CERN COURIER

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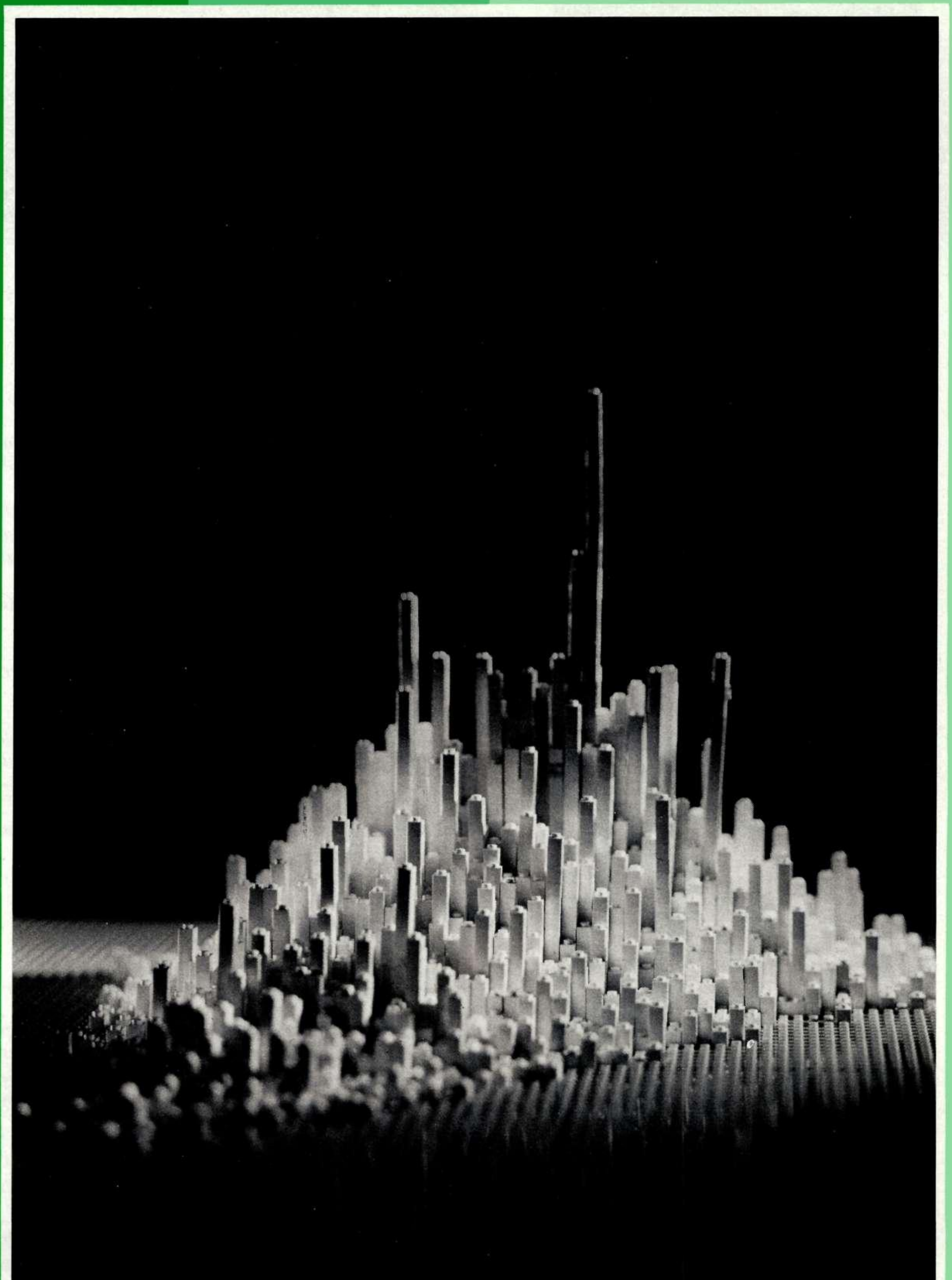

CERN, the European Organization for Nuclear Research, was established in 1954 to '... provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto'. It acts as a European centre and co-ordinator of research, theoretical and experimental, in the field of sub-nuclear physics. This branch of science is concerned with the fundamental questions of the basic laws governing the structure of matter. The Organization has its seat at Meyrin near Geneva in Switzerland. There are two adjoining Laboratories known as CERN Laboratory I and CERN Laboratory II.

CERN Laboratory I has existed since 1954. Its experimental programme is based on the use of two proton accelerators — a 600 MeV synchro-cyclotron (SC) and a 28 GeV synchrotron (PS). Large intersecting storage rings (ISR), are fed with protons from the PS for experiments with colliding beams. Scientists from many European Universities as well as from CERN itself take part in the experiments and it is estimated that some 1500 physicists draw research material from CERN.

The CERN Laboratory I site covers about 80 hectares almost equally divided on either side of the frontier between France and Switzerland. The staff totals about 3200 people and, in addition, there are about 1000 Fellows and Scientific Associates. Twelve European countries contribute, in proportion to their net national income, to the CERN Laboratory I budget, which totals 410 million Swiss francs in 1975.

CERN Laboratory II came into being in 1971. It is supported by eleven countries. A 'super proton synchrotron' (SPS), capable of a peak energy of 400 GeV, is being constructed. CERN Laboratory II also spans the Franco-Swiss frontier with 412 hectares in France and 68 hectares in Switzerland. Its budget for 1975 is 237.9 million Swiss francs and the staff totals about 450.

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Contents

CERN News

Around the Laboratories

Cover photograph: Presenting the results of a high energy physics experiment in an interesting way while depriving the sons of several physicists of their favourite building blocks. The Manhattan skyline which appears in the photograph is a three-dimensional representation of the data from a recent search for charmed particles. A 3.6 GeV/c antiproton beam was used to investigate the interaction $\bar{p}p \rightarrow \bar{K}^0K^+\pi^+\pi^-\pi^-\pi^0$ *and blocks are mounted vertically to count mass values of* $(\bar{K}^0\pi^+\pi^0)$ *against the mass values of* $(K^+\pi^-)$ *of which there are two possible combinations giving the x and y horizontal axes. Peaks are evidence for the existence of charmed particles but those that are seen in these results do not tower sufficiently above their surroundings to be convincing. (CERN 332.5.75)*

More particles
More excitement

This time it was the DESY Laboratory in Hamburg that reactivated the fever in the world of high energy physics by finding a new particle linked to those discovered at the end of last year. Within hours of the DESY find, Stanford was churning out additional information and theoreticians were again pacing their offices without their feet quite touching the floor.

We begin with a rapid recap. Towards the end of last year, at Brookhaven and at Stanford a heavy particle of exceptional stability was discovered. Its mass is 3.1 GeV and it lives a thousand times longer than any other particle with that sort of mass. Stanford then found another at 3.7 GeV. The theoreticians favourite explanation is that they consist of a quark (Q_C) wrapped together with its antiquark (Q_C), these quarks having a completely new property given the name 'charm'. (See December 1974 issue for the story of the discoveries and the April issue of this year for an explanation of charm.)

The charm idea best fits the observations (though other interpretations, in particular one involving a different property called 'colour', are certainly not dead) but it is not proving easy to isolate a charmed particle. The new discovery has come along at a good time to prop up the belief in charm.

A team from the Technical University of Aachen, the University of Hamburg, DESY, Max Planck Institute for Physics at Munich and the University of Tokyo were using the DASP detection system (a double arm spectrometer described in December 1974) at one of the interaction regions on the electron-positron storage rings, DORIS. They looked at electron-positron collisions which created the 3.7 GeV particle and watched the decay of the (3.7) into the (3.1) with photons coming off. They saw photons of distinct energy around 400 MeV and 200 MeV indicating that the (3.7) had decayed to an intermediate particle

$$(3.7) \rightarrow X + \gamma$$

which had then decayed to the (3.1)

$$X \rightarrow (3.1) + \gamma$$

At the time of writing, sixty-five such events have been recorded in DASP.

On 14 July the team at DESY were confident of what they were seeing and the telephone lines started humming again. Someone jumped on a plane to Geneva clutching the results to be passed to the Editor of Physics Letters summoned to the airport. And then the SPEAR storage ring at Stanford joined in. SPEAR was able to say that the first photon to come off was the 200 MeV photon (a Doppler broadening effect was seen with the 400 MeV photon since its parent particle was moving). Thus the new particle is pinned down at 3.5 GeV and the decay chain is

$$(3.7) \rightarrow (3.5) + \gamma \text{ (200 MeV)}$$
$$(3.5) \rightarrow (3.1) + \gamma \text{ (400 MeV)}$$

Data from SPEAR on decays involving mesons was then analysed and has also shown the (3.5) particle, reinforcing the photon data. These decays are, for example

$$(3.5) \rightarrow \pi^+ + \pi^+ + \pi^- + \pi^-$$
$$(3.5) \rightarrow \pi + \pi + K + \overline{K}$$

It is possible that other particles are lurking around the same energy region and the hunt is on for these.

The charm advocates are delighted about the discovery. First of all if the (3.1) and (3.7) are, as we believe, particles which feel the strong interaction (hadrons) then, as with the well known hadrons, there is likely to be a sizable family of them. Secondly, if the hypothesis that the (3.1) is a charmed quark — charmed antiquark pair is correct, then the combination can be expected to exist in several energy states rather close together

This phenomenon is familiar from atomic physics where we can think of an electron sitting in an orbit around a nucleus. The different possible combinations of its own spin and of its angular momentum as it swirls around the nucleus enable it to live in one of several energy states. It is when electrons move from one orbit to another giving off energy as a photon that we see these different possible energy states because of the distinct emerging photon energies. It is fascinating that a similar sending off of a distinct quantity of energy as a photon seems to be telling us that the new particles are (Q_C, $\overline{Q}_C$) combinations in different energy states. Many theorists expect that three states (three particles) will be found around 3.5 GeV. Note that these particles are more tortuous combinations of (Q_C, $\overline{Q}_C$) than the (3.1) and (3.7). They will have different characteristics (or different quantum numbers) from the (3.1) and (3.7). They cannot be formed directly in the electron-positron collisions giving a photon which then converts to a particle because the quantum numbers are not right and this explains why they were not found in the initial search six months ago.

CERN News

Extended collaboration with Soviet scientists

On 10 July a Protocol was signed by Director General W.K. Jentschke, representing CERN, and Deputy Chairman I.G. Morozov, representing the USSR State Committee for the Utilization of Atomic Energy, extending the collaboration which already exists between CERN and high energy physics centres in the Soviet Union. The Protocol opens up, for the Soviet scientists, access to the CERN Intersecting Storage Rings and the 400 GeV proton synchrotron. It is a further stage of the collaboration which gives Western European scientists access to the 76 GeV proton synchrotron at Serpukhov which was for several years the highest energy accelerator in the world.

Participation in the research programme at Serpukhov was under the auspices of an Agreement signed in 1967 (see July issue 1967). The new Protocol is an addition to the Agreement which was evolved during meetings in the USSR in October 1974 and in February. Its main elements are as follows:

Proposals for experiments, involving Soviet and Western European scientists in collaboration, may be submitted for the experimental programmes of CERN or the Institutes of the USSR State Committee or of the USSR Academy of Sciences. They will be submitted through a joint scientific committee to the Laboratory where they would be carried out, for approval in accordance with the normal Laboratory procedures. CERN reserves the right to limit the number of such collaborative experiments to one at a time though there could be overlaps, particularly during the setting up stages. All the associated administrative measures (exchange of personnel and equipment, etc...) will be carried out on a reciprocal basis as far as possible. Financial and other obligations will reflect the scientific and material contributions of the collaborating teams and will be defined in advance.

The Protocol has now become the formal mechanism of co-operation between CERN and the Institutes of the State Committee and Academy of Sciences — such as Serpukhov, Yerevan, Gatchina, Novosibirsk and ITEP Moscow. Relations with the international Laboratory at Dubna will continue under a separate system as in the past.

Discussions on the participation of Soviet scientists in the SPS experimental programme had already begun in advance. In the West experimental hall a CERN/Clermont-Ferrand/Gatchina/Lyon/Uppsala team will carry out a high precision study of elastic scattering. The Gatchina scientists are bringing with them a novel type of ionization chamber (see February issue page 39). In the North experimental area a CERN/Dubna/Munich/Rome team will be looking at muon scattering on hydrogen and deuterium. The Dubna scientists are bringing with them iron which will be used in a special toroidal magnet. Meanwhile experiments at Serpukhov involving CERN scientists continue. The Karlsruhe/Pisa/Serpukhov/Vienna experiment (whose identification of the h particle decay is reported later in this issue) has just finished and the Dubna/Milan experiment watching pion clusters travelling through nuclei is taking data.

A detailed account of the development of the collaboration between CERN and Laboratories in the Soviet Union has recently been published as a CERN 'Yellow Report' available from the Scientific Information Service. It is entitled 'A History of the Collaboration between the European Organization for Nuclear Research (CERN) and the Joint Institute for Nuclear Research (JINR) and with Soviet Research Institutes in the USSR, 1955-1970' and is written by W.O. Lock who was involved in many of the formative discussions from which the collaborations emerged.

CERN 124.7.75

Signature on 10 July of the Protocol which extends the collaboration between CERN and the high energy physics centres in the Soviet Union. On the left Deputy Chairman I.G. Morozov signs for the USSR State Committee for the Utilization of Atomic Energy. On the right Director General W.K. Jentschke signs for CERN.

West Hall close down

Originally planned for 30 June, the close down of the West experimental hall was delayed until 2 July for the Omega spectrometer to gather some additional data. The 3.7 m European bubble chamber (BEBC) had been turned off a few days previously. The next beams to this hall will be those from the 400 GeV proton synchrotron at the end of next year and the intervening time will be fully absorbed in preparing for their arrival.

The hall was invaded immediately after the shutdown by the teams carrying out the reorganization. All of the existing beam-lines have to be dismantled and the new lines installed. A great deal of heavy labour lies in store — some 40 000 tons of concrete and 6 000 tons of iron have to be moved.

During this time, the two large detection systems will be able to take a breather. BEBC has taken 425 000 photographs since coming into service on 5 March — 300 000 with 12 GeV antiprotons looking for charmed particles, 100 000 with 22 GeV negative pions. Tests have been carried out on the EMI (external muon identifier) hybrid installation, the purpose of which is to identify muons in the high energy neutrino experiments with the SPS. For these tests, 16 000 photographs have been taken with wire chambers located upstream and downstream of the bubble chamber.

BEBC will not become rusty. An immediate start has to be made on preparations for SPS experiments and on improvements emerging from the experience of the first long operating period. A series of technical tests are planned before the end of the year, one investigating double-cycling operation. BEBC may be able to take two photographs during the same SPS pulse with an interval of about 500 ms. Other tests are planned for next year, particularly in order to put the final touches to a target for neutrino experiments and to check use of the chamber with neon-hydrogen mixtures.

Omega has operated for about 50 days since the beginning of the year and three experiments have been performed. The first was a charmed particle search. Three million triggers

At a meeting of the Track Chamber Committee on 30 June, Ch. Peyrou received yet another tribute to his achievements during the years he has been head of track chambers at CERN. The photograph shows D.C. Colley, Chairman of the Committee, presenting Professor Peyrou with a first edition copy of the collected works of the 18th century physicist J. Bernoulli. Peyrou was respected by physicists and engineers alike and his passion for bubble chamber physics has been an inspiration to the European high energy physics community throughout the years of CERN's existence.

CERN 50.7.75

On 27 June Dr. H. Firnberg, the Austrian Minister of Science and Technology, visited CERN. She is pictured here in conversation with W. Schnell, Director of the ISR Department, during a tour of the Intersecting Storage Rings.

CERN 346.6.75

Dr. E.G. Michaelis, Head of the Synchro-cyclotron Division, (second from left) escorts distinguished attendees at the inauguration of SCII on a tour of the improved machine.

CERN 13.7.75

were initially recorded and there was a tantalising indication that new particles might be there but the statistics were insufficient. This led to the delay of the West Hall close down to enable the team to acquire further data. The second experiment searched for exotic particles produced in $\pi^- n \rightarrow pX^{--}$ interactions, triggering on the fast proton. The third examined insufficiently known parameters concerning D°, E° and F_I resonances. During the analysis an attempt will also be made to pin down the η_c, a hypothetical particle of the pion and eta family, consisting of charmed quarks. A million triggers were obtained from 1.5×10^{10} incident particles.

Preparations for SPS experiments are now under way. Omega will be fed either by a beam of tagged photons, produced from a beam of electrons, or by a separated hadron beam, (using two superconducting radiofrequency cavities being built at Karlsruhe). A UK group (Glasgow, Lancaster, Manchester, Sheffield and Daresbury) will provide the photon tagging system and a large hodoscope, to be located behind the Omega magnet, as well as electron shower detectors and a high speed electronics system for triggering the reactions produced by the photons.

A group from the Paris Ecole Polytechnique and Orsay will supply lead-glass counters to cover an area 3 m in diameter with a thickness of 50 cm. This will measure the energy of the photons emerging from Omega. CERN will supply optical spark chambers, proportional chambers and drift chambers (to be located inside the Omega magnet aperture) and a more powerful data acquisition system as well as programmes to analyze the data. Saclay, Birmingham and Rutherford will build a second Cherenkov counter 8 m long (which can be shortened to 4.5 m) and hodoscopes. A photon position detector is under study.

Inauguration of SC II

On 1 July, the improved 600 MeV synchro-cyclotron was officially inaugurated. The Director General of CERN Laboratory I, Professor W.K. Jentschke gave the Inaugural Address. E.G. Michaelis, Head of the SC Division, described the improvement Programme and Sir Denys Wilkinson spoke about the physics that the machine can now tackle.

The accelerator has been modified so that its internal beam current can increase from 1.3 to 10 μA and its ejection efficiency from 1 % to 70 %. This has involved the installation of a new type of ion source, of a rotating condenser in the r.f. accelerating system, of a magnetic beam extraction channel and a variety of other modifications which are needed to cope with higher intensities. (A detailed description can be found in the February issue 1973.)

