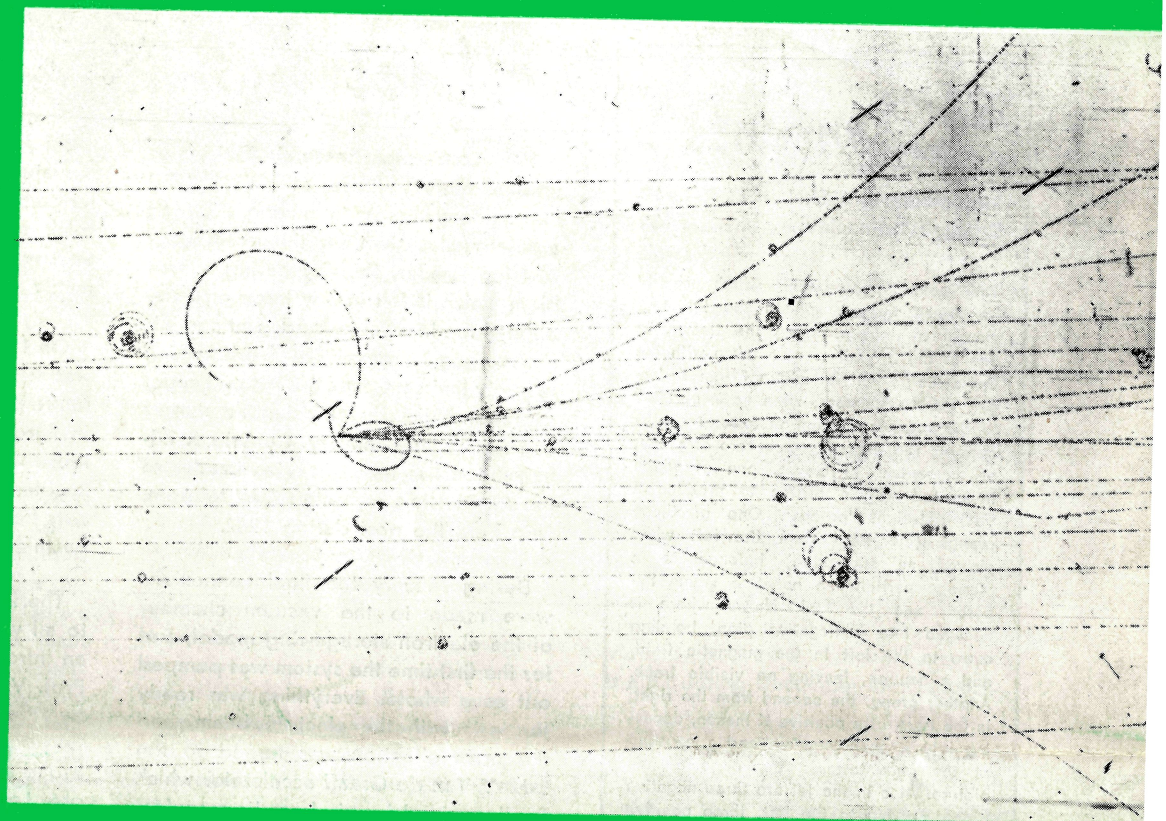
CERN COURIER



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VOL. 3

pp. 17 - 28

February 1963

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

The European Organization for Nuclear Research (CERN) came into being in 1954 as a co-operative enterprise among European governments in order to regain a first-rank position in nuclear science. At present it is supported by 13 Member States, with contributions according to their national revenues : Austria (1.92 %), Belgium (3.78), Denmark (2.05), Federal Republic of Germany (22.47), France (18.34), Greece (0.60), Italy (10.65), Netherlands (3.87), Norway (1.46), Spain (3.36), Sweden (4.18), Switzerland (3.15), United Kingdom (24.17).
Contributions for 1963 total 92.5 million Swiss francs.

The character and aims of the Organization are defined in its Convention as follows

'The Organization shall provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto. The Organization shall have no concern with work for military requirements and the results of its experimental and theoretical work shall be published or otherwise made generally available.'

Contents

The cover photograph, which should be turned through 90° to the left and viewed by looking along the tracks, is one of the 2 million or so taken with the Saclay/École Polytechnique 81-cm hydrogen bubble chamber, seen as it appears to the scanner (though at lower magnification). The incident tracks are of pions, of momentum 10 GeV/c, one of which interacted with a proton to produce a 'jet' of eight 'prongs'. One of these prongs (the third from the left when viewed as suggested) belongs to a 'strange particle', a negative sigma hyperon, and the kink shows where it decayed into a negative pion, bending more to the left in the magnetic field, and a neutron, leaving no visible track. Another prong, the second from the right, is the track of a positive K meson, decaying into a positive muon and a neutrino at the kink towards the edge of the picture. Also in the jet are three negative pions, curving to the left, three positive pions, curving to the right, and probably some neutral pions, which cannot be seen. The two highly curved tracks, which can be seen at the base of the jet, belong to a 'Dalitz pair' of electrons, probably coming from one of these neutral pions. The subject of bubble chambers and their photographs forms a large part of the article 'Spotlight on nucleons' which begins on page 3.

Photo credits : bubble-chamber prints by CERN/SIS, all others by CERN/PI.

CERN COURIER

is published monthly in English and in French. It is distributed free of charge to CERN employees, and others interested in the construction and use of particle accelerators or in the progress of nuclear physics in general.
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Published by the
European Organization for
Nuclear Research (CERN)

PUBLIC INFORMATION
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CERN, Geneva 23, Switzerland
Tel. 34 20 50

Printed in Switzerland

Last month at CERN

The **Accelerator Research Division** is unique among those at CERN (and unusual anywhere), in having adopted a rotational system for the position of Division Leader, thereby easing a problem which is felt in any large organization — the inevitable burden of administrative and committee work which severely limits the time a Division Leader can spend directly on scientific studies as such. From 1 January, **Cornelis J. Zilverschoon** has taken over as **Leader of the AR Division,** replacing **Kjell Johnsen,** who held the post during 1962.

During January the final connexions were made to the vacuum chamber of the electron storage-ring model, and for the first time the system was pumped out as a whole. Everything was ready for tests with the electron beam, and the main attention was turned to the **2-MeV Van de Graaff** accelerator which finally arrived by air from its manufacturers in the U.S.A. on 20 January. This accelerator, the only one in existence which produces two beams at the same time, has been built to a very exacting specification, although, in fact, not all of its possibilities will be used immediately. The Van de Graaff accelerates electrons to an energy of up to 2 MeV, with beam currents of over 1 ampère. This means an instantaneous power of about 2 million watts, but the average power is very much lower since the beam is pulsed in short bursts of length 0.4 microseconds, with a repetition rate variable from 50 to 500 times a second.

