 May. A major part of the exhibition concerned particle physics and was prepared by CERN in collaboration with Finnish physicists led by Hannu Miettinen. The exhibition was a great success, attracting some 20 000 visitors during the week it was open.

(Photo CERN 563.5.82)

DORIS II turns on

After six months of rebuilding and reconstruction, the DORIS electron-positron ring at DESY was switched on again on 9 May. The new single ring DORIS aims to reach energies of 5.6 GeV per beam to permit upsilon spectroscopy, and with significantly reduced power consumption. Luminosity is expected to be boosted by a factor of twenty. After some initial runs for synchrotron radiation experiments, first electron-positron collisions are scheduled for mid-July, when the Crystal Ball detector, recently arrived from SLAC, will be installed in one of the two interaction regions.

25 years of the Particle Data Group

This year's edition of the Particle Properties Data Booklet, the high energy physicists' bible for many years, marks the 25th year of the 'Particle Data Group'.

The style of the tabulation stems directly from a 1957 article in the Annual Review of Nuclear Science by Murray Gell-Mann and Al Rosenfeld. At that time, many new particles were being discovered, and even before the first 'Annual Review' was published, W. H. Barkas and Rosenfeld were working on the first update of the table of masses and mean lifetimes.

In 1958, the first 'wallet card' appeared, containing six pages of vital information. This has since expanded by a factor of twenty into today's booklet.

The full version of the tabulation contains some 35 000 data cards, and is published alternately by 'Reviews of Modern Physics' and 'Physics Letters'.

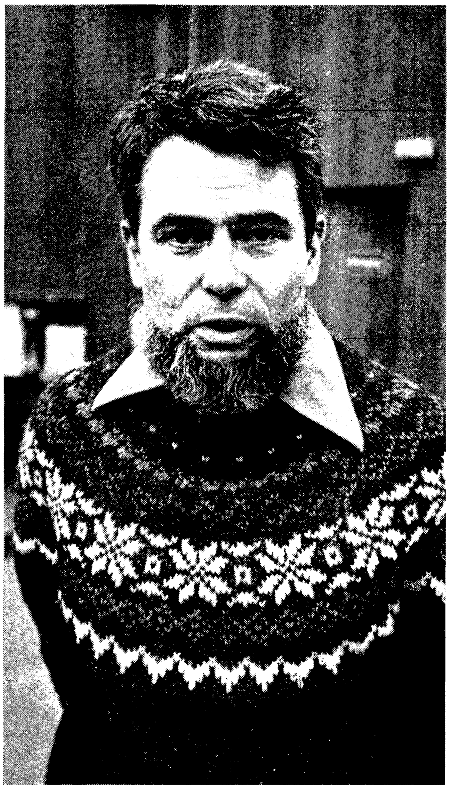
A whole physics generation grew to know the listings by the name 'The Rosenfeld Tables'. However in 1968 the Rosenfeld team adopted the name 'Particle Data Group' (PDG) and called their periodic publication 'Review of Particle Properties'.

The PDG is composed of three independent teams, one dealing with each of the three main tables — Stable Particles, Mesons and Baryons. The Meson team is CERN-based and is mainly a European effort, while the other two are based at Berkeley and are dominantly US efforts. Technical work of tabulating and editing is done at Berkeley and printing and distribution is shared between Berkeley and CERN.

This year's edition is a few months late due to severe budget problems which have reduced the manpower available at Berkeley by about half. At the same time the volume of work continues to grow. The increased information available demands adequate treatment.

The level of future operations is uncertain, but it is clear that as long as spectroscopy remains an active field, the high energy physics community expects its booklet to be updated at regular intervals. The Particle Data Group hopes that this need will be recognized by the funding authorities.

Tom Walsh, new spokesman of the DESY Theory Group. He takes over from Hans Joos.



Data Compilation Meeting

Representatives of seven groups concerned with data compilation in particle physics met in April at the Rutherford Appleton Laboratory to discuss the present status of the numerical data services they provide for a large community of experimental and theoretical physicists. The participants included from the CERN High Energy Reaction Analysis (HERA) Group, E. Flaminio (Pisa), G. Moorhead and D. R. O. Morrison; from the CERN Scientific Information Service, A. G. Hester; from DESY, P. Joos; from the Fachinformationszentrum, Karlsruhe, G. Ebel; from the Particle Data Group in the UK, R. L. Crawford (Glasgow), F. D. Gault (Durham) and R. G. Roberts (Rutherford and Appleton Laboratory); from the Rutherford Appleton Laboratory, B. J. Read; and from the Serpukhov COMPAS Group, N. E. Tyurin, V. V. Ezhela.

The participants were brought up-to-date on the work of each of the groups and there was a discussion of standards in compilation and the exchange of data. The desirability was expressed of greater coordination in the work of particle physics compilation. The group members, who met previously at CERN in October 1980, agreed to continue their discussions in about a year and anyone interested in contributing should contact one of the above.

