CERN

COURIER

I Vol. 10 January 1970

European Organization for Nuclear Research

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. CERN is one of the world's leading Laboratories in this field.

The experimental programme is based on the use of two proton accelerators — a 600 MeV synchro-cyclotron (SC) and a 28 GeV synchrotron (PS). At the latter machine, large intersecting storage rings (ISR), for experiments with colliding proton beams, are under construction. Scientists from many European Universities, as well as from CERN itself, take part in the experiments and it is estimated that some 1200 physicists draw their research material from CERN.

The Laboratory is situated at Meyrin near Géneva in Switzerland. The site covers approximately 80 hectares equally divided on either side of the frontier between France and Switzerland. The staff totals about 2850 people and, in addition, there are over 450 Fellows and Visiting Scientists.

Twelve European countries participate in the work of CERN, contributing to the cost of the basic programme, 244.1 million Swiss francs in 1970, in proportion to their net national income. Supplementary programmes cover the construction of the ISR and studies for a proposed 300 GeV proton synchrotron.

CERN COURIER is published monthly in English and French editions. It is distributed free to CERN employees and others interested in sub-nuclear physics.

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Editor: Brian Southworth
Assistant Editor: Philippe d'Agraives
Advertisements: Micheline Falciola
Photographs: PIO-CERN photographic Section

Public Information Office
CERN, 1211 Geneva 23, Switzerland
Tel. (022) 41 98 11 Telex 2 36 98

Printed by: Ed. Cherix et Filanosa S.A.
1260 Nyon, Switzerland

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Cover photograph: The neutrino tunnel photographed in January, now restored to health after the fire at the end of August last year (see CERN COURIER vol. 9, page 269). At present the tunnel houses an electrostatically separated kaon beam, k 11, being used in a series of experiments with the 1.2 m CERN heavy liquid bubble chamber. The present series of experiments began mid-January. The neutrino beam itself will be reinstalled in the course of the year, at times when the k 11 beam is not in action, so as to be ready in the second half of the year for neutrino experiments using the large new heavy liquid bubble chamber, Gargamelle. (CERN/PI 41.1.70)

CERN Scientific Programme for 1970

A paper entitled 'General Outline of Scientific Programme for 1970' was presented to the Scientific Policy Committee at the end of last year. It is reproduced here with a few minor modifications.

The main programme of CERN for the coming year is shaped by the fact that the physics within the energy range of the 28 GeV proton synchrotron turned out to be richer than had been anticipated several years ago, and the many details which have appeared warrant a high precision experimental analysis. Strong interactions in the region up to a few GeV contain a wealth of resonances. Establishing their quantum numbers and their decay schemes requires extensive statistics experiments with the appropriate energy and angular resolution, polarized targets, etc. Above resonance energies up to 25 GeV, one is not yet in the asymptotic domain. This region could be related to the resonance region and is of considerable complexity. Nevertheless, there is at present, on a phenomenological level, a quantitative theoretical description of these phenomena, which were completely in the dark several years ago.

For electromagnetic interactions of electrons and muons, there is an excellent theory which has been tested to a precision of 10^{-6} to 10^{-8}, and further improvements, like the new g-2 experiment, obviously require a great deal of effort. Finally, the situation for weak interactions is characterized by the fact that one has, on the one hand, a good theory, thus enabling weak interactions to be used as a tool for studying strong interactions and, on the other, the exceedingly small effect of CP violation or possible deviations from the $\Delta S/\Delta Q$ rule. Clearly, the study of all these subtle features requires refined experiments.

In view of this situation, it appears fortunate that in 1965 the Council decided on the CERN improvement programme. The increased intensity of the PS and other new equipment will enable CERN to meet the challenge of these problems, and CERN will remain a first-rate laboratory in this field. Correspondingly, the CERN programme for 1970 devotes about one half of the effort to the completion of the improvement programme and the other half to the continuation of 25 GeV physics on the previous scale.

This trend is also reflected in the budget planned for 1970 — the ratio between 25 GeV physics and improvements is about 1 : 1. The former includes buildings and site equipment, part of services and power, part of equipment and development, and research and operations. The latter concerns improvement, construction proper, ISR construction, part of equipment development and services, and part of the construction of the two big bubble chambers (BEBC and Gargamelle). Thus, the improvement effort will still be at its peak in 1970. For the year 1971, this ratio is about 3 : 2 and for 1972 it is 3 : 1. Thus, the programme for 1970 will, on the one hand, be a continuation of the experimental programme of the previous years, in which CERN made many of the most important contributions to high energy physics; the large effort put into the completion of the improvement programme guarantees, on the other hand, that CERN, in the early 1970's, will in many respects be in a competitive position with all other existing high energy laboratories.

As far as the 600 MeV synchro-cyclotron is concerned, the situation is such that this instrument will have a rather unique position until the middle of the 1970s, at which time the meson factories in Switzerland and America will be in full operation. For the year 1970, a continuation of the present programme is planned, before the improvement of this machine guarantees its usefulness until the end of its lifetime. The SC programme contains many interesting items of intermediate energy physics. Two main lines of research are mesic atoms, which are a rich source of information on nuclei not available otherwise, and the ISOLDE programme for the study of highly neutron-deficient nuclei, which will remain a unique endeavour until the middle of the 1970's.

Since the start of operation of the Serpukhov machine, it became clear that for physics of the asymptotic region CERN can no longer compete. Correspondingly, a collaboration with Serpukhov has been established and the first quantitative experiment at very high energies has been carried out at Serpukhov by a mixed CERN-IHEP (Serpukhov) group. It is planned to continue this trend, and the missing-mass spectrometer, which has been operated successfully at CERN, will operate in 1970 at Serpukhov at higher energies.

Since the ISR will come into operation in 1971, a considerable effort is being made by CERN and universities in the Member States to prepare the experimental programme for this unique instrument. So far, this effort is in the planning stage and does not appear significantly in the budget. In view of their unchallenged position, one can proceed rather systematically in the use of the ISR. A first class of experiments covers a refined beam survey and consists in studying the production of known particles. Another class of experiments uses the fact that this instrument makes the biggest step forward into the asymptotic region to be expected in the next decades and measures total and differential elastic cross-sections. Finally, some daring experiments will be devoted to the search for new particles. So far, everything confirms the expectation that the ISR will be a great asset for European physics.

CERN News

The ISOLDE experimental hall with the isotope separator in the upper left corner. Beam lines branch out to various items of spectroscopic equipment where the short-lived isotopes can be studied.

ISOLDE success

The isotope separator on-line, ISOLDE, came into operation at the 600 MeV synchro-cyclotron two years ago. (ISOLDE and its experimental programme were described in CERN COURIER vol. 7, page 23. The purpose of the facility is to make available for study short-lived radioactive nuclides, particulary neutron-deficient nuclides.) During this time, nuclear spectroscopy experiments and further technological development of the experimental equipment have proceeded in parallel resulting, by now, in a facility which in many ways surpasses the original expectations of its designers.

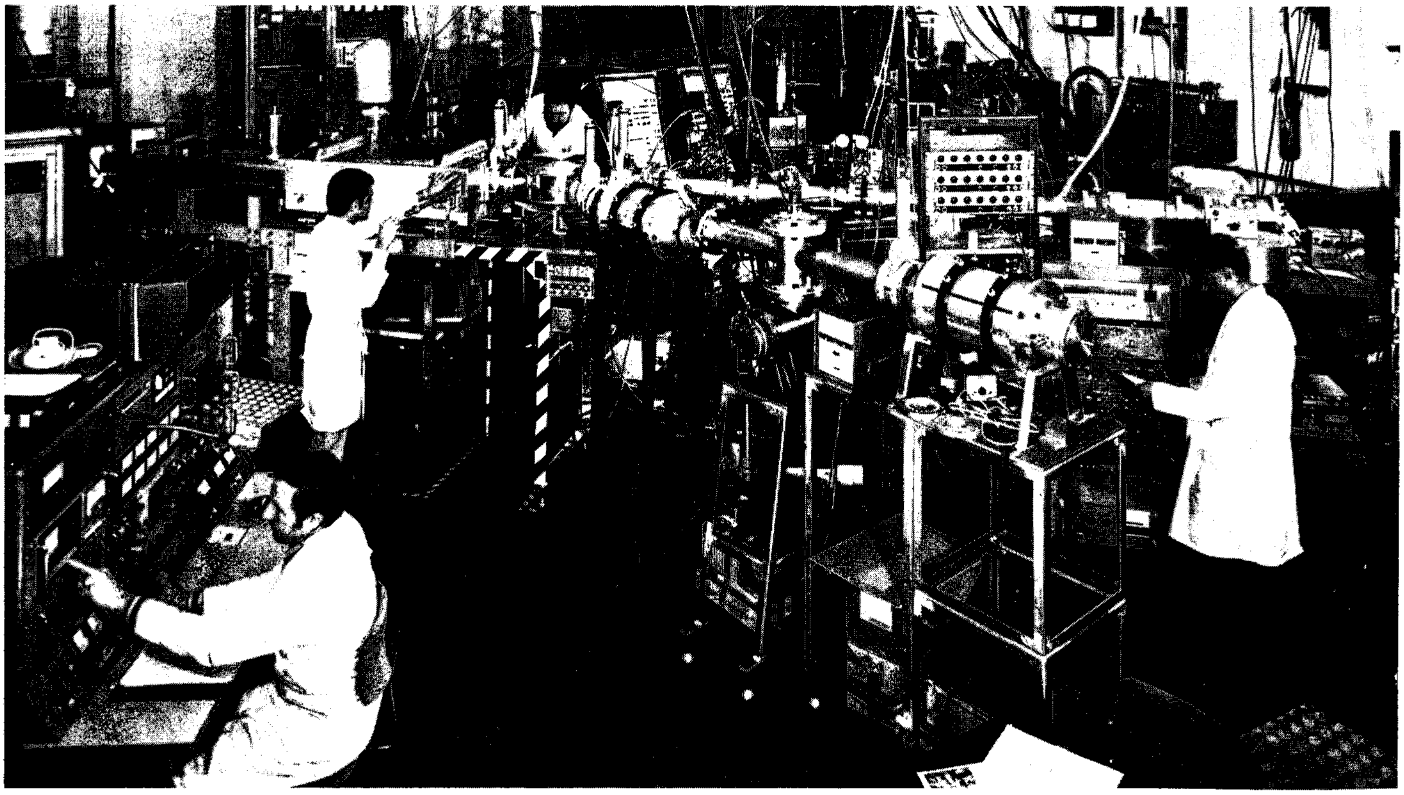
One measure of this success is the high standing which ISOLDE has gained among scientists interested in nuclear structure research. There has been a steady flow of visitors coming to discuss the experiments and the operational experience with a view to developing similar facilities at their own research centres. Visitors have come from the Los Alamos Meson Physics Facility (LAMPF), from the Dubna Laboratory, from the Joffe Institute in Leningrad, from TRIUMF in Vancouver, from SILAB in Darmstadt, from Texas A and M University, from the Princeton Pennsylvania Accelerator, from SIN near Zurich, etc... All these centres have plans for ISOLDE type research in various stages of realization.

To consider first the development of techniques at ISOLDE, there have been two major contributions to the growing success of the experiments — the improvement in intensity of the proton beam provided to ISOLDE by the synchro-cyclotron, and the mastery of the problems of producing appropriate targets.

The SC has proved very well suited to this type of research. It has fed beams to ISOLDE, transporting them down through the foundations of the SC building and along a tunnel to the underground ISOLDE laboratory, with exceptional reliability. During the past year, the beam intensity has more than doubled (to a peak of about 5×10^{11} protons per second focused in a spot about 3 cm^2 at the ISOLDE target) compared with the intensity when the experiments began two years ago.

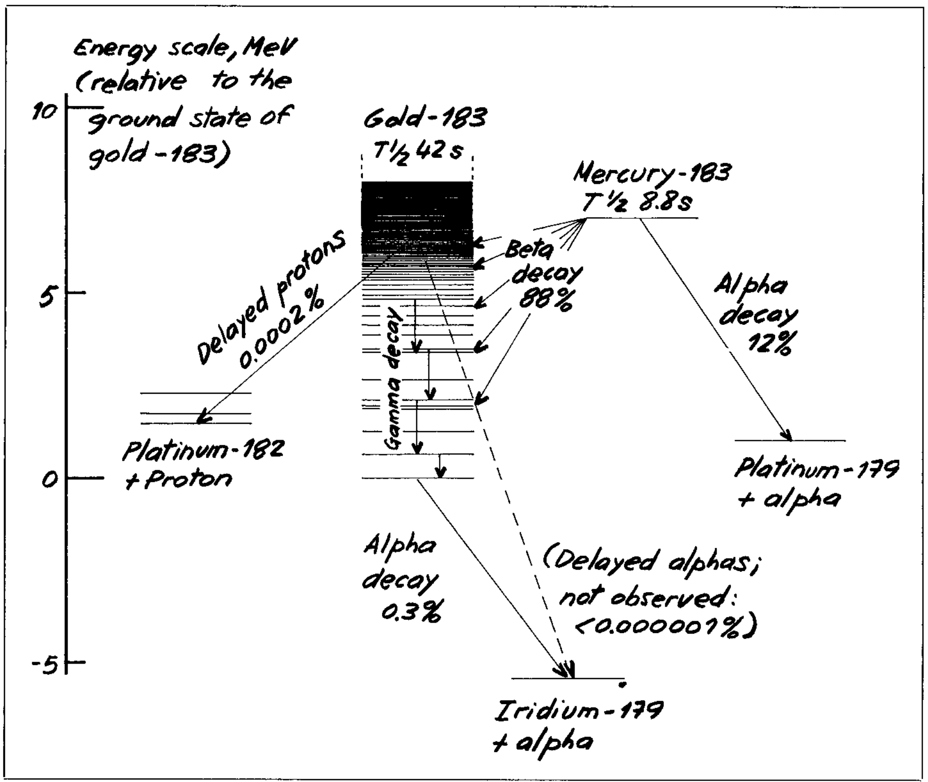
At the beginning of operation, target techniques had a large question mark over them and it was obvious that the success of the experiments would depend to a great extent on whether good targets could be made. The targets have to present the beam with appropriate atoms to bombard, so as to produce the nuclides of interest, and have to be in such a form that the nuclides can emerge from the target very quickly, so that they can be examined before they have decayed. It has proved possible to produce targets to meet the requirements of the research so far — though not without difficulties. Radiation damage can be substantial, giving rise to gaseous byproducts which can interfere seriously with the operation of the isotope separator.