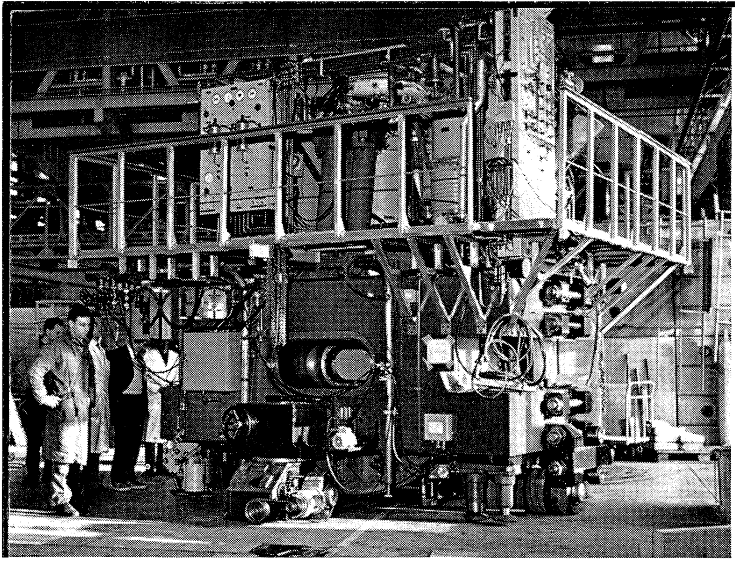
The voltage stability of the machine itself is very high, and the energy of the emerging electrons can be kept constant to ± 1 kV. However, to keep the electron beam circulating in the storage ring, the field provided by the electromagnets round the ring must be very closely related to the electron energy. The twelve ring magnets have therefore been electrically connected in series with a thirteenth, and the second beam from the Van de Graaff will pass through this extra magnet and be deflected by it on to a screen. The deflection of the second beam will correspond to the curvature of the main beam in its circular path; any departure from the desired track can thus be detected, and the energy of the accelerator kept continually at the correct value.

On 17 and 18 January a small meeting was held at CERN to discuss possible **future plans for high-energy accelerators** in Europe. The participants, apart from those who are considering the technical problems at CERN, were senior physicists from the Member states who would be interested in using such machines.

The first part of the programme, open to all who were interested, consisted of an introduction by the Director-general, Prof. V.F. Weisskopf, preceding papers by Prof. L. Van Hove, K. Johnsen, G. Cocconi and M.G.N. Hine on various broad aspects of accelerator design and use. Later sessions, which were held in private, went more deeply into the possible physics programme, and included considerations of the financial and manpower requirements. A continuing committee was set up during the meeting, with Prof. E. Amaldi as chairman, to gather more detailed information on the choice of machine (or machines) and the energies to be aimed at.

A further stage in the CERN **building programme** was marked by the completion early in January of the second laboratory wing (Laboratory 12) for the Track Chambers Division. The outer structure and glazing of the East experimental hall of the proton synchrotron was also finished. The 40-ton travelling crane, with a span of 41 metres, was raised into position in this hall in December.

In common with much of the rest of Europe, however, CERN suffered from the bad weather during January and, in particular, all the outside construction work was seriously delayed owing to the intense cold and the snow. For part of the time, the use of special additives and infra-red heaters to warm the



Even when partially dismantled for transport the Saclay/École Polytechnique 81-cm hydrogen bubble chamber weighs about 70 tons. Equipped with its own power-driven wheels, it is seen here during its positioning in the South hall of the PS on 14 January. On the left can be seen (from left to right) **M. Demoulin (École Polytechnique), G. Setrin (Ateliers d'Ivry), and R. Jacob, P. Asesio and C. Bastard (C.E.N., Saclay).**

aggregate enabled concreting to continue for Laboratory 4, but even these measures were useless once the temperature dropped below —5° C or so.

Frozen pipes, particularly the downpipes from gutters, caused considerable trouble.

At the **proton synchrotron** in January, experiments were mostly those using electronic counters or spark chambers as detectors. The momentum of the primary proton beam ranged from 12 GeV/c to 26 GeV/c, according to the main experiment scheduled, and the repetition period varied correspondingly from 1.2 to 5 seconds. Once every four minutes the beam was directed on to the target for the Wilson cloud chamber.

A particularly interesting, and highly successful, use of the k_3 beam was made by the joint efforts of the CERN **emulsion group** and many visiting physicists early in the month, when enough material was obtained in a week's machine time (20 shifts) to keep 17 laboratories occupied for a year or more. Only the first part of the beam was used, the emulsion stacks being placed beyond the bending magnet between the two electrostatic separators. The magnet was, however, fitted with a specially prepared heavy collimator. The background of fast pions and muons that remained was not as serious with nuclear emulsions as it would have been with the bubble chambers for which the original beam was designed, and the number of kaons per pulse was increased by a factor of five, owing to the shorter path for these short-lived particles.

Ten large emulsion stacks were first exposed, each forming a volume of about 1.5 litres of photographically sensitive material made up of 100 to 150 pellicles. A total of 3 million negative kaons were stopped in the stacks — considerably more than has ever been obtained anywhere else. To search for and analyse the various kaon reactions in the emulsion, the stacks are being divided among groups in Belgrade, Bombay, Bristol, Brussels, Chicago (Fermi Institute), Dublin (Institute of Advanced Studies and University College), Florence, Genoa, London (University College and Westfield College), Lyon, Rehovoth, Stockholm and Strasbourg.

Immediately after this exposure, between 2 and 3 million positive kaons were stopped in a single stack, for the University of Copenhagen. This was the largest number of such particles ever collected in one stack. By changing the beam parameters again, a further emulsion stack was exposed to stopping antiprotons. This will be examined at CERN.

Another interesting experiment was carried out in the d_{13} beam during December and January by the Harting group. They were measuring the elastic scattering of negative pions and positive pions on protons, to study the form of the 'diffraction peak' at incident particle energies of 8 to 18 GeV. The particle tracks were observed with an array of nine spark chambers, all 18 stereoscopic views being recorded on the same film frame (24 mm x 36 mm) with the aid of some 40 carefully adjusted mirrors, which were supported by an impressive array of tubular scaffolding. A high-speed camera was used, so that several exposures could be made for each burst of the PS. The 400 000 pictures that were taken are being analysed at the Universities of Bologna, Liverpool and Michigan, the Massachusetts Institute of Technology, and CERN.

The Saclay/École Polytechnique **81-cm hydrogen bubble chamber** was transferred from the North hall to the South hall and installed at the end of the m_2 beam in place of the **CERN heavy-liquid bubble chamber.** This was moved to a position in the path of the future neutrino beam and completely enclosed by the shielding of steel billets which is still being built up. For moving this chamber, a new ball-mounted turntable was successfully tried out, carrying a weight of 70 tons. Also in the South hall, the second 10-m electrostatic separator, previously removed to make way for an experiment for which it was not required, was replaced in the m_2 beam. The **École Polytechnique heavy-liquid chamber** was returned to its former position in the North hall, at the end of what is now the k_3 beam.

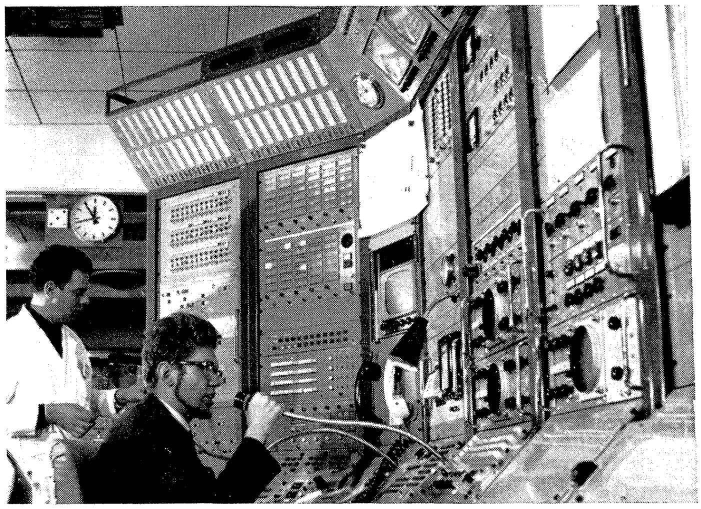
One of the disadvantages of increased beam intensities is the increased risk of radiation damage to the accelerator. It has been found, for instance, that the **glass vacuum tubes in the accelerating cavities** of the PS gradually become coloured and, at the same time, less good as electrical insulators. A demountable tube, which can be removed for cleaning or replacement, has therefore been developed jointly by the PS radio-frequency group and the Engineering Division. The first of these new tubes, which are manufactured almost entirely by one of the SB workshops and, incidentally, cost much less than the previous type, was tested with success at the PS during December and January.