On people

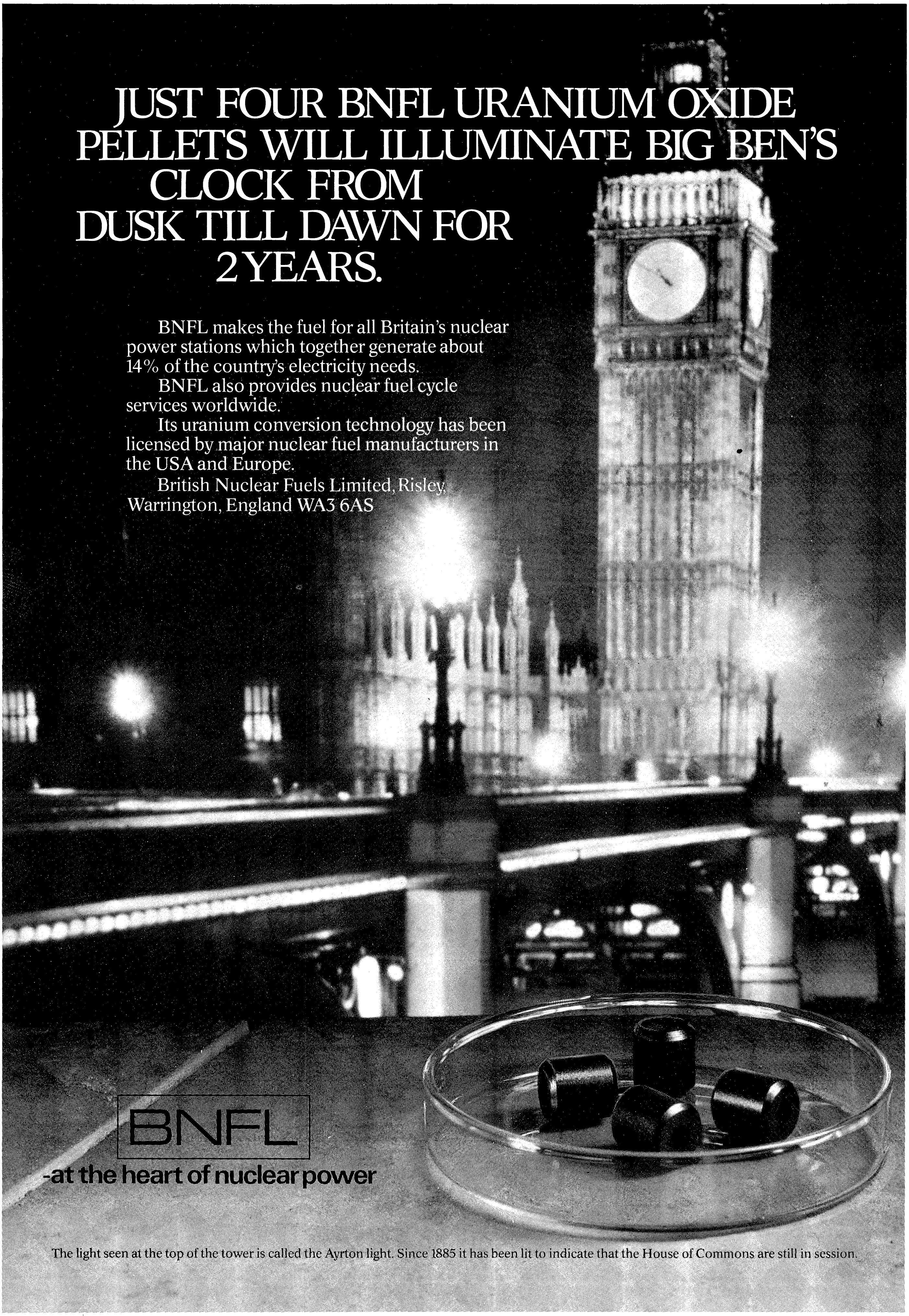
Nick Samios has been appointed Director of Brookhaven National Laboratory.

After 11 years on the faculty of the University of California at Los Angeles, John P. McTague has come to Brookhaven to head the recently organized National Synchrotron Light Source Division.

Stephen Hawking of Cambridge has been awarded the prestigious Franklin Medal 'for his revolutionary contributions to, among others the theory of general relativity, astrophysics and cosmology, and the dynamics, thermodynamics and gravitational effects of black holes'.

Signing of the new agreement between CERN and the Orsay Laboratoire de l'Accélérateur Linéaire for the development of linacs for LEP. Director General Herwig Schopper (left) signs for CERN, and J. Yoccoz for the French Institut National de Physique Nucléaire et de Physique des Particules (IN2P3). In the background is Diether Blechschmidt of CERN.

(Photo CERN 392.3.82)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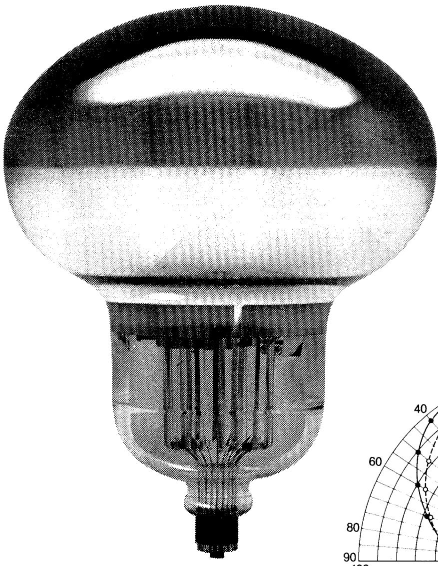

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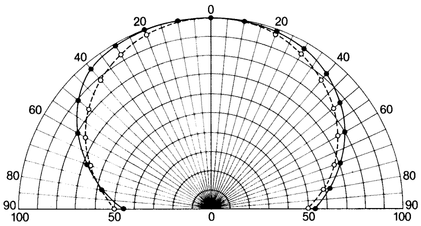

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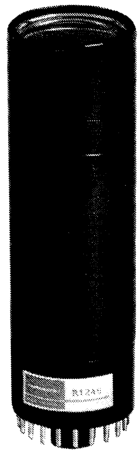

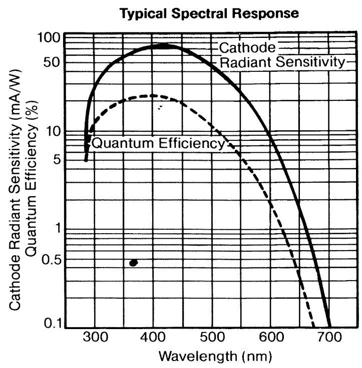

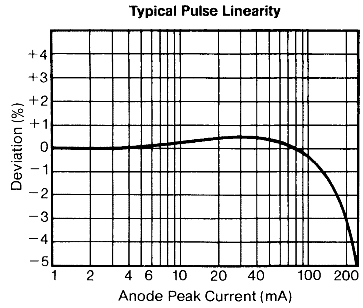

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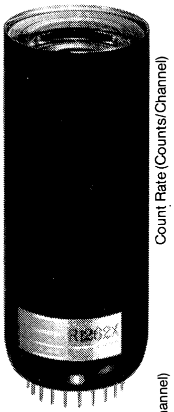