Nevertheless many good targets have been developed including some very reliable targets involving the use of molten metals. For example molten tin is used for the production of cadmium isotopes — a



CERN/PI 414.10.69

Delayed particle emission in the decay chain of the mercury-183 isotope. The 'mother' isotope (top right) decays predominantly by beta decay and gives the isotope of gold-183, populating the closely spaced upper energy levels. The spacing of these excited levels near the top of the spectrum is in the range 1 to 10 MeV and the lifetime before the nuclide decays is about 10^{-14} seconds. The decay is predominantly by the emission of gamma rays but proton emission has been observed to occur in a very small percentage of cases (350 events seen). Decay by the emission of alpha particles has not so far been observed.



vacuum oven in the form of a horizontal cylinder heats 300 grams of tin to 1200° C. Cadmium isotopes produced by the beam are quickly distilled off and pass through a transport line at a temperature of 600° C into the ion source of the isotope separator. Towards the end of last year a target for the production of zinc isotopes was used. The target material was 300 grams of molten germanium kept at 1200° C. The experiments with this target demonstrated that in favourable conditions ISOLDE can also yield neutron-rich isotopes. For example, ^{74}Zn was produced from the heaviest stable germanium isotope ^{76}Ge. Even though the production reaction, ^{76}Ge(p, 3p)^{74}Zn has a very low cross-section and the target nucleus is of low abundance (8 % of stable germanium) sufficient amounts of ^{74}Zn were produced to begin meaningful studies.

Other technical work has concerned the 'sampling' devices. These are the systems which take the small samples of a nuclide, which have been separated out, from the separator to the detectors which are then able to observe the behaviour of the nuclide. For example, the separator can deposit samples at different positions on a magnetic tape, which can then be rapidly wound on to bring the sample in front of an electron detector, which will observe any beta-decay of the nuclide, or of other detectors. The magnetic tape is marked with a signal for position determination and the signal stops the tape when the sample has reached the measuring position. Three sampling devices are now installed inside the collector tank of the isotope separator. Also three beams of nuclide ions can be taken further into the experimental hall beyond the collector tank where heavier detection equipment is installed. In most experiments, combinations of these systems can be used in parallel so that different experimental teams can look at different isotopes simultaneously, which gives more efficient use of the available time and effort.

It has been possible to examine nuclides with half-lives down to as low as one second. Isotopes of radon, mercury, xenon, antimony, zinc, tin, cadmium, krypton and argon have been selectively released from various targets and separated into continuous beams of isotopes in the separator.

Some of these isotopes can have decay chains yielding as many as seven other nuclides. For example, mercury isotopes can give radioactive isotopes of gold, platinium, osmium and rhenium. Thus the total number of nuclides available for investigation is very great. Some thirty isotopes of various elements have been identified and studied for the first time.

To give an idea of how systematic, and thorough, studies of the nucleus can be using ISOLDE — all mercury isotopes, produced from a lead target, have been obtained between ^{179}Hg and ^{206}Hg. It has thus been possible to examine nuclei each of which has 80 protons but with numbers of neutrons varying from 99 to 126. It is a great advantage to be able to study the nucleus in this systematic way.

It is difficult to select particular experimental results — each of the twelve participating research centres is likely to have its own ideas as to the priority of importance ! Of generally recognized interest however is to extend the knowledge of the energy in the nucleus (the nuclear energy surface) far from the region of beta stability (i.e. under extreme conditions of nuclear formation). Such knowledge has been gained by systematic studies of alpha and beta energies for a large number of nuclides. Much remains to be done however to overcome experimental difficulties which up to now have only been superficially mastered.

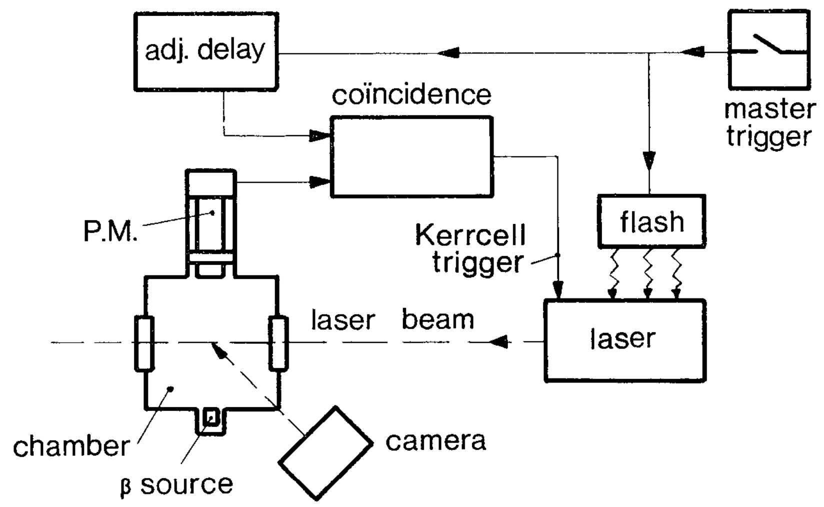
A more exotic field has concerned studies of the decay to daughter nuclei in highly excited states where the energy levels in the nucleus are very close together, having an almost continuous character. The strengths of the beta feeding of these excited states are of great interest and quite extensive studies have been performed. Also the highly excited nuclei decay generally by the emission of gamma rays, but there is a possibility of decay with the emission of a proton or an alpha particle (there may in some cases be enough energy available for such decays).

The search for alpha particles in such decays has so far been negative but in a very successful experimental period towards the end of last year three new delayed-proton emitters were observed. The first was in the decay of a xenon isotope ^{115}Xe and the others in the decays of mercury isotopes ^{181}Hg and ^{182}Hg. Previously the heaviest proton emitters observed were isotopes of tellurium (measured at Berkeley and at Dubna).

These studies involve the examination of samples which have short radioactive half-lives (in other words large decay energies) which is precisely where ISOLDE scores, with its on-line technique, over previous experimental facilities.

There have also been systematic studies of excited nuclear energy levels to find how they are affected when the nucleus changes from a spherical to a deformed shape. This has been done, for example, for cadmium isotopes from mass number 100 and upwards (this is close to the doubly 'magic' number $^{100}_{50}Sn_{50}$ and for mercury and its decay products just below the doubly magic number $^{208}_{82}Pb_{126}$.

Most of the experiments up to now have used conventional, though highly developed, detection techniques of nuclear



Scheme of the various units used in the experiment to test the idea of using laser light in the detection of particle tracks.

spectroscopy. It is hoped that a new technique, which is in an advanced stage of testing, can be brought into operation soon. It will be used to study the ground state properties (spin and nuclear moments) of cadmium isotopes by optical pumping, measuring the degree of alignment in a magnetic field by observing asymmetry of the beta decay along the magnetic field and at 90°. This borrowing of a technique from atomic physics for the study of nuclear properties could yield results of importance in their own right and will also give 'fix-points' for many of the decay-scheme studies which are going on. It should be possible to extend the technique to isotopes of other elements such as mercury, rubidium and cesium.

To conclude, the twelve research centres participating in the ISOLDE collaboration, backed by the excellent performance of the CERN synchro-cyclotron, have developed a very fruitful experimental programme. They have already fed a great deal of new information into the knowledge of nuclear structure.

Laser chambers in the future?

A first experiment has been carried out to test the idea of using laser light in the detection of charged particle tracks with very high precision. The experiment was carried out in conditions that were far from ideal but it produced evidence that the idea should work though much development would be needed to bring it into useful application in particle physics experiments.

From the beginnings of nuclear physics the phenomenon of gas amplification has been used for particle detection — the Geiger Muller counter was an early example. A widespread application in accelerator laboratories is in spark chambers which have been developed over the past decade in a number of versions — small gap, wide gap, wire chamber, streamer chamber... They are all based on the formation of plasma from a free electron under the effect of an electric field. The primary electron, which may result from the ionization produced in a gas by the passage of a high energy particle, accelerates in the field and, if the field is strong enough, ionizes further atoms in its path. The secondary electrons thus liberated behave in the same manner, so that each primary electron can produce an 'avalanche' propagating towards the anode.

If the number of secondary electrons reaches a critical value, the field of the electrons and ions themselves begins to become significant in the amplification process and the result is that the avalanche also propagates towards the cathode, giving rise to a streamer. Depending on the duration of the electric field pulse, the system operates either as a streamer chamber or as a spark chamber (where the streamer extends from one electrode to the other).

In the streamer chamber, the field is cut off very rapidly before the streamer reaches the electrodes. The shorter the electric pulse the better the primary electron (and thus the path of the ionizing particle) can be located, but the streamer will not be so luminous, since its luminosity depends on the strength of the electric field and the pulse duration. It is now possible to obtain streamers only one to two millimeters long (but of insufficient luminosity to record directly on a film — requiring image intensifiers) by applying voltages of several hundred kV for almost 10 ns over distances of the order of several tens of cm. In order to obtain a direct photograph, streamers of at least 5 mm or more are required, and the spatial resolution is then comparatively poor.

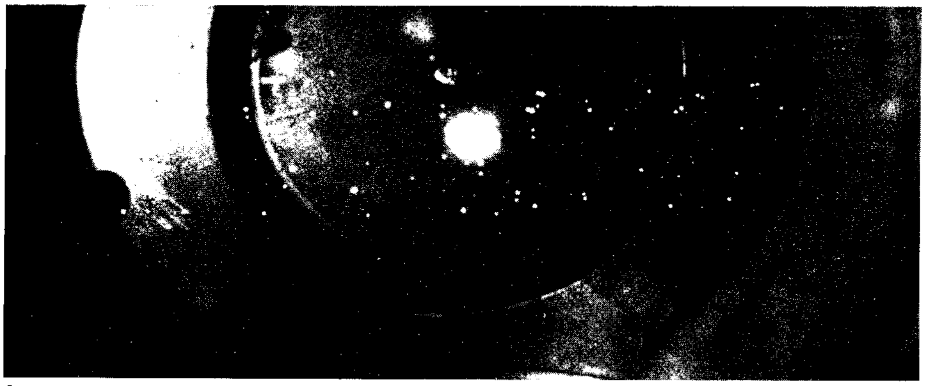
From what is known about streamer formation, it seems difficult with d.c. pulses to reduce them to less than a millimetre while retaining adequate luminosity. If, however, an a.c. field of very high frequency (10 GHz or more) could be used, the plasma would remain localized in a very small volume. What happens then would be a rapid gain in energy of the localized electrons, leading to an increase in their number and in the number of excited atoms.

Unfortunately, it is at present impossible to obtain uniform electric fields of the necessary intensity and frequency. However, light waves are very high frequency electromagnetic fields and, if their intensity were sufficiently high, they would produce conditions very similar to those of a very high frequency electric field.

In 1963, F. Schneider (who had also proposed the streamer chamber in 1959, many years before it was brought into practical realization) put forward the idea of using a laser beam to detect the ionization produced in the path of a particle. He showed that it should be possible to obtain, with lasers, a sufficiently intense energy flux to generate, from the electrons liberated by ionization along the track of a particle passing through a gas, small globes of plasma luminous enough to be photographed without need of an image intensifier.

It was difficult to test these ideas when they were first put forward because lasers did not then have the required power. (It can be calculated that the required energy flux density to make direct photography possible is several tens of joules/cm^2 with a gas pressure of about 10 atm.) There have since been major advances in laser technology and there are now models of very high power. In 1969, the CGE (Compagnie Générale d'Electricité) kindly offered to make

Photographs taken in the experimental laser chamber. 1. With the clearing electrode under voltage; 2. Without the clearing electrode under voltage. The chamber was filled with argon at 14 atm pressure. The energy was not uniform in the laser beam but concentrated in two regions where the amplification is higher. Small spots of light, which are about 0.1 mm in diameter, originate from free electrons in that part of the chamber volume in the path of the laser beam. The bright flare in each photograph comes almost certainly from the electrons left in the wake of a charged particle. The experimental conditions led to too high an amplification and to overexposure.



1.

2.

available lasers of sufficient power for an experiment.

A small experimental chamber was constructed, by E. Gygi and Schneider, measuring about 10 × 10 × 10 cm^3 with two windows for the laser beam and one for the cameras. It contained a beta source, a clearing electrode (to sweep out free electrons) and a scintillation counter to trigger the laser when it detected a particle. The tank was designed to withstand pressures of up to 20 atm — the higher the gas pressure, the faster the amplification.

It was taken to CGE's Marcousis centre where it was hoped to use the most powerful laser in the world — giving 50 GW of power in 10 ns with a beam 6 cm in diameter. Unfortunately, because of the laser's control system, it proved impossible to ensure that the laser would fire immediately after the scintillation counter recorded the presence of a particle. A less powerful model — giving about 4 GW in a 7 ns pulse with a beam 1.5 cm in diameter, whose power was not evenly distributed over the beam, had to be used.