The **emergency diesel equipment** on the site was tested in earnest during the night of 16-17 January, when a sudden breakdown of the electricity supply to the region threw Geneva into darkness just after midnight. Work with the synchrotron was impossible for five hours. although the breakdown itself lasted only for just over two, during which vacuum pumps and other essential equipment continued to operate from the emergency supply, which was switched in automatically within about ten seconds.

The shut-down of the **synchro-cyclotron,** planned to last from 23 December until 10 January, resulted in more work than had been foreseen, and the accelerator could not be started again until 18 January. The repair of minor leaks in the water cooling system showed up other defects in a sequence which unfortunately did not end until an overhaul of the entire system had been undertaken. As a result, the machine took some time to get back to a normal performance. However, apart from this, good use was made of the shut-down period. One of the major jobs carried out was the first overhaul, after five

Continued on page 26

Spotlight on Nucleons



Part of the PS main control desk at CERN.

a discussion between F. Le LIONNAIS Ch. PEYROU and V.F. WEISSKOPF

At the invitation of the Public Information Office, Mr. F. Le Lionnais, President of the French Scientific Writers' Association, last year recorded one of those interviews which he does so well, for a broadcast by the 'Radiodiffusion Télévision Française' in their series 'La science en marche' ('The progress of science').

For this broadcast Mr. Le Lionnais had two members of CERN, Prof. V.F. Weisskopf and Prof Ch. Peyrou, before the microphone. The interview (in French) was broadcast on 'France III' on 9 October, 1962. The RTF and Mr. Le Lionnais have kindly given CERN COURIER *permission to publish an adapted version of this programme. It began with the following introduction to the subject to be discussed :*

F. Le Lionnais : — I have just visited CERN, the laboratory of the European Organization for Nuclear Research, at Meyrin in Switzerland, a few kilometres from Geneva beside the French frontier. There I was able to admire equipment which no country in the world, except for the United States and the Soviet Union, could afford. In addition to a 600-MeV (600-million-electronvolt) synchro-cyclotron, CERN possesses a second accelerator, a 28-GeV (28-thousand-million-electronvolt) proton synchrotron (we shall tell you later on what these machines are for). At present it is the biggest in the world, with a sister machine in the United States, and, just as in days gone by a king was surrounded by his courtiers and nowadays a celebrity is surrounded by journalists and photographers, these synchro-cyclotrons and synchrotrons are surrounded by cloud chambers, bubble chambers, spark chambers, and a host of other apparatus which is often very intricate and costly.

I would like to recall that CERN is an organization created in 1952 by twelve European states with a view to providing our continent with high-energy-physics installations comparable to those possessed by the United States and the Soviet Union. It is a magnificent and, I think, unique example of international scientific co-operation.

What goes on at CERN ? It is a vast laboratory engaged exclusively in fundamental research, both experimental and theoretical. It has no concern with work for military requirements and it publishes all its results ; it also refrains from carrying out research with an eye to future applications. Moreover, the experiments performed at CERN are done in such a way that there is no radioactivity outside the laboratories and no danger of any kind for the local population. The only thing which interests CERN therefore is pure research, the pursuit of new knowledge. This should come out very clearly from my talk today with Professor Weisskopf and Professor Peyrou, whom I would like to thank for taking part in this programme.

Professor Victor Weisskopf is the Director-General of CERN, and he has the enormous advantage for a physicist of being at the same time a theoretician of international repute and an excellent judge of experimental physics. Professor Charles Peyrou, Leader of the Track Chambers Division (six months ago we devoted a whole programme to these chambers), is a great bubble-chamber expert; these chambers play an outstanding role in the research which we are now going to discuss. Professor Weisskopf : the progress of modern physics depends on the possibility of submitting matter to tests involving increasingly high energies, does it not ?

AT THE FRONTIERS OF PHYSICS

Prof. V. F. Weisskopf : — True. The history of this research can be divided into three stages, corresponding to the exploration of the atom, of the atomic nucleus and finally of the nucleons, that is, of protons and neutrons.

F. L. L. : — I think it would be a good idea if we took these three stages which you have just mentioned one by one, going rather more fully into the last, which is now of the greatest interest because it is the most recent and the most mysterious, because it concerns protons and neutrons.

V. F. W. : — Yes. As many people now know, the atom, after having been regarded as indivisible for a long time, was finally found to have a rather complicated structure. As you know, in the centre of each atom there is a nucleus — which we will neglect for just a few moments — around which revolve negative electrons, varying from a single negative electron in the hydrogen atom to 92 in the uranium atom. These electrons are retained in the atoms by electrical forces. To study these electron layers we use what are called low energies. A few volts — two, three, perhaps ten — are sufficient to remove the electrons from an atom.

Prof. Ch. Peyrou : — It is these electrons in the outer layers of the atom, and just such phenomena involving only a few volts, which form the basis of the chemical reactions of atoms and molecules, that is, all we are familiar with, heat, light and practically all the phenomena which we encounter in our day-to-day life on earth.

F. L. L. : — But with radioactivity, first natural radioactivity and then artificial radioactivity, with atomic decay, and also with the study of cosmic rays, physicists went much further and finally succeeded in penetrating even the atomic nucleus ?

V. F. W. : — Yes. This was done with energies a hundred thousand times greater, of the order of several million electronvolts. These energies are obtained by accelerating electrons or protons in machines such as cyclotrons — we shall say something about them in a few minutes — and bombarding the atomic nuclei with these missiles. In this way, models of atomic nuclei have been constructed which look somewhat like models of atoms in that they are made up of concentric layers. The nuclei consist of protons and neutrons — which are often called by a single name, nucleons. The forces binding the protons and neutrons in the nucleus are not electrical forces, like those holding the electrons in the atom; they are completely new — nuclear forces.

C. P. : — Yes, nuclear forces play a much greater part in our lives than is generally believed ; they actually play a much greater part in the universe than the chemical reactions which we have just mentioned. The heat of the sun and the light of the stars are the result of nuclear reactions — we are almost certain of this now. Even radioactivity, which remained unknown for a long time, plays a much greater role on earth than one might think. The heat of the earth, the fact that as one goes deeper into the earth the temperature rises, is partly due to the radioactivity of uranium.

F. L. L. : — But physicists are never satisfied. Now that they have reached the heart of the atom and of the atomic nucleus, instead of having a rest they want to go still further ! And naturally what they want is to find out the anatomy of the particles which they have found inside the atomic nucleus, which, as we have just said, are the nucleons, that is, the protons and the neutrons. Perhaps the day will come when the same question is posed for electrons or other particles which we do not yet know how to penetrate.

V. F. W : — But naturally our victims, the protons and neutrons, had to be bombarded with particles endowed with still greater energies, about a thousand times greater, of the order of thousands of millions of electronvolts.

