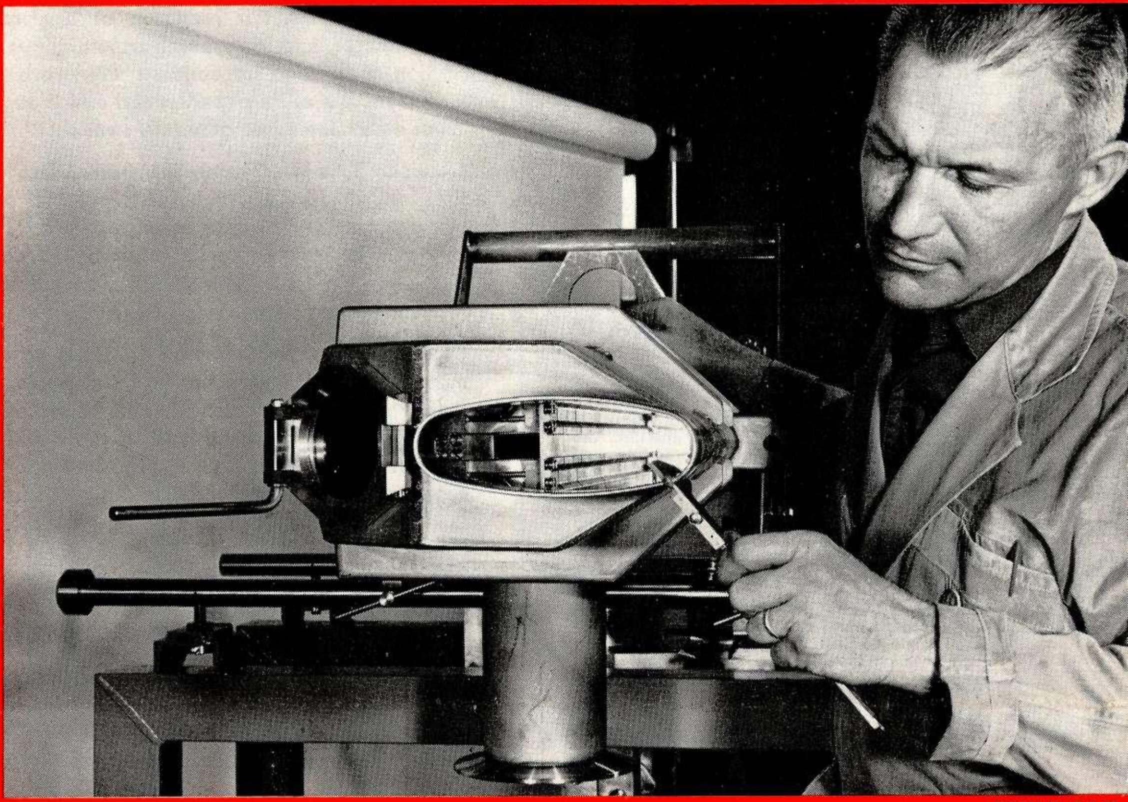
CERN COURIER



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The cover photograph shows Lucien Vuffray, of CERN's West workshop, with the vacuum tank containing the septum magnet designed in the MPS Division for the new ejection system in the East area of the proton synchrotron. The vertical pipe projecting from the bottom of the tank is for the connexion to the vacuum pumps when it is installed in the synchrotron, and above this can be recognized the characteristic outline (roughly oval in shape) of the accelerator vacuum tube. The magnet is visible through this opening. It consists really of two similar magnets, each of the 'septum' type, placed end to end to form one long one. The aperture can be seen as a dark rectangle, closed on the right-hand side by the septum, which is 3 mm thick and pierced along its length by seven channels for cooling water, each 1 mm x 1.2 mm. Inside the aperture, the field is 10 kilogauss in the first section and 20 kilogauss in the second but outside, in the unobstructed part of the vacuum tube to the right of the septum, the field is less than 0.2% of that inside and the beam normally circulating there is hardly affected. In the slow-ejection system, for which this magnet will be used, the beam is caused to oscillate more than usual in its passage round and round the ring; during each revolution some of the protons will be displaced so far from their normal orbit when they come to this part of the ring that they will pass on the left-hand side of the septum, thus entering the magnet and being ejected. To facilitate setting-up, the magnet can be displaced and adjusted inside the tank and the beam can be observed by television through the window on the left. The basis of the slow-ejection system was described in CERN COURIER, vol. 3, pp. 110-111, September 1963, and the tests on this magnet were mentioned in vol. 5, pp. 19-20, February 1965. The photograph also forms a suitable illustration to the article by Prof. Weisskopf that begins on p. 54, showing again the complex and highly refined apparatus that is essential for the adequate conduct of present-day research into the fundamental laws of nature.