The laser had an operating cycle lasting four minutes — the beam can be fired during a period of less than 100 μs after optical pumping has produced a sufficient number of atoms in the excited state. The beta source in the chamber used for the experiment was chosen so that there was a probability of having at least one particle track during the time (100 μs once every 4 min) that the laser could be fired. The scintillation counter triggered the laser as soon as it registered a particle but having to use the smaller laser beam meant that the track often lay outside the volume made sensitive by the laser. Out of a total of fifty photographs taken there was then a probability of ten tracks. This was reduced further by having to use the less powerful laser whose power output varied from cycle to cycle and was sometimes too low to produce the necessary amplification in the chamber.

Nevertheless several photographs were obtained which showed the presence of electrons. These were obtained with argon in the chamber at a pressure of 14 atm. (No perceptible amplification was observed with helium and neon. With argon at 20 atm the amplification was so great that the film was overexposed.) Two examples are shown in the photographs. Free electrons (ionization products from the passage of previous beta particles) appear as spots of light 0.1 mm in diameter. A track of free electrons due to the passage of a charged particle immediately before firing the laser is believed to be at the origin of the white flares of light. Obviously, when it is possible to refine the experimental conditions to control the amplification, the particle track should appear as a line which can be measured with very great precision. The main purpose of the experiment — to show that laser light could be used to make free electrons visible — was achieved.

Two possibilities exist for future development of the technique. Gas lasers which are larger and produce more homogeneous beams could be used rather than solid lasers. By reason of their lower frequency they can also produce the same amplification at lower energy density levels. But perhaps their most important advantage is that it is possible to reduce their electrical pumping time. If this became of the order of microseconds a laser chamber could be almost continuously 'sensitive'. A second possibility is to achieve large sensitive volumes by reflecting the laser beam across the chamber many times.

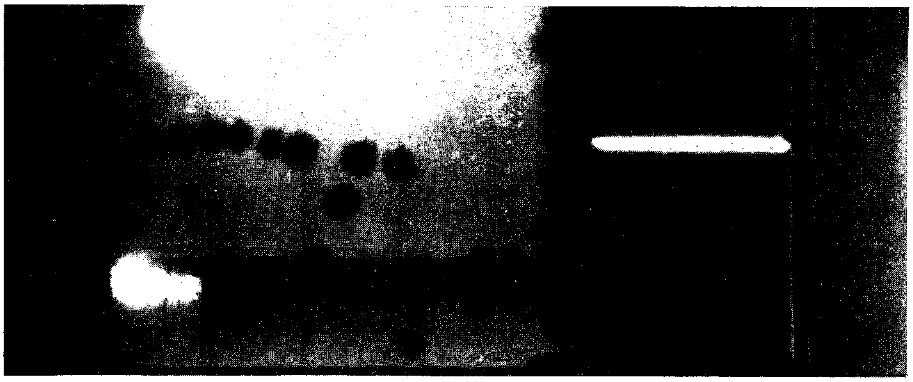
Both these possibilities are far from realization at the moment but it looks as if the basic idea is correct and the development of laser technology is now so rapid that we may well see laser chambers in the future.

More ultrasonic chamber experiments

Just over a year ago a CERN group achieved the first ever photographs of particle tracks in a bubble chamber in which the necessary pressure changes were caused by ultrasonic waves rather than by a conventional piston system (see CERN COURIER vol. 8, page 316). The first success was with liquid helium (helium requiring a comparatively small pressure swing of about ± 0.2 kg/cm^2) and efforts are now being concentrated on liquid hydrogen (requiring a pressure swing of about ± 2.6 kg/cm^2) which is the most useful target, with its single proton as nucleus, in particle physics experiments.

The ultrasonic tests have therefore moved to the 'one-metre model' — a hydrogen chamber used to check features of the 3.7 m large European chamber (BEBC) — and have been carried out by R. C. A. Brown, G. Harigel and M. J. Hilke in collaboration with the BEBC group.

The piezoelectric crystals used to generate the ultrasonic waves in the first experiment were of the type PZT 4 which were expected to be capable of generating pressure swings of about ± 2 kg/cm^2 but not much more. To achieve tracks in hydrogen it was therefore necessary to apply the ultrasonic waves on top of a small pressure swing from the conventional system (insufficient in itself to make the hydrogen sensitive to the passage of charged particles). This method of operation has already been successfully performed at Dubna (see CERN COURIER vol. 9, page 237). The Dubna team used



An electron track in a hydrogen bubble chamber in which the pressure swing required for the formation of the bubbles is achieved partly by a conventional piston expansion system and partly by an ultrasonic wave. It has been found that the formation of bubbles under ultrasonic conditions is very rapid — ultrasonic pulses of about 1 ms duration are enough to make them visible.

sound waves (14 kHz), rather than ultrasonic waves, which results in a smaller proportion of a track being made visible. (Standing wave patterns are set up in the chamber and bubbles can appear only in the region of the antinodes; with ultrasonic waves — 360 kHz in CERN's case — these regions are much closer together.)

The pressure swing produced by the piston in the one metre model was kept below that necessary to 'sensitize' the hydrogen. The PZT 4 crystals were then powered with a voltage of 1 kV to give a pressure variation of ± 1 kg/cm². The piston stroke was progressively increased from that giving 1.4 kg/cm² (when no tracks were observed) until tracks appeared. The diameter of the crystals was only 5 cm so that the volume subject to ultrasonic pressure was small and the photographs of the whole chamber volume showed clearly the effect of the piston alone and of the piston plus crystals. Precise information was collected on the conditions when the hydrogen became sensitive, on the amplitude of the ultrasonic waves, and on the ratio of the crystal voltage to this amplitude.

The results of this first stage of the experiment were very satisfactory and it was decided to push the piezoelectric crystals as far as they would go in an attempt to achieve the first photographs of tracks in hydrogen sensitized by ultrasonic waves alone. The voltage was increased to 2.6 kV corresponding to a pressure swing of ± 2.6 kg/cm². Before tracks were seen, the crystals were stressed too much and shattered bringing the experiment to an abrupt end. Nevertheless this final fling was not without use for it showed that even PZT 4 crystals could almost get to the required pressures. In future experiments, a crystal capable of producing pressures some 30 % higher will probably be tried. Several types, such as PZT 8, are currently being tested.

Another most important result came from the observation of the rate of bubble growth in hydrogen. The time needed for a bubble to grow to photographable size is an important factor in bubble chamber design. It has a strong influence on the accuracy with which particle trajectories can be recorded. A crucial observation in the first ultrasonic pictures was that bubbles are not snuffed out as the wave pressure swings the other way. The latest observations in hydrogen have shown further that the bubbles grow much faster than under the conditions of a conventional expansion system.

MASCOT for the PS

A contract, worth about 568 000 Swiss francs, has been awarded to Selenia (Italy) for the supply of an improved type of remote handling device known as MASCOT III (MAnipolatore Servo COntrollato Transistorizzato). It will be installed in the proton synchrotron tunnel to carry out certain operations which will become difficult due to the increase in radiation when the beam intensity goes up as a result of the machine improvement programme.

A remote handling device was installed at the PS in 1967 to find out the advantages in using this type of equipment and to investigate the problems of its operation. The use of these devices in an area where direct visual observation is impossible (unlike the situation in many laboratories where only a lead glass window separates the operator from the device) presented new problems such as the transmission of television images of the operation, transmission of control and monitoring signals, moving the equipment over long distances, etc.

These first experiments have resulted in a reliable remote handling device capable of carrying out operations such as the dismantling of a septum magnet or searching for beam losses with an ionization chamber during machine operation. However, the existing equipment has serious limitations. It has a slow working speed (twenty to sixty times slower than a man) with a single 'arm'. But above all, its movements are switch-controlled and the motion given by starting and stopping each motor has to be visually assessed using television.

The new device differs radically from the old in that it is not switch-controlled but operated by simulation. This means that all operations are carried out on a control, or 'master', robot which is exactly the same as the 'slave' robot inside the tunnel. The operator makes the appropriate movements, which are then automatically followed by the slave. The master and slave may be up to 300 m apart without any need for amplifiers. An 'artificial feel' system allows the exact force applied to the slave to be felt on the master controls. The sensitivity is such that when a large comb is held by the slave, the operator can feel individual teeth when the comb is run across the hard edge of a table. The device has two arms, thus providing a degree of dexterity almost equal to that of a man. In addition, the inertia of the arms is low and the speed of movement is relatively fast — up to 80 cm/s — depending on the type of movement.

Each of the arms of MASCOT III has seven degrees of freedom of movement (three translation, three rotation and squeeze) and each arm individually can handle a continuous load of 20 kg, or loads of up to 25 to 30 kg for periods of ten minutes at a time. All motions are fitted with overload clutches which come into action when external forces applied to the arms of the slave exceed a certain level.

The artificial feel amplifiers are transistorized and fitted in plug-in chassis in racks close to the master. Each unit serves one main function, which greatly facilitates repair. Also, one of the arms can, to a certain extent, be used to repair the other!

MASCOT III was designed in the CNEN (the Italian National Committee for Nuclear Energy) for the special purpose of providing equipment for the remote handling of active fuel elements. It was, however, constructed in such a way as to be as versatile as possible. CNEN also intends to investigate the possibility of building a radio-controlled version which could, for example, be installed in space or used over very long distances on earth. After building the MASCOT III prototype, CNEN granted the manufacturing rights to Selenia of Rome.

Installation of MASCOT III is scheduled for around September 1971. At present, the cable handling system, which allows

CORRECTION: In listing the companies exhibiting at CERN in November (caption to photograph on page 388 of the last issue) we succeeded in naming every company with the exception of Avica Equipment Ltd.

the existing manipulator to move up to 40 m from a fixed junction box, is being developed to disconnect automatically and then reconnect to further junction boxes around the ring. Complete coverage of the ring will then be possible without manual assistance inside the tunnel.

When the proton beam intensity reaches levels ten times higher than are usual today, the use of remote handling equipment which can be brought into action without delay will be very important. It will, on the one hand, reduce the problem of maintenance and repair staff being exposed to high radiation levels and, on the other, shorten machine shutdowns due to breakdowns in equipment such as ejection systems, since it will be possible to start repairs immediately regardless of the radiation intensity.

LUCY

In common with a number of other Laboratories, CERN has for many years been developing cathode ray tube digitizers for the automatic scanning and measurement of track chamber film. LUCY is the most recent of these CRT devices; it has been designed specifically for the measurement of most types of hydrogen bubble chamber film. In particular, it is intended to derive from the LUCY prototype a measuring system for the new chambers such as the large European chamber (BEBC). In comparison with fixed raster scan devices, such as the HPD (see CERN COURIER, vol. 6, page 7; vol. 8, page 79), a CRT digitizer offers a useful flexibility in the manner by which photographs are scanned, using the film effectively as a store which is interrogated only in the areas that are likely to contain relevant data. Thus the amount of core store required by the associated data processing programs can be significantly reduced.

On the other hand, it is difficult to obtain a sufficiently small scanning spot and great enough stability to give a resolution and measuring precision comparable to that of an HPD. However by careful design of all components, application of both dynamic focusing and astigmatic corrections, etc., the development work for LUCY has shown it will be possible

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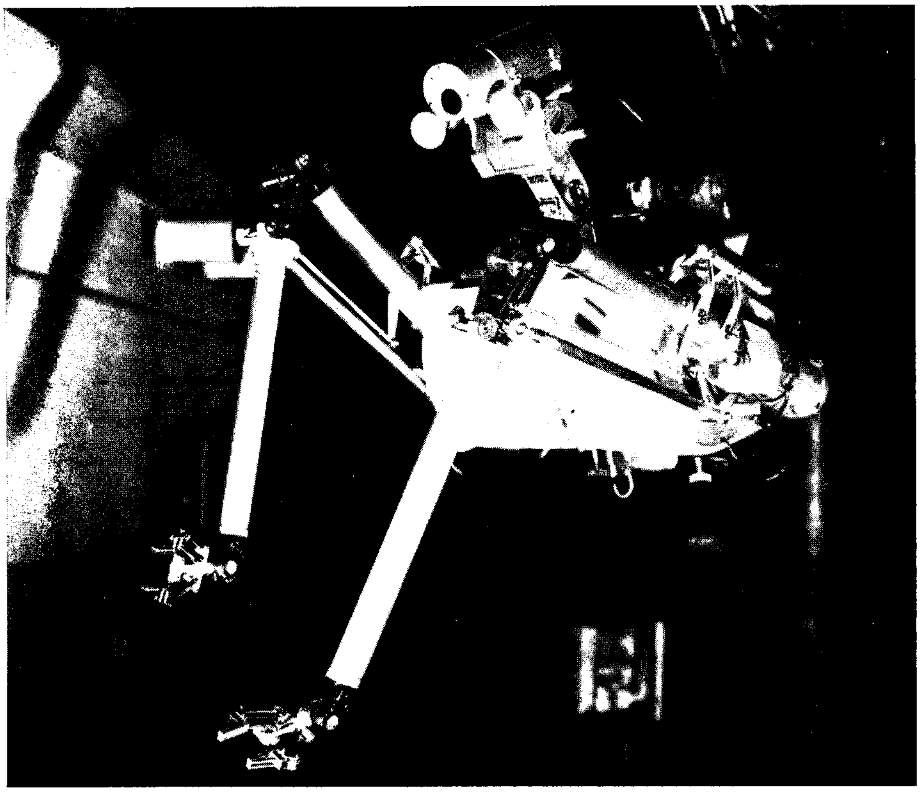

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1. The control robot or 'master' of MASCOT III a remotely controlled manipulator which is being acquired for the proton synchrotron. It is on the master, installed in a control room, that the operator will guide the work of the manipulator.

2. The manipulator itself or 'slave'. This will be installed inside the PS tunnel and will be capable of performing work anywhere around the ring. It will be particularly useful for work in highly radioactive areas.