F. L. L. : — And what did you find ?

V. F. W. : — We found a great many phenomena, which we hope will provide some of the answers... and some new problems. And first we discovered the emission of a certain category of mesons, the pions . . .

F. L. L. : — I should like to interrupt you for a moment to say that our listeners, or rather regular listeners to our programme, already know something about the problems connected with particles and are acquainted with the present list of particles and their names.* But I interrupted you just as you had mentioned pions or pi mesons. What part do the pions play ?

V. F. W. : — Pions are quanta of nuclear force. They therefore have a similar role to photons, which are quanta of electrical force.

C. P. : — Yes, but their role is rather like that of electrons in atoms. They are responsible for the reactions, the interactions of nucleons at a certain distance. On the other hand, further towards the centre, they are, as it were, replaced by heavier mesons, the K mesons or kaons.

V. F. W. : — Yes, here we have two kinds of mesons. In addition, we have also discovered that the excited states of protons and neutrons are not exactly the same as those of atoms. They involve particles which have been named 'strange particles' because they obey new and strange laws.

F. L. L. : — It would certainly be interesting to discuss these strange particles and also strangeness numbers ; perhaps also isospins, baryon numbers, and all the questions bound up with the new particles.

V. F. W. : — Yes, there are many fascinating problems in this field. Another highly important chapter in particle physics is the existence of antiparticles or antimatter. Each particle has a partner which is its opposite, to such an extent that when a particle meets its antiparticle the two masses disappear and an equivalent quantity of energy appears. Furthermore, if a particle has an electric charge, its antiparticle has the same amount of charge but of opposite sign. Finally, there is another very important field of research, that of weak-interaction phenomena. This shows us that we cannot form an idea of all that is happening in the universe with only three kinds of forces, gravitational, electromagnetic and nuclear, but that we have to admit the existence of a fourth kind, weak-interaction forces.

C. P. : — Yes... and finally the weak interactions have aroused the most interest in the last few years for the very simple reason that we cannot yet fully understand strong interactions, but, on the other hand, much light has been thrown on the field of weak interactions by the discovery of the new particles. Finally, these weak interactions have been in the forefront recently through the discovery of the non-conservation of parity, a discovery for which Lee and Yang received the Nobel Prize.

V. F. W. : — Perhaps I should mention here that a very strange thing has been discovered in the field of weak interactions : a second electron, a heavy electron known as the muon and which has the properties of an electron, except that it is heavy, about two hundred times heavier.

F. L. L. : — And all these new particles have an extremely short life ; they decay after a very short period which does not make them any easier to observe.

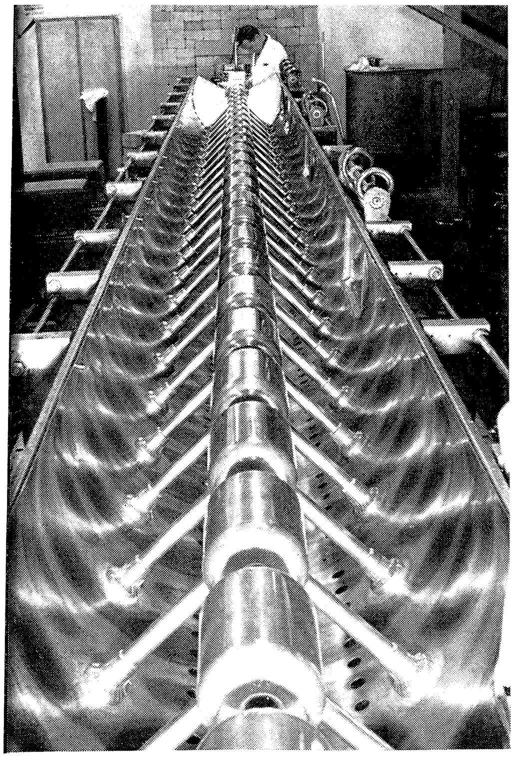
V. F. W : — Yes and no. Everything is relative. They 'live' from 10^{-10} to 10^{-8} second. As compared to a human life this is not long. It would take a great many of these decays to last seventy years ! But in particle physics there are much shorter periods. An atomic year, or the time that it takes an electron to go round the nucleus to which it is bound, lasts 10^{-16} second ; and a nuclear year, or the time taken by nucleons to go round the centre of the nucleus, is 10^{-22} second.

This means that a comparison between the life of a strange particle and a nuclear year would be similar to that between a human life and the life of a strange particle.

F .L. L. : — This is a most impressive comparison. Well, the particles finally disappear and what happens when they die ?

V. F. W : — When they decay, they give birth to more stable particles. This is not unlike the phenomena of radioactivity.

* Most readers of CERN COURIER will also recall that there are at present about 30 names on the list of nuclear particles (to be published in a forthcoming issue), to which can be added a dozen excited states or 'resonances' of certain particles.



This is the interior of the linear accelerator used for accelerating protons to 50 MeV before they are injected into the proton synchrotron at CERN. The beam travels along the axis of the cylindrical electrodes (the aperture through which it passes can just be seen in the first one) and is accelerated in passing across each gap.

At the begnning of 1963, there were four large bubble c

The table below summarizes the salient points of the first four, t

Chamber (and abbreviation)	**CERN 32-cm liquid-hydrog chamber (HBC 3**
Design Laboratory	CERN (Track Chambers D
Operating Laboratory	CERN (Track Chambers Di
Date completed	May 1959
Approximate cost	–
Size of visible volume	320 mm diameter, 150 mm
Strength of magnetic field	15 000 gauss
Filling liquid, and volume	liquid hydrogen ; 13 litres
Operating temperature	26°K (–247°C)
Operating pressure (absolute)	5.5 to 6.0 kg/cm²
Sensitive time	2 milliseconds
No. of cycles possible per minute	30
No. of views photographed at once	3
Size of film	35 mm unperforated
No. of operators required	teams of 4
Total weight of magnet and chamber assembly	30 tons
First operated at CERN	August 1959
No. of photos* taken at CERN so far	500 000
Total length of film* involved	150 km
No. of laboratories taking film for analysis	15
Representative experiments**	first proof of predominantl emission of hyperons in
Modifications envisaged	none

* One 'photo' in this sense includes all three stereoscopic views.

** The most well-known experiment with the chamber has been cited in each c

HOW ARE DISCOVERIES MADE ABOUT MATTER ?

F. L. L. : — Perhaps we should now say how we manage to find out so much about particles which are so small and so mysterious ? How are the questions put to them to get the right answers ?

C. P. : — As we have already said, to get these answers we must first of all have particles accelerated up to very high energies, over a thousand million electronvolts, and at present of the order of 30 thousand million electronvolts. This acceleration cannot be produced in the same way as for x-rays, that is with a difference of potential of a few thousand volts, which is amply sufficient. In the field that we are discussing, no machine exists which can give a potential difference of 30 thousand million volts. Consequently, the only known way of speeding up the particles is to accelerate them progressively by giving them a series of 20-thousand-volt flips, one after the other, until we reach 30 thousand million electronvolts. This takes time, and consequently the unstable particles which we have just mentioned cannot be accelerated. All that can be done is to accelerate stable particles, either electrons — but they have no strong interactions — or protons, which are more interesting because they give rise to strong interactions.