Physics began again on the machine at the end of 1974. The machine is now operated for about two thirds of the time for physics delivering beam to the on-line separator, ISOLDE, to a liquid deuterium target for the production of 600 MeV neutrons and to a system of four internal targets giving beam sharing of the extracted beam. Devices such as a pulsed field coil, giving a 2 ms burst of protons per cycle free from r.f. structure, and a cee electrode, powered to give a long burst of about 20 % duty cycle, have been successfully tested.

Proton transmission, from 40 cm radius to the extracted beam, exceeds 70 % — an efficiency which has never before been achieved in this type of machine. Already the extracted beam intensity has reached 1.5 μA though the r.f. system has not been pushed to its full capability. This is being done gradually. The design figure of 10 μA for the internal current should be possible with the full duty cycle being used but with the accelerating voltage at two-thirds the design value. At full voltage the intensity could be double the design value.

Shortly after the inauguration with the extracted beam at 1.5 μA, 1.2 μA went to ISOLDE and this was sufficient (providing 300 W of power) to keep the ISOLDE lead target molten at 700 °C without additional heating! Intense secondary beams of mercury isotopes emerged from the target feeding five experiments simultaneously. Some spin measurements were possible for the first time and two new isotopes were discovered. One of them, ^{177}Hg, is the most neutron deficient mercury nucleus identified to date.

With a performance at these levels, the CERN synchro-cyclotron provides facilities for physics which are competitive with the new meson factories at LAMPF, SIN and TRIUMF.

55th Session of CERN Council

The Council met on 25, 26 June under the Presidency of M.P. Levaux

The June Council session tends to be one of rather broad discussion on overall policy compared to its December counterpart where practical decisions, particularly on the CERN budgets, are dominant. This session was no exception and the thinking which emerged will dictate the development of CERN in the coming years. There are two important measures to report — the foreseen financial pattern through to the end of the decade and the new internal structure of the Laboratory.

The 55th Session of CERN Council presided over by M. Pierre Levaux (centre of picture) was the scene of important discussions concerning the financial framework of CERN's future activities.

CERN 270.6.75

Professor W.K. Jentschke reported on progress in Laboratory I during the past six months. He described the continuing crop of unique information coming from the Intersecting Storage Rings, the charmed particle searches and the identification of a new decay channel of the h particle in a collaborative experiment at Serpukhov.

On the equipment side, all is well with the accelerators and the major detection systems and a lot of attention is now being given to preparations for the start of experiments using beams from the 400 GeV proton synchrotron, the SPS. In the West experimental area in addition to the neutrino physics programme (using the big bubble chambers, BEBC and Gargamelle and large electronic systems) ten other electronics experiments are approved. The first five North Hall experiments are also approved.

Professor Jentschke brought out a cause for concern regarding physics at the SPS. The teams preparing for experiments include very few physicists from the smaller Member States. Experiments at these higher energies are on a much larger scale (in terms of size of detection systems, time-scales, etc...) than at the proton synchrotron or the ISR. It seems that, up to now, the mechanisms for participation from regions where extensive 'home' support is not available have not been found. One contributing factor may be that these physicists are already heavily involved in the present CERN research programme, at a scale with which they can cope, and do not have sufficient backing to prepare at the same time for the coming of the SPS. This situation is being investigated.

To mark the end of his term of office as head of track chambers, Professor Ch. Peyrou reviewed the years of bubble chamber research at CERN. He described some of the physics which has poured out from bubble chamber experiments and demonstrated how ideally the technique is adapted to the idea of European collaboration in high energy physics. A map of Europe showing the home stations of teams using the chambers at CERN was strewn with flags. Prof. G. Salvini added a remark not unrelated to the problem raised by Professor Jentschke — that experiments involving electronic detectors could usefully pursue still further some of the features of data distribution to centres in the Member States which have always been characteristic of bubble chamber research.

Dr. J.B. Adams in his report on progress at Laboratory II concentrated on the magnet system showing an impressive film of the magnet construction and describing the worries earlier this year when some magnets were found to be breaking down despite previous successful tests (see April issue page 110). Despite the additional work in repairing and rebuilding over 200 magnets, it is expected that the last magnet to complete the ring will be lowered to the tunnel on schedule at the end of this year.

There are some remaining worries, particularly in connection with the delivery of quadrupole focusing magnets for the beam-lines which are behind schedule. Dr. Adams remarked that the construction of a large technologically advanced machine like the 400 GeV proton synchrotron appeared to stretch European industry to its present limits and that the rate of advance is now dictated by the capabilities of industry rather than the ingenuity of designers. He reflected on the problems which would have arisen had the decision been taken at this stage to incorporate superconducting magnets. Dr. G.H. Stafford, Director of the Rutherford Laboratory later remarked, however, that if we set our sights on the stars we must expect to trip over our feet occasionally.

CERN budgets for the coming years

Professor B. P. Gregory acted as spokesman for the Member States in presenting their attitude to the financing of CERN's activities which has emerged from recent discussions.

The problems lie not simply in the magnitude of the figures, which are inevitably a concern in times of financial trouble, but also in the growing disparity between expenditure at CERN and what is then available for the research groups based in the Member States. Long term, CERN cannot continue to function as it is intended to do if the home groups are too severely weakened by financial restrictions.

The wishes of the Member States were summed up under three headings. Firstly, since it is the total contribution to CERN which has impact on the national research budgets, the total figure should be examined and the consequent effect on the programmes considered afterwards. Secondly, the cost variation index (which modifies the CERN budget figures to take account of the movements of prices and salaries in Europe), though still remaining under the annual control of Council, should generally be applied and not used as an instrument affecting policy by cutting back on previously approved figures. A proviso to this is the concern that the salaries of CERN staff should be carefully watched. Thirdly, there is a wish to return to the 'Bannier procedure' whereby at the end of each year figures for the four subsequent years (with varying degrees of 'firmness') are put on paper. This enables CERN to do sensible long term planning and the Member States to know their commitments for years in advance.

The Member States therefore propose that CERN should prepare programmes which assume, as a planning figure, a decrease in the total budget of 3% per year for the next four years. This means that the present total budget of 645 million Swiss francs would fall to 565 million Swiss francs in 1979. (These figures are at 1975 prices — the actual figure appearing on paper in 1979 will be higher depending upon the increases accorded as a consequence of the cost variation indices.) Despite the restrictive moves, the Council reasserted its determination to preserve the high quality of CERN and thus the high quality of research in Europe.

Replying for the CERN administration, Dr. Adams recognized that CERN can only exist in the economic environment prevailing in its Member States. Also firm guidelines on which to base the long term programmes are very important and the Council's attitude to the cost variation index and the Bannier procedure will establish such firm guidelines.

CERN would prefer to see reductions applied in the light of the events which are foreseen in the life of CERN for the coming years. The major event will be the change in 1979 from construction to operation of the 400 GeV proton synchrotron. A first look at the budgetary consequences of this change suggest that the major CERN programmes could be sustained with an annual budget reduction of 2.4%, possibly extending through to 1980 so as to arrive (a year later) at the end figure proposed by the Council.

No decisions were taken on the budgets but the discussions of the next few months will be in this region of 2.4 to 3% reductions.

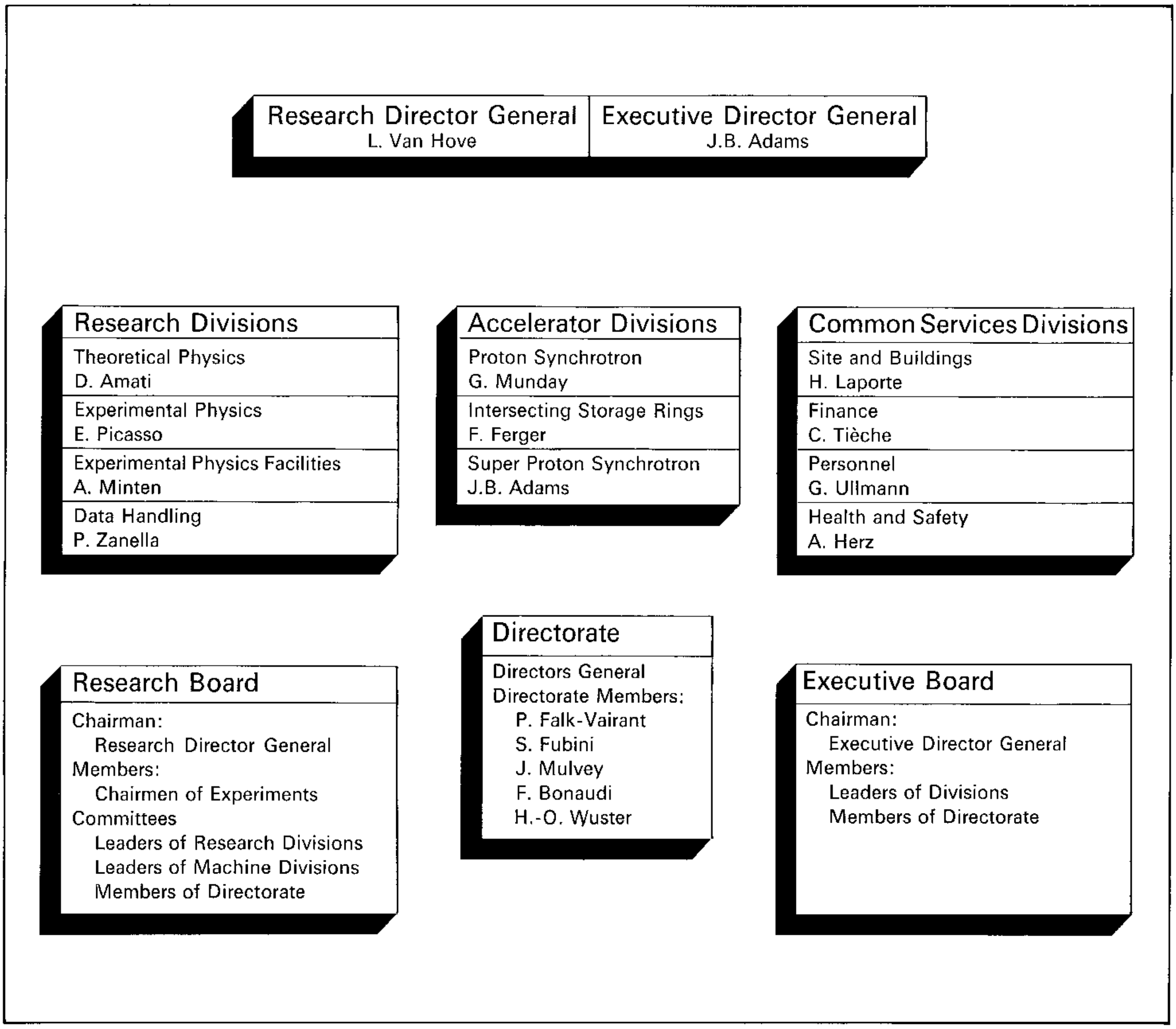
Reorganization of CERN management

As from the beginning of next year the two CERN Laboratories will be united under two Directors General. A new management structure, which will then prevail, was approved by the Council.

The structure is detailed in the diagram which also indicates the people who will initially fill the various posts. We add here, for those who are familiar with the existing CERN management, some notes which bring out the major changes.

The Directors General are directly responsible to the Council and the Council has clearly defined their respective areas of responsibility so that as far as possible they can act independently. The Executive Director General (D.G.E.) is responsible for administration, for operation of equipment and services and for the construction of buildings and major equipment; the Research Director General (D.G.R.) is responsible for the research activities. Many decisions, however, spread into both areas of responsibility and the management structure tries to cater for the interlocking relationships.

A Directorate will consist of the Directors General and six Directorate Members (five of whom have been appointed) who will assist the D.G.s in evolving and executing the general



Research Director General
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Executive Director General
J.B. Adams

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D. Amati
Experimental Physics
E. Picasso
Experimental Physics Facilities
A. Minten
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Accelerator Divisions
Proton Synchrotron
G. Munday
Intersecting Storage Rings
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Super Proton Synchrotron
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Research Board
Chairman:
Research Director General
Members:
Chairmen of Experiments Committees
Leaders of Research Divisions
Leaders of Machine Divisions
Members of Directorate

Directorate
Directors General
Directorate Members:
P. Falk-Vairant
S. Fubini
J. Mulvey
F. Bonaudi
H.-O. Wuster

Executive Board
Chairman:
Executive Director General
Members:
Leaders of Divisions
Members of Directorate

policies and programmes and in the deployment of resources. The Directorate Members will supervise programmes involving many Divisions — three Members having responsibilities in the research activities (P. Falk-Vairant, S. Fubini and J. Mulvey) and three in administration and operation (initially H.-O. Wuster and F. Bonaudi). Another reflection of this 'horizontal' organization, across Divisional boundaries, is the setting up of a Programme Budget System (under H.-O. Wuster) which will allocate and manage financial and manpower resources on the basis of agreed programmes.

There will be eleven Divisions with Division Leaders directly responsible to the two Directors General. There are some changes compared with the existing list of Divisions. The two present experimental physics research Divisions, Nuclear Physics and Track Chamber, emerged from the days when experiments using electronic techniques and bubble chambers were quite distinct. Now the trends are towards amalgamation of the two approaches and this is reflected in reorganizing the two Divisions. An Experimental Physics Division will house all the experimental research physicists; an Experimental Physics Facilities Division will house staff working on the large experimental facilities such as bubble chambers and spectrometers.

In the Accelerator Divisions, Laboratory II will become the SPS Division, and the present small Synchro-cyclotron Division will be absorbed into the Proton Synchrotron Division. A new Division, to be known as Health and Safety Division, has come into being as from July of this year.

Two Boards will be created. A Research Board will largely take over the responsibilities of the present Nuclear Physics Research Committee but with a broader mandate. It will concern itself with the research programmes, the research facilities and the corresponding budget and staff estimates. An Executive Board will be concerned with the execution of the agreed programmes and the corresponding budget and staff estimates.

To conclude, we record the other appointments made at the Council in addition to those which are evident in the diagram. R. Armenteros was appointed Director of the Physics II Department until the end of the year in succession to Ch. Peyrou. G.H. Hampton, E. Picasso and W. Schnell had their appointments as Director of the Administration Department, Leader of the Nuclear Physics Division and Director of the ISR Department respectively, extended until the end of the year. In the Scientific Policy Committee, G. Salvini and P. Lehmann will succeed E. Amaldi and F. Perrin. V.F. Weisskopf will remain a member for a further three years.

Santa Fe Conference

The sixth International Conference on High Energy Physics and Nuclear Structure was held at Santa Fe from 9-14 June. This is the 'big one' in the field of intermediate energy physics and serves as a bridge between the nuclear and the high energy communities. The beautiful city of Santa Fe was invaded by nearly 500 physicists, well beyond the 'official' Conference attendance of 300. In addition a TV link to the nearby Los Alamos Laboratory swelled the audience still more. A lot of fresh information on the nucleus was presented and we will attempt to bring out some of the main themes.

For the first time the electron machines of MIT and Saclay with their high intensity and excellent energy resolution, which came into action a few years ago, were a prominent source of new data. It seems that there is a canonical time-lag between the first operation of a machine and when it starts pouring out significant results. This is apparent with the meson factories which are now in operation but which have not yet flooded the Conference with pion experimental data.

Among the important things to learn about the nucleus are its geometric and electrical features. What is its shape? How is matter distributed within the nuclear volume? How is the electrical charge carried by the protons distributed? And so on. The new data from electron scattering gives remarkably precise information on the charge distribution. For example, at Saclay the scattering cross-section for a nickel nucleus has been measured spanning twelve orders of magnitude.

This precision has come at a time when the theoreticians have evolved techniques for reconstructing the spatial distribution of charge in the nucleus (the distribution involves both the charged protons and the effect of the magnetic moment of the neutrons). This analysis is almost independent of any model of the nucleus — it does not have a theory imposed on it. All that is needed is a reference scale which can be extracted from the data on mesic atoms and then an actual contour map of how charge is distributed in the nuclear volume emerges. Compared with the data which was available before, it is as if we now have an actual photograph in our hands rather than an unresolved hologram.

Quite dramatic contour maps of this sort came from MIT just before the Conference. Looking at rare earth nuclei such as ytterbium, they detected two centres of higher density as if the nucleus was already exhibiting a predilection for breaking into two. It will be fascinating to see how these two islands within the nucleus develop as fissionable nuclei, such as uranium, are examined.

High energy electron experiments on deuterium at Stanford have indicated that the number of electrons bouncing off at wide angles falls off much faster than is expected from nuclear models. The data lines up with the hypothesis that the electrons are actually bouncing off individual quarks within the proton or neutron in the deuterium nucleus which is very puzzling to many theoreticians. It will be interesting to test this further by seeing what happens when the electrons are fired at helium nuclei — will they still scatter as if confronted by the greater number of quarks in the helium? Other data, such as that from proton-deuterium scattering, seems to be saying that whole nucleons and not their quark constituents are responsible for scattering and the picture is not clear.

The interaction between nucleons and the consequences in terms of possible nuclear states has been looked at with a fresh eye in recent years. One possibility involves nucleon and antinucleon systems which have been examined particularly by I.S. Shapiro in Moscow. It seems that theoretically there is nothing to stop nucleon and antinucleon hanging together for a significant time without annihilating and such states could be observable. There is a growing volume of experimental evidence which indicates that something unusual is going and several groups claim to be seeing such states. Not all the experimental evidence is in agreement, however.

The new pion data was not very spectacular with the exception of data from SIN and Moscow which indicates that when a pion is stopped in a nucleus it has a surprisingly high tendency to result in a nucleus in a high spin state. It is as if the pion lodges in the outer rim of the nucleus and its interaction throws off one nucleon leaving a high spin nucleus behind it but why this should be such a popular mechanism is not known.