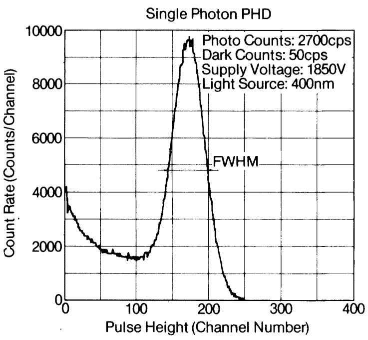

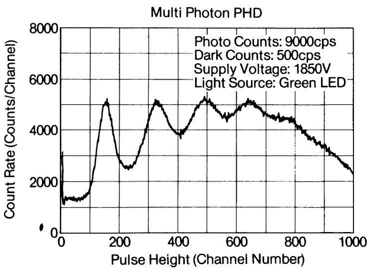

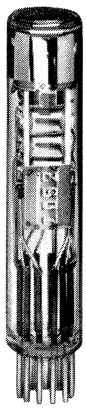

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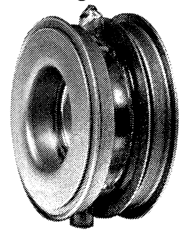

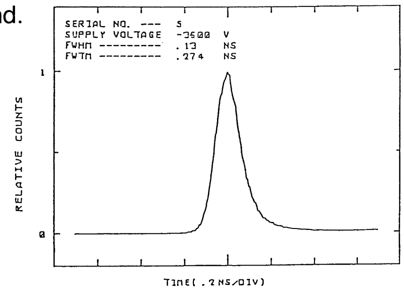

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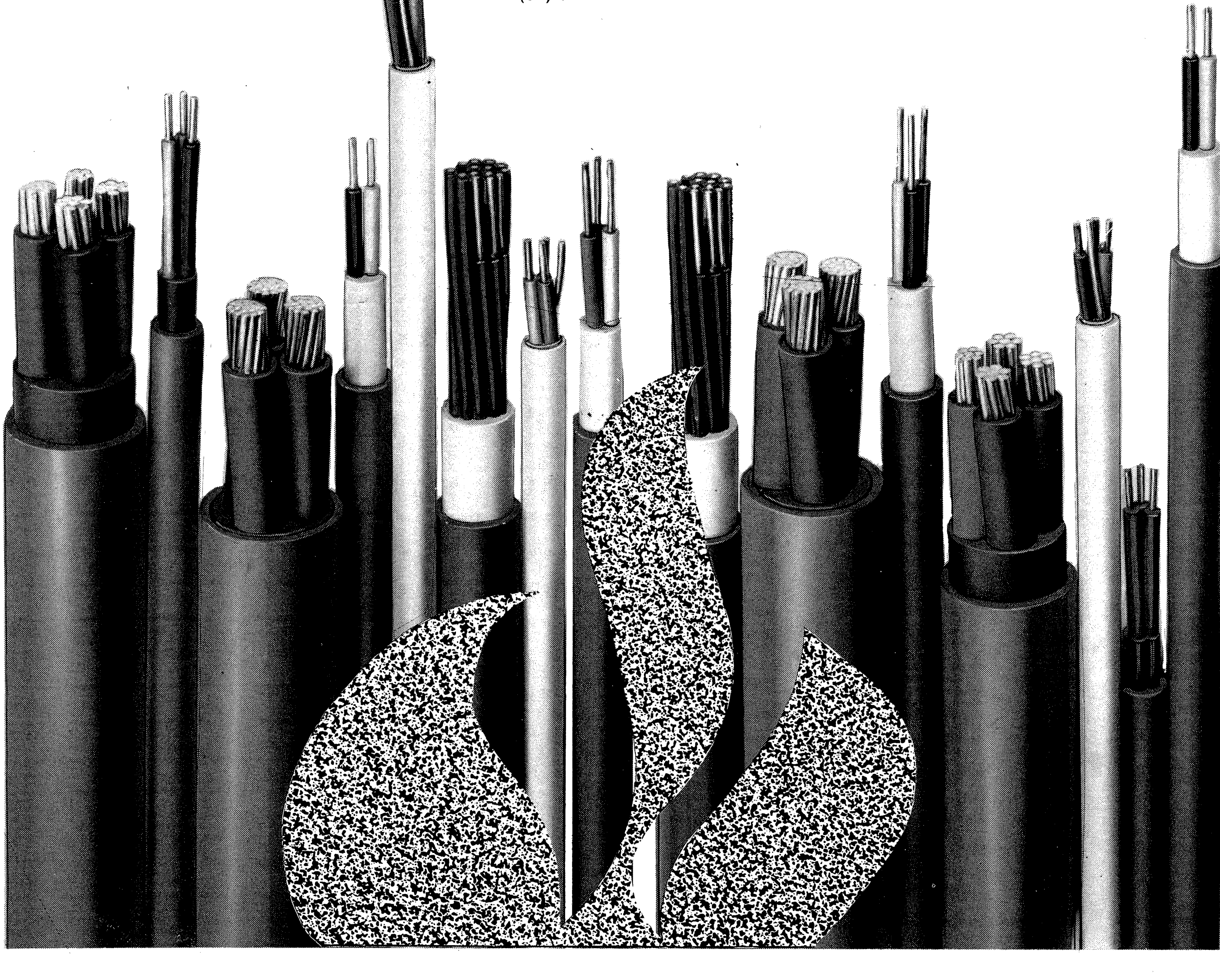