CERN COURIER

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The European Organization for Nuclear Research, more commonly known as **CERN** (from the initials of the French title of the original body, 'Le Conseil européen pour la Recherche nucléaire', formed by an Agreement dated 15 February 1952), was created when the Convention establishing the permanent Organization came into force on 29 September 1954.

In this Convention, the aims of the Organization are defined 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.'**

Conceived as a co-operative enterprise in order to regain for Europe a first-rank position in fundamental nuclear science, CERN is now one of the world's leading laboratories in this field. It acts as a European centre and co-ordinator of research, theoretical and experimental, in the field of **high-energy physics,** often known as **sub-nuclear physics** or the **physics of fundamental particles.**

High-energy physics is that front of science which aims directly at the most fundamental questions of the basic laws governing the structure of matter and the universe. It is not directed towards specific applications — in particular, it plays no part in the development of the practical uses of nuclear energy — though it plays an important role in the education of the new generation of scientists. Only the future can show what use may be made of the knowledge now being gained.

The laboratory occupies an area of 41 hA (100 acres) at Meyrin, Canton of Geneva, Switzerland, next to the frontier with France. A similar area on adjacent French territory is expected to be taken over shortly.

Its main experimental equipment consists of two large particle accelerators:
- a 600-MeV synchro-cyclotron,
- a 28 000-MeV (or 28-GeV) proton synchrotron,

the latter being one of the two most powerful in the world.

The CERN staff totals some 2000 people.

In addition to the scientists on the staff, there are nearly 300 Fellows and Visiting Scientists, who stay at CERN, either individually or as members of visiting teams, for periods ranging from two months to two years. Although these Fellows and Visitors come mainly from universities and research institutes in the CERN Member States, they also include scientists from other countries.

Thirteen Member States contribute to the cost of the Organization, in proportion to their net national income:

Austria (1.95%)
Belgium (3.83%)
Denmark (2.07%)
Federal Republic
of Germany (22.74%)
France (18.57%)
Greece (0.60%)
Italy (10.78%)
Netherlands (3.92%)
Norway (1.47%)
Spain (2.18%)
Sweden (4.23%)
Switzerland (3.19%)
United Kingdom (24.47%)

Poland, Turkey and Yugoslavia have the status of Observers.

The budget for 1965 amounts to 128 760 000 Swiss francs (= $29 800 000), calling for contributions from Member States totalling 126 400 000 Swiss francs (= $29 300 000).

A supplementary programme, financed by eleven states, covers design work on two possible future European projects in high-energy physics — intersecting storage rings for the 28-GeV accelerator at Meyrin and a 300-GeV accelerator to be built elsewhere ●

Last month at CERN

Experiments at the proton synchrotron in February

As mentioned in the previous issue of *CERN COURIER* the first fortnight of PS operation during February was devoted mainly to counter experiments, four groups operating in beams derived from internal target no. 1 and two others working in beams coming from targets no. 6 and no. 61 respectively. Among the first four, the CERN/E.T.H. group continued with its experiment on charge-exchange reactions using a liquid-hydrogen target in the d_{18} beam, with spark chambers in a magnetic field as detectors. Pictures were taken with negative pions and negative kaons incident at momenta of 5 GeV/c and 12 GeV/c, and also with antiprotons of momentum 7 GeV/c, the latter to study the process in which the antiproton interacts with a proton to give a neutron and an antineutron. At the same time the 'Paplep' group collected data on the antiproton/proton annihilation giving an electron/positron or a muon/antimuon pair, using a total of about 5×10^9 antiprotons incident on their apparatus which now enables both reactions to be investigated at the same time. In the q_3 beam, additional data was collected in the experiment to study the decay of the rho meson, and in the neutral b_7 beam further spark-chamber photographs were obtained in the experiment on the decay of the K^0_2 meson. Background tests and checks of the regeneration of K^0_1 mesons from the K^0_2 in the presence of matter were also carried out in the latter experiment. On the inside of the synchrotron ring, in the North experimental hall, the CERN/Ivry group took another 100 000 photographs in their experiment to measure the backward scattering of negative pions from a proton (liquid-hydrogen) target, using pions of momentum 3.5 GeV/c. In the East hall, the group using sonic spark chambers in conjunction with a computer to investigate various aspects of proton scattering employed a liquid-deuterium target and protons of 19.2 GeV/c momentum (c_8 beam) to measure proton/deuteron scattering at small angles. The aim is to investigate the excited states of the proton and the neutron. About 750 000 events were recorded during this run; data on proton scattering from nuclei of lithium-6 and lithium-7 were also obtained (75 000 events in each case).