From SIN and Rutherford there is also the first clear observation of hyperfine effects involving the strong rather than the electromagnetic interaction. This is seen in pionic and kaonic atoms with particularly large effects in deformed nuclei. The cigar shape of such a nucleus means that the pion or kaon orbits vary considerably in their proximity to the nuclear charge depending on whether they swirl round the equator or poles of the nucleus. This gives the difference in the energy levels of the orbits which is seen as hyperfine structure and may prove to be a new route to information on nuclear matter distribution.

Among other mesic atom information were important results from CERN and Canada which have brought X-ray measurements with heavy atoms back into line with the predictions of quantum electrodynamics. Nothing seems to survive for very long if it is out of line with quantum electrodynamics. Mesic atoms have also given new high precision mass measurements for the pion, the kaon and the antiproton and magnetic moment measurements for the antiproton and the sigma.

Experiments at CERN are giving fresh information on the nucleus by looking at nuclei in which a neutron has been replaced by a lambda particle. On the one hand, spectroscopy of such hypernuclei has opened up with the observation of decays from higher energy levels emitting a gamma ray in hypernuclei of hydrogen, helium and lithium. Gamma rays have been measured emerging from hypernuclei corresponding to about ten different energy states. On the other hand, 'strangeness analogue states' have been identified where the lambda sits in specific energy states. A remarkable amount of information can be extracted from a modest amount of data.

A very ingenious experiment looking for parity violation in polarized proton-proton scattering was reported by D. Nagle from Los Alamos. By modulating the polarization they were able to eliminate the effect of asymmetries in the detection system and push the precision down to about 10^{-4}. To get beyond this level, beam stability onto the target was controlled by a feedback system and the precision moved to 2×10^{-7}. No asymmetry was seen but the measurement is now close to the level were theory predicts that asymmetries will appear. The technique is being pushed further at Los Alamos and Argonne.

The parity results make it even more important to check again the experiment of Lobashov which indicated parity violation two orders of magnitude higher than expected in the neutron-proton interaction giving a deuteron and a gamma. A similar experiment is under way at Grenoble.

The vital links between our understanding of the smallest components of the Universe and our understanding of the largest objects of the Universe are emerging again. High energy physics has recently added the neutral current interaction to its list of ways in which the weak interaction can act. Nuclei can have coherent interactions via neutral currents and the interaction probability then grows as the square of the number of nucleons rather than linearly. When this is fed in to the calculations of supernova properties an intriguing picture emerges.

It is believed that in these dense stars the emission of neutrinos is the major mechanism for getting energy out from the interactions which take place in the centre. Neutrinos, with their very low interaction probabilities, are the only particles which can escape through the densely packed matter, in particular penetrating an outer crust of heavy nuclei. We now have to feed into the sums that there are additional ways in which the neutrinos can interact and, depending upon the neutrino interaction cross-sections we use, this can bring us quickly into a situation where the outer crust is opaque to the neutrinos. The supernova would then have to explode to release its energy.

Measuring neutrino cross-sections on heavy nuclei is so difficult, however, that D. Walecka bet a rather safe bottle of champagne against them being measured for anything heavier than carbon. The more adventurous experimenters have thought of aiming a neutrino beam into the ground and looking on the opposite side of the earth.

Another entertaining astrophysical calculation has been done by Turkevitch. Considering the Van Allen radiation belts around the planet Jupiter, he estimated that the flux of protons with energy of a few hundred MeV on the inner moon was about equal to that created on earth at our meson factories. A rich crop of nuclear interactions, for free, is therefore available to anyone who cares to go and look.

Around the Laboratories

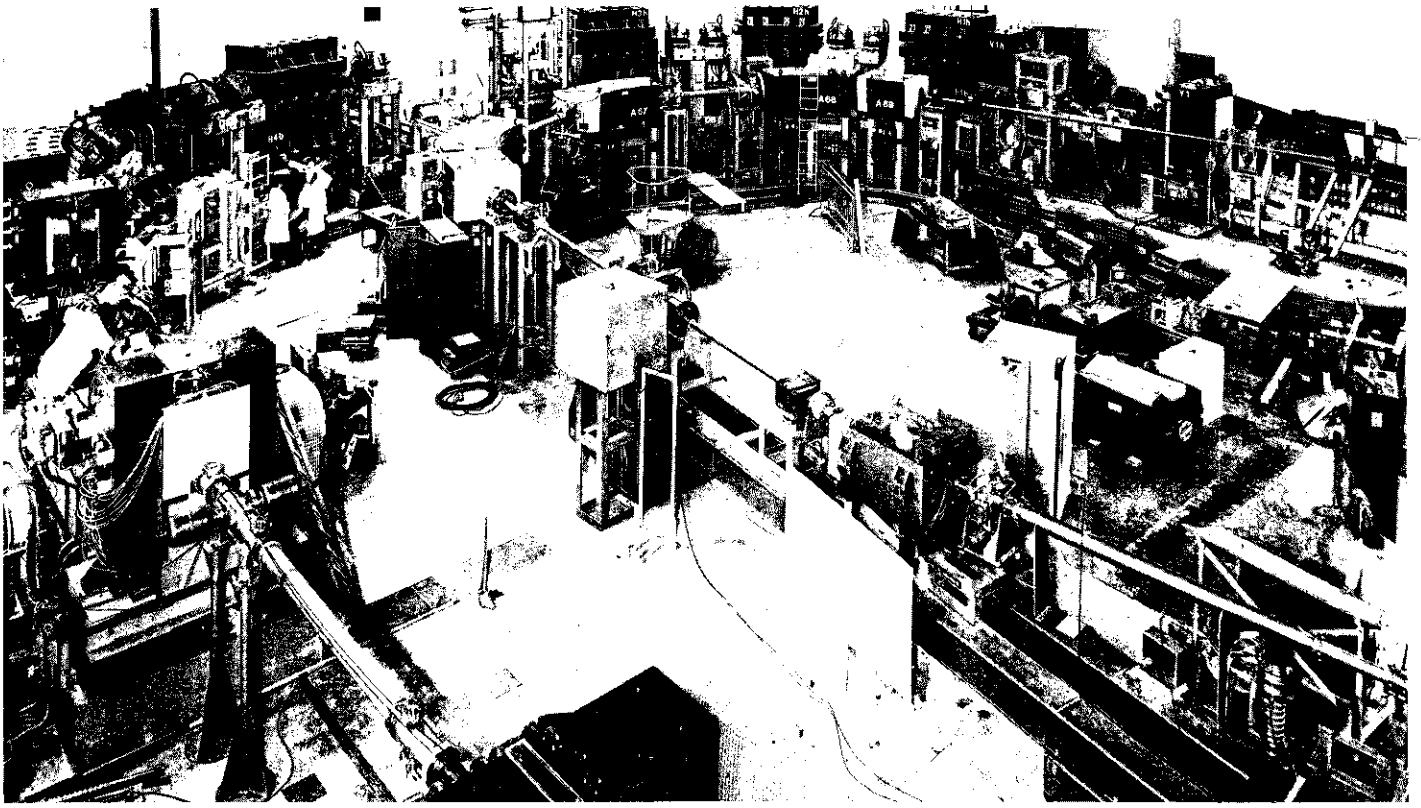
ORSAY
Start up of DCI

During the night of 9, 10 July one of the two rings of DCI, the 1.8 GeV electron-positron colliding beam machine being built at Orsay, was brought into action for the first time. After optimizing the beam from the linear accelerator, which serves as injector, electrons were fed into the ring and circulated. Tuning the ring led to particles orbiting for some hundreds of revolutions. Electrons were then stacked during ten minutes and beam parameters were measured. A new electron-positron colliding beam machine has thus joined the high energy physics armoury at an exciting time.

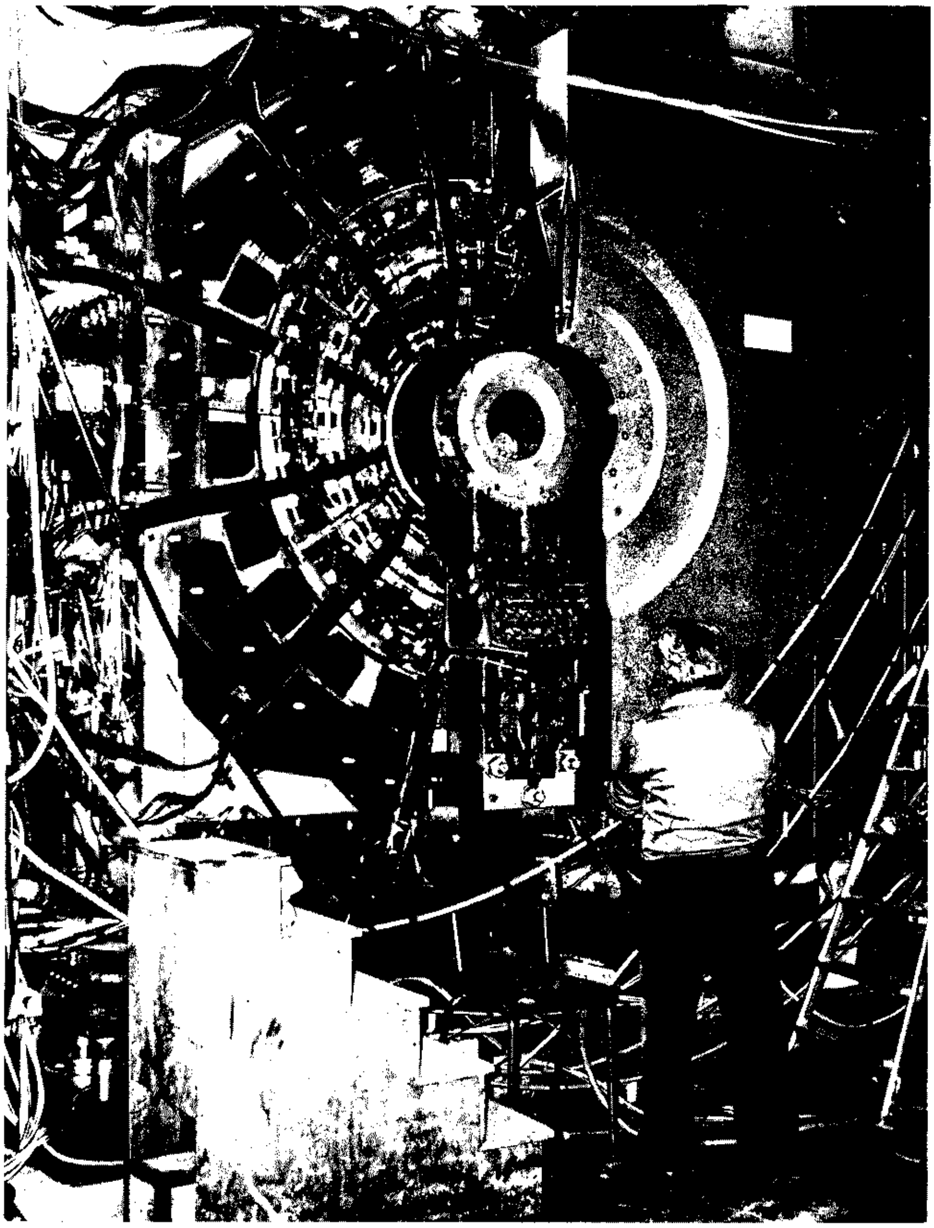
DCI (Dispositif de Collisions dans l'Igloo) takes its name from the circular building which houses it. This is 36 m in diameter, whitish in colour and covered by a dome-shaped roof. Until 1972 it was used as an experimental area by physicists working on the 2.3 GeV electron linear accelerator. Since the DCI budget (41.5 million French francs) did not include the cost of a new building, the storage rings had to be squeezed into the igloo to the extent that some of the components are actually touching the walls.

DCI has two superposed rings, capable of a maximum energy of 1.8 GeV, and each designed to carry an electron and a positron beam. It is hoped to achieve a luminosity of about 10^{32} cm^{-2}s^{-1} by means of 'space charge compensation' — a method of reducing the disruptive effects of dense bunches of particles passing through one another by ensuring that the intersecting bunches have zero overall space charge. Two bunches, one of electrons and one of positrons orbit each ring of DCI. When they collide, in the straight sections common to both rings, the four bunches come together to form two intersecting bunches. One consists of electrons from the top ring and positrons from the bottom ring; and the other of electrons from the bottom and positrons from the top. The overall charge in each bunch is zero and space charge phenomena disappear. Collisions in the straight sections thus involve a pair of e^+e^- beams travelling in one direction and a pair of e^-e^+ beams travelling in the other.

Each ring has four half-periods containing three horizontal bending magnets, two vertical bending magnets and seven quadrupoles. The quadrupoles have secondary windings to separate the beam parameters in each ring. This allows different working points to be used with energies ranging from 1.3 to 1.65 GeV at an r.f. power of 125 kW per beam. The two straight sections are 6 m long — one



Part of the DCI electron-positron storage rings. On the left is the straight section to be used for experiments. On the opposite side of the ring in the injection straight section and an injection beam-line can be seen doing a U-turn to reach there. (This is a consequence of the building space restriction which dominated the design of the machine.) At the moment only the lower of the two super-posed rings has a vacuum chamber installed. It came into action in July.



The solenoid magnetic detector now in operation at the lower energy ACO storage ring at Orsay which will move to DCI. Its aperture contains an array of cylindrical wire chambers and scintillation counters.

(Photos Orsay)

is used for injection and the other for experiments. The accelerating cavities (one per ring) operate on the eighth harmonic of the revolution frequency. Eventually each of the cavities will be powered by a 350 kW supply giving 250 kW to the two beams in each ring.

The injection energy is 1.2 GeV using the existing linear accelerator. Two beam-lines are used to inject particles in the two directions and can be readily switched from electrons to positrons. With one bunch per beam the injection rate should reach 6 A/h. With only one beam per ring (e.g. to study positron-positron collisions), eight bunches per beam are possible with an injection rate of 20 A/h.

During the first stage of operation (expected to last about a year) only one ring will be in action to study e^+e^- collisions. The maximum luminosity will be of the order of 10^{30} cm^{-2}s^{-1} at an energy ranging from 1.4 GeV to 1.7 GeV. When the second ring comes into operation, physicists will be able to study two types of collisions: e^+e^+ and $e^\pm e^\mp$. For the positron-positron collisions each beam will consist of eight bunches and the luminosity will be about 10^{31} cm^{-2}s^{-1}. This mode will be used for 'two-photon' experiments and electron-positron annihilation events, which normally are a troublesome background to this type of experiment, will not be there. Furthermore, a simple but efficient electron-tagging system can be operated using vertical bending magnets as spectrometers at the end of the straight section. A charged particle and neutral particle detector filled with cylindrical wire chambers and scintillators (which is currently installed at the lower energy storage ring ACO) will be used. Synchrotron radiation from DCI will also be used by physicists from various fields at the 'LURE' Laboratory where the radiation from ACO has already been exploited.

Synchrotron radiation experiments in LURE

The 'Laboratoire pour l'Utilisation du Rayonnement Electromagnétique' involves both the CNRS (Centre National de la Recherche Scientifique) and the Université Paris-Sud. It was set up in 1971 to use the light emitted by both the Orsay storage rings, ACO and DCI. It began work at ACO where various experiments required monochromatic light in a vacuum of about 10^{-6} torr. Two problems had to be overcome — the light had to be transferred from the ultra-high vacuum in the ring (10^{-10} torr) without using a window (to avoid cutting off radiation 1000 Å) and the light had to be made monochromatic.

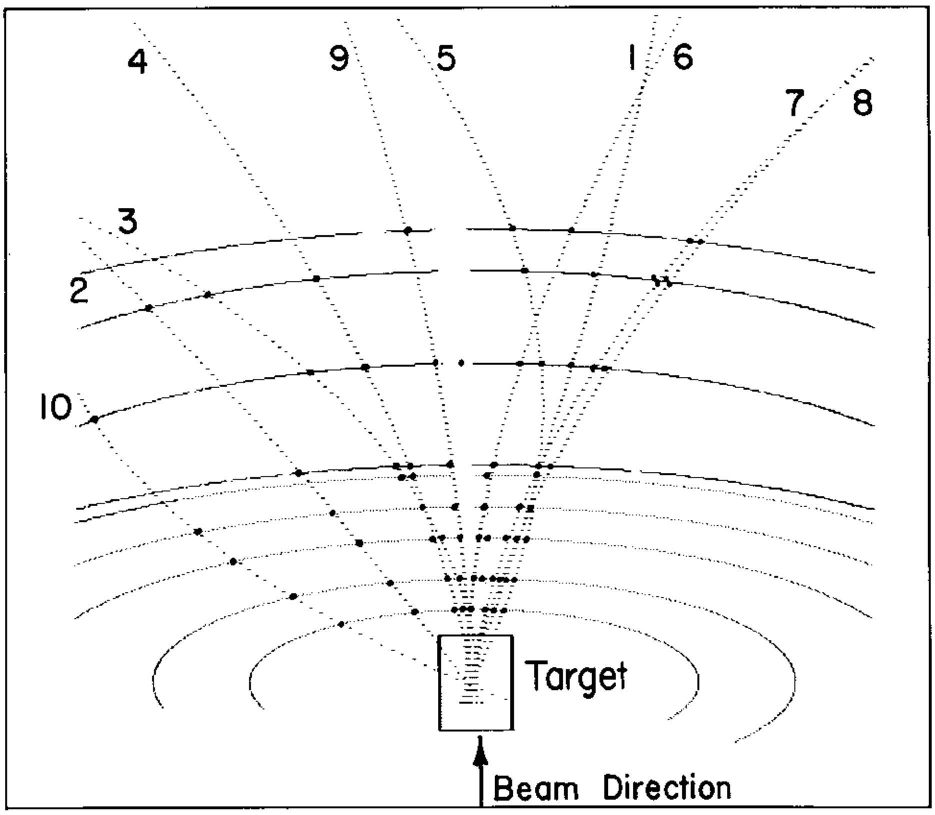
ACO has one light output where three ion pumps ensure the changeover from ultra-high to normal vacuum. The light beam is then distributed among several beam-lines so that many experiments can be run simultaneously. The experimental hall has two levels — two thirds of the light is fed to the first floor (5 × 10 m) and directed towards one of two monochromators and the remainder is used on the ground floor (4 × 12 m) where there are three lines, two of which can be used simultaneously.