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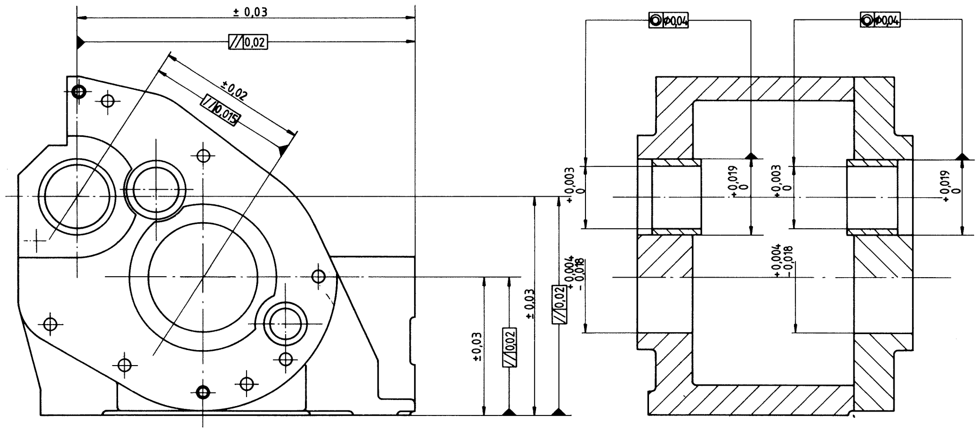

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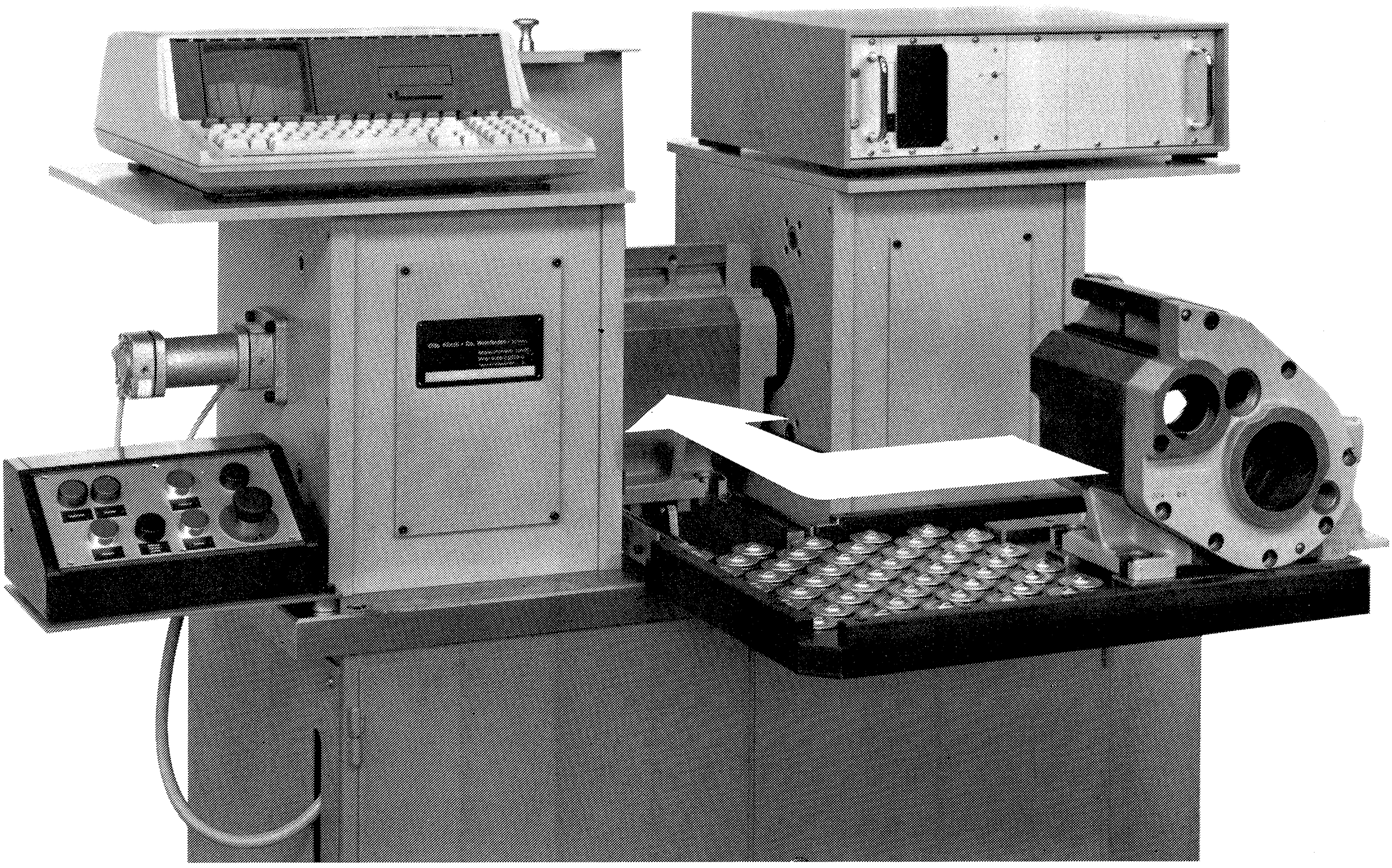

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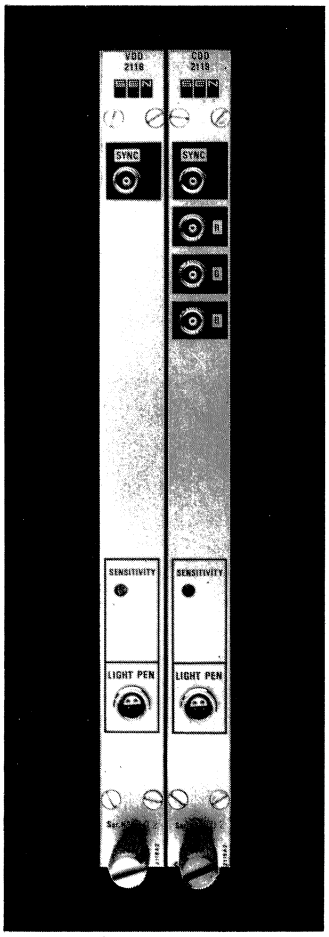