(Photos Selenia)

to reach this desirable level of performance. Typically it should be feasible to project a spot of about 15 microns diameter on the film anywhere within a 70 mm square measuring zone. Long-term stability has been shown to be better than 1 part in 30 000. During measuring scans, the spot will move with a velocity of about 20 microns/μs. To handle the film from chambers with long picture formats that will not fit within the measuring zone, the film gate is mounted on a small stage that can be used to bring all parts of a frame rapidly into this zone.

A PDP-9 computer has been built into the system as an integral part of the device. This computer is used to control all functions of the machine such as: detailed control of the way in which regions of the film are scanned, buffering information read off the picture; controlling the stage and film transport systems. It is expected that in the operational system to be prepared for 1972, the PDP-9 will in turn be linked to a much larger computer which will interpret the data resulting from scanning small areas of the film, instruct the PDP-9 as to where the next scan should be, and generally control the scanning and measuring process.

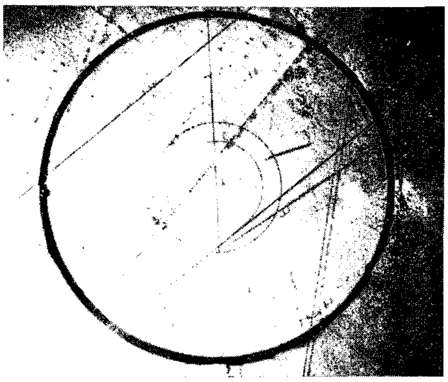
It is intended that LUCY will have an operator who will assist the measuring process to a varying extent depending on the characteristics of the film to be measured (in a similar way to the POLLY system at Argonne, see CERN COURIER vol. 9, page 275). Thus LUCY has been provided with a number of displays and convenient controls such as a 'trackball'.

Most of the hardware for the prototype form of LUCY has been constructed, installed, and tested; digitizings have been transferred into the memory of the PDP-9. Whilst no fundamental difficulties are expected in digitizing the film from the 2 m hydrogen chamber, measuring the film from the coming large European bubble chamber (the 3.7 m BEBC) could present serious problems. To get an idea of how difficult it will be to achieve digitization of the small bubble images in the low contrast film from the chamber, trials have been made on the film from the 1 m model. An example of this is shown in the figures.

Visitors to CERN in 1969

The number of people visiting CERN in 1969 reached the record total of 12 679. This compares with totals from the previous two years of 11 386 (1967) and 9415 (1968). The '67 and '68 figures are influenced by the fact that a CERN 'Open Day' was organized attracting, for example, 2472 visitors in 1969.

The majority of visitors come to CERN on Saturday when there are guided tours arranged in the mornings and the afternoons. Almost any language group can be catered for. On week-days there are occasionally more specialized visits involving, for example, University physics departments, where a more detailed technical presentation of some aspects of CERN's work is required. In addition, there is a steady flow of journalists and television teams whose interests obviously receive special attention.



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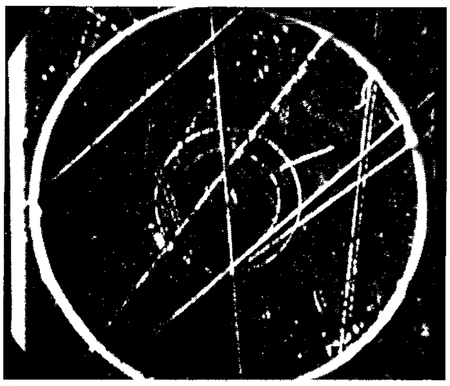

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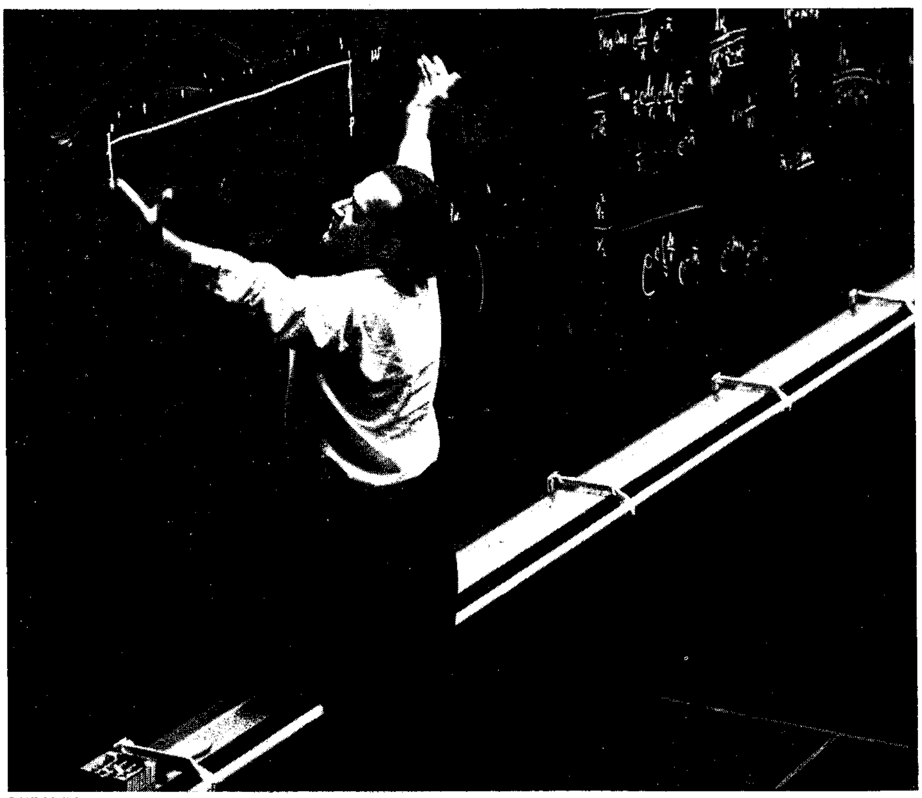
1. An enlargement of the central area of a photograph taken in the 1 m hydrogen bubble chamber model.

2. An oscilloscope display of the digitized output of the tracks in the central area as seen by LUCY.



CERN/PI 111.1.70

Visiting CERN in January was R. P. Feynman who has recently been working on strong interaction theory. On 8 January, he packed the lecture theatre, as usual, when he gave a talk on inelastic hadron collisions and is caught in the photograph in typically graphic pose in the course of his talk.

Induced Radioactivity at CERN

A description of some of the problems and some of the advantages associated with the phenomenon of induced radioactivity at accelerator centres such as CERN. The author has worked in this field for several years and has recently written a book 'Induced Radioactivity' published by North-Holland.

M. Barbier

High energy accelerators produce radiation when they are in operation in the form of 'secondary' particles emerging from any object which is in the path of the accelerated particles (either intentionally, such as a target, or unintentionally such as the vacuum chamber wall). The secondary particles are mainly neutrons which penetrate deeply into surrounding matter. Accelerators are also a source of radiation when they are switched off since the accelerated particles or the secondary particles, can split nuclei in their path resulting in unstable nuclei which can later decay emitting gamma, beta or alpha rays. This phenomenon can persist for a very long time and is usually referred to as induced radioactivity.

Prior to the coming into operation of the present generation of accelerators, comparatively little was known about radiation phenomena caused by high energy particles. The CERN synchro-cyclotron and proton synchrotron were built with little consideration for this aspect of their life (apart from the limited knowledge when they were built there was also the expectation of beam intensities far below what has been achieved). From the early 1960s, induced radioactivity began to receive serious attention partly with a view to minimizing, in any future accelerator construction, the problems it brings. Data was brought together on the types of radioactive nuclei which could be produced, their half-lives, the type of radiation they emit, how readily this is absorbed by matter, etc. The important outcome is that it is now possible, knowing the accelerator operating conditions, to have a good estimate of the radiation levels which will be produced in the accelerator environment.

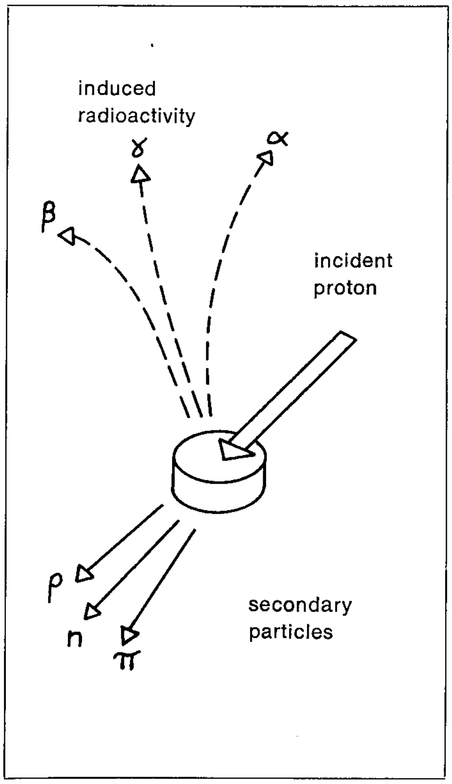
1. Diagram of the phenomena accompanying the bombardment of a nucleus by a proton. The solid lines represent the immediate emission of secondary particles; the broken lines, the alpha, beta or gamma radiation emitted after a certain time which constitutes the induced radioactivity.
2. A photograph of a man at work in the radioactive environment of the CERN synchro-cyclotron.

Problems of induced radioactivity

The radiation emitted by the CERN machines when they are shut down gives rise to many problems. First of all, it affects the people who have to work in the immediate vicinity of the accelerators and experimental equipment. Access to the more radioactive regions has therefore to be prohibited for a fairly long time after the machine is shut down. The radiation level drops in time, and thus a waiting period of eight to forty-eight hours, depending on the particular case, is imposed before allowing people near the equipment.

It is not only necessary to wait some time before work can begin, but also the period during which work can be carried out is strictly limited. There are legal stipulations concerning the radiation doses to which human beings can be exposed even when they are 'radiation workers'. These ensure that people working in a radiation environment can do so without danger. Thus the time for which a man may work in a given area where there is radiation must be no longer than that during which the permitted dose is received.

Another problem with induced radioactivity is that special precautions become



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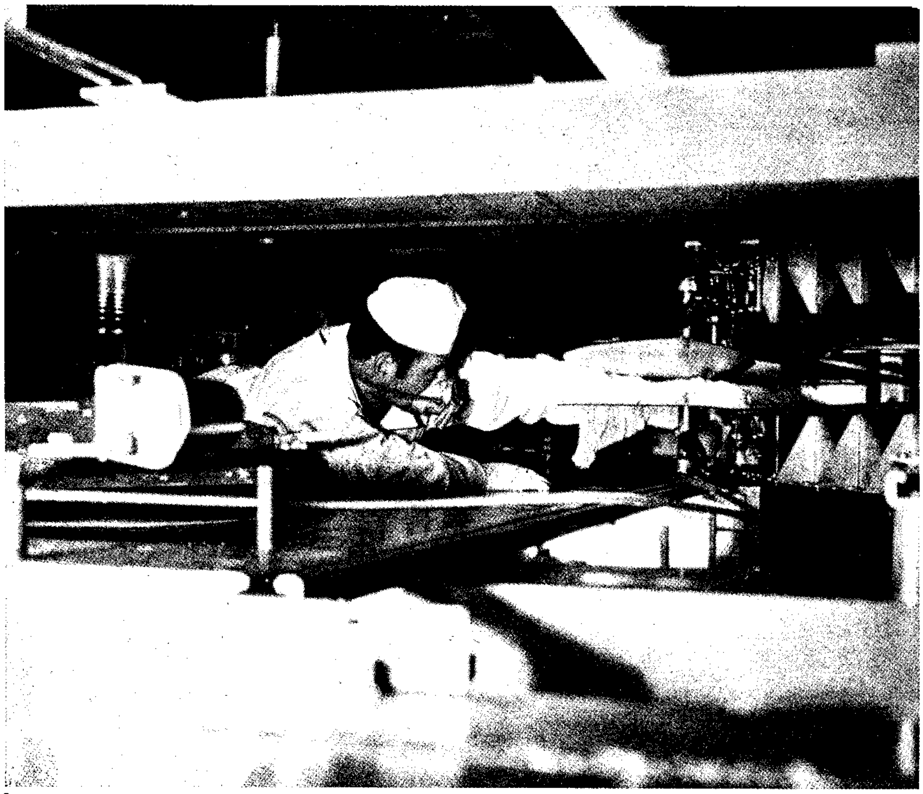

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necessary when work on radioactive components has to be done in the workshops. The swarf and dust produced in machining these components must be carefully collected to prevent it being dispersed throughout the workshops, since such dust could be dangerous if inhaled though the nose or mouth, or if carried on the skin.

Other objects, like concrete, iron or lead shielding blocks, which often have to be manhandled, become radioactive when struck by the beams, and after some time must be replaced. The same applies to the magnets of the accelerator and even to the walls of the buildings although these, of course, cannot easily be replaced. Similarly, the detectors used in the physics experiments which are located in a particle flux may become radioactive. They then begin to record and measure their own radioactivity, and can thus become useless for experimental purposes.

Radioactive components

Inside the synchro-cyclotron and its immediate surroundings are two of the most radioactive areas at CERN. Next come the target chambers at the proton synchrotron. Other radioactive objects include, for example, the targets themselves, the beam ejection magnets, the collimators (long components pierced with a very small aperture which are designed to stop those particles which are not properly centred in the beam) and the beam dumps (components designed to receive and absorb the beam after use).

The table gives a few radiation field values measured at various points in CERN. The unit used is the rem per hour (rem/h); the permissible weekly dose is 0.1 rem. Thus, at a point where the rate is 1 rem/h, a man may work for six minutes per week.