Seven experiments are installed and four run simultaneously. They cover a variety of fields such as spectroscopy below 1000 Å, atomic physics, molecular physics, solid state physics, chemistry and biology. The teams share time with a high energy physics experiment but, as from 1976, ACO will be used exclusively for synchrotron radiation research, and more light outputs will be added.

The use of DCI for synchrotron radiation is being developed to use the range below 4 Å, and an experimental hall is being built with four

Our picture of an event recorded by the ISR Split Field Magnet detectors led to us receiving this computer reconstruction of a ten particle event seen by MASS (Multiparticle Argo Spectrometer System) at the Brookhaven synchrotron. It has been described as an 'all electronic bubble chamber' designed to study proton-proton interactions which give many outgoing particles. The data taking rate is many orders of magnitude higher than in an 'all bubble chamber bubble chamber'.

MASS has a vertex spectrometer (the section illustrated) of nine cylindrical wire spark chambers clustered around hydrogen target located in a large volume 1 T magnetic field. Further downstream, high momentum and low momentum spectrometer arms (picking out tracks 1 and 2 respectively in the picture) trigger the whole detection system on appropriate events. A pattern recognition program in a CDC 6600 computer reconstructs the event from the signals received from the detectors.



X-ray monochromators. They are scheduled for operation at the beginning of next year.

JAPAN First experiments for KEK

Twenty-eight proposals for experiments on the 12 GeV proton synchrotron at KEK were presented by groups at the beginning of May. Two counter experiments and two bubble chamber experiments were approved by the Program Advisory Committee and scheduled to run from April 1977 to June 1978.

The approved experiments are:

1. Measurement of the differential cross-section and polarization parameter in the negative pion-proton charge exchange interaction giving a neutral pion and a neutron from 1.8 to 3.0 GeV/c (Kyoto);
2. Precision measurement of the differential cross-section and polarization parameter in negative pion-proton elastic scattering from 2 to 4 GeV/c (Nagoya / Hiroshima / KEK / Osaka / Tokyo / Kyoto);
3. Study of inelastic reactions in pion-nucleon interactions in the intermediate energy region which will involve 300 000 negative pion pictures in the initial run (KEK);
4. Study of three body reactions in diffraction dissociation which will involve 200 000 negative pion pictures in the initial run (Tokyo Metro. Univ./ Nagoya/Tokyo Univ. of Agri. and Tech./Chuo).

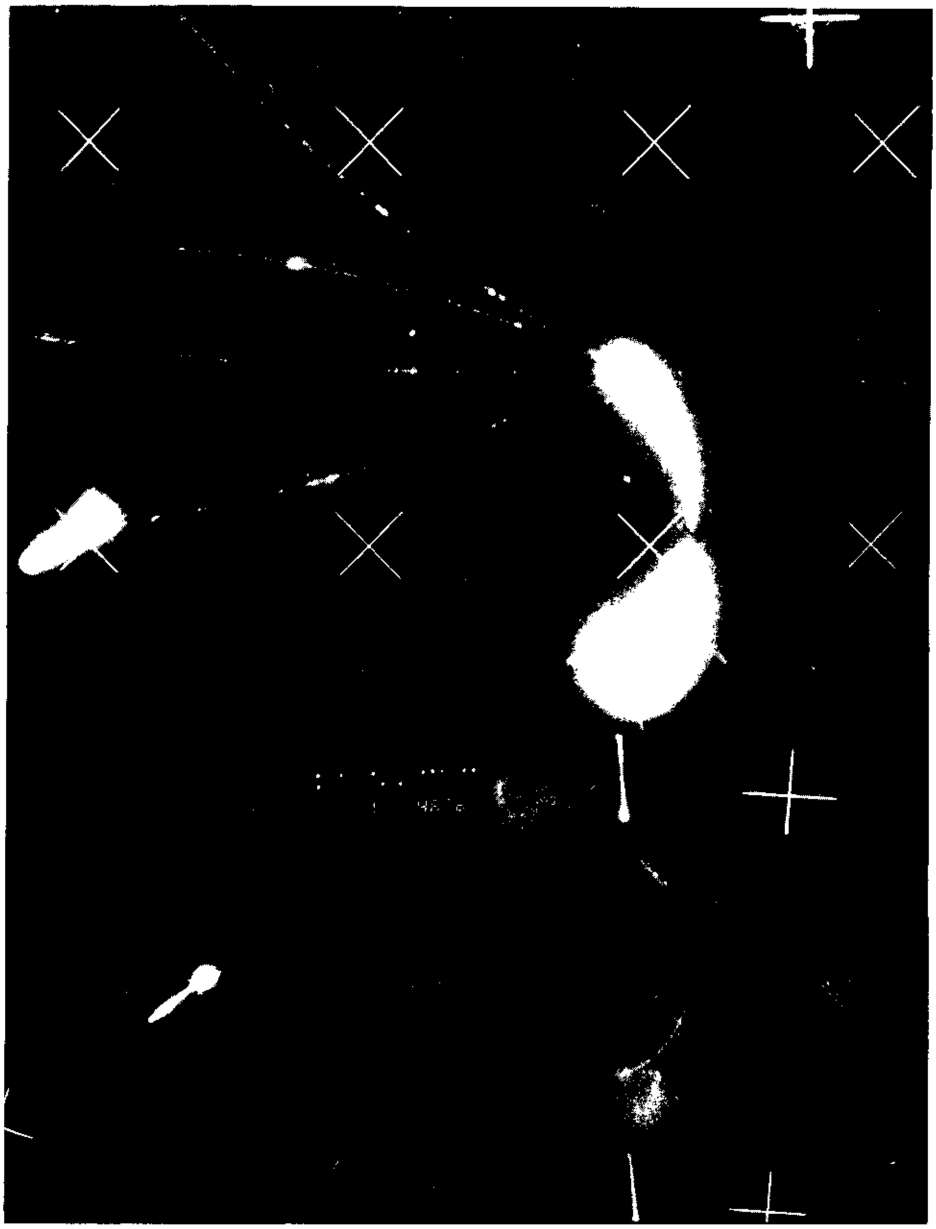
The counter experiments will use an unseparated 4 GeV beam-line in the internal target area. The KEK 1 m bubble chamber will be filled with hydrogen for this initial picture taking.

Construction of two low energy separated kaon beam-lines — one in the momentum range below 1 GeV/c and the other between 1 and 2 GeV/c — was strongly recommended for the slowly extracted beam area. It is intended to build unique facilities at KEK in this direction.

Eight of the proposals were in the fields of nuclear physics, radiochemistry and solid state physics. These were examined by the Committee on 17 June. A radiochemistry experiment, proposed by Kyoto together with five other institutes, was approved to use the negative pion beam in the internal target area parasitically. Two other experiments have been recommended for feasibility tests using the test beam-line in the internal target area. Decisions on experiments which would use the slow extracted beam-line were postponed until the high energy physics experiments situation becomes manageable.

Turning to construction progress on the accelerator: Tests of the main power supply with the main ring magnets as load began in July. The supply is of the static compensator type (no motor-generator set) and hence careful checks of the impact on the commercial power lines are part of the commissioning procedure. The 500 MeV booster is now operated regularly for two days per week. Its maximum intensity is 2 × 10^{11} protons per pulse (design figure 5 × 10^{11}) and to advance this figure, attention is being concentrated on improving the position and phase feedback systems of the r.f.

First beam ejection tests from the booster took place in June with good results. Ejection efficiency seems high (precise measurements have not yet been done) but the beam stability problem which is being attacked via the feedback systems has a bad effect also on ejection. When this is improved, both quantity and quality in the ejected beams should go up ready for feeding the main ring.



An inelastic interaction with a 6 GeV/c polarized proton on helium in the Argonne 1.5 m streamer chamber. Each event is recorded with two pictures — one to see the dim minimum-ionizing tracks of the emerging high energy particles and the other, stopped down to see the bright track of the recoil nucleus (such as is shown in the lower part of the picture).

ARGONNE
First helium experiment in streamer chamber

A preliminary run to study polarized protons interactions in helium has been carried out at the Argonne Zero Gradient Synchrotron by a group from Strasbourg and Orsay. It involved a 6 GeV/c beam into a streamer chamber filled with one atmosphere of pure helium gas which serves as both the target and the detector. (For a description of some of the advantages of the streamer chamber as a detector see the June issue 1973, page 179). The Argonne 1.5 m chamber represents a target mass of only 0.025 g/cm^3 and the mass upstream of the chamber had to be minimized to cut down interactions occurring other than with the helium and the trigger had to be made insensitive to such other interactions. The trigger consisted of a beam telescope of scintillation counters upstream and a beam veto counter and multiwire proportional chamber plane downstream of the chamber which counted the number of emerging charged particles.

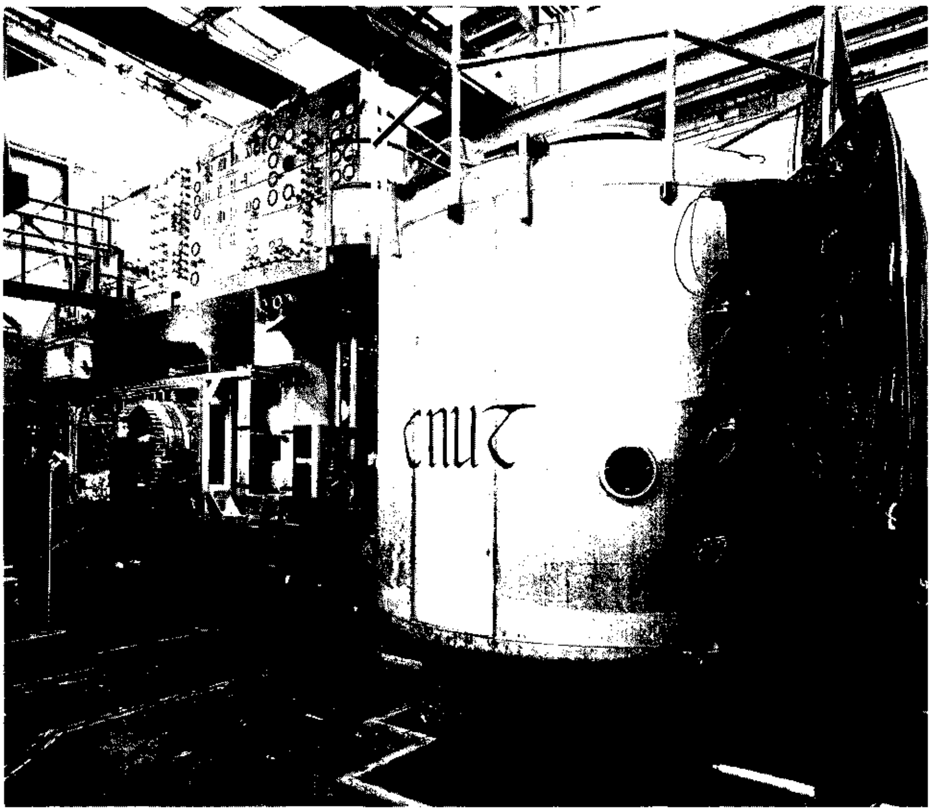
To produce streamers in pure helium, a pulse of approximately 900 kV with a 20 ns width was used (the usual neon-helium mixture requires a 700 kV, 15 ns pulse) and no difficulties related to the higher voltage were encountered. In fact, the system operated at a 15 per cent lower voltage than expected because of the higher efficiency of a new transmission line to the chamber.

Good quality tracks were achieved with little tuning and the chamber memory was held to a few microseconds by adding to the gas a little sulphur hexafluoride. The recoiling helium nuclei produce tracks much brighter than the singly charged high energy particles and to achieve good photographs of both, each camera photographed two images through two lenses; one set at f/2 and one stopped down to f/5.6 which was sensitive only to the bright recoil tracks. A system of shutters was used to cover the f/2 lenses during part of the flash to record the fiducials so as to balance the fiducial brightness in the double photographs.

The goals of the experiment are to study N* production, proton diffraction dissociation, π^4He enhancements, and ^{4}He fragmentation distributions. The 1.5 m streamer chamber, which is the largest chamber to operate with pure helium, is needed in order to see cleanly the very low energy helium recoiling helium nucleus. The recoil nucleus travels approximately 20 cm in the chamber before stopping whereas in the liquid of a bubble chamber it would travel only approximately 0.3 mm. Over 49 000 pictures were taken in the test run and the film is now being analysed to determine the interaction rates and to see whether there are possible modifications which would increase the rates in a large production run.

STANFORD
New hybrid facility coming into action

Not many years ago, the bubble chamber and electronic-type detector were two distinct animals and the practitioners of the respective techniques met at International Conferences. Important moves towards their amalgamation in hybrid systems began when bubble chambers were developed to pulse many times per second so that the fast data taking abilities of the electronic detectors would not be completely wasted while they were used in the same detection system.



Side view of the hybrid detection system which is coming into action at Stanford. The bubble chamber magnet is opened on the left, revealing the chamber volume, and the large cylindrical Cherenkov counter is pulled back. On the downstream side of the chamber is the frame for holding multiwire proportional chambers and on the right is the black shrouded scintillation hodoscope. The lettering on the Cherenkov counter evolves from the name of its designer Knut Skarpaas and the legend of King Canute.

(Photo SLAC)

At the same time, the excellent abilities of the bubble chamber to capture all that happened (charged particle-wise) at the interaction point was preserved. Pioneering systems included that at the 30 inch chamber at Argonne (see June 1970), which has now moved to the FermiLab still in a hybrid system, and at the 40 inch chamber at Stanford (see September 1971).

Now electronic detectors are becoming progressively more bubble chamber like in their use. They are often built as large multipurpose systems capable of catching all the produce of an interaction (see for example the picture from MASS at Brookhaven on page 230). On the other hand bubble chambers are hardly ever used without associated electronic detectors.

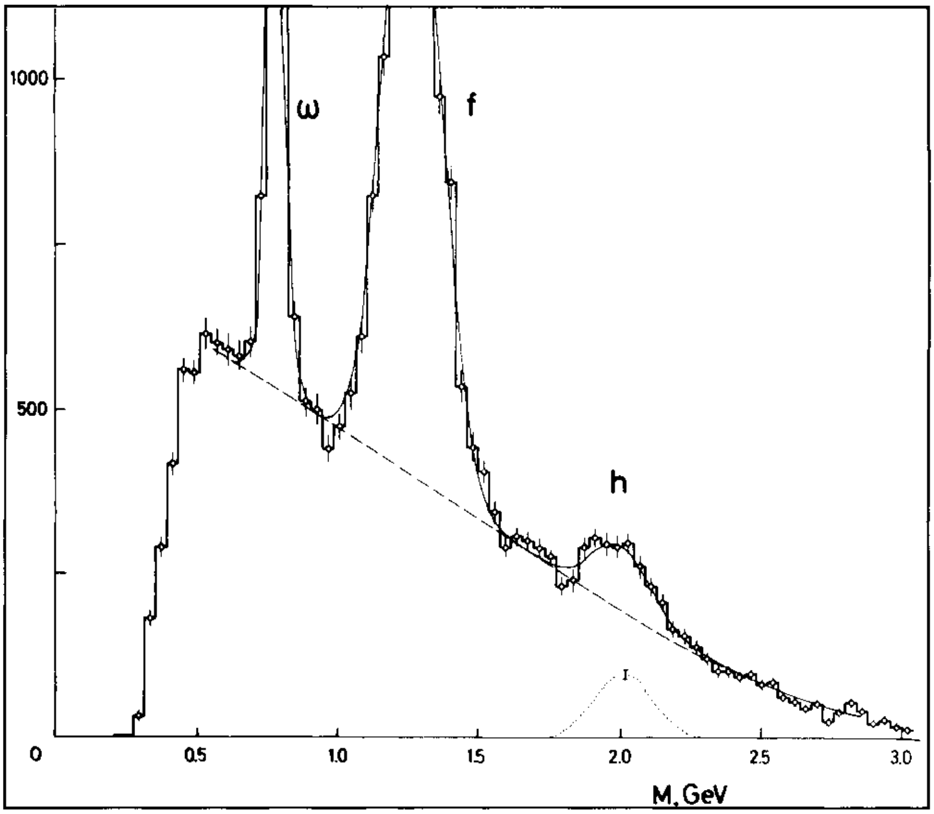
Stanford have a new hybrid facility under test. It consists of the 40 inch chamber with a 2.6 T magnetic field and a wide exit aperture, multiwire proportional chambers upstream and downstream to define incoming and outgoing particle directions, a large Cherenkov counter and a scintillation hodoscope. In a later stage a large spectrometer magnet and drift chambers could be added.

The bubble chamber has been developed to pulse at the rate of 12 per second. This hardly nibbles at the total electron output of the 22 GeV linear accelerator (360 pulses per second) and the hybrid facility can operate during almost all operation periods. The separated beam to the chamber takes pions, kaons or protons from a target bombarded by the electrons to the chamber. The downstream MWPCs are of honeycomb sandwich construction with 2 mm wire spacing. In conjunction with the information from the upstream MWPCs they can read particle angles on-line to an accuracy of 3 to 12% (depending on the location of the interaction). The Cherenkov distinguishes pions, kaons and protons over a broad momentum band.

The whole system has about 3 ms to make up its mind, via the on-line computer (a Nova 840), whether to flash the bubble chamber lights and thus to take a picture of the interaction region of an event. In between pulses (about 100 ms), the computer can busy itself with such things as sample analysis.