F. L. L. : — Therefore this only concerns the acceleration of stable particles. How do you observe unstable particles ?

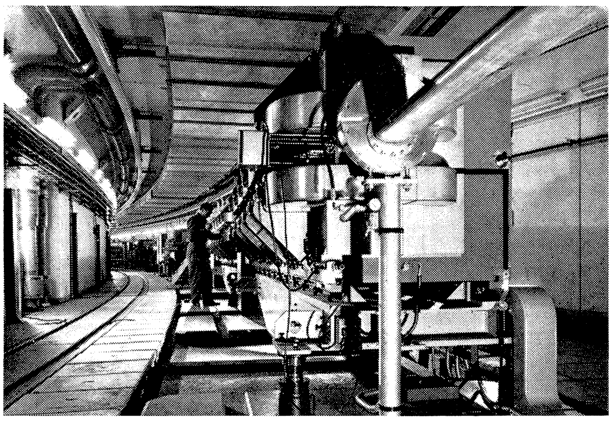
C. P. : — It is the stable particles which, projected with high energy at a target, produce unstable particles.

F. L. L. : — Yes, suppose we describe the methods for producing high-energy particles.

C. P. : — I have already said that these high energies can only be reached by progressive acceleration... there are two ways of achieving this. Accelerating stations can be placed one behind the other, and this is sometimes done ; this is known as a linear accelerator, which has the drawback of being very long. The other method, which is the one used most since the cyclotron was invented by Lawrence, consists in sending the particles round in a circle in a magnetic field. Each time they pass through the accelerating station, each time the same, they receive a flip, provided that they arrive in phase with the accelerating pulse. It is one of the most interesting characteristics of the big CERN accelerator, and, moreover, of the Brookhaven one, that techniques have become so advanced that it is now the particle beam itself which announces its time of arrival by means of electronic equipment and regulates the phase of the accelerating voltage which will give it a push.

F. L. L. : — Thus we now know that there are various types of particle accelerators. There are linear accelerators and circular accelerators which can be subdivided in all sorts of ways, into cyclotrons, which are the forebears, proton synchrotrons, etc. I will not talk about the way in which they operate, but I would like to ask Professor Peyrou to recall the characteristics of the big proton synchrotron which is the pride of CERN.

C. P. : — The CERN proton synchrotron is one of the two biggest accelerators in the world ; the other is at Brookhaven. There is a slightly smaller one at Dubna in the U.S.S.R., which does not operate on the strong-focusing principle. With the CERN synchrotron protons can be accelerated to 28 thousand million electronvolts ; the particles are kept in an orbit 200 m in diameter by a magnetic field of 14 000 gauss produced by 100 electromagnets.



Guided by 100 electromagnets, each proton accelerated in the CERN PS travels some 450 000 times round the ring – 300 000 km inside a tube 14 cm wide and 7 cm high (top right).

PRINCIPAL BUBBLE CHAMBERS USED AT CERN

ambers at CERN available for use, together with two more under construction (the British 1.5-m and the CERN 2-m liquid-hydrogen chambers).
o of which (those using liquid hydrogen) operate as part of the Track Chambers Division, and two as part of the Nuclear Physics Apparatus Division.

n bubble	École Polytechnique 1-m heavy-liquid bubble chamber (BP3)	CERN 1-m heavy-liquid bubble chamber	Saclay/École Polytechnique 81-cm liquid-hydrogen bubble chamber (HBC 81)
ision)	'Laboratoire de Physique' of the 'École Polytechnique', de Paris	CERN (Nuclear Physics Apparatus Division)	'Saturne' Department of the 'Centre d'Études Nucléaires de Saclay', France
sion)	'Laboratoire de Physique' of the 'École Polytechnique'	CERN (Nuclear Physics Apparatus Division)	'Saturne' Department of C.E.N. and 'Laboratoire de Physique' of the 'École Polytechnique', Paris
	March 1960	end of 1960	January 1961
	2.5 million francs (French)	about 1 000 000 francs (Swiss), without installations	6 million francs (French)
eep	1000 mm long, 500 mm high, 500 mm deep	1150 mm diameter, 500 mm deep	810 mm long, 320 mm high, 320 mm deep
	22 000 gauss (max.)	27 000 gauss	20 000 gauss
	propane, freon, or mixtures of these ; 300 litres	freon 13 B1 ; 500 litres	liquid hydrogen ; 127 litres
	30°C (freon) to 60° C (propane)	29°C	26°K (–247°C)
	20 kg/cm² (freon) to 25 kg/cm² (propane)	18.2 kg/cm²	5.6 kg/cm²
	5 milliseconds	10 milliseconds	2 milliseconds
	33	38	40
	3	3	3
	50 mm	70 mm	35 mm unperforated
	teams of 4	teams of 4	teams of 4
	85 tons	112 tons	80 tons
	July 1960	December 1960	May 1961
	about 1 500 000	510 000	more than 2 million
	about 450 km	115 km	over 600 km
	11	7	22
backward ion-proton collisions	test of $\Delta S = \Delta Q$ rule in kaon decay	CERN neutrino experiments	materialization of the antiparticle of the negative xi
	installation of liquid-hydrogen target inside the chamber	none	use with liquid deuterium

ase. All four chambers have naturally made other valuable contributions to various fields of high-energy physics.

F. L. L. : — Fourteen thousand gauss is a very high field compared to the magnetic field of the earth !

C. P. : — About fifteen-thousand times higher. It would be a good thing if it could be even higher. Unfortunately, if more powerful magnetic fields are produced iron magnets can no longer be used. However, questions connected with particle optics call for very special field configurations necessitating the use of iron. The protons circulate inside a torus, a cylindrical ring with a radius of 100 m.

F. L. L. : — But if you make these protons circulate in this ring-shaped tube, how can you be sure that at the right moment they will be in a spot which is, after all, very clearly defined ?

V. F. W : — Oh, this is achieved by magnetic optics, one of the great problems connected with the construction. The result is excellent, when you consider that the distance travelled during acceleration is about 300 000 kilometres or seven times round the earth ; yet the beam path is adjusted to within a few millimetres.

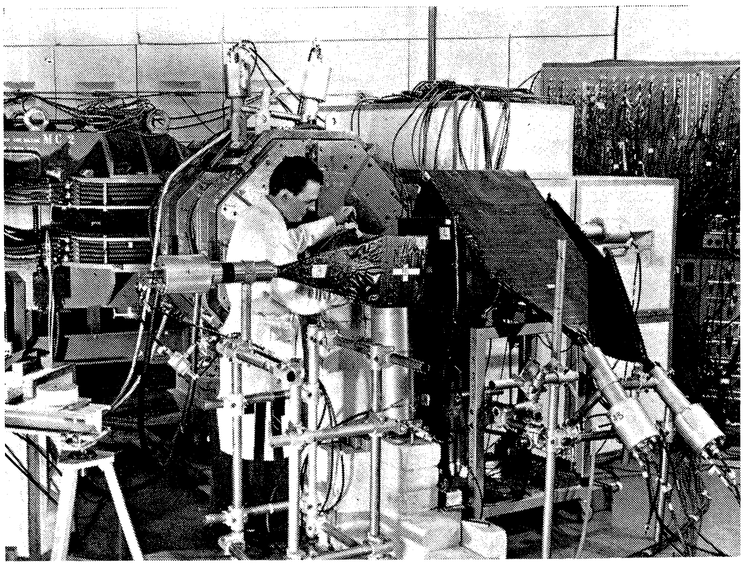
C. P. : — Moreover, as I said before, not only is the beam kept in orbit, from a geometrical point of view, but it is also made to pass at exactly the required moment through what are called the accelerating cavities.