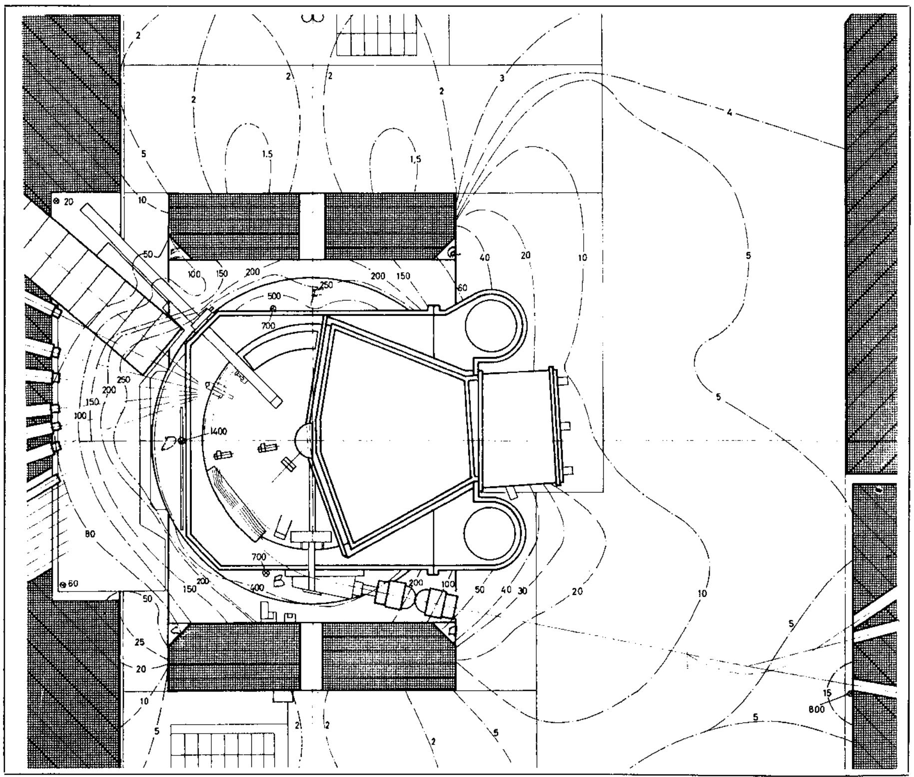
Very little can be done to reduce this radioactivity, for it is, of course, out of the question to reduce the intensity of the accelerators — on the contrary the experiments usually call for as high an intensity as possible. It is however possible in certain cases to reduce the hazard by the judicious choice of materials used. It has been found that elements with an atomic weight lower than that of aluminium (e.g. hydrogen and oxygen (in water), carbon and beryllium) are only slightly radioactive, at least after a few hours. Aluminium and titanium are similar, but substances with atomic weights beyond that of titanium, e.g. iron, copper and almost all the elements up to lead, become very radioactive.

Figure 4 shows a chart of the nuclides, above each of which is a line whose length is proportional to the gamma radiation hazard (measured in rem/h per curie at a distance of one metre) from those with a radioactive half-life of longer than one day. By way of example, the last line on the right gives the radioactivity of radium.

The common metals are not, therefore, very useful for the purpose in view here, while of the heavier materials only calcium (usually used in the form of its carbonate — marble or chalk — where the other atoms are carbon and oxygen) exhibits a relatively low level of induced radioactivity. In some cases, sheets of marble have been used to cover iron

The table below lists some radiation levels at CERN in units of rem/hour.

Inside the synchro-cyclotron 24 hours after shutdown	2 to 12
Internal target of the synchro-cyclotron at a distance of 18 cm 24 hours after shutdown	130
Internal target of the synchrotron at a distance of 40 cm 24 hours after shutdown	0.7
External target of the synchrotron at a distance of 40 cm 24 hours after shutdown	6.5
Target area E_5 of the synchrotron extracted beam (target removed)	0.05 to 0.1
In contact with ejection tank 58 of the PS 1½ hours after shutdown	30
ISOLDE target at a distance of 40 cm 2 hours after shutdown	0.5 to 2



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3. A chart showing the radiation levels, in mrem per hour, around the synchro-cyclotron eight hours after shutdown.

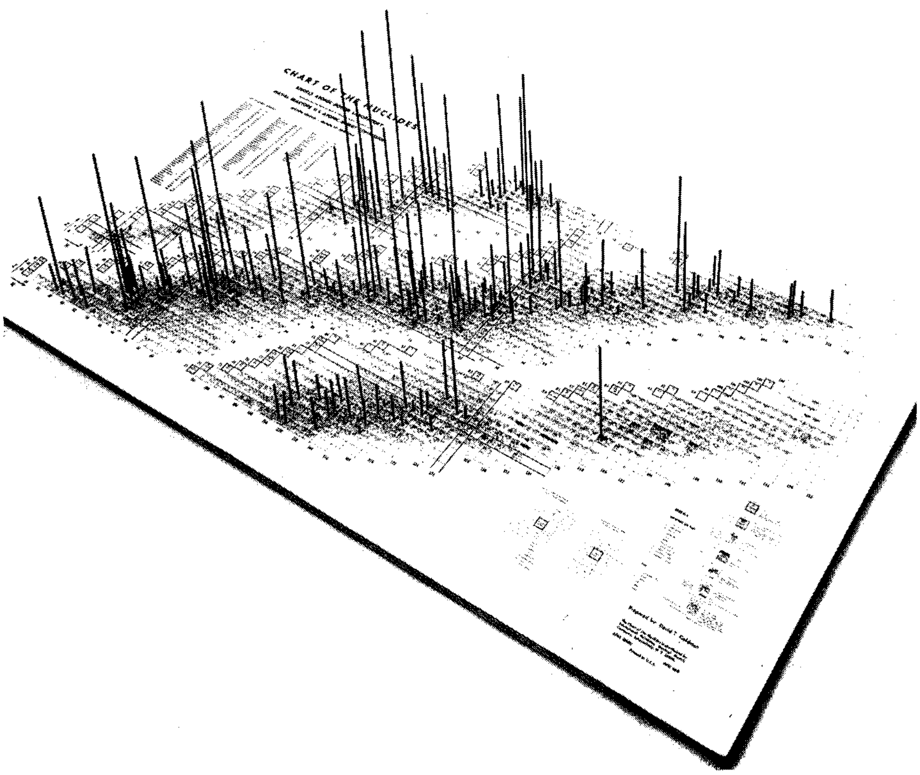
blocks which are in the path of intense beams. Unfortunately such coverings are cumbersome, since the thickness of marble needed is of the order of 25 cm, and this method cannot often be used.

Advantages of induced radioactivity

A phenomenon seldom has drawbacks only. Radioactivity is no exception and can be a very important source of information to the physicist. First of all, it acts as a kind of memory, allowing the history of a radioactive object to be traced. By measuring the radioactivity it is possible in certain cases to find out the number of particles that have passed through an object. Alternatively, if this number is known, it is possible to calculate the date of bombardment.

To measure the flux of the particles produced by an accelerator, thin pure metal foils are placed in the path of the beam and left there for a given time. Then, by measuring the induced radioactivity, the intensity of the flux or the beam can be calculated precisely. (In a similar way, the measurement of the radioactivity of meteorites had provided a measure of the particle fluxes present in the cosmos before man ever ventured into space.) Further application is in the determination of the age of old or prehistoric objects from radioactivity measurements on the carbon they contain. The carbon is made radioactive by the flux of cosmic rays whose intensity is known in the Earth's atmosphere. It it thus possible to find the age in which the object was formed.

Another application of induced radioactivity is in the identification of new nuclei artificially produced in the bombardment of nuclei by high-energy particles. The bombardment can result in the production of new nuclei whose properties are examined by means of observing their radioactivity. CERN in collaboration with many European Universities is concerned with the creation and investigation of new nuclei by this method of bombardment and uses the radioactivity of the products to examine them (the ISOLDE project). This is one of the major fields of research at the CERN synchro-cyclotron.



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4. Chart of the nuclides showing the radioactivity of those with a half-life of longer than one day, in rem/h per curie.

Around the Laboratories

BATAVIA
Progress report

We have neglected the 200 GeV Laboratory for several months and include here news of their construction progress through to December. For fiscal year 1970 the appropriated Laboratory budget is \$ 70 million which is far short of the \$ 96 million requested. Nevertheless the scheduled date of 30 June 1972 for achieving 200 GeV beams is still held, though the budget cut will mean that less experimental facilities than were planned will be ready to make use of them.

The building for the 200 MeV linac is complete; construction and testing of linac components is well-advanced. On 11 December, 10 MeV beams of 160 mA were achieved with an emittance of 12 cm mrad (80 % of beam) and a momentum spread of 9×10^{-3} (85 % of beam). This indicates that the linac could produce 200 MeV beams considerably better than required by the design specification. Intensive studies have been carried out with the 10 MeV tank I using a spectrometer to observe the effects of tuning on emittance and momentum spread. Tank 2 is expected to be delivered in March and Tank 3 soon afterwards.

Prototype focusing and defocusing magnets for the 8 GeV Booster were received and checked in November and were within the specified tolerances. Contracts were then placed with two manufacturers to produce fifty magnets each, while seven of each type will be made at the Laboratory as spares. The prototype magnets were used to produce a second Booster module and the two modules have been used for power supply and vacuum tests which have proved very successful. They were run continuously for 100 hours in December being monitored and controlled by a control computer.

The performance of the vacuum system was particularly gratifying. A major change from the original Booster design was to eliminate the vacuum chamber between the magnet poles and to have an external vacuum sheath outside the magnet as in the Cornell electron synchrotron. With this new design a turbo-molecular pump is used for each pair of Booster modules to

Ground-breaking for the main ring at Batavia. Machines were eventually allowed to take over on condition that they would work faster... the completion date for installation of main-accelerator components has been brought forward six months. The Laboratory Director, R. R. Wilson, is easily distinguished — he is the only man who has got a head without a hat !

achieve rough vacuum and operating conditions are then established by ion pumps (one in each module). During the December tests, vacuum of 3.7 × 10^{-7} torr was achieved near the pumps and 7 × 10^{-7} torr remote from the pumps. This indicates that the design pressure of 5 × 10^{-7} torr average should be achieved.

The next big date for the Booster is to have a quarter of the Booster ring installed in its tunnel, pumped down and powered by May. 8 GeV protons from the Booster are scheduled for April 1971.

Since progress on the 200-400 GeV Main Ring had not been going quite so fast as had been hoped, Professor Wilson decided to advance the date for completion of installation of the Main Ring components by six months ! Testing of the complete accelerator is now scheduled to begin on 1 July 1971 rather than 1 January 1972. A ground breaking ceremony for the ring was held on 3 October and excavation is now well under way. In December, the contract for the underground enclosure was placed and has worked out cheaper than anticipated. The contract price for the underground parts of the Main Ring is about $ 7 million.

Construction of magnets is under way using a new method of making the coils of the bending magnets. Each coil is made in three parts so that conventional tolerances and manufacturing methods can be accepted for the top and bottom windings while the four-turn coil at the median plane is specially manufactured to very tight tolerances. Production of the four-turn coils is being done by the Laboratory in a rented factory in West Chicago. The next big date for the Main Ring is 20 March when a prototype cell of eight bending magnets and two quadrupoles is scheduled to be installed and operating in the prototype tunnel.

DARESBURY

Some topics from the Daresbury Nuclear Physics Laboratory where research is centred on the use of the 5 GeV electron synchrotron, NINA.

Experimental programme

The experimental programme at NINA now involves teams from five northern universities (Glasgow, Lancaster, Liverpool, Manchester and Sheffield) in addition to the experimental physicists at Daresbury itself. An experiment on backward pion photoproduction, involving a collaboration between Orsay, Strasbourg and Daresbury, has just finished taking data and an experiment on pion electroproduction, involving a collaboration between Pisa and Daresbury, is planned.

Altogether ten experiments have been completed and nine are either currently using or preparing to use the machine. The programme can be divided into three main categories (examples of experiments in each category are added).

1. Fundamental investigations of quantum electrodynamics. A wide angle electron pair production experiment has confirmed the validity of quantum electrodynamics down to small distances. The experiment was similar to those previously done at Cambridge and DESY except that it was the first to do the measurements on hydrogen (the others had used carbon). The result supports that of the DESY Columbia team.

2. Photoproduction of hadrons. A series of experiments are being done or are completed on the production of hadrons —π^0, η, N*, etc. Of particular interest is an investigation of the electron pair distribution from the decays of rho and omega vector mesons. Preliminary results show an interference between the rho and omega which is in contradiction with experiments performed elsewhere.

Healthy fluxes of kaons can be obtained by photoproduction and have been used in an experiment looking at the spectra of the long-lived neutral kaon decaying into three particles.

The kaon beam has fine bunch structure and 'time of flight' techniques can be used. Kaon-proton interactions are to be investigated looking for the possible production of resonances with strangeness + 1. This would be in violation of SU3 theory and of the quark model of mesons.

3. Electroproduction (including inelastic electron scattering). An experiment is currently underway investigating the electroproduction of resonances and there are further experiments planned on electroproduction of the pion and the eta meson.

The Science Research Council has approved a grant of £ 150 000 to set up a 'National facility for synchrotron radiation' at Daresbury. Using the synchrotron light emitted from the intense circulating beam in NINA this facility will be the finest of its type in the world. NINA gives synchrotron radiation with an intensity distribution which can be calculated, extending smoothly over the region from visible light to wavelengths below one angstrom.

A building to house the experimental equipment has been designed and two beam lines will feed it. Use of synchrotron radiation will, of course, be entirely parasitic and will not affect the rest of the research programme. The facility will be used for experiments in atomic, molecular and solid state physics.