Most components of the system are now operating and three experiments calling for pion or kaon beams are lined up. A SLAC/CIT team will use the positive pion-proton interaction triggering on fast kaons or high transverse momentum protons. They aim to study the Y* particle, interactions giving high transverse momentum particles and to survey events such as boson decays. An Imperial College London team will look at positive pion-proton and at negative kaon-proton interactions to study Y* production. A Purdue team will use the same interactions to collect data on a long list of events with an increase of at least a factor of ten on present data. All the experiments use the ability of a hybrid system to sift comparatively rare events from a morass of others thus avoiding scanning millions of bubble chamber pictures en route to the required analysis.

The latest news that we have on the Berkeley-Stanford PEP project, for the construction of a 15 GeV electron-positron storage ring, is that the House of Representatives has passed a $2.9 million appropriation for Fiscal Year 1976 (starting now) for work on PEP. This goes to the Senate for approval and the Senate is likely to be more favourably disposed to PEP than the House. The Laboratories had hoped for around $13 million this year to make a serious start on the project.



Results from the Serpukhov-CERN (Karlsruhe, Pisa, Vienna) experiment on the 76 GeV synchrotron looking at pion-proton interactions giving neutral particles. Measuring neutral pions shows clearly the two well-known neutral mesons ω and f and, for the first time reveals the decay into neutral pions of the h meson which has an energy of near 2 GeV.

Meanwhile the scientific pressure is being kept on by holding a Summer Study (28 July-20 August) and the engineering pressure is being kept on by moving PEP some tens of metres so as to take particles from the end of the linear accelerator rather than just before the end. The opportunity is being taken in changing the location of the ring to improve the magnet lattice of the machine.

At the SPEAR storage ring the background problem, which was inhibiting the climb to higher energies, appears to have been overcome. At about 3.7 GeV the synchrotron radiation coming from the electron beam as it was bent into the straight interaction region was swamping the detection systems. By reducing this radius of curvature the radiation has been greatly reduced.

SERPUKHOV
New particle decay identified

The 4th collaborative electronics experiment between CERN (Karlsruhe, Pisa, Vienna) and Serpukhov, completed data-taking on the 76 GeV Soviet accelerator at the end of June.

During three years it has been assembling large quantities of information (10^7 triggers per year) on pion-proton interactions which give neutral particles. This has been done by spotting the photons, coming from the decays of the neutral mesons which are produced, in a spectrometer recording both photon energies and positions. (The detection system was described in the March issue 1973 page 83.)

At the end of the experiment a new decay of a particle was seen for the first time. A 40 GeV negative pion beam was fired at a hydrogen target and the detectors picked up the photons coming from two neutral pions in the interaction

$$\pi^- + p \rightarrow \pi^0 + \pi^0 + n$$

The familiar ω and f neutral mesons were identified as they decayed and in addition, a particle known as the h meson was seen decaying into two neutral pions. It has a mass of about 2 GeV and its most remarkable property is its high spin value of 4.

SACLAY
Present and future research programmes

It is some time since we reviewed activities at the Saclay Laboratory in France and we shall therefore give a broader account than usual.

Nuclear and particle physics in France is done within two organizations — the National Institute of Nuclear Physics and Particle Physics (IN2P3) and the Atomic Energy Commission (CEA). IN2P3, is one of the institutes of the National Scientific Research Centre (CNRS) and groups all the French University laboratories. CEA's work is done at Saclay with a relatively small part at Grenoble. For particle physics most experiments are now concentrated at CERN and overall funds are about equally divided between CEA, IN2P3 and CERN. Programmes are examined by a Co-ordination Committee for nuclear and particle physics to ensure coherent planning in a field governed by a number of different authorities (the Ministries of Foreign Affairs, National Education and Industrial and Scientific Development).

The creation of IN2P3 in recent years and of the Co-ordination Committee has helped to harmonize programmes and to forge closer links between the various laboratories. As a result, despite the financial difficulties affecting fundamental research in Europe, it has proved possible to confront significant projects on a national scale, such as the modernization of the Saturne synchrotron and the proposed construction of the heavy ion accelerator, GANIL.

Research at Saturne and ALS

At Saclay, experiments are done on two complementary machines: the 3 GeV proton synchrotron (Saturne) and the 600 MeV electron linac (ALS).

Saturne is a weak focusing synchrotron 22 m in diameter which accelerated its first protons in August 1958. With a maximum energy of 3 GeV, it is at present producing beams of 10^{12} protons per pulse with a duty factor of about 9 %. The intrinsic energy spread is of the order of 10^{-3} but the ejection system is such that, for high resolution spectroscopy experiments, this can be brought down to about 3×10^{-4}. High energy experiments have obviously by now moved to higher energy machines, in particular those at CERN and Serpukhov. But nuclear physics experimenters have turned towards the use of heavy ion beams (tandem Van de Graaff energy range) and of intermediate energy particles (0.2 to 2 GeV from Saturne and ALS).

In February 1972 a spectrometer for nuclear physics experiments known as SPES I came into service with Saturne with an energy resolution of the order of 100 keV for particles of about 1 GeV. It has a precision of 6×10^{-5} in measuring the momentum of the emerging particles and has been used to study elastic and inelastic scattering, and two-body reactions where the incident proton is absorbed by the target nucleus with emission of a pion, a deuteron or other particles. It has thus been discovered that the deuteron is not necessarily made up of two simple nucleons (proton and neutron), but may also exist in other forms such as the N* particle and proton or two Δ particles.

These results led to the decision to extend spectroscopy with Saturne and a second spectrometer, SPES II, has just been brought into service. It has a solid angle ten times bigger, and a momentum analysis range five times wider (though with inferior resolution). With this instrument it will be possible to study processes with very small cross-section, such as the associated production of kaons and lambda hyperons and the excited states of hypernuclei. It is planned to have a third spectrometer, SPES III, to be used in association with SPES II, to study three or four-body reactions but this project is not yet financed.

The 600 MeV linear electron accelerator (ALS), which reached design energy in 1968, complements Saturne as a tool for nuclear physics research. The machine is exploited about equally by Saclay users and by users from outside.

Electrons and photons interact with nuclear matter via the electromagnetic interaction and thus provide different information to strongly interacting particles. The electromagnetic effects can be calculated very precisely but the interaction rates are low and it is difficult to study rare processes experimentally. An electron accelerator has to compensate for this by producing beams of high intensity. ALS produces intensities of several hundred microamperes; it is operated at energies of several hundred MeV with duty cycles from 1 to 2 %.

There are four experimental areas around the machine one receiving particles at one third of the maximum energy, the other three at maximum energy. The low energy hall is devoted to experiments on photonuclear reactions with a beam produced by positron annihilation. The monochromatic photon beam flux is from 2 to 5×10^{4} per second with an energy variable from 20 to 120 MeV.

A 'photon hall' is devoted to the study of photonuclear reactions. It has a very comprehensive detection system, known as the 'roundabout', consisting of two spectrometers and a telescope pivoting round a vertical axis centred on the target. The photon beam is produced either by electron bremsstrahlung (2 cm spot on the target with a flux at 300 MeV of about 4×10^{9} per second with an electron beam of 100 μA at 400 MeV) or by positron annihilation (1 to 3 cm spot, 10^{8} per second for a positron beam of 0.1 μA at 300 MeV).

An 'electron hall' has two large spectrometers, one each side of the beam, able to turn on a vertical axis centred on the target. Experiments on elastic scattering are done with very high resolution and low background using the spectrometer known as '900', with a resolution of 1 to 2×10^{-4} (the name comes from the maximum momentum, 900 MeV/c, which can measure). It has relatively low acceptance, but can analyse heavy particles. The other spectrometer, the '600', has a very high momentum acceptance. It is used for the analysis of scattered electrons, while the '900' records heavy particles in coincidence experiments. The whole system is an impressive installation, 12.5 m high and weighing some 1 000 tonnes.

The fourth experimental area is for the study of pion and muon interactions. The pions are produced in a copper target bombarded by the electron beam. One channel, in operation since 1970, accepts pions produced at an angle of 120° to the left of the incident electron beam, an angle which reduces contamination due to elastic and quasi-elastic scattering of the electron-positron pairs created in the target. The electron beam and target are 5 m below ground level, and an 8 m beam-line conveys the pions to ground level. In this beam-line there is an appreciable probability of decay of the pions into muons and neutrinos The muons are confined in the channel to yield a low energy muon beam also. It is possible to select the energy, energy spread and geometry of the pion beam. The energy can go as high as 100 MeV and, from a 300 μA electron beam, the pion flux at 70 MeV is 10^{6}/s while that of the muons is 10^{4}/s. A second pion channel of similar design on the other side of the electron beam has recently been completed. The channels can operate independently.

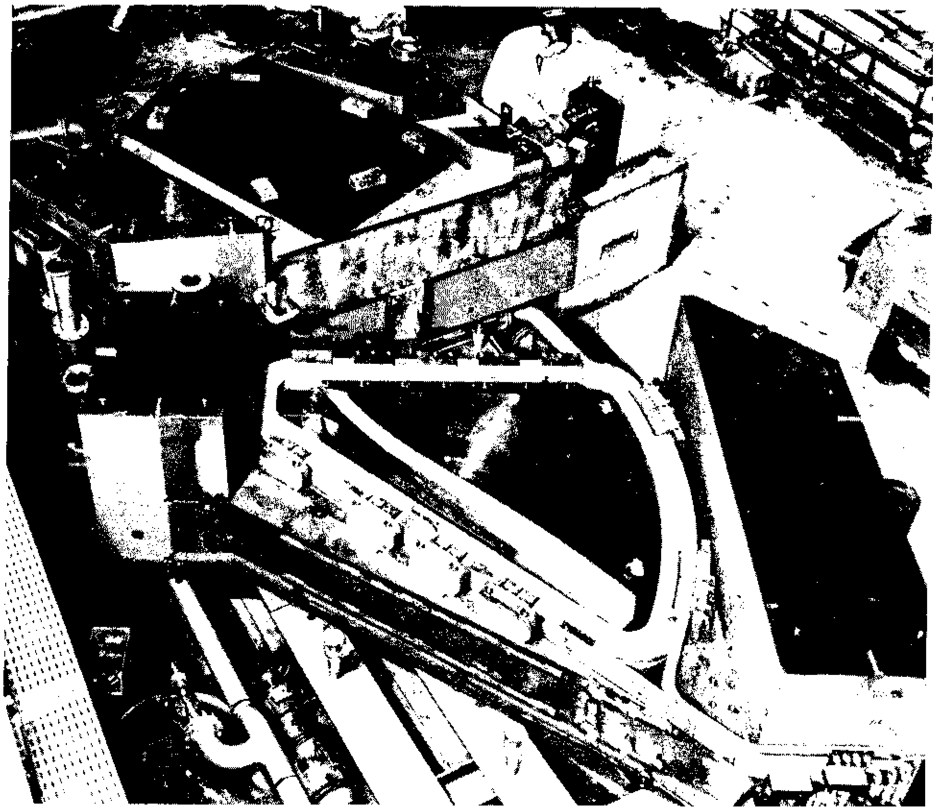
Collaboration with Serpukhov

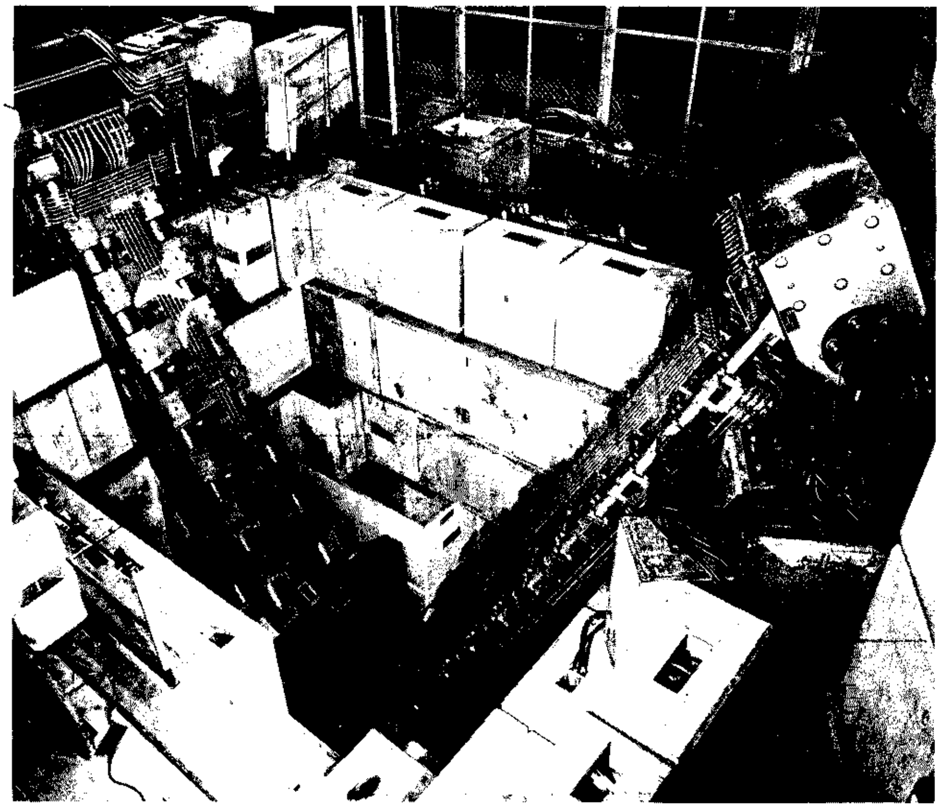
Under the terms of an Agreement between the Soviet State Committee for the Utilization of Atomic Energy and the French Atomic Energy Commis-

The SPES II spectrometer during assembly in the experimental area at the Saturne synchrotron. The two analyzing magnets, which are here seen open, are installed on a platform supported on an air-cushion and are able to rotate around a vertical axis.

The two channels of the secondary beams of pions and muons at the Saclay 600 MeV electron linear accelerator, ALS. The maximum energy in these channels is about 100 MeV and the pion flux at 70 MeV is 10^6 s.

(Photos Saclay)





sion, signed in 1966, Saclay built the 4.5 m bubble chamber, Mirabelle, and operates it at Serpukhov with beams from the 76 GeV accelerator. Since its commissioning in 1971, Mirabelle has taken over 700 000 photos with proton, kaon, pion and antiproton beams.

An electronic experiment, HERA, is also being carried out at the Soviet accelerator by a Saclay-Serpukhov collaboration. It makes use of a polarized proton target and is designed to measure the polarization and rotation parameters in elastic scattering. The experiment is in fact one link in an extensive experimental chain, stretching from Saturne to the CERN PS and the Serpukhov accelerator, which is due to continue with the CERN SPS.

Development of superconducting magnets

The Saclay Laboratory has considerable experience in the construction of superconducting magnets. Prominent among these are a quadrupole doublet, OGA, used in a Saturne beam, which has functioned satisfactorily for over 2 500 hours and the pulsed superconducting magnet, ALEC, built as part of the GESSS collaboration, which has given a field of 5 T with a pulse repetition rate of 0.1 Hz (see April issue page 121).

Another project, CESAR, also part of the GESSS programme, has just got off the ground. It involves the construction of two superconducting d.c. dipoles to be used on one of the beamlines of the North experimental area of the 400 GeV SPS. These magnets will have an aperture of 10 cm diameter and a total length of 2.83 m. The integrated field will be 9.15 Tm and the field homogeneity (using superconducting correction windings) will be 2×10^{-4}. The central field will reach 4.5 T and the stored energy

520 kJ. A joint CERN-Saclay working group has been formed and assembly and testing of the dipoles will be done at Saclay.

The first superconducting dipole will replace a conventional magnet and will achieve the same bending power in half the length. The second will double the bending power. Energy consumption was another factor determining the choice of these superconducting magnets. They will use about one-sixth of that needed for equivalent classical magnets.

Reconstruction of Saturne and the GANIL project

We turn now to the future projects under study at Saclay. Saturne, built on the weak focusing principle, no longer meets the experimenters' requirements. When it was commissioned in 1958, it was used essentially for elementary particle physics, but has been progressively abandoned as machines of higher energy came on. On the other hand, nuclear physics experimenters are attracted by the beams in the GeV range offered by Saturne.

In view of this interest and of the difficulties encountered in providing the high quality beams for high resolution spectroscopy, the decision was taken to reconstruct Saturne completely. A budget of 40 million French francs has been assigned to the project, CEA providing 65 % and IN2P3 35 %.

The main objects are to obtain a duty cycle of 20 % and an intensity of 10^{12} protons per second (by increasing the machine's pulse repetition rate) with very high beam qualities in emittance and energy spread. The maximum energy of 3 GeV will not be altered but it will become a strong focusing machine with a separated function magnet lattice. The ring, 22 m in diameter, will consist of 16 dipoles with a bending radius of 17 m and 24 quadrupoles. The dimensions of the vacuum chamber will be 230 × 130 mm holding a pressure of 5×10^{-7} torr which could be brought to 5×10^{-8} torr if is later decided to accelerate light ions.

The ring will include four straight sections, one for injection, one for the r.f. acceleration system (frequency range 0.8 to 8 MHz) and two for beam ejection. Slow ejection will be used ejecting over periods from 0.2 to 0.6 s. The two ejection channels will be usable simultaneously.

The machine will provide protons at energies ranging from 0.5 to 3 GeV into the experimental areas and will also accelerate deuterons and alphas as well as polarized protons and deuterons. The acceleration of light ions is under discussion.

The shutdown of Saturne for this rebuilding is planned for the first quarter of 1977, and the reconstruction will take a year. The bending magnets and quadrupoles are already being manufactured in Yugoslavia, and the r.f. cavities, vacuum pumps and injection line are being ordered.

GANIL (Groupe pour un Accélérateur National d'Ions Lourds) is a project for the construction of a machine which would be the main nuclear physics installation in France in the 1980s. CEA and IN2P3 would participate equally in the financing.