F.L.L. : — I can see that your ballistics are superior to those of modern artillery, but nevertheless so far you are only firing shells and are in what you have just called the first phase of your experiments. Your ultimate aim is to obtain other particles, mainly the strange particles.

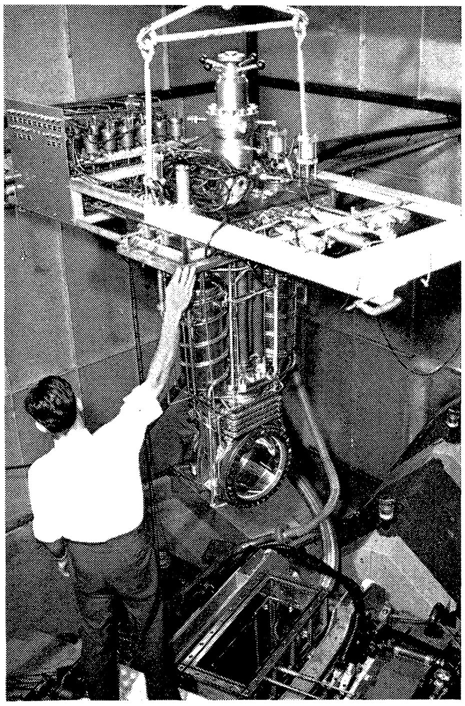
C.P. : — During the second phase, when the protons have reached the maximum energy that the accelerator can give, they are made to strike a target. This impact is brought about, for instance, by disturbing the magnetic field slightly. The material of the target is not of great importance. It is important, of course, from the point of view of experimental technique, but the same particles will be produced by any type of target. Consequently, according to the type of experiment, very light metals like beryllium or very heavy ones like tungsten are chosen.

F.L.L. : — Evidently, the missile will in any event encounter nuclei containing protons and neutrons...

C.P. : — Then, once the new particles have been produced — and have left the target —, magnetic optics is again used to direct them to the place where the experiment is to be performed, endeavouring to lose as few as possible and to give them the most precise characteristics possible.



An experimental arrangement using counters at the CERN synchro-cyclotron. The slabs covered with black tape are transparent plastic scintillators which give flashes of light when ionizing particles pass through them. The light from each one is detected by a photomultiplier (in the cylindrical housing) and converted into an electrical pulse. These pulses pass through circuits which ensure that a 'count' is recorded only when certain counters give pulses simultaneously (or separated by some fixed time) while others do not.



CERN's first liquid-hydrogen bubble chamber had a useful diameter of 32 cm. The chamber body, suspended beneath its cooling and expansion systems, is seen here being lowered into its magnet.

F.L.L. : — I should like to recall at this point that detection techniques utilize at least two basic kinds of instruments. There are the counters, which are capable of recording the passage of every particle and noting when it passes : Geiger-Müller and Cherenkov counters, etc. There are also track detectors, which render the trajectory of the particle visible and so make it possible to distinguish and analyse the events occurring along this trajectory as it passes through the instrument.

V.F.W. : — Yes, both these methods are currently in use, each employing a variety of instruments corresponding to different fields of application.

C.P. : — Both the counter method and the visible-track method are used. They both have their own field. The advantage of counters is that they give a remarkable definition in time of the passage of the particles. Consequently, they offer the possibility of distinguishing a given phenomenon. That is a good thing, but they are rather blind in the sense that... they find only what they are looking for. Now this is a very new and unexplored field where the use of very high energies creates considerable complications. An interaction does not simply produce one particle but a great many, and consequently we want to observe the maximum number of those produced. For this reason we use specialized track instruments: cloud chambers, photographic emulsions, and especially, since their invention by Glaser in 1952, bubble chambers, which have almost all the advantages of the other two with practically none of the drawbacks.

F.L.L. : — The former, the counters, do a kind of arithmetic and the latter, the track chambers, work out the geometry of the events and so make more information available. I should also like to say what a pleasure it was for me to see for the first time at CERN, in flesh and blood as it were, the spark chambers which I have heard about recently. I was familiar with the principle but had never seen them in action. Like everything really new it is an impressive sight. However, spark chambers are the latest novelty and I believe you would prefer to talk mainly about bubble chambers here.

C.P. : — Of course I am not a spark-chamber expert. They come, in fact, somewhere between counters and bubble chambers in the sense that they have the resolution time of the counters and that they make the trajectories visible, although with less detail than in the bubble chambers. Since I work with bubble chambers, I will stick to my subject.

The great interest of bubble chambers lies in the existence of liquid-hydrogen bubble chambers. Hydrogen is the only element with an atomic nucleus formed from an elementary particle, the proton. It is therefore not a complex nucleus.

F.L.L. : — It is, practically speaking, a proton... if the peripheral electron is removed only a proton remains.

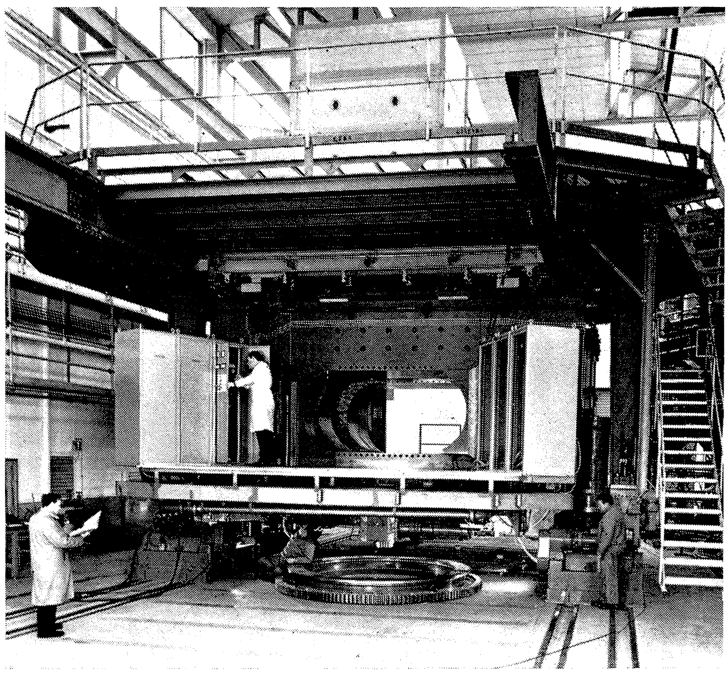
C.P. : — Yes, and consequently, when we observe a reaction in a hydrogen bubble chamber it is a reaction between elementary particles and there are no unpleasant neighbours to interfere with the phenomena.

V.F.W. : — Moreover, the bubble chamber is a very docile and agile servant, capable of following the rhythm of the accelerator which produces a burst of protons every two or three seconds ; thus in a very short time photographs of a great many events can be taken and much information obtained.