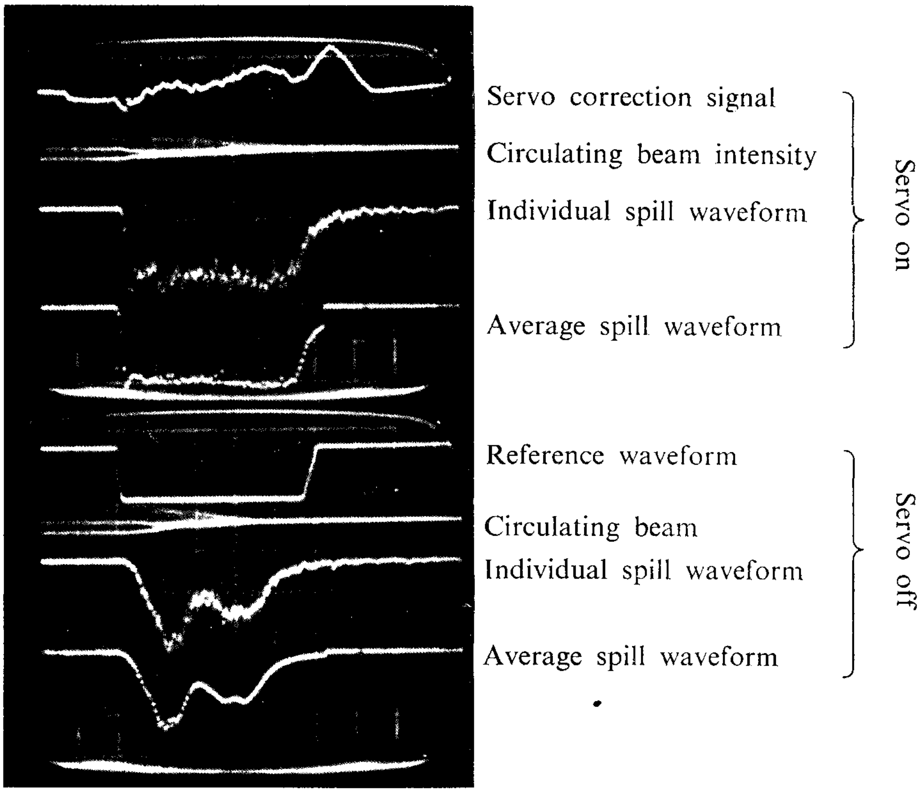
Machine operation

In machine operation, the accelerator physicists have been having a difficult fight to keep the average accelerated beam current close to 1 μA. NINA has built-in capability for 10 μA and it was

1. Oscilloscope traces illustrating the use of the servo loop to obtain even spills of photons with a duty-cycle of up to 12 %. The improvement in individual and average spill waveforms is clearly seen. These traces were recorded at a machine energy of 4 GeV and the horizontal scale is 0.5 ms per division.

2. The Orsay experiment set up in the NINA experimental hall. The experiment, which finished taking data on 23 January, looked at photo-production of positive pions in the backward direction in the energy range 0.5 to 4 GeV.

(Photos Daresbury)



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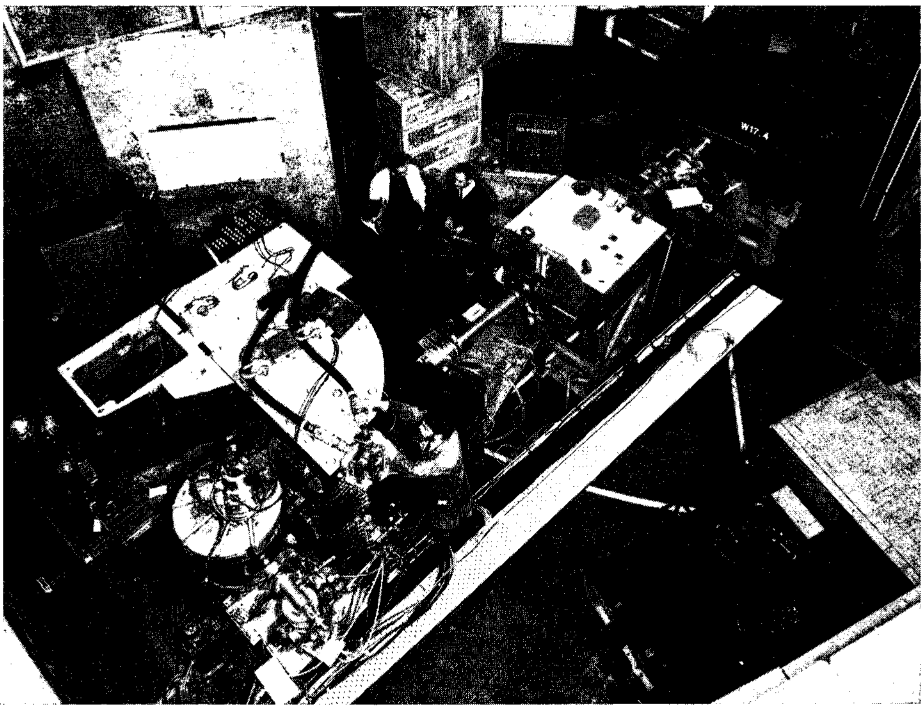

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hoped that currents of 2 to 3 μA would be achieved by this stage of machine development. Instead there has been a gradual deterioration in the accelerated current.

One reason for this is believed to be the regular spacing of the r.f. cavities which induces resonances leading to beam blow-up. The cavities will be shuffled, when there is time in the machine programme, to avoid this effect. Another contribution to increased intensity will come in July when the 40 MeV linear injector will give beams, modulated at the synchrotron frequency using a beam chopper, injecting one bunch (out of seven possible from the linac during the synchrotron r.f. cycle) at the stable phase angle. This will require much higher peak beams for the electron source so as to capture more in the synchrotron.

Installation of a ceramic vacuum vessel replacing the initial stainless steel vessel was satisfactorily completed six months ago. A second ejected electron beam has been commissioned and it is planned to use computer control of the beam-line later this year using on IBM 1800 computer. Ejection efficiencies have recently reached 70 %.

A servo loop was recently brought into operation to improve the photon beam 'spill' from a target in NINA produced when the electron beam is guided on to a tungsten target. Without refined control, the observed spill is uneven (see the lower traces in the photograph). In the servo loop a correction signal is generated and fed back to an amplifier feeding back-leg coils which control the way in which the electron beam is guided onto the target. This has resulted in a uniform spill over about 3 ms which is equivalent to production of a good quality photon beam with a 12 % duty-cycle. In December the servo loop was also successfully used on the ejected electron beam. Uniform spill was achieved over 1.5 ms with 70 % ejection efficiency during normal machine operation. Control of ejected beams has improved to the point where three beam lines (electron or photon) can be fed sequentially or two simultaneously — meaning either feeding one beam line after another on successive pulses (NINA operates at 50 pulses per second) or feeding two beam lines on the same pulse (giving down each beam line about 30 % of the intensity corresponding to the full pulse). The accelerated beam intensity is however not yet sufficiently high to make full use of these techniques.

15-20 GeV 'Booster'

A design study is underway for a higher energy extension to NINA usually referred to as the Booster (see CERN COURIER vol. 9, page 44). The study is approved by the Science Research Council. By adding another synchrotron ring, fed by NINA, it is aimed to provide electron beams with a maximum energy of 15 to 20 GeV. If this project were approved in the near future the Daresbury Laboratory would be the first in this energy range with high duty-cycle electron beams. The Stanford linear accelerator is already there with low duty-cycle and the Cornell electron synchrotron may reach 15 GeV, though probably without the facilities to mount an extensive experimental programme. Preliminary discussions between Daresbury and DESY have already considered ways in which future collaboration on the use of the complementary facilities at the two Laboratories (the high energy Booster at Daresbury and the 3 GeV storage rings

3. A tagged photon beam is to be used for two experiments which are now in preparation at Nina. The photograph shows the system for detecting the electrons whose energies and angles are measured to calculate the energies of the associated photons.

(Photo Daresbury).

now under construction at DESY) could be organized. This may be carried further and discussed in ECFA to see the place of the future facilities of the two Laboratories in the overall European programme.

The present studies at Daresbury are concentrating on selecting the optimum design of machine components from among various possible alternatives. On the magnet this involves deciding between conventional construction and construction with the vacuum enclosure outside the magnet (as in the Cornell machine). The new idea from the Rutherford Laboratory of 'concrete' magnets (pumping in castable ceramic as insulation) has already been considered but looks less suitable for fast cycling machines which require stranded cables.

For the vacuum chamber two possibilities are being studied. The first follows the idea from Berkeley to use a thin (few mm) stainless steel tube sprayed with aluminia. This is a very neat method but needs special care in manufacture. The second is to use a thin walled corrogated chamber. Model work is being done on r.f. structures and enquiries with klystron manufacturers indicate that there will be no problem in acquiring klystrons to meet the specifications.

Finally more thought is being given to the choice of siting the new synchrotron ring. One alternative crosses the existing NINA ring and would cause serious disruption of its programme while gaining in cost by being able to use the existing experimental hall. The other alternative for a completely separate ring involves construction of a new experimental area. Experimental physicists are working on the possible programme of experiments in the new high energy range that the Booster would make available.

PRINCETON

Budget axed

The Princeton Pennsylvania Accelerator Laboratory took a very severe cut in its budget in the allocations announced by the US Atomic Energy Commission. With effect from 1 January, the annual spending rate is reduced by about $ 1.2 million out of an operating budget originally planned at $ 4.69 million. It proved impossible to persuade the AEC to ease the blow by reducing the cut or applying it less abruptly.

The effect on the Laboratory has been that about 40 % of the staff (about 100 people) have had their contracts terminated. This has been done mainly by length of service — the recently employed have had to go. The plans for the future development of the 3 GeV rapid cycling proton synchrotron, described in CERN COURIER vol. 9, page 310, will obviously be hard hit by these decisions.

Nevertheless there is great determination to push through some of the planned improvements. The normal divisional boundaries have been swept aside to bring maximum effort to bear on the 'flat-topping' project. Operation of a solid-state power supply will make it possible to flat-top for times up to 50 ms with reduced repetition rate (down to 10 Hz). It is planned to achieve this in February of this year. When it is completed, effort will move onto the 75 MeV fast cycling booster which is essential for the efficient acceleration of heavy ions — a major aim of the Laboratory.

For this it will also be necessary to install ceramic vacuum chambers (to reach pressures of 10^{-8} torr or better). Some tests with xenon ionized four times, Xe^{4+}, went well. Acceleration was achieved for some way but was frustrated by further stripping of the ions due to too high a residual gas pressure. Three ceramic chambers have been bought but about $ 200 000 is needed to complete the ring. When it is possible to do this, xenon could be taken to 10 MeV per nucleon and Princeton could be the first Laboratory to accelerate uranium ions to high energy.

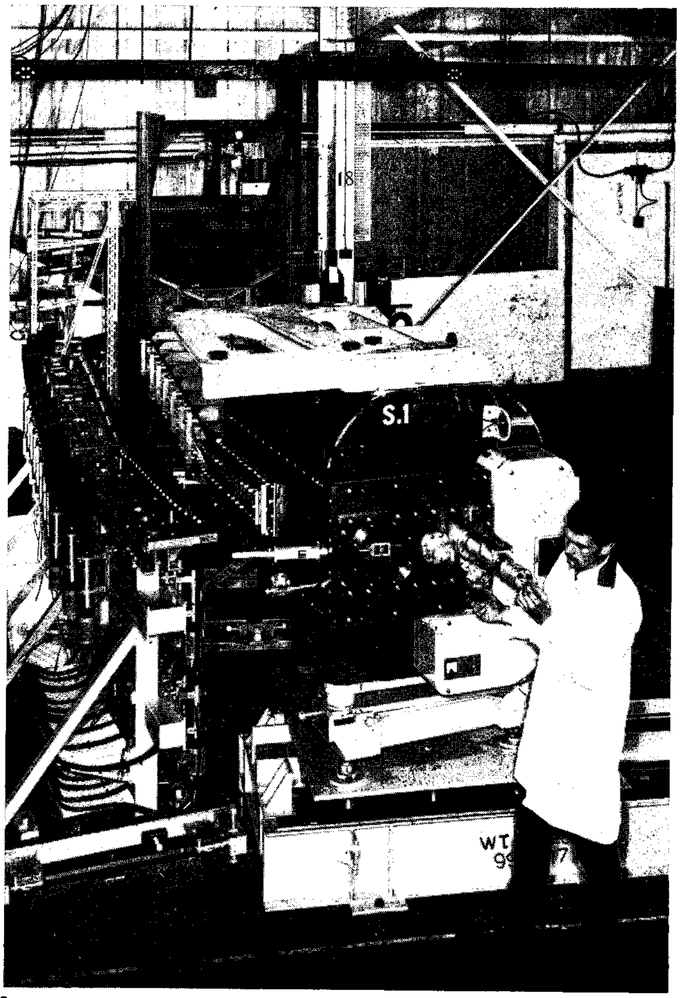
Quarks undiscovered

We reported in CERN COURIER vol. 9, page 309, the experiment of a Sydney team led by C.B.A. McCusker which seemed to have evidence of quarks. From a large number of cloud chamber photographs exposed to cosmic ray showers they had observed five tracks, composed of less droplets than their neighbours, suggesting the passage of particles with a charge $^2/_3$ that of the electron charge. This property of fractional charge is one of the distinctive features of the proposed quarks.