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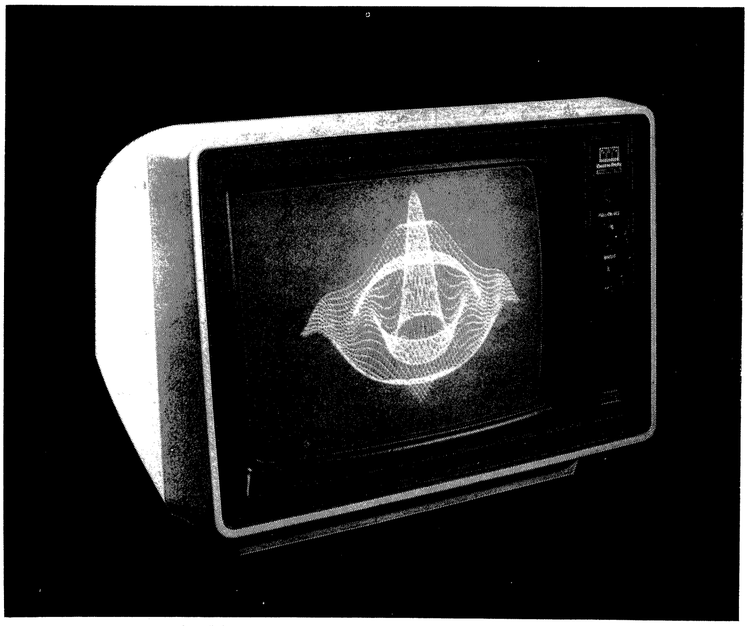

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Any enquiries regarding subscriptions should be addressed to:

Monika WILSON
CERN COURIER/CERN
1211 Geneva 23 Switzerland

Interface to a wide variety of host CPUs -

2050 - 2088 Series

our powerful CAMAC highway drivers

★ ★ ★

COMING SOON

Look for FASTBUS interface capability from Kinetic Systems with these new FASTBUS products now under development:

- Active Segment Extender
- Segment Display Module
- Register and Scaler Modules
- Test and Data Storage Modules
- Data Filter and Processing Modules

Watch for more information.

This series of CAMAC highway drivers provides an efficient interface between a CAMAC highway and your host computer. Offering you the option of both serial or parallel highway interfaces, these drivers can be used in a variety of applications requiring distributed control, high-speed communication, or data acquisition. Compatible software includes device drivers and FORTRAN-callable subroutines to support transparent communication between your computer and the remote crates.

HIGHWAY OPTIONS

* Serial highway driver
* Parallel highway driver
* Combined serial/parallel highway drivers

COMPUTER INTERFACES

* Digital PDP-11, LSI-11, and VAX
* Systems 32
* Modcomp II, III, IV, and Classic
* Hewlett-Packard 1000 and 2100

FEATURES

* Offers D-port and U-port options for serial highway conditioning
* Supports single command, Q-Scan, Q-Stop, Burst, and Execute List modes with full DMA
* Controls up to 7 parallel and/or 62 serial highway crates
* Includes automatic error recovery
* Provides FIFO storage for up to 64 serial Demand messages

concept systems

Please contact us for additional information

Kinetic Systems International S.A.

Dept. CC72 * 3 Chemin de Tavernay * 1218 Geneva, Switzerland * Tel. (022) 98 44 45 * Telex 28 9622
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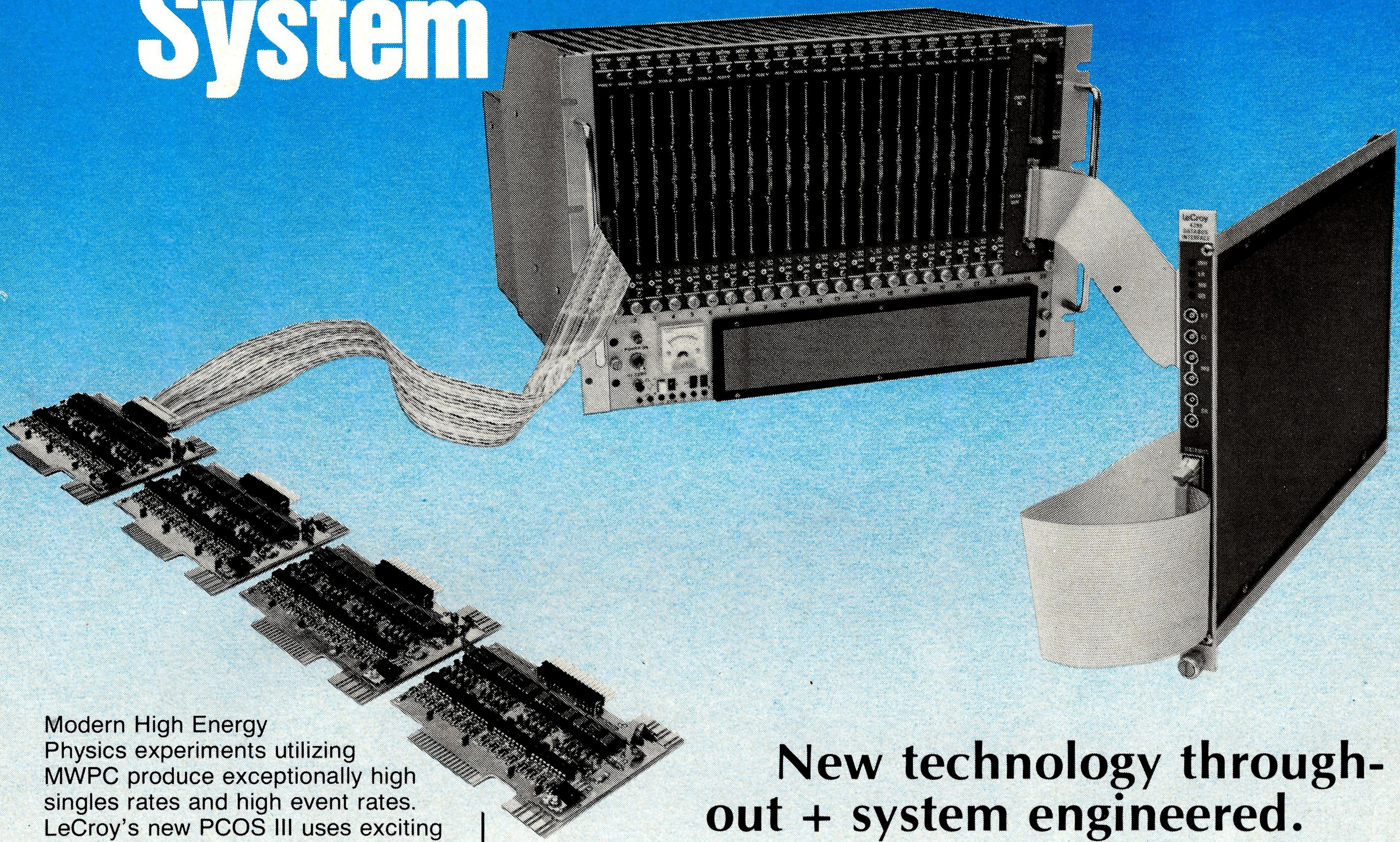
PCOS III... Multiwire Proportional Chamber System