For the last eighteen months or so, a working group of some twenty physicists has studied the building of a machine to provide research possibilities not accessible to the existing heavy ion accelerators or those under construction at Darmstadt and Daresbury. The accent has been on an area ranging from ions of neon, whose energy could reach 100 MeV/nucleon, to uranium, whose energy could reach 8 MeV/nucleon. The project specifies an intensity for neon ions of 10^{12} ions per second with high beam quality or 10^{13} with lower beam quality. The intensity decreases progressively the higher the atomic number of the nucleus, but for uranium it is still 10^{10} ions per second.

In considering the choice of machine, the working group compared tandems, linear accelerators and cyclotrons. The solution finally adopted was two identical separated-sector cyclotrons, each of a diameter of 6 m and comprising four sectors each of 400 tonnes.

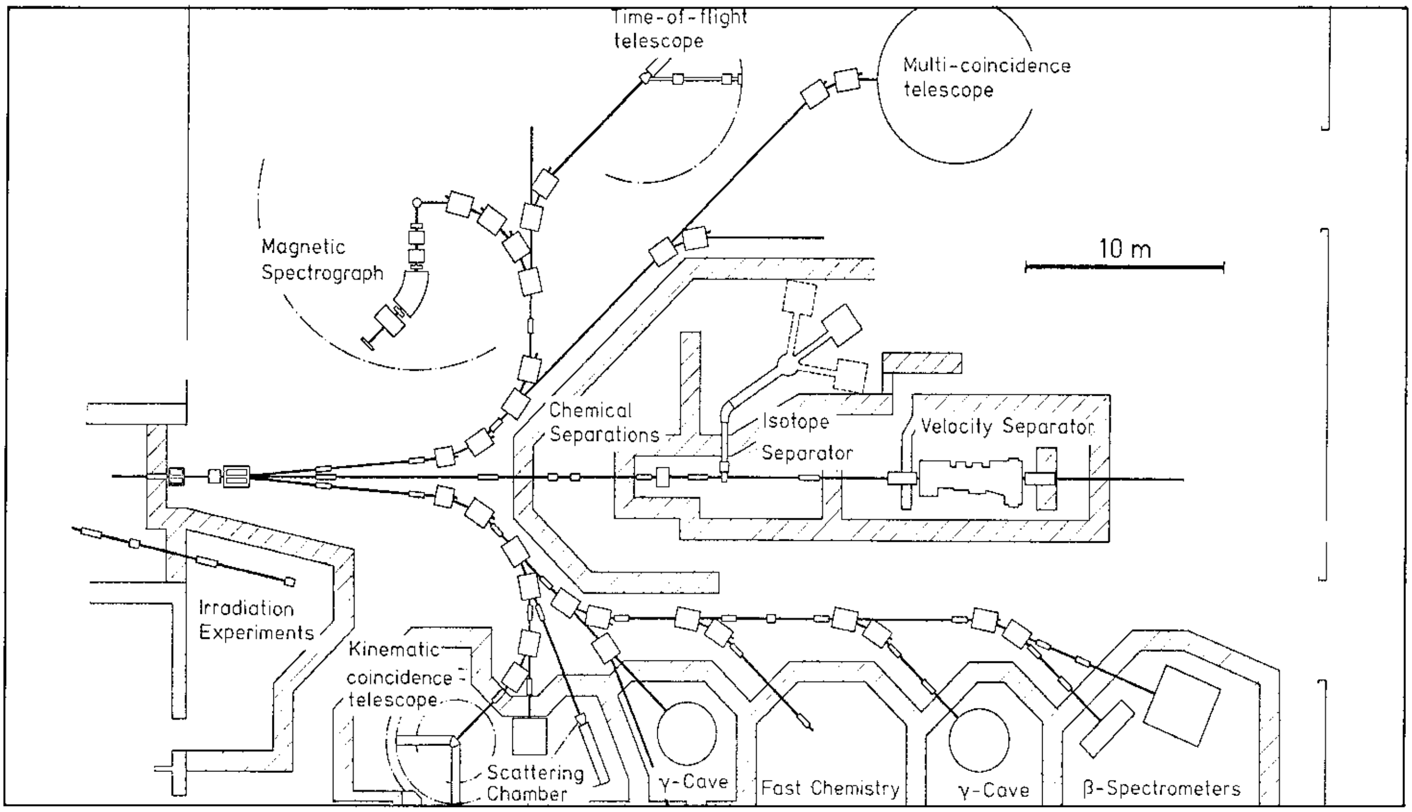
The injection system is a conventional PIG source, giving charge states of 2 to 8 and a small cyclotron in which the ions are given a preliminary acceleration before injection into the first cyclotron of the machine. Here the ions, not completely stripped, will be accelerated onto a solid stripper target, which will increase their charge state. They will then be injected into the centre of the second cyclotron and undergo further acceleration.

The GANIL working group has now moved on to work on an actual model, 1/4 scale, of a magnet and an accelerating cavity. Though the project is a national one it is open to international collaboration. Researchers are in close contact with physicists from Darmstadt and Daresbury. The project is well advanced and the question of authorization is before the French government.

DARMSTADT
Preparing for full energy beam day

The heavy ion linear accelerator, UNILAC, is nearing completion at GSI (Gesellschaft für Schwerionenforschung), Darmstadt. The machine is described in the June 1973 issue.

A schematic drawing of the layout scheduled for the high energy experimental area at the Darmstadt heavy ion linear accelerator, UNILAC. The variety of experimental zones reflects the variety of disciplines which will be involved in research with the heavy ion beams.



The Wideroe section, powered at a frequency of 27 MHz, is working well and ions have been fed into the low energy experimental area at 1.4 MeV per nucleon. The magnet settings needed careful tuning to bring the beam transmission up — initially only some 50 nA of ions was squeezed through to the low energy experiment stations from about 1 μA injected into the first Wideroe tank. However, in June the transmission was improved to near the theoretical values. Argon and xenon ions have been used on the targets. Typically, from 1.2 μA of Xe^{6+} fed to the Wideroe, 42 nA of Xe^{23+} reaches the target. The Alvarez section is virtually ready apart from some transients in the r.f. powering system, operating at 108 MHz, which need damping out. Finally, the single gap cavities (also at 108 MHz) are being progressively installed. Their correct phasing when they are coupled together is the major outstanding task.

It is hoped to have ion beams into the high energy experimental area in the Autumn and to reach the mystical goal of accelerating uranium ions before the end of the year.

A Users Committee has been set up consisting of 21 members of whom 11 come from outside GSI. A call for letters of intent for experiments at the beginning of the year brought about 120 replies. It is expected that when the experimental programme is in full swing it will involve about 100 scientists at any one time from many different fields. The total pool of scientists likely to use the machine is twice this number.

FERMILAB
Increased scope for experiments

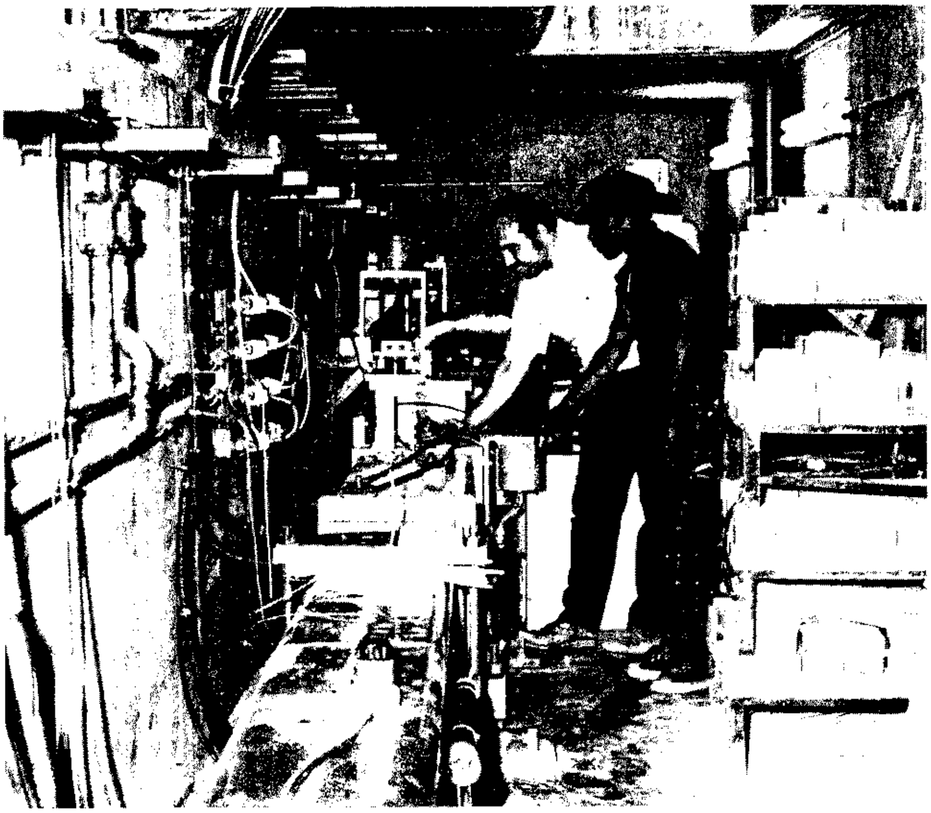
The last of the beam-lines which were put on paper in the design of the experimental areas of the proton synchrotron at the Fermi National Accelerator Laboratory was successfully tested in June. It is the third beam-line, P-West, in the Proton Area which can handle protons up to an energy of 500 GeV. The P-West line is designed to use a beam with an intensity of 10^{12} protons focused on a target spot of 2 mm.

There were initially problems in the Proton Area because of the 'halo' around the beam which was spraying detectors with particles coming from interactions with beam-line components, etc., rather than from the target. This situation has been greatly improved. In the first P-West test with 10^{11} protons/mm^2 on the target the intensity 10 cm away was below 10^2/mm^2.

The first three experiments to use P-West are: A Fermilab/John Hopkins team will search for heavy particles

Inside the focusing enclosure of the P-West beam-line at the Fermilab which has helped remove the halo around the beam. P-West is the last of the beam-line array to come into action and is feeding three experiments with a high intensity, high quality beam.

(Photo FermiLab)



which decay into photons or neutral pions and will study charged particle-photon correlations. They have two spectrometer arms with multiwire proportional chambers, Cherenkov hodoscopes and lead glass arrays. A Cornell/McGill/Northeastern/Lebedev team will study elastic scattering with extremely high momentum transfer. They have a forward arm with a septum magnet and two beam-line dipoles and a recoil arm with two large aperture magnets. A Fermilab/Northeastern/Northern Illinois team will look at inclusive production of pions, kaons and antiprotons. They have a double focusing split quadrupole spectrometer.

As P-West came into action the number of experiments taking data at the machine was 30, with ten experiments at the test stage. 97 experiments had completed taking data.

Meanwhile the accelerator is manoeuvring towards higher intensities. A major bottleneck en route to the design goal of 5 × 10^{13} protons per pulse has been the throughput of the 8 GeV fast cycling booster. On 13 June the accelerator team, now under P.V. Livdahl, succeeded in squeezing 2.22 × 10^{13} through the booster and 2 × 10^{13} from the main ring cannot be far away.

The FermiLab accelerator was recently generously made available to CERN to investigate an instability which it was feared could limit the SPS intensity. The instability can arise during the debunching-rebunching procedure which is necessary to convert the 20 bunch beam from the PS into the 4 000 bunch beam of the SPS. E.J.N. Wilson and D. Boussard from CERN worked with the FermiLab accelerator team simulating the SPS conditions. They happily returned with the message 'Don't worry'. The instability is weaker than predicted and slow to develop.

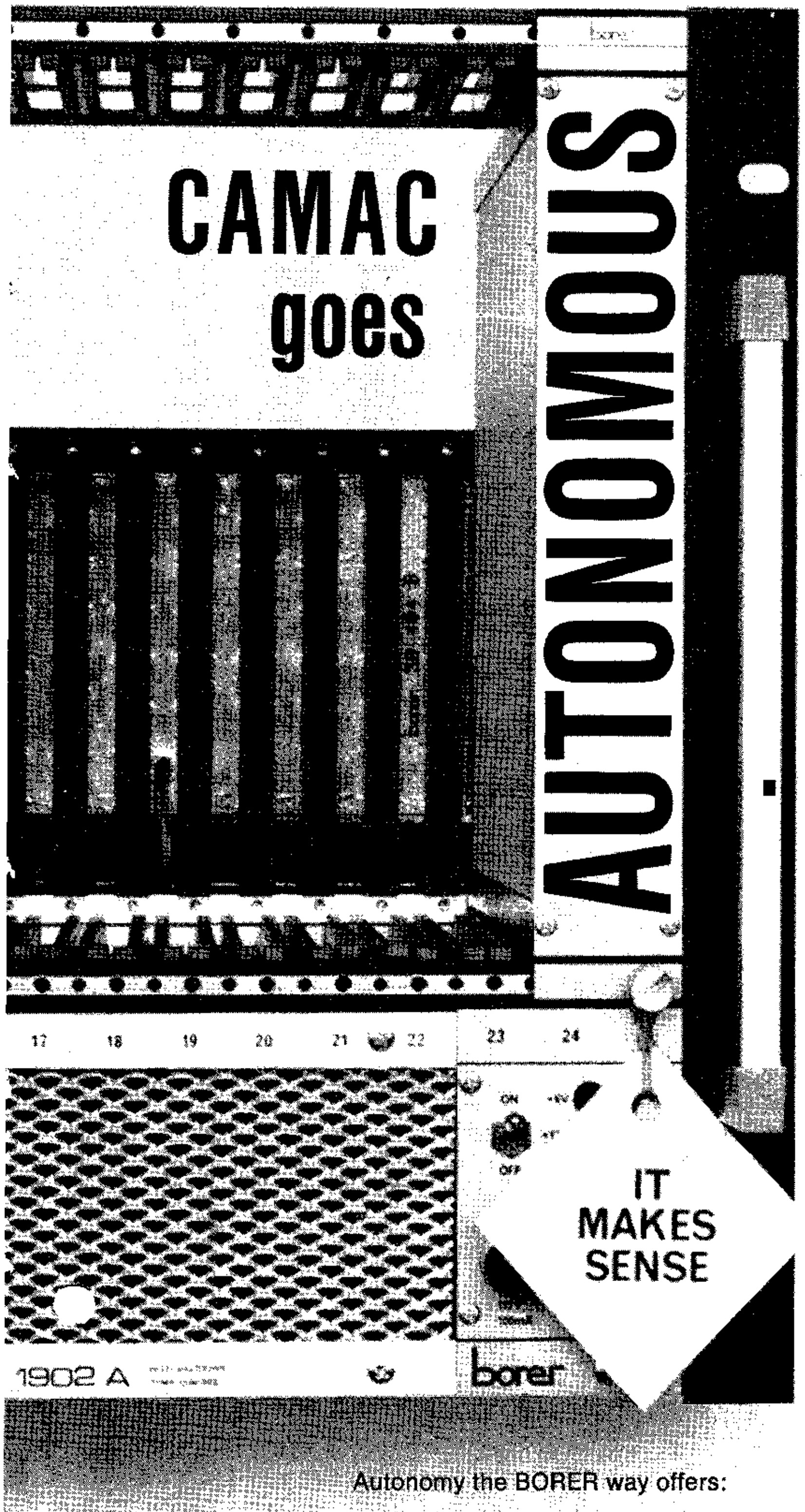
FRASCATI
Future role under discussion

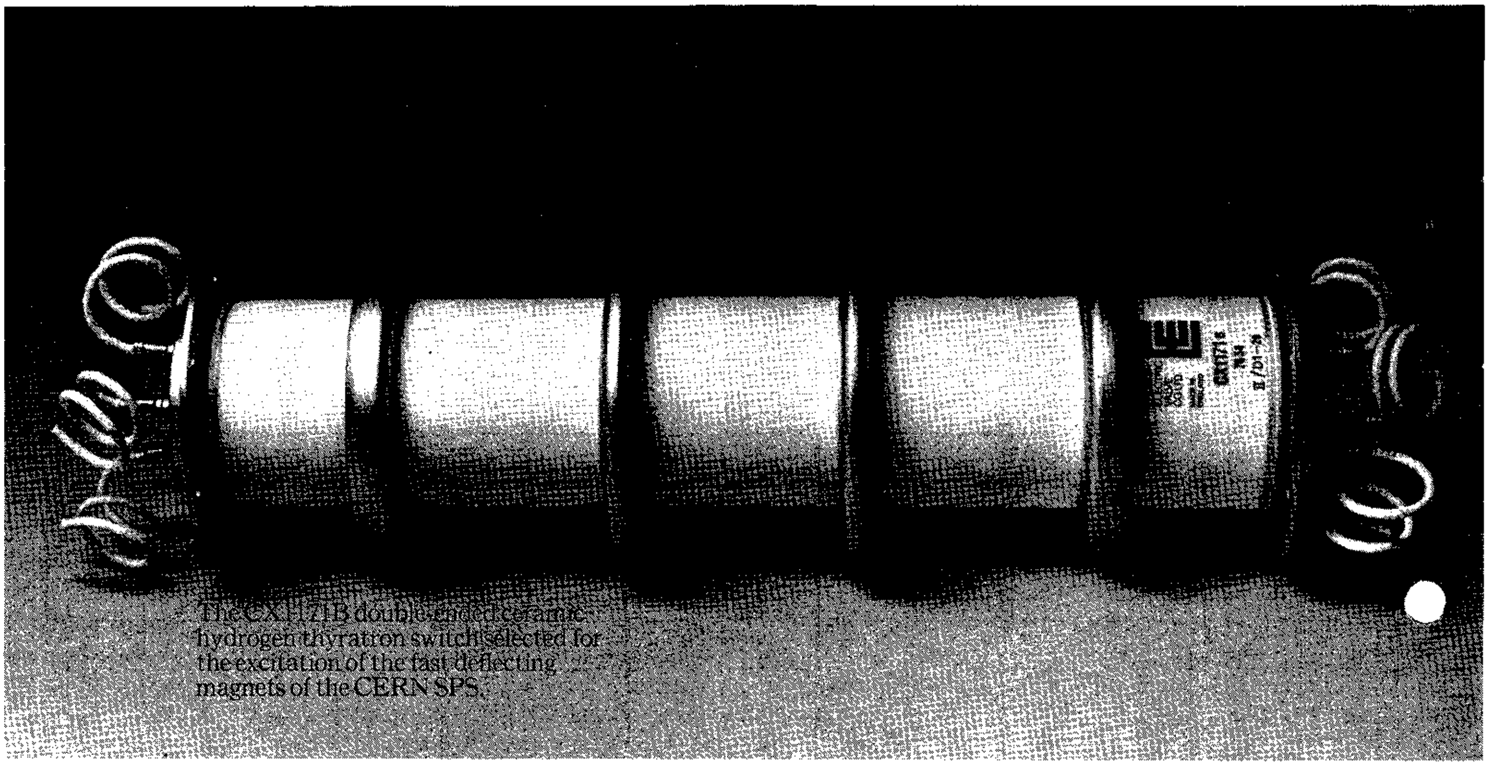
It was announced on 3 July that an Agreement has been signed by the President of CNEN (Comitato Nazionale per l'Energia Nucleare), Prof. E. Clementel, and the President of INFN (Istituto Nazionale de Fisica Nucleare), Prof. C. Villi, concerning the transfer to INFN of all activities, equipment and personnel in its sphere of activity — which includes nuclear and high energy physics. This establishes INFN's independence.