The suggestion that the five tracks were due to quarks was strongly questioned at the time the experimental results were first announced. Given such things as the 'acceptance' of the Sydney detection equipment, the average spread of a cosmic ray shower etc., the observations indicated that about ten quarks with $^2/_3$e charge are produced in every shower which has energy of the order of 3×10^6 GeV. The flux of these quarks could be calculated as 5.5×10^{-10} cm^{-2} s^{-1} steradian^{-1}. Other experiments searching for quarks in cosmic rays ought to have seen them if the flux is as high as this. On the other hand no one could put forward convincing alternative explanations for the low density tracks.

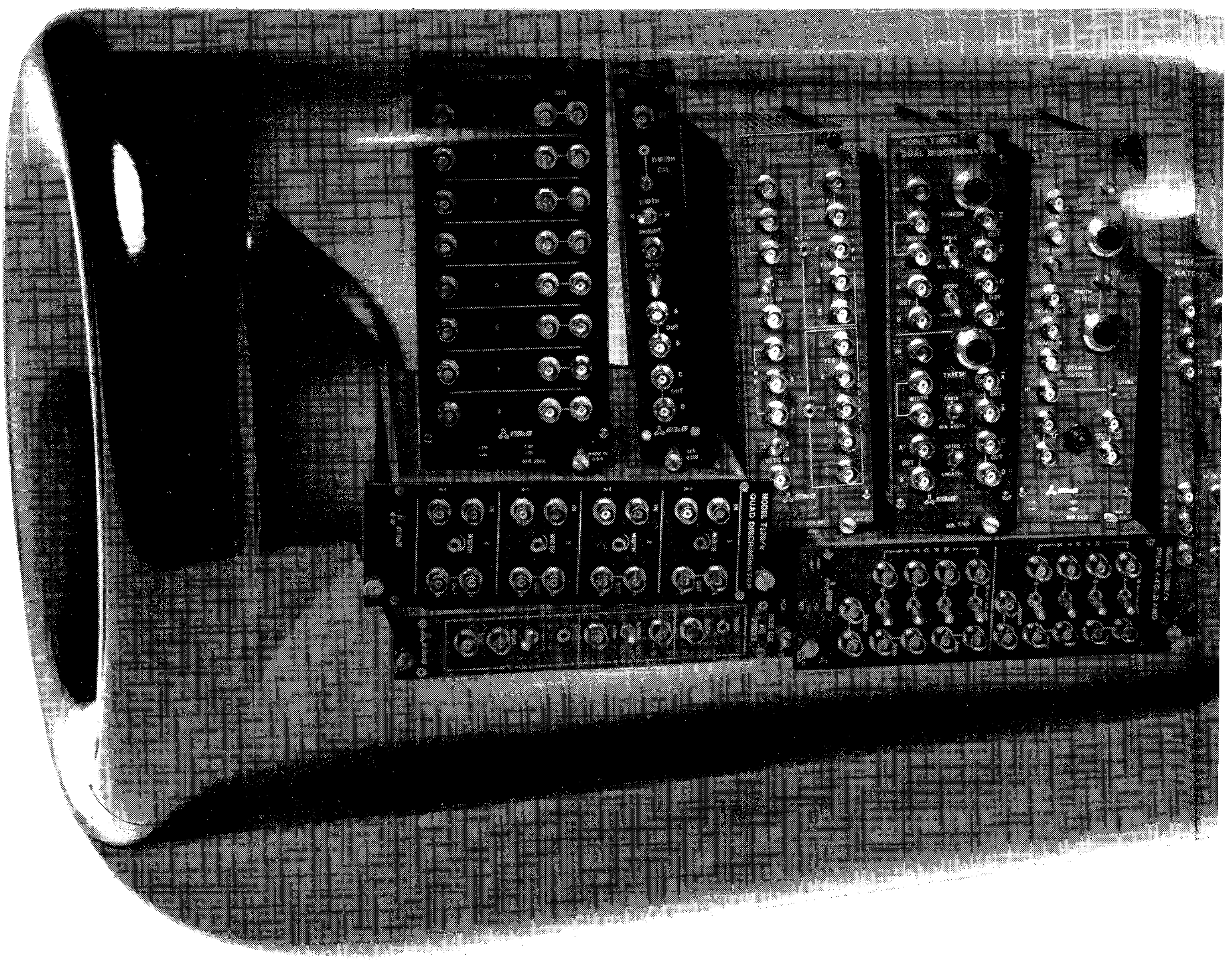
One experiment conducted by R. K. Adair of Yale and H. Kasha of Brookhaven saw no quarks and had set a limit for the flux as 10^{-10} cm^{-2} s^{-1} steradian^{-1}. If the Sydney results were correct they should in fact have seen 1000 quarks. Adair and Kasha thus had a very good reason for thinking about alternative explanations of the low density tracks and they presented their conclusions in Physical Review Letters of 8 December 1969.

They suggest that the 'quark' tracks are in fact due to low energy electrons or muons — the electrons from delta rays and low energy pair production (from the abundant electromagnetic energy associated with a cosmic ray shower) and the muons from hadronic cascades in the shower. They show that a large proportion of the low energy particles could be expected to pass through the cloud chambers, where the particles are recorded, at wide angles to the shower direction. This ties up with the fact that all five quark tracks were not parallel to the particles coming from the core of the shower. They show that a large production core they would be expected to be accurately parallel to the other core particles. Finally they attribute the low droplet density in the five 'quark' tracks to statistical fluctuations in the ionization produced by low energy electrons or muons, where the expected ionization is already lower than average because of relativistic effects.

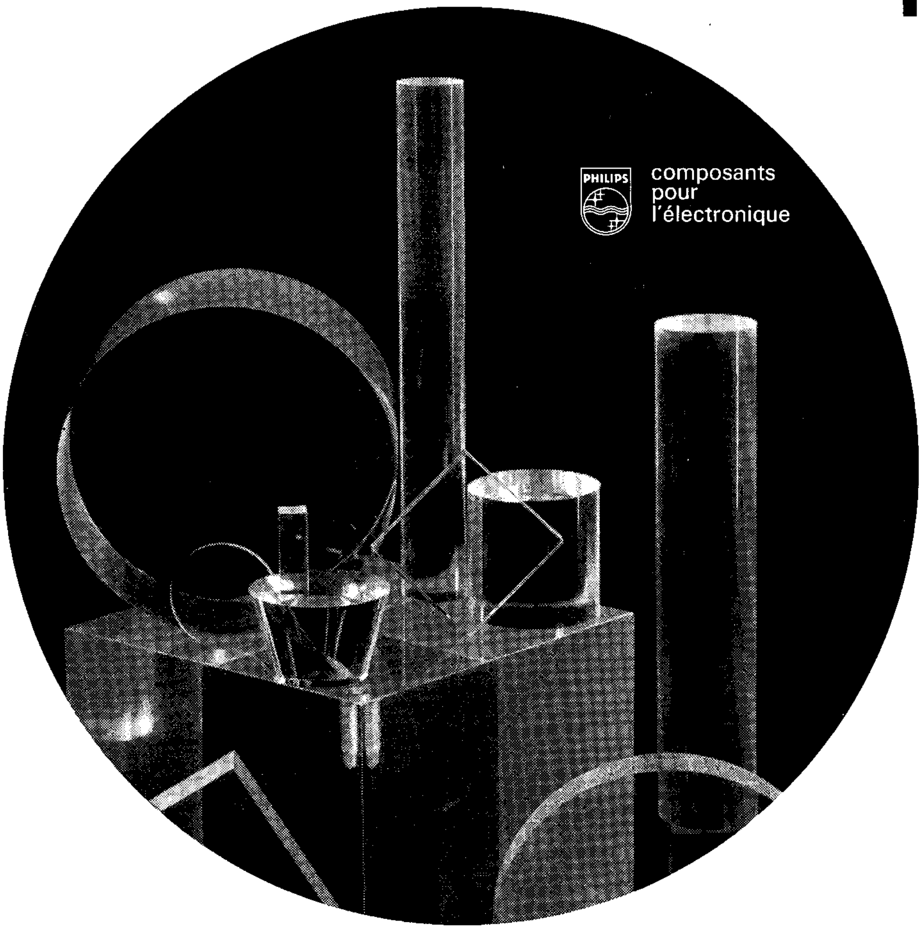


3.

1969 was a very good year



Scintillateurs plastiques?
Voici les meilleures formules



SPF .

Excellente transparence, facile à usiner, grande stabilité mécanique et optique.

SPP

En raison de son rendement lumineux et de sa rapidité, particulièrement indiqué pour les mesures où il est nécessaire de tirer le meilleur parti de l'électronique rapide et de diminuer les fluctuations d'amplitude du signal.

SPT

Aux qualités du SPP, ce scintillateur joint une stabilité mécanique renforcée. Exécuté en planches jusqu'à 250 x 150 x 2 cm, le SPT est parfaitement usinable sans précautions particulières et il se polit sans difficulté.

Caractéristiques		SPF	SPP	SPT
Longueur d'onde au maximum de l'émission	nm	440	425	425
Amplitude relative des impulsions lumineuses par rapport au SPF		1	1,27	1,2
Temps de décroissance	ns ± 0,1	3,6	2,2	2,1
Largeur du spectre à mi-hauteur	nm	80	50	50
Transmission du lumière : longueur moitié *)	cm	256	114	100

*) scintillateur recouvert de Mylar métallisé

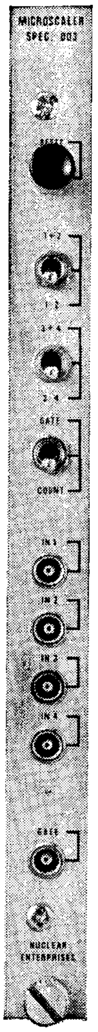
PHILIPS

Philips SA
Département tubes électroniques et pièces détachées.
Case postale, 8027 Zurich
tél. 051 44 22 11

CAMAC

Scalers, Controllers and Display

Scalers



9003 Microscaler
Four 16 bit 25MHz scalers
Can be connected as two 32 bit scalers

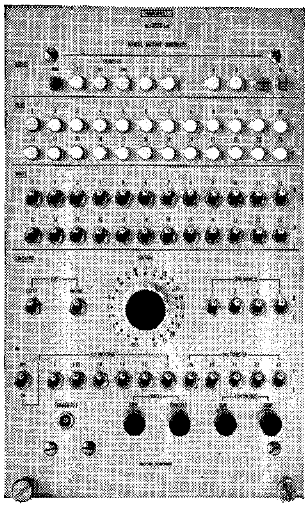
9008 Miniscaler
Two 16 bit 30MHz scalers, with indication of overflow and least significant bits

7070 Counting Register
Single 24 bit 15Hz scaler

7039 Preset Counting Register
Preset countdown 16 bit 10MHz scaler

Microscaler 9003

Controllers



Manual Dataway Controller 7024

7024 Manual Dataway Controller
Enables modules to be tested and systems to be evaluated

7022 Dataway Controller
Controller for Honeywell DDP 514 and 416 computers

7048 Data Controller
Controller for PDP8 computer

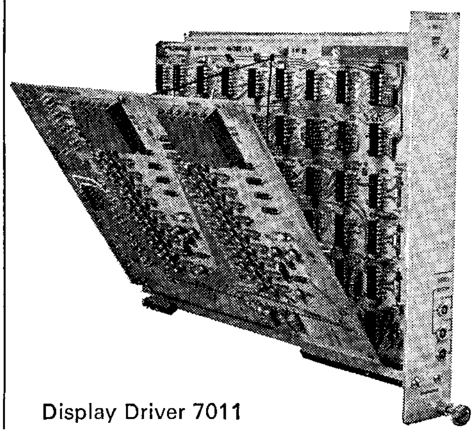
7025 Dataway Controller
Programmed controller for non-computer controlled system

Display

7011 Display Driver
Designed to control oscilloscope display

9006 Display Controller
Decimal display system incorporating binary to BCD conversion

9007 Decimal Display
Display for scalers addressed by 9006



Display Driver 7011

1966

NUCLEAR ENTERPRISES LIMITED

CAMAC the new modular data handling system for computer-aided measurement and control is being rapidly expanded. It conforms with ESONE Standard EUR 4100, can operate with all computers and is compatible with NIMS modules such as the Nuclear Enterprises International Series. Full details of the units listed above and complete range are available on request. (Bulletin No. 44)

Bath Road, Beenham, Reading, England Telephone: 07-3521 2121 Cables: Devisotope, Woolhampton Telex: 84475
Sighthill, Edinburgh 11, Scotland Telephone: 031-443 4060 Cables: Nuclear, Edinburgh Telex: 72333
Germany: Nuclear Enterprises GmbH, Karlstrasse 45, 8 Munich 2, Western Germany. Telex 529938
U.S.A. (West): Nuclear Enterprises Inc., 935 Terminal Way, San Carlos, California 94070. Telephone 415-593-1455
U.S.A. (East): Capintec Inc., 63 East Sandford Blvd., Mt. Vernon, N.Y. 10550. Telephone (914) 664-6600

Swiss Agents : *HIGH ENERGY AND NUCLEAR EQUIPMENT S.A.*
— 2, chemin de Tavernay - GRAND-SACONNEX - *1218 GENEVA* - Tél. (022) 34 17 07/34 17 05

Since late 1968,
SAC has been delivering

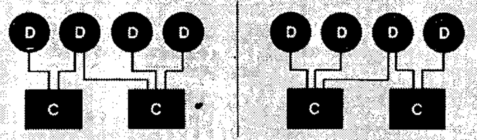
MCEL™

(pronounced "MEKKEL")