Modern High Energy Physics experiments utilizing MWPC produce exceptionally high singles rates and high event rates. LeCroy's new PCOS III uses exciting advanced technology to produce a totally integrated system for these applications.

New technology throughout + system engineered.

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

Exceptional Compactness
16 channels of amplifier/discriminator on an 8x12 cm. card! Two new LeCroy monolithics make this possible.

Programmable Threshold
CAMAC programmable in 0.06 μA steps. Makes computer-controlled plateau a reality!

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

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

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

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

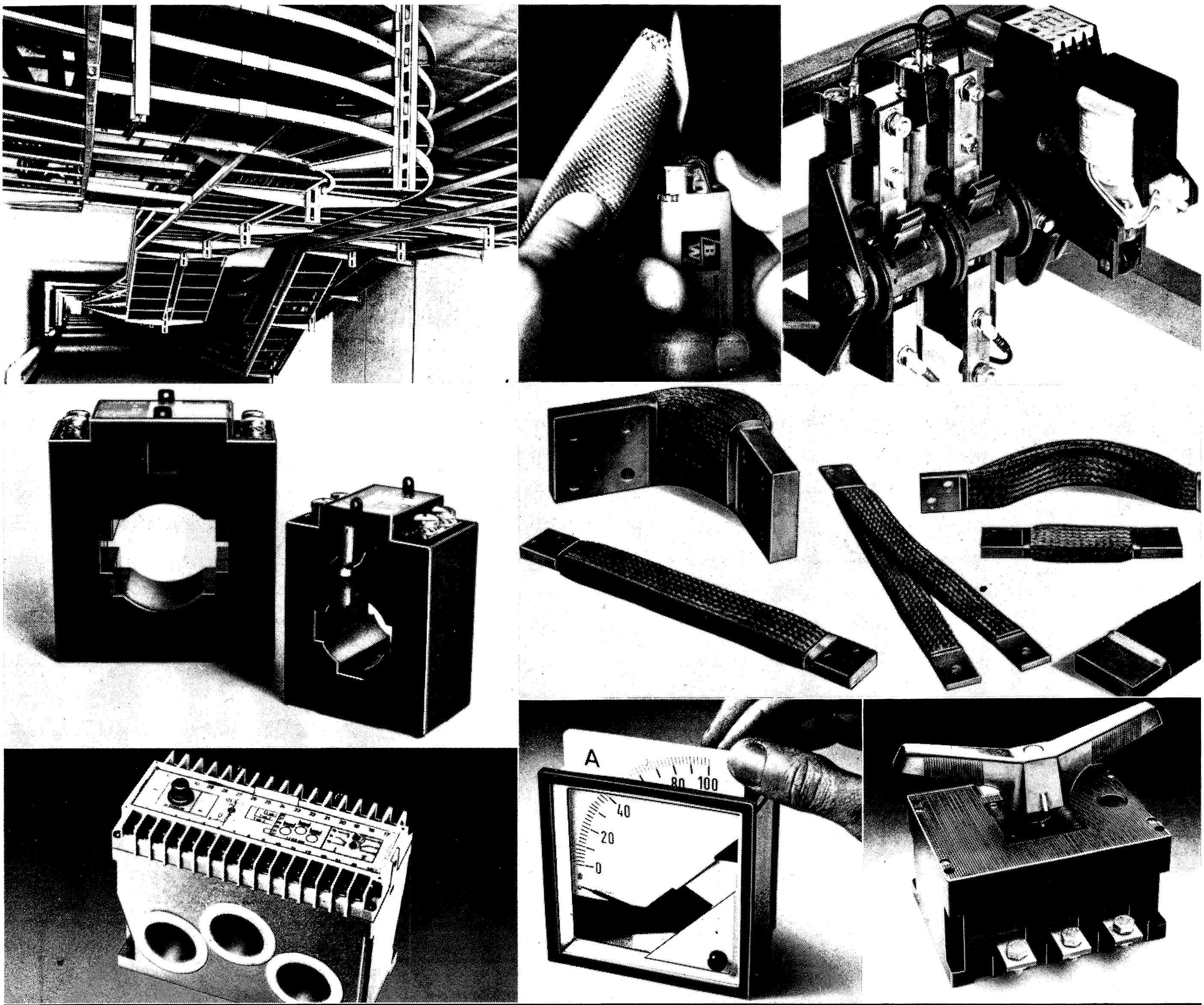
Interface to a Track Finder
Addresses of hit wires are supplied as they are encoded. Unique ECLport format optimizes readout rate.