Discussion has centred on the future of the Frascati Laboratory where the work is relevant to both the CNEN's nuclear power programme and INFN's research programme. In signing the Agreement, the attention of the Italian government was drawn to the importance of the work at Frascati with an appeal for sufficient financial support to carry it out efficiently. The Agreement has been put before the Minister for Industry and the Minister for Education.

Patient irradiations

Some careless wording in the June issue failed to acknowledge quite a lot of work in the medical uses of particles. In reporting the tests at Los Alamos (page 193) the references to 'first irradiations' should, of course, have been qualified by saying each time that we were referring to negative pion beams. Much work with other particle beams has been done, for example at the cyclotrons at Harvard and at the Hammersmith Hospital in London. The pedantic could also insist that all X-ray treatments are particle irradiations. Apologies to all whose work was thus ignored.





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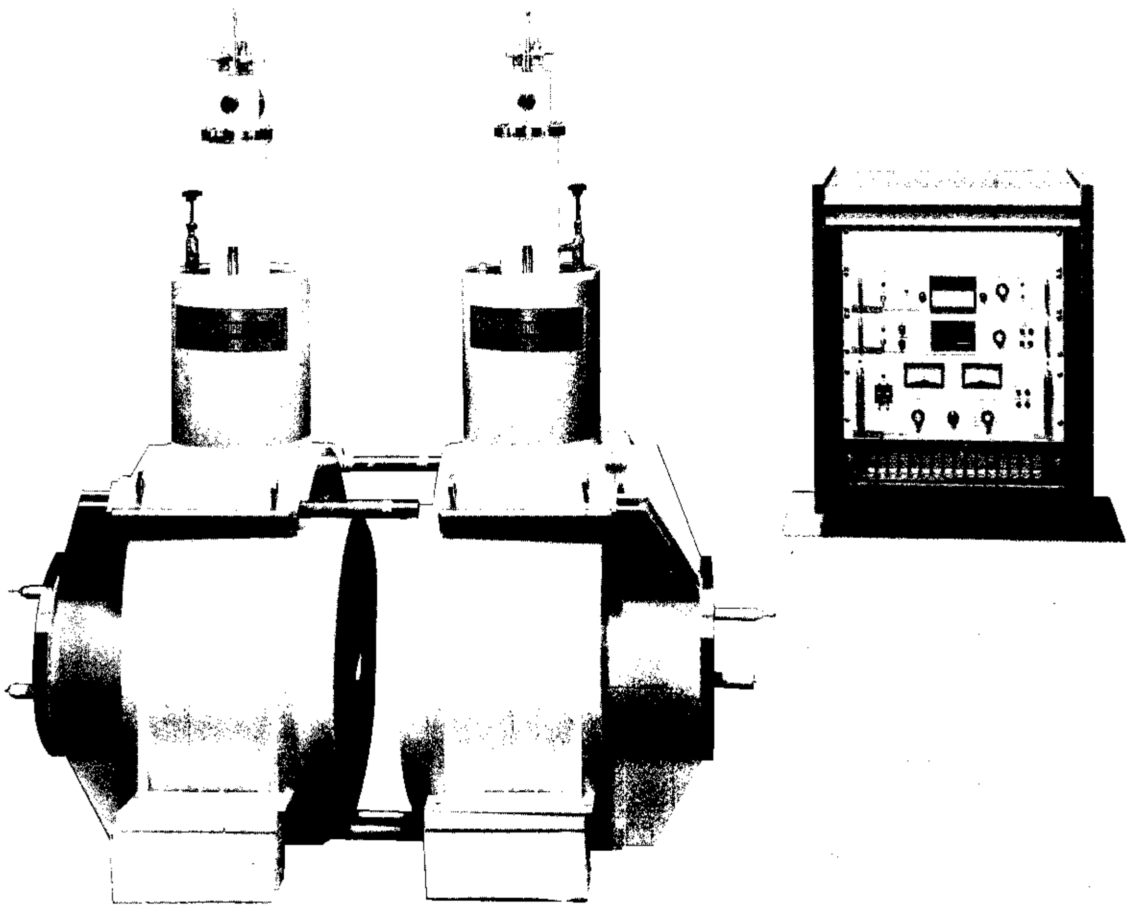

New Superconducting Magnet System Demonstrates IGC Full Systems Capability.

A significant magnet system for nuclear fusion studies has been produced by Intermagnetics General Corporation (IGC) under contract to Fusion Energy Corporation. All system elements and components — the superconducting material, the magnet coils, the cryostat and the electronic controls — were designed and manufactured completely in-house by IGC. The system contract was taken on a fixed price, guaranteed performance basis, manufactured to full specifications and delivered within the specified seven month delivery time. It will be used to study self-colliding deuterium beams, in accordance with the Migma Approach to Controlled Fusion.*

The coils are manufactured from multifilamentary Nb-Ti superconductor produced by IGC. At full operating field, the maximum field-on-windings of each coil is in excess of 60 kiloGauss, and the average current density in the winding space is approximately 11,000 A/cm^2. To achieve this rather high current density without evidence of magnetic instability or "training," the coils were epoxy encapsulated under vacuum using impregnation techniques refined at Intermagnetics General Corporation.

At its full operating field, the stored energy of the system is approximately 500 kiloJoules, and the compressive forces between the two magnet halves, tending to implode the system *is approximately 50,000 kilograms.* This large compressive force is transmitted directly from the superconducting coils to the four room-temperature pins separating the two halves of the magnet system. By utilizing both the cold vapor of the boiling helium as well as liquid nitrogen to cool the mechanical support structure, the total helium boiloff per dewar *is less than two liters per hour at full operating field.*

With the combined use of Nb-Ti and Nb_3Sn superconductors, the design techniques employed by IGC in this system should lend themselves to the construction of still larger and higher field split magnet systems, perhaps generating fields in the range of 100 kiloGauss and higher.

IGC CONDUCTOR SPECIFICATIONS

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Copper-to-Superconductor Ratio	3.4:1
Critical Current at 6 Tesla	315 Amps
Conductor Diameter	1.05 mm
No. of Nb-Ti Filaments	108
Conductor Length — Total	22,000 meters
Twist Pitch	0.4/cm

MAGNET SPECIFICATIONS

Type	Split Pair
Central Field	40 kG
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Design Current	120 Amps
Current Density	11,000 A/cm^2
Stored Energy	500 kJ

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* B. Maglich, Nucl. Instr. Methods *111*, 213 (1973); B. Maglich et al. Nucl. Instr. Methods *120*, 309 (1974).

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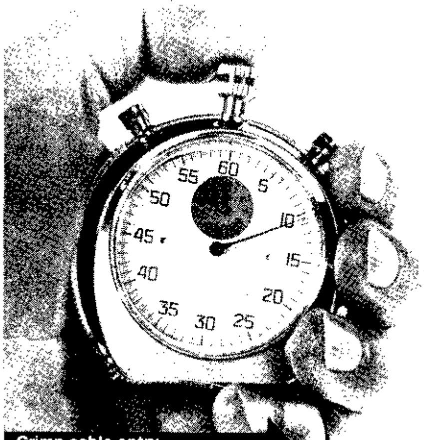

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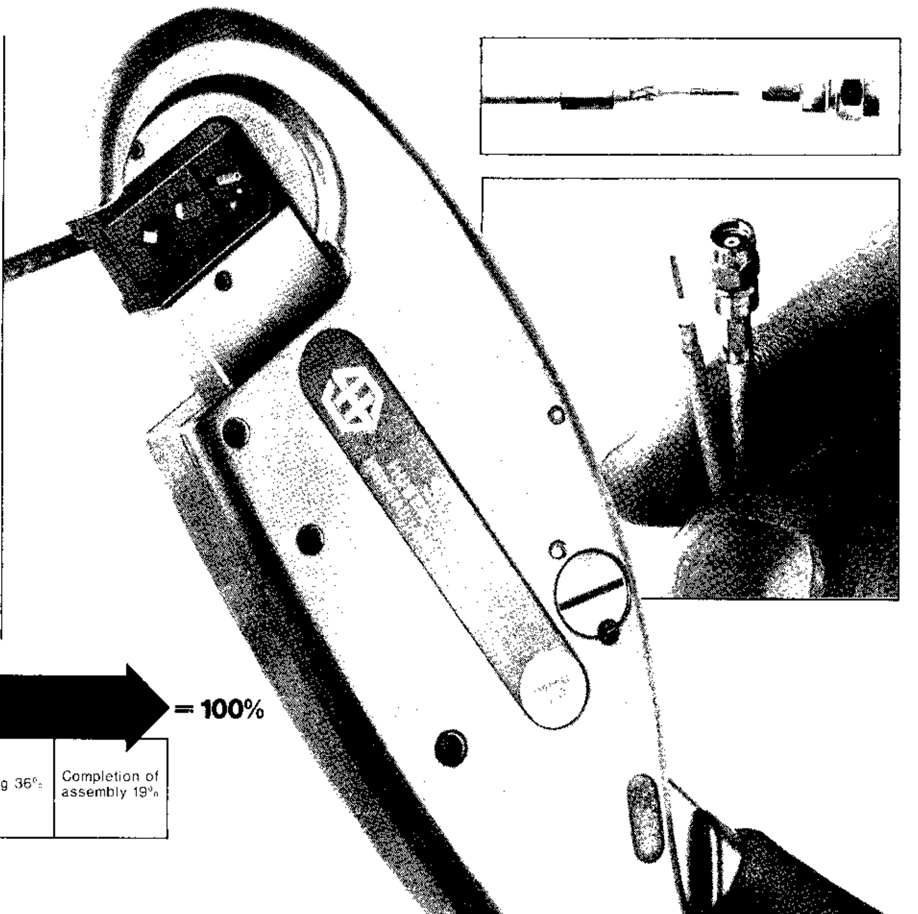

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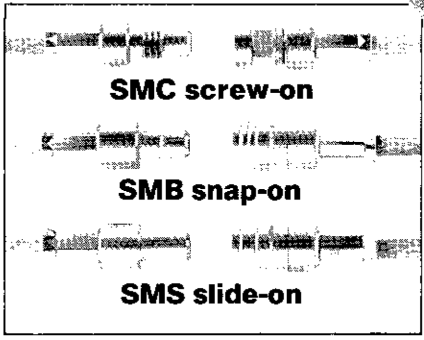

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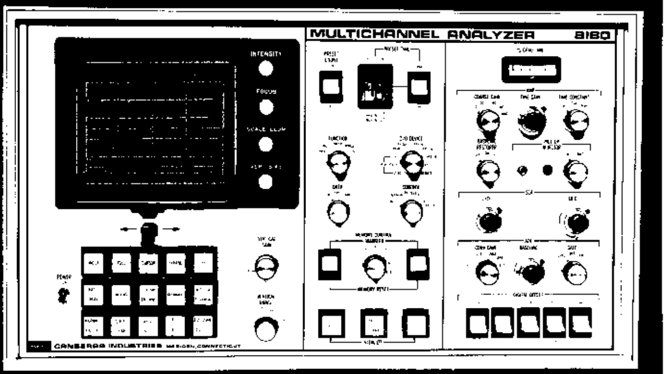

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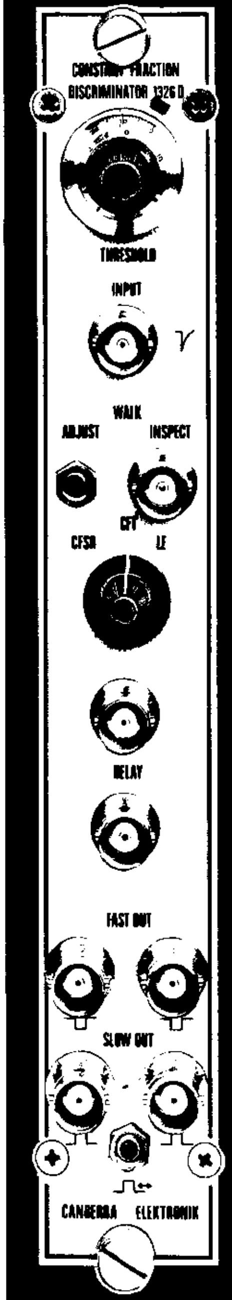

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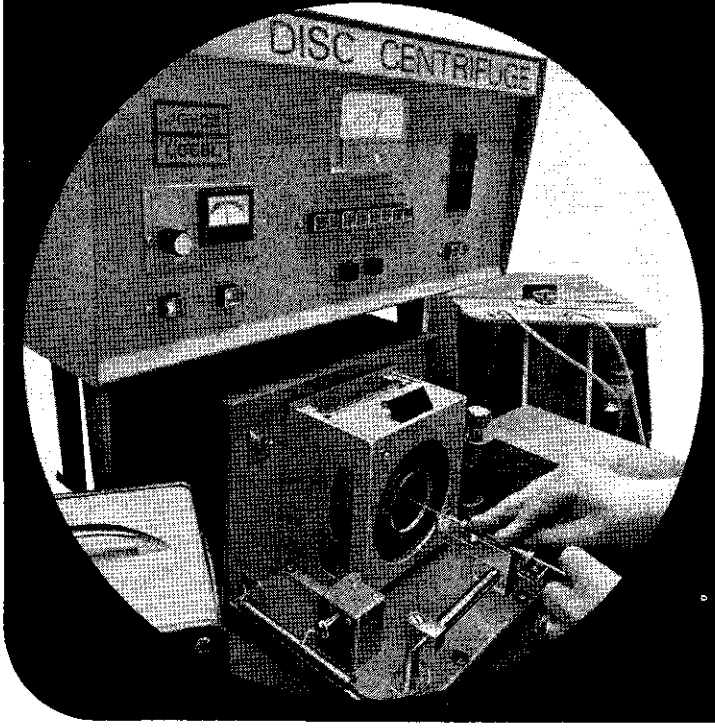
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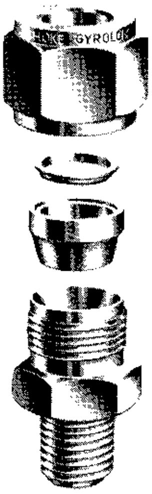
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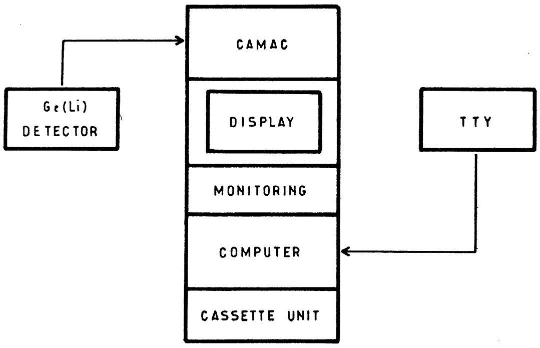