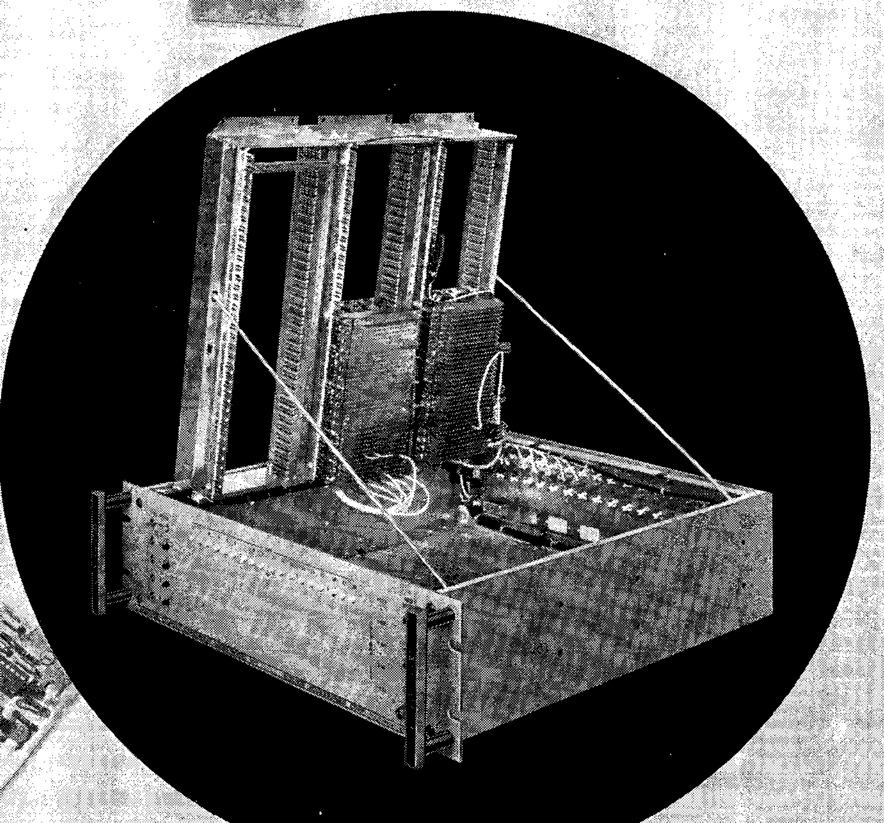
(Multiple-Counter Experiment Logic)

a family of IC logic cards and bins for versatile counter/computer interfacing.

Innovated at UCRL and developed further by SAC, **MCEL** is the broadest and most economical logic system available today for use with large arrays of counters.

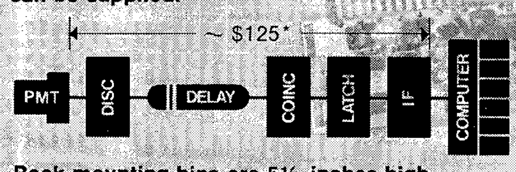


Coupled with high-performance low-cost photomultiplier tubes, **MCEL** enables the experimenter to construct hodoscopes of great complexity (at about $125 per channel between counter and computer, including the discriminator) with logic re-routing by computer during experiments to accommodate the increasing sophistication of studies in high-energy physics.



Our **MCEL** library comprises cards* for all logic functions — 80 cards per bin providing an average of more than 400 logic functions.

Special IC cards for complex functions can be supplied.



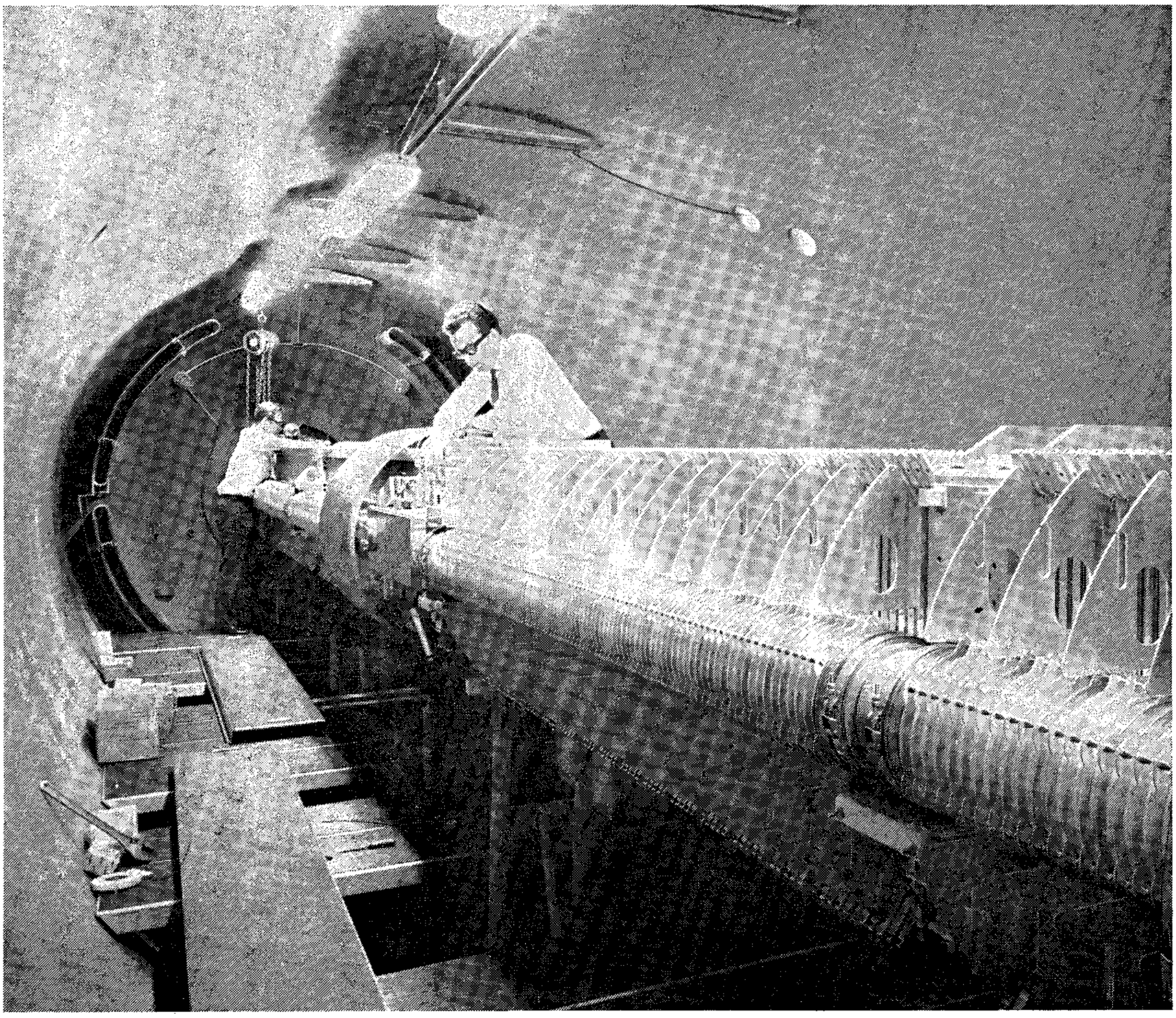
Rack-mounting bins are 5¼ inches high. All fast inputs and outputs are NIM-compatible level on 50 Ohms. Fast outputs are available to control data-acquisition instruments such as spark chambers. Latches "set" with a 3-nsec pulse-pair overlap. Delay-curve widths can be as low as 4 nsec. Test points and monitor lights show system performance.

Write for full details about **MCEL**

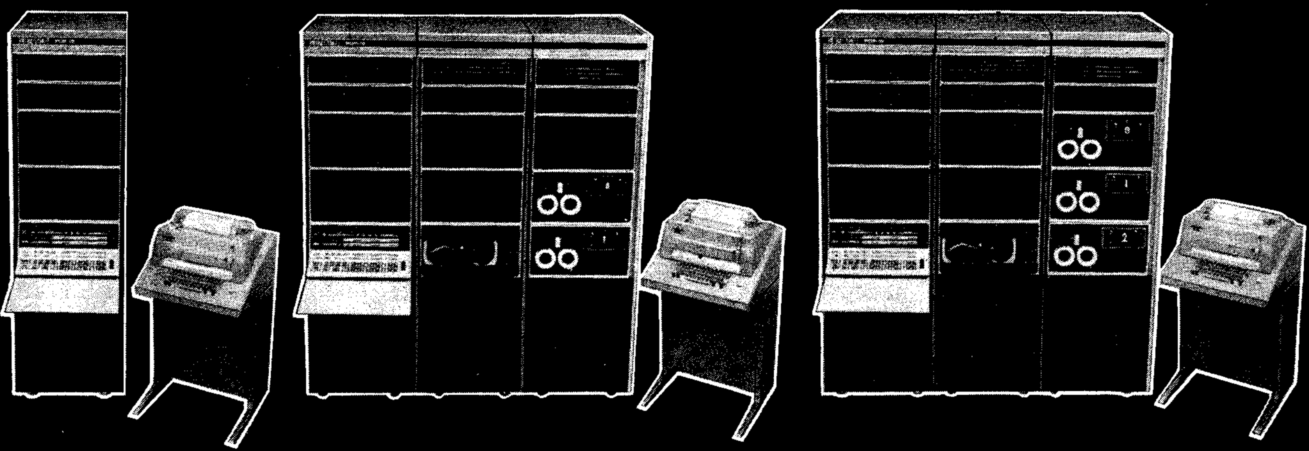
---

*constructed with
Motorola Emitter-Coupled Logic ICs.

SAC SCIENCE ACCESSORIES CORPORATION
a subsidiary of amperex electronic corporation
65 STATION STREET
SOUTHPORT / CONNECTICUT / 06490 / USA
PHONE 203-255-1526



For people who want to choose the best, no matter how little it costs



The new Digital PDP-15

First, we'll tell you something about medium-sized computers, you know already.

They're a pain in the neck.

Because all the ones you've ever seen up to now come with big price tags and nothing like the kind of versatility you want, unless you're willing to fork out a fortune to get them tailor-made to your requirements.

Hence, the new Digital PDP-15 medium-sized computer. Really four medium-sized computers for you to choose from. Not just one. All costing you far less than any comparable competitive computers.

It won't have escaped you that a range of four computers means a fair old bit of versatility. But you couldn't possibly know just how much versatility.

So we'll tell you. Because the PDP-15 comes in four different packages you get different peripherals and different levels of software, for different budgets and different needs. All upward compatible.

Offering peripherals and software in standard configurations is what allows us to offer substantial price reductions on all four systems.

All but the basic PDP-15/10 configuration are monitor-controlled to permit ease of use and device independence. This means that you get your programs 'on the air' quickly. Without having to change them every time you add new devices.

Actually, the PDP-15 is both new and not new. New in its high-speed I/C technology. Expanded instruction set. Improved expandability. Not new because PDP-15 users can draw on the software and applications expertise that stand behind several generations of Digital computers. Some 900 of our machines are in use in Physics applications throughout the world.

Major areas include Nuclear data acquisition and analysis, reactor and instrumentation control and film scanning Not to mention hundreds of other applications in various sciences.

In addition to all the standard PDP-15 software, new users can share in the Program Library and exchange of information at regularly scheduled meetings of DECUS, the Digital Equipment Computer Users Society.

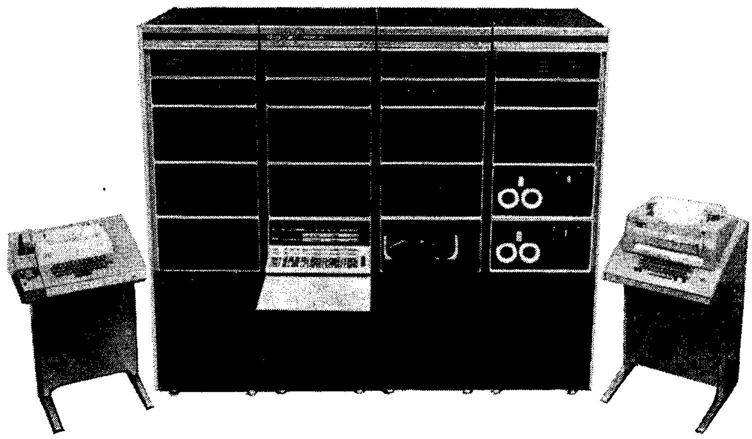
Now that you've discovered a medium-sized computer that's anything but a pain in the neck, undoubtedly you'll want to find out all about it.

PDP-15/10 4,096 18-bit words of 800-nanosecond core memory, Teletype Model ASR-33 console teleprinter. COMPACT Software System including assembler, editor, debugging aids, and mathematical and utility routines.

PDP-15/20 Advanced Monitor System: 8,192 words of core memory, KSR-35 Teletype for extra reliability, two DECtape transports and control units, high-speed paper tape reader/punch, Extended Arithmetic Element for high-speed arithmetic operations and register manipulation. Advanced Monitor System with FORTRAN IV, FOCAL-15, MACRO-15 macro assembler, linking loader, batch processor, system generator, scientific library, and comprehensive debugging and utility routines.

PDP-15/30 Background/Foreground System: 16,384 words of core memory, KSR-35 Teletype, Extended Arithmetic Element, Automatic Priority Interrupt System, Memory Protect System, high-speed paper tape reader/punch, three DECtape transports and control unit, real-time clock, and a second on-line Teletype for background use. Background/Foreground Monitor System combining all Advanced Monitor functions with concurrent execution of real-time foreground tasks and program development or other lower-priority background computation.

PDP-15/40 Disk-Oriented Background/Foreground System: 24,576 words of core memory, KSR-35 Teletype, Automatic Priority Interrupt System, Memory Protect System, high-speed paper tape reader/punch, two DECtape transports and control unit, RF15 DEC-disk control and two RS09 random-access disk files, real-time clock, and a second on-line Teletype for background use. Disk-oriented version of the Background/Foreground Monitor System, allowing concurrent execution of real-time tasks and background computation, in addition to all standard Advanced Monitor functions.



CER 1

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