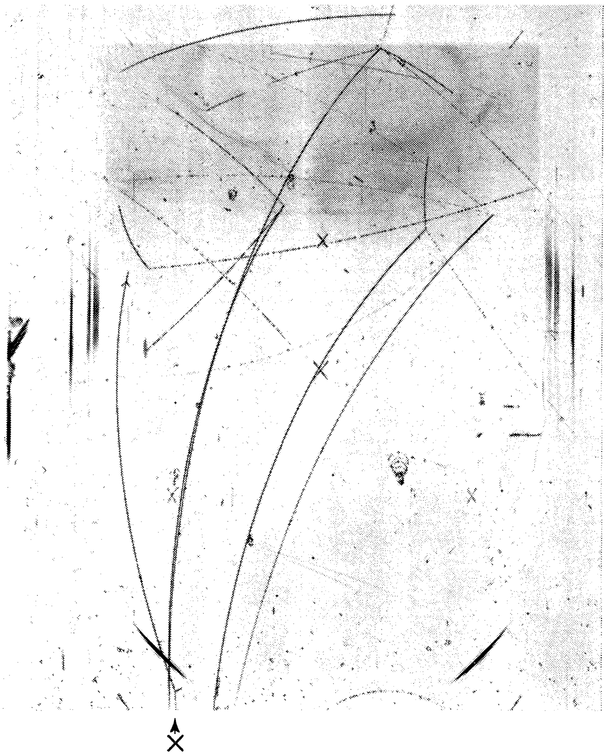
F.L.L. : — I imagine, and I suppose most other people do too, that the events appearing on the photographs taken in the track chambers are varied and difficult to explain. If one of these photos is shown to a layman it may appear uninteresting and will not convey the extraordinary interest which it may hold. To initiate a layman into the interpretation of these photographs would mean covering a great deal of paper. However, instead of an explanation which would be far too technical and long for us, could you, Professor Peyrou, give us an example of what can be seen on a photograph taken in a bubble chamber ? Choose an example and we shall imagine that the others are more or less similar.

C.P. : — Well, I may as well give you two*. The first is very spectacular and shows what happens when an antiproton arrives in a bubble chamber and stops there. It is possible to produce slow antiproton beams. If it seems strange to obtain slow antiprotons from such a high-energy machine, this is because antiprotons can be produced only by such a machine ; afterwards they

* The photos described by Prof. Peyrou are slightly different to those shown here and on the cover of this issue, though the events are basically similar.



CERN's latest liquid-hydrogen chamber will have a length of 2 m in the direction of the beam and, as can be seen from this picture of it under construction in the East bubble-chamber building, involves engineering of a completely different order. The size of the chamber body can be judged from the aperture of the magnet, in the centre of the picture. Concrete blocks, on the bridge from which the chamber will be suspended, are only temporary.



A photograph taken with the 81-cm hydrogen bubble chamber, with five antiprotons entering at the bottom of the picture. The one marked X is scattered by one proton (which forms the short spur) and is then annihilated with another (where the track ends). Two neutral kaons are emitted in opposite directions, leaving no tracks, and each decays into one positive and one negative pion, whose tracks form a characteristic V. The other four antiprotons annihilate into charged pions, which form visible tracks, and perhaps also neutral pions, whose existence can only be deduced by detailed analysis of the photograph.

can be used as slow antiprotons. When they penetrate the bubble chamber they have little energy, and in the liquid hydrogen they lose what little they have and are then 'at rest'. This term is not quite accurate ; the antiprotons are still in a state of thermal agitation. Since their electric charge is negative they are captured by the positive proton of the hydrogen which we have already mentioned. The antiparticle and the particle immediately annihilate each other. In the chamber one can therefore see tracks curved by the magnetic field of the chamber — the energy can be measured according to the curve — which really look like shell trajectories, and at the end an explosion, or rather two, four, six or eight pions emitted by the explosion.

Another series of events which are also very typical of our studies are what are called high-energy phenomena. For instance, a very-high-energy beam of pi mesons (or pions) is sent into a chamber. You can see the trajectories there. Most of them do not interact but simply cross the chamber. Suddenly one will break off and at the end, at the place where there is a break in the trajectory, a certain number of particles can be seen to emerge in a forward direction. This is known as a 'jet' and looks rather like a paint brush ; these are generally tracks of other pions. The original pion has thus reacted on the proton to produce several other pions. From time to time inside this shower or jet two tracks can suddenly be seen springing out of nothing. This is a sign of what we are looking for, it is a neutral particle emitted in the interaction which has travelled a certain distance in the chamber without leaving a track, because it is not electrically charged, and at the end of its short lifetime decays into two charged particles. This is called a V event.

F.L.L. : — I would like to get to the heart of the matter. So far you have observed interesting things but you are still like Sherlock Holmes when he had found footprints and cigarette ash after a crime but had not yet identified the criminal or explained the motives of the crime. There is still something else to be discovered.

C.P. : — Obviously, at first we only recognize the things with which we are already acquainted. In order to find something new it is very rare that what we call a single event can be of service. In the past these events were used, and with great success, in cosmic-ray physics. However, it does not happen very often now. On the contrary, our problem lies in the systematic study of a great many similar events which have to be detected and then measured and finally interpreted. This calls for very complex methods which have led to the use of big electronic computers.

WHAT IS THE POINT OF THIS RESEARCH ?

F.L.L. : — And where does all this lead ? It may lead to the emergence of new knowledge and that is CERN's aim. As I said at the beginning of this discussion, CERN is not in search of applications. There are some very honourable applications, although there are others which are less so. But I repeat that the quest is for new knowledge in an endeavour to extract new secrets from Nature. Personally, I am not going to ask you 'what is the use of all this effort ?' As a mathematician I am a firm believer in science for its own sake and, as the mathematician Jacobi said in the first half of the nineteenth century : 'to seek truth is enough for the honour of the human mind'. Nevertheless, I am sure that a lot of our listeners would like to hear why it is necessary and why it is a good thing to carry out such research.

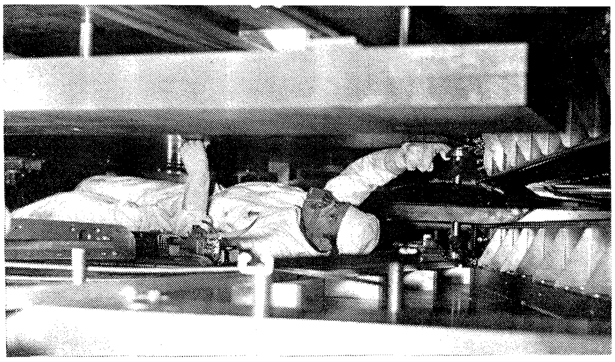
V.F.W. : — At least three reasons can be given. In the first place, this is a question which could have been asked — and certainly was — at any given stage of science and especially of the progress of physics. For instance, when the electronic layers surrounding the atomic nucleus were penetrated, the secrets of most of the material phenomena surrounding us were revealed. Electrical engineering, electronics, and chemistry were revolutionized, and our whole life with them.

The following stage, when we penetrated the atomic nucleus, brought us face to face with nuclear forces. At that time this knowledge may have been thought beautiful but useless. In fact, it offered us the solution to many problems ; we learned why the stars and our sun shine and it opened the way for applications which are still in their infancy, for instance the production of radioactive products in nuclear reactors which are now in use in medicine, in agriculture, in industry, etc., and at some future date the energy which will replace chemical fuel, coal and petrol.

What will be the consequence of the discoveries to be made inside protons and neutrons ? We have no idea, since the consequences of scientific discoveries are never apparent when they are made. Nevertheless, it is these discoveries which transform the world.

Perhaps we can hope that our cosmologists will be better equipped to deal with the problems of the whole structure of the universe, the relation between the structure of the universe and microscopic structure, and the question of the origin of the universe. In particular, we may perhaps find some connexion between the four categories of forces which we spoke about before : nuclear forces, electromagnetic forces, weak-interaction forces and gravity.

Perhaps in twenty or thirty years we shall have a more unified idea of the structure of our universe. In any case, whatever the practical consequences, we shall certainly be more familiar with the innermost structure of matter, and this will completely transform our idea of the world and our philosophy ●



The inside of the SC vacuum chamber had to be cleaned.