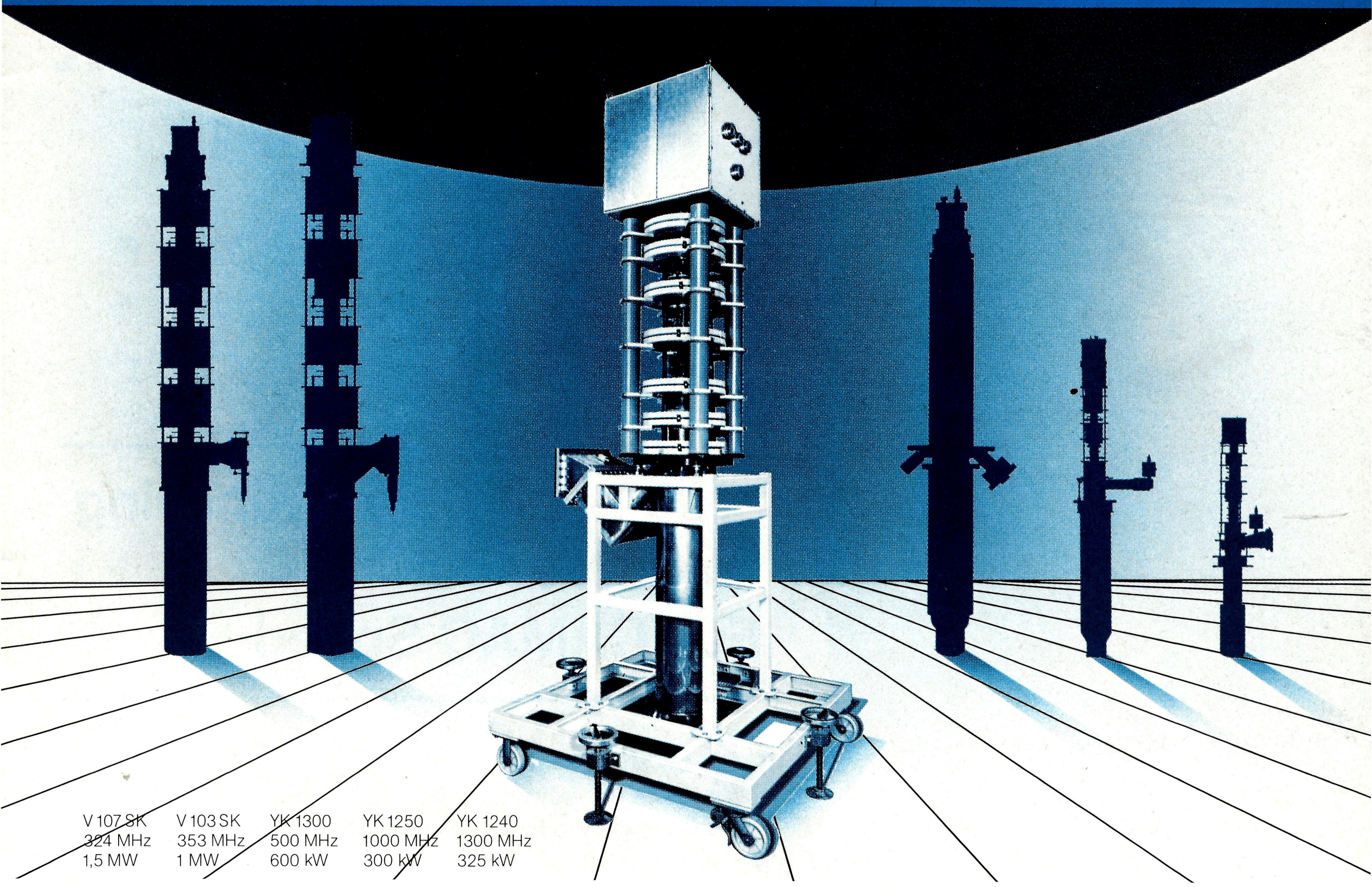
Future FASTBUS Compatibility
Utilization of LeCroy's CAMAC DATABUS standard makes this system readily upgradable to the FASTBUS standard with the Model 2799 FASTBUS interface, scheduled for design soon.

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

LeCroy

700 S. Main St., Spring Valley, N.Y. 10977, (914) 425-2000; Geneva, Switzerland, (022) 98 97 97; Heidelberg, W. Germany, (06221) 28192; Les Ulis, France (6) 907.38.97; Botley, Oxford, England, (0865) 72 72 75. Representatives throughout the world.





More Big Klystrons for Big Science

At GHz frequencies only klystrons can deliver the r. f. power needed for research in Pure and Applied Physics. The increasing demand for the highest possible output power per unit at different frequencies led to a variety of klystron types in the range between 300 and 1300 MHz, the biggest klystrons ever built in the world.

In the course of 1981 Valvo has delivered the prototype klystron V 103 SK to study and find out the optimum and most efficient way of generating the enormous r. f. power of 1 Megawatt per unit at 353 MHz. As particle research is extending to extremely high energies, the need for r. f. powers up to 100 MW presents a new challenge for manufacturers of high power klystrons.

Valvo is a member of the worldwide Philips organization. Please contact your nearest Philips representative.