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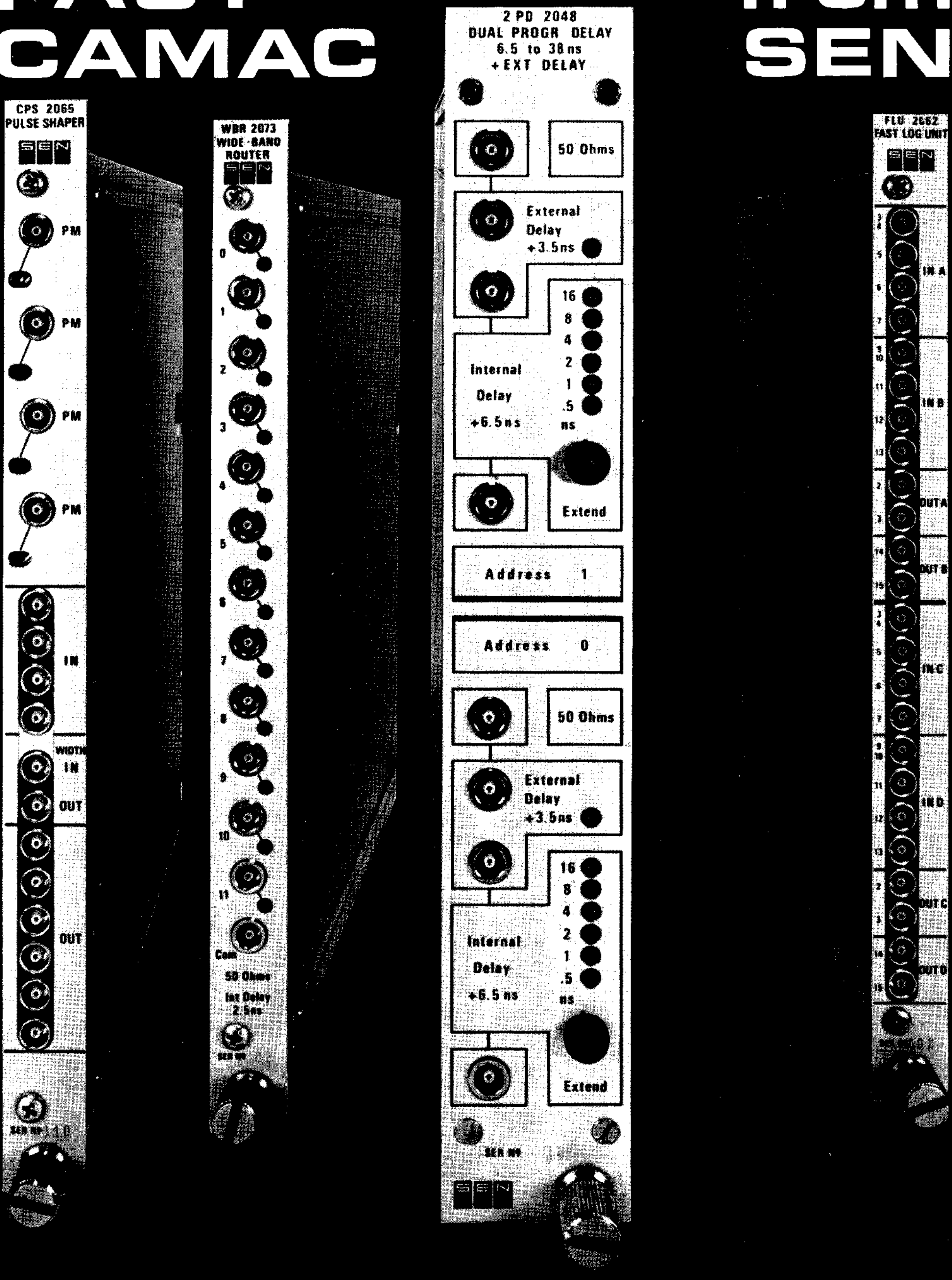

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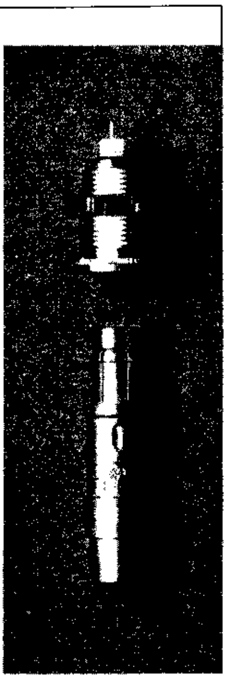

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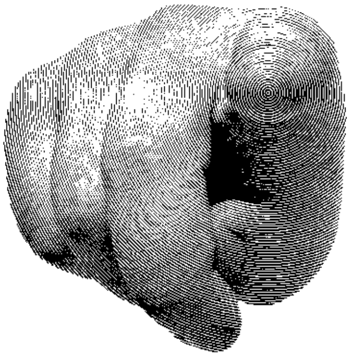

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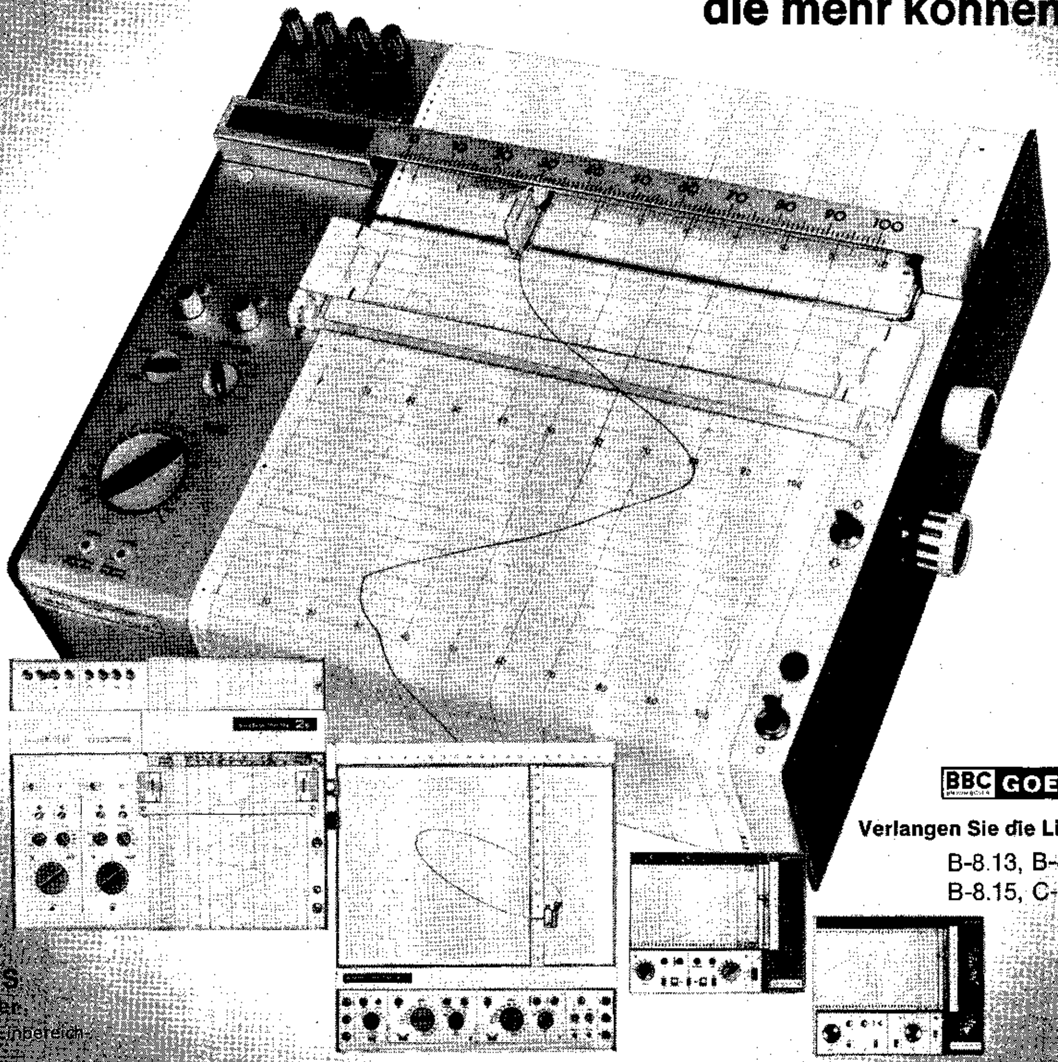

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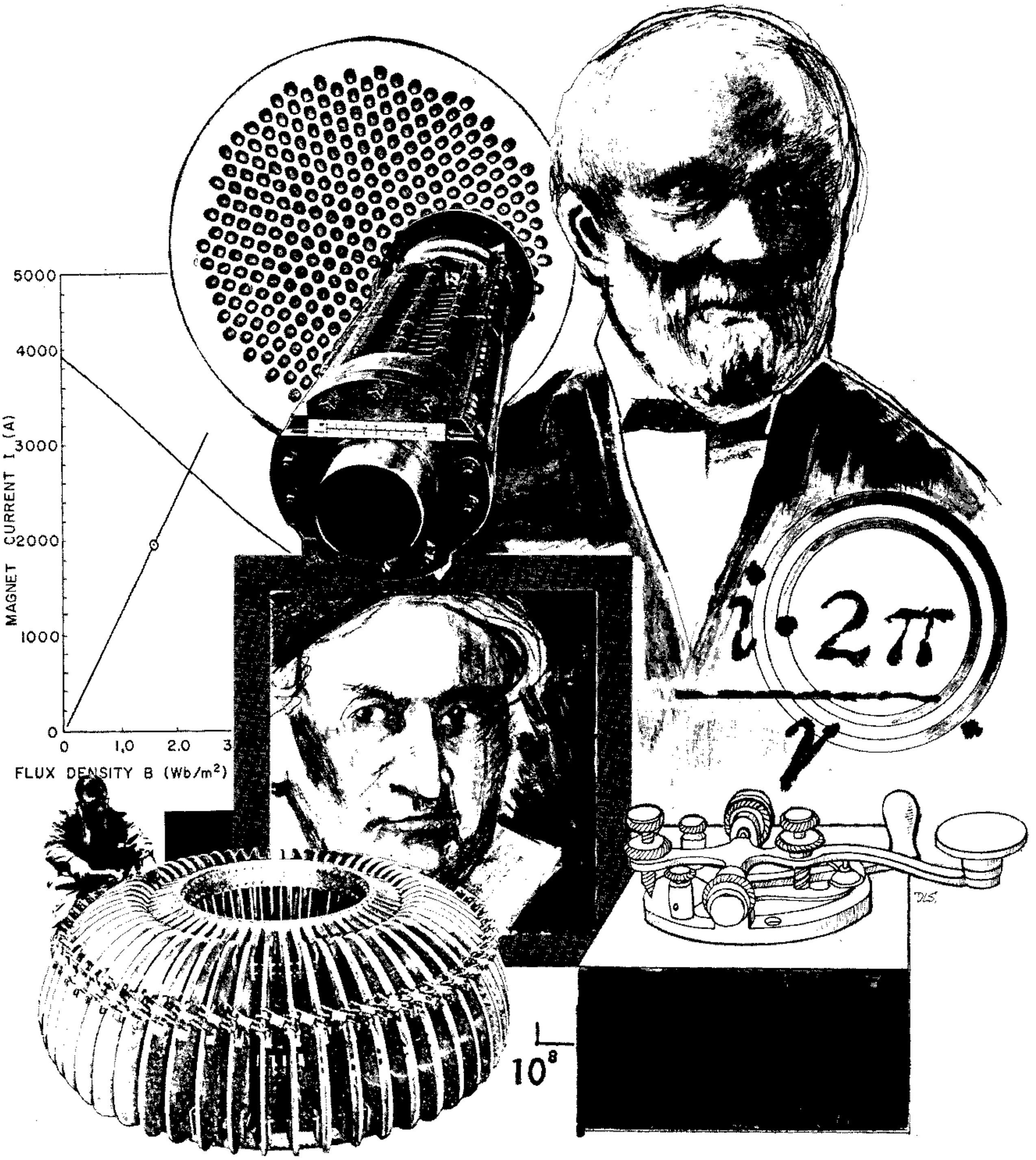

Make history with us.

When Wilhelm Eduard Weber developed the laws of forces between charges he was making history. The German physicist worked with Karl Gauss in a study of terrestrial magnetism and in the invention of an electromagnetic telegraph. He originated the absolute system of electrical units, based on Gauss's system. And the fundamental unit of magnetic flux is named Weber after him.

Today, Wilhelm Weber's work is being utilized in a variety of sophisticated applications.

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C'est pourquoi les spécialistes en communication de S.W.I.F.T.* ont passé au peigne fin les 30 meilleurs constructeurs en mini-informatique (et certains en maxi-informatique) avant de retenir les fournisseurs pour leur réseau bancaire international.

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LRS
PROPORTIONAL CHAMBER ENCODER
MEMORY FULL
COINCIDENCE

readout in CAMAC!

For Drift Chambers

Model 2770 TIME DIGITIZER

- Accepts outputs from LRS LD 604 hybrid discriminators (or any other MECL differential output discriminator) via low-cost flat cable.
- 96 channels in #3 CAMAC module provide high density and direct computer compatibility.
- Standard CAMAC packaging means standard crate, standard power supply distribution.
- Each wire provided with one complete channel which digitizes the time between the common event trigger and wire pulse.
- One 16-bit output word per "hit" wire (8 bits of time data, 7 bits of address, 1 bit for event separation flag).
- Full-scale time intervals of 0.5 usec and 1.0 usec permit use with various wire spacing.
- 8-bit resolution gives up to 0.1 mm spatial resolution.
- Continuously updatable — a new "start" interval begins each time a wire pulse is received, until a "stop" (delayed event trigger) defines the event.
- Differential inputs mean compatibility with long transmission lines.
- Built-in, 40-deep, first-in/first-out (FIFO) memory accumulates wire address and corresponding time information for several hits, several events.
- Built-in event separator provides end-of-event flag within FIFO contents.
- Fast processing time in conjunction with FIFO memory helps optimize data-taking rates.

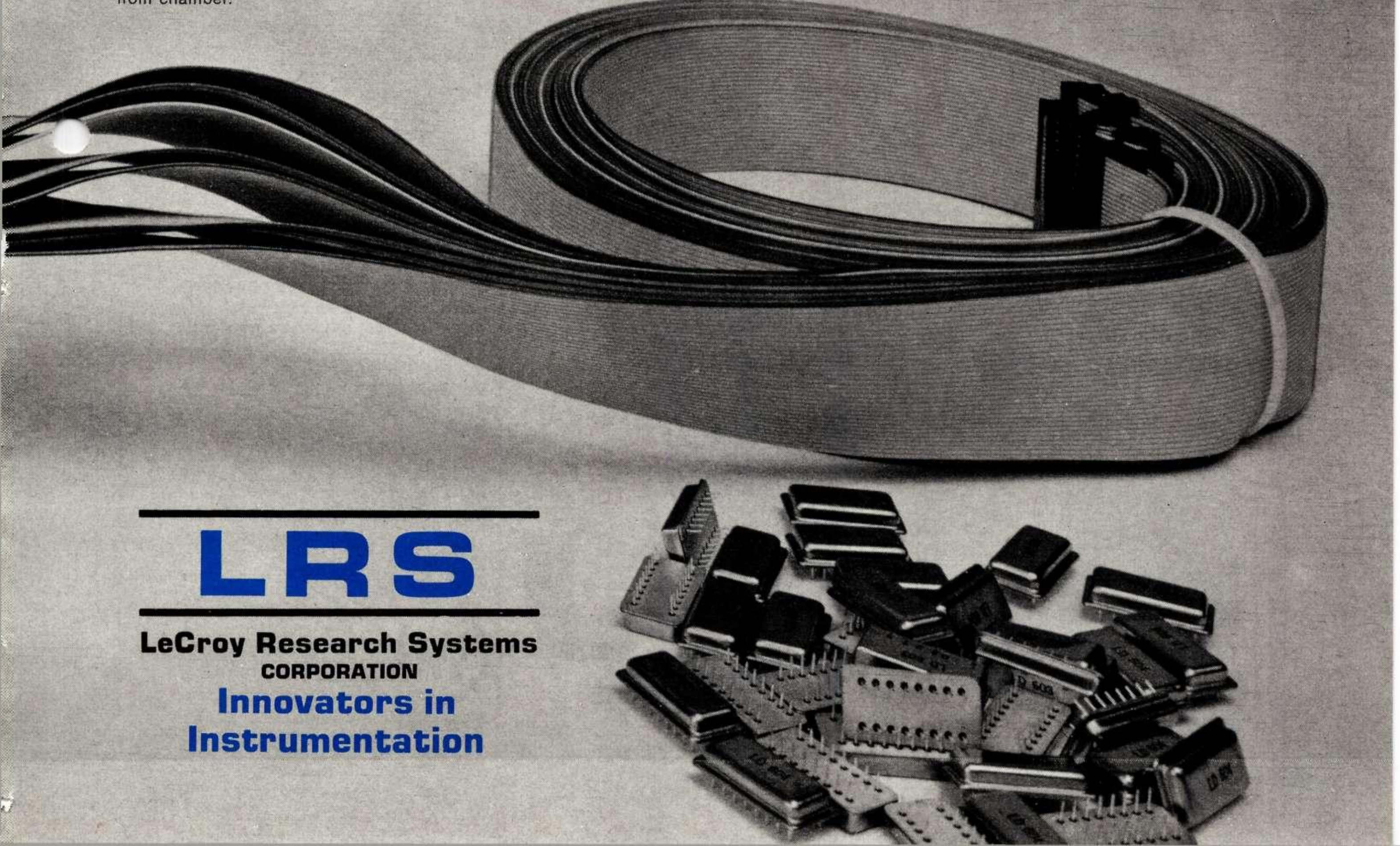
For Multiwire Proportional Chambers

Model 2720 MWPC ENCODER

- Accepts outputs from LRS hybrid MWPC discriminators (or any other MECL differential output discriminator) via low-cost flat cable.
- 128 channels in #2 CAMAC module means that a standard crate and power supply inexpensively and effortlessly solve the problems of power supply distribution and mounting.
- Each channel acts as a receiver, delay, latch, and event buffer for signals from one MWPC wire.
- Output consists of 2 fully encoded wire addresses read out as one 16-bit word.
- Full CAMAC compatibility provides an easy solution to computer interfacing.
- Two optional hybrid circuit front ends permit inclusion or omission of monostable delay.
- Differential inputs eliminate crosstalk and common dc offsets when receiving signals from long transmission cables.
- Built-in, 40-deep, first-in/first-out (FIFO) memory accumulates wire addresses from several hits, several events.
- Fast output provisions, permit usage of MWPC's in trigger decisions.
- Fast processing time and FIFO memory, in addition to provision for DMA transfers, permit high data-taking rates.
- Fast transfer inhibit permits latching wire signals without encoding, then either clearing or encoding on the basis of your fast logic before transfer to the memory.

Model LD604 DISCRIMINATOR for both Proportional and Drift Chambers

- Low threshold of -200 uV assures operation with all chambers and gas mixtures and causes triggering low enough on input risetime to eliminate signal shape as a source of time dispersion.
- Differential inputs help minimize noise and allow optimum connections to chamber wire and ground, even when some distance from chamber.
- Low time slewing permits optimum spatial resolution for drift chambers and very narrow coincidence gate and lower accidental rate for proportional chambers.
- Excellent threshold stability of <2uV/°C assures reliable operation over typically varying experimental conditions.
- Differential ECL-compatible outputs permit operation with twisted pair or other transmission lines.
- Standard 16-pin DIP package permits mounting directly on chamber, even in tight spaces.



LRS

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