Last month at CERN

(cont.)

year's operation, of the giant tuning fork that controls the frequency of the electric field. Further progress was made with the transfer of the radio-frequency equipment to the new halls, and much work was also done on improving the safety and control system of the accelerator.

Beginning 1 January, the Health Physics group is exchanging **gamma film-badges** once a month instead of once a fortnight, except in the case of a few special groups. This is partly because the doses recorded have, in general, been quite low, and partly a result of the setting up of the emergency service for immediate reading of the badges in cases of suspected high exposure.

As part of the new scheme for technical training, two series of **Technical Seminars** began at CERN in January. Under the general heading of 'Selected subjects in electronics', the first of five talks by A. Susini, dealing with 'Simplified wide-band circuit analysis', was held on 7 January. On the 16 January, G. Konried gave the first talk in the series 'Some workshop processes'. These seminars, which have the double aim of providing general information on special or new techniques and improving knowledge through discussion with experts, are intended mainly for workshop or laboratory technicians, designers, and junior engineers and physicists, with some practical knowledge in the fields concerned.

On 16 January, at the Eighth Annual Awards Dinner of the Thomas Alva Edison Foundation, in New York, Prof. V.F. Weisskopf, CERN's Director-general, was presented with the **1962 Edison Award** as the author of 'The best science book for youth' for that year. The book, 'Knowledge and Wonder : the natural world as man knows it', was published towards the end of last year by Doubleday and Company, of New York, and a copy has been presented by Prof. Weisskopf to the CERN library.

During his visit to the U.S.A., Prof. Weisskopf attended an international conference — on photon interactions in the BeV energy range — at the Massachusetts Institute of Technology (M.I.T), from where he is on extended leave.

On 6 January, the main auditorium was filled to overflowing by an audience of some **640 local children,** who had come to be entertained not by lectures, scientific or cultural, or even by music, but by a programme consisting of cartoon films, a conjurer-ventriloquist, and the Drama Group of the International Organizations, 'Arlequin et Cie'. Half the children were from Switzerland, the others from France. After these diversions they were conducted to the canteen for tea, and each received a small present to take home.

This party followed the similar one given for about 480 children of members of the CERN staff on 16 December. Both were the result of much voluntary work by the members of the CERN Transport, Cleaning and Security services ●

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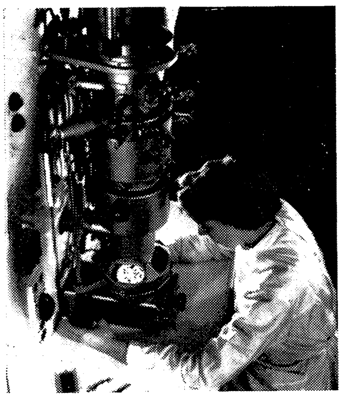

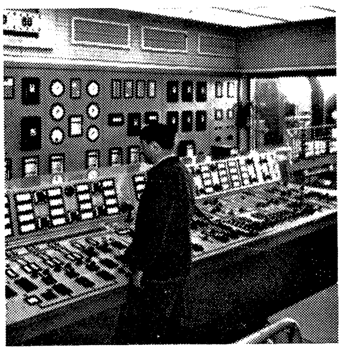

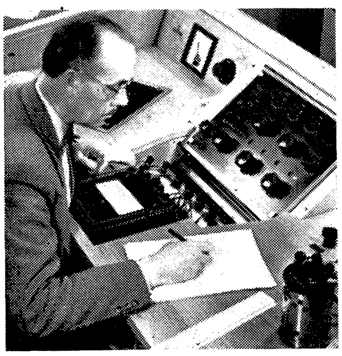

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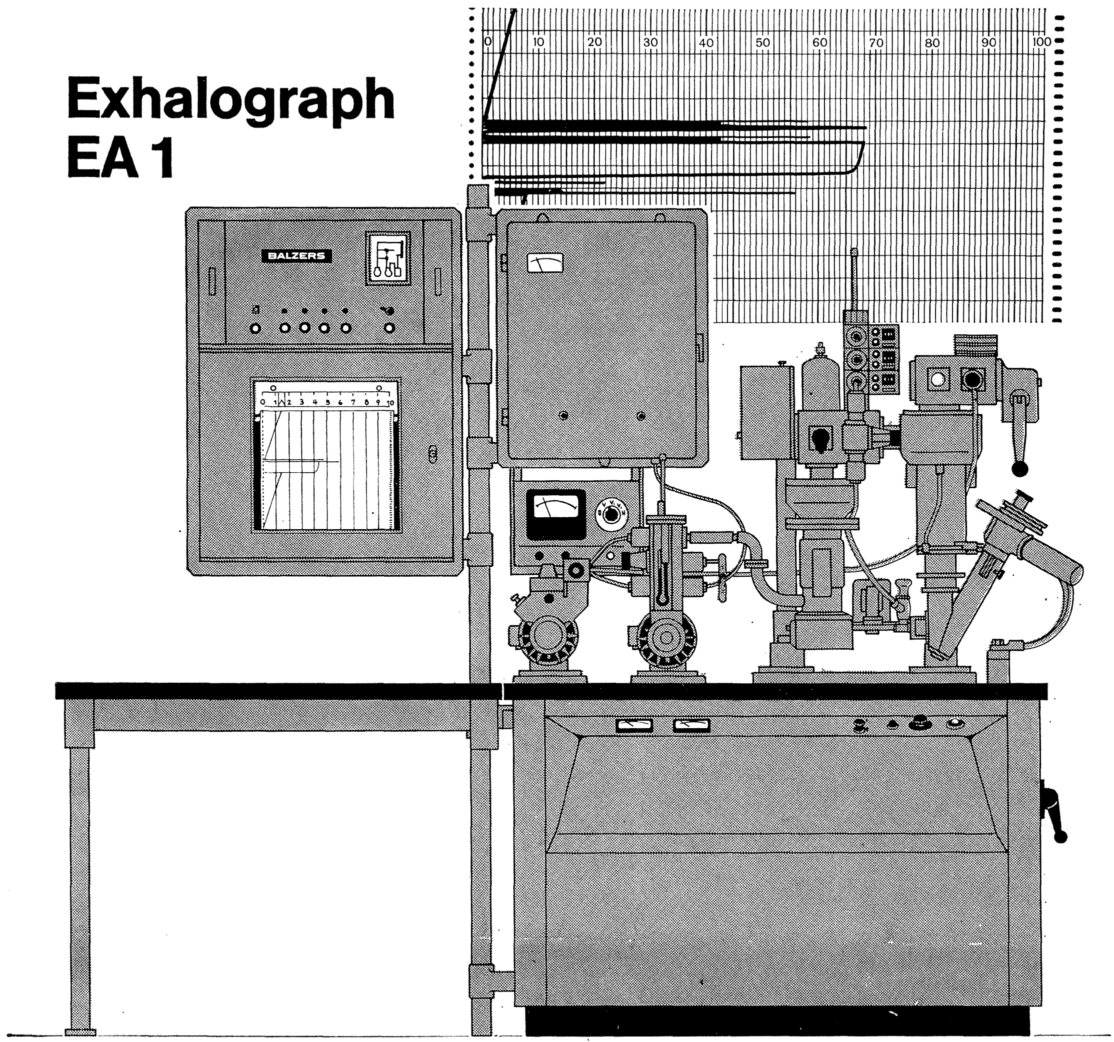

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