A 1595/2f

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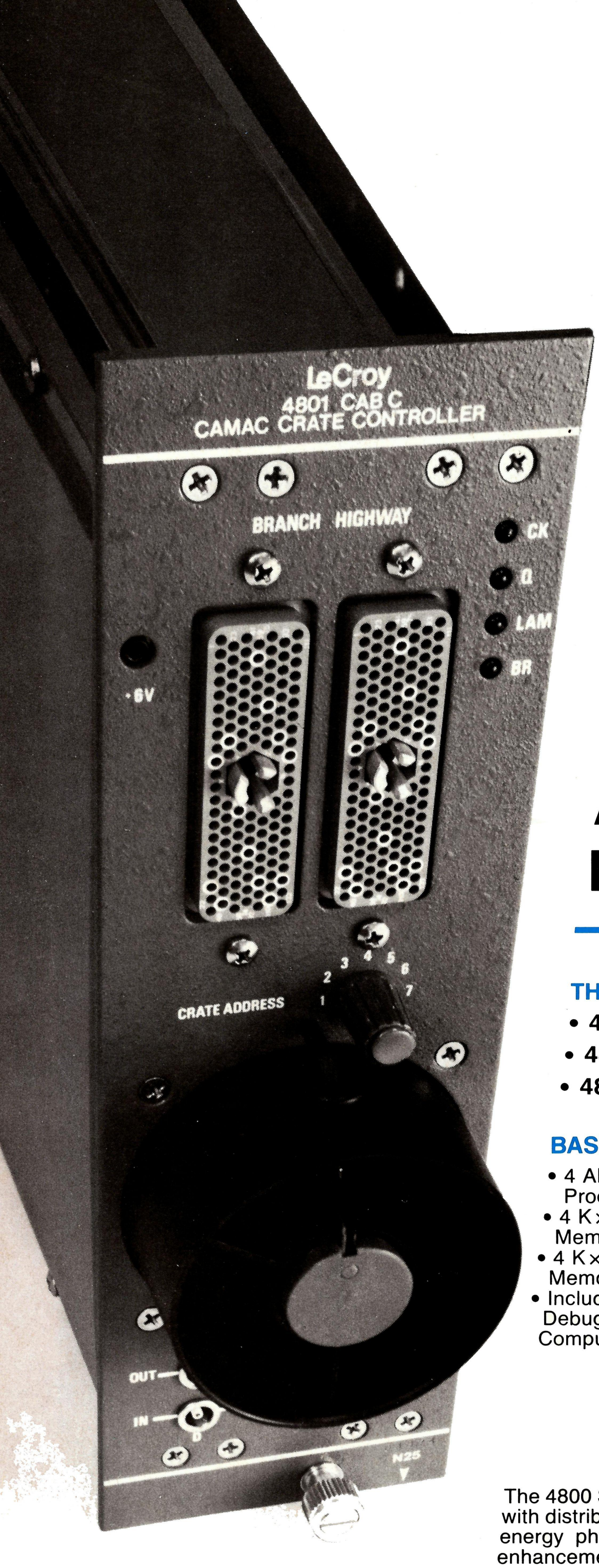

LeCroy 4800 Series

Fast, Intelligent CAMAC Processors (CAB*)

200 nsec Data Crunching And Readout at Full CAMAC Speed

THREE CONFIGURATIONS

- **4801 Crate Controller**
- **4802 Crate Controller/GPIB Interface**
- **4803 Branch Driver**

BASIC ELEMENTS:

- 4 AM2901 Bit Slice Processors
- 4 K × 16-Bit RAM Data Memory
- 4 K × 24-Bit RAM Instruction Memory
- Includes Cross-Assembler and Debugger Running on Host Computer

FEATURES:

- Executes up to 5 instructions (200 nsec each) in a single CAMAC cycle.
- Executes programmed CAMAC functions at the maximum rate permitted by the CAMAC Standard.
- No sacrifice of data acquisition rate for data sampling and on-line control.
- High rate data formatting.
- Adequate processing power for optimizing fast software triggers.
- Currently in use in high energy physics experiments at CERN.

The 4800 Series is widely useful in any application that requires fast data handling with distributed intelligence in a CAMAC network. Whether your application is high energy physics data acquisition, video digitizer image processing and on-line enhancement, Fast Fourier Transform (FFT) analysis and related transient recorder data handling, or on-line process control for research or industrial applications—consider the 4800 Series to meet your requirements. Contact LeCroy for details.

*Initial development by LPNHE/Ecole Polytechnique, Paris.

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Publicité dans le COURRIER CERN

Format A4 **Publication mensuelle**

Les annonces paraissent simultanément dans chacune des deux éditions anglaise et française. Les insertions dans la deuxième langue sont publiées sans supplément.

Espace (page)	Surface utile (mm) largeur x hauteur	Prix par insertion (en francs suisses)			
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Supplément:
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Couverture 3 (1 couleur): 1750 Fr. s.
Couverture 4 (1 couleur): 2250 Fr. s.
Date de publication: 1er du mois
Délai de réception des films positifs et textes: 1er du mois qui précède
Les frais de fabrication des films et de traduction des annonces sont facturés à part.
Trame offset: 60 ou 54 suisse (150 anglaise et française)
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La publicité est limitée à 50% du volume de la publication.
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EIMAC's 4CW300,000G Power Tetrode. A new generation of high-performance power tubes.

EIMAC's 4CW300,000G combines all the desired features transmitter designers look for: high peak plate current, low grid emission, low internal capacitances and low internal inductance. This is the first of a new generation of high performance power tubes for LF, HF, VHF and pulse service.

Laserfab pyrolytic graphite grids

The control grid and screen structures of the 4CW300,000G are precision-cut by a laser beam. Each element is monolithic and combines extremely low coefficient of expansion with low structural inductance. These features permit the 4CW300,000G to have a very high transconductance—10^6 micromhos—and allow efficient, high-frequency operation.

Rugged mesh filament

The EIMAC mesh filament provides exceptionally high peak plate current and permits low plate voltage operation. This leads to power supply economy, making the 4CW300,000G the economic choice for 300 KW AM broadcast service or long-pulse switch service, each of which demands a reserve of peak emission.

Improved anode structure

EIMAC's multi-phase cooling technique provides high plate dissipation to extract heat evenly and quickly from the anode, contributing to long tube life and operating economy.

EIMAC expertise

EIMAC's expertise in electron ballistics pyrolytic grid production, thermodynamics and circuit techniques combine to bring tomorrow's tubes for today's transmitter designs. More information is available from Varian EIMAC. Or the nearest Varian Electron Device Group sales office.

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Application Engineering
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