About ten per cent. of the primary proton beam during this time was directed on to target no. 60 in the synchrotron, enabling two further experiments to be carried out. In the o_2 beam itself, originating from this target, the 152-cm British liquid-hydrogen bubble chamber obtained 200 000 pictures showing positive-pion (5 GeV/c) interactions. Some photographs were also taken of proton interactions in the chamber, and it was during this time that the millionth photograph was reached, as mentioned in last month's report. The monitor beam arising from the same target, normally used to measure the fraction of the primary proton beam intercepted by the target, was employed again for tests on Cherenkov counters. During the second fortnight of February, in addition to the first run with the r.f.-separated beam reported in last month's issue, the 81-cm Saclay/Ecole Polytechnique bubble chamber continued its successful operation in the k_4 beam in the North hall. A hundred thousand good photographs were obtained of antiprotons stopping in the chamber, filled this time with ordinary liquid hydrogen, with an average of about four antiprotons per picture, and 105 000 photographs were collected showing the interactions of positive kaons of momentum 750 MeV/c and 800 MeV/c.

Because of troubles with the British chamber during the first part of this fortnight the target programming was changed to give a 'long burst' on target no. 1 during two days. This enabled the missing-mass-spectrometer group to carry out successful tests of their new d_{21} beam line at momenta of 4, 4.5 and 5 GeV/c. This beam line is similar to their previous one, but shifted a metre or so to one side so as to avoid interference with the b_7 beam. For the rest of the period the target for this beam was operated on a 'parasitic' basis, taking around 10% of the accelerated protons, and the group tested and installed a number of new counters and spark chambers aimed at improving the operation of the spectrometer.

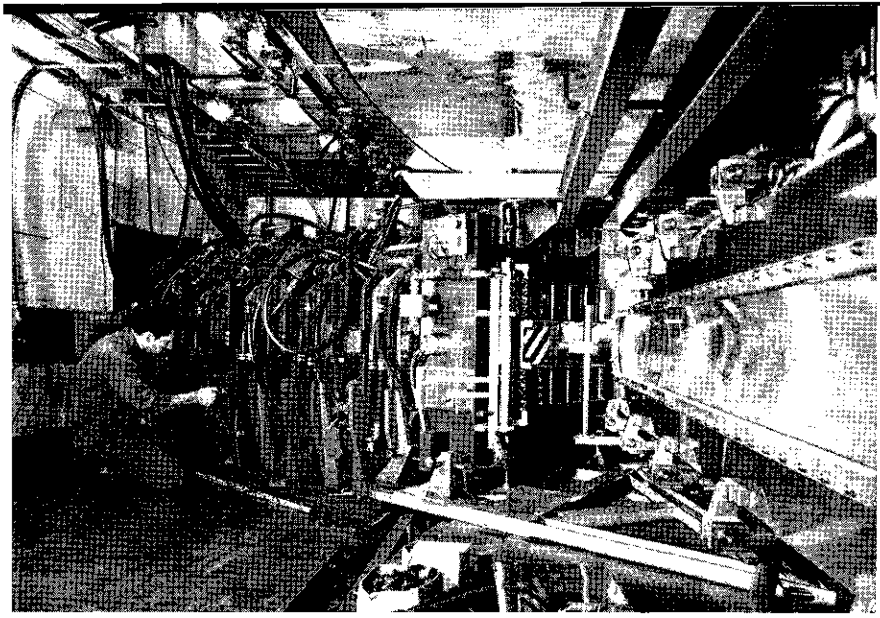
By modifying the currents in the magnets of the c_8 beam line it can be made to collect protons from the o_2 target (M60) rather than from its own (61) and thus operate at the same time as the 152-cm bubble chamber. During part of the second period this beam (changed slightly at the end also and known as c_{8a}) was used to test the stability of the latent image in nuclear emulsions exposed at a temperature of –253°C. The emulsion stacks were exposed to the protons first at room temperature then, 24 hours later, at the temperature of liquid hydrogen, subsequent investigation of the developed tracks enabling the two exposures to be compared. The same beam was later used to test a small freon bubble chamber detecting doubly charged particles.

SC maintenance and improvements, 26 December — 3 March

During the shut-down scheduled for CERN's 600-MeV synchro-cyclotron in the first two months of this year (see *CERN COURIER*, vol. 5, p. 20, February 1965) a large amount of maintenance and repair work was carried out and a number of items of new equipment were installed. The most important operations, providing the prime reason for the shut-down, were

- the installation of the new slow-extraction system for the accelerated proton beam,
- the inspection of the accelerator magnet coils,
- the overhaul of all the bending and focusing magnets used for beam transport,
- the installation of a new inflector magnet at the beginning of the muon channel.

The new slow-extraction system is a fully engineered version of the one previously installed, which was primarily a laboratory development. It can be operated at higher power, and the frequency and amplitude of the high-voltage pulse applied to the deflecting electrode can be adjusted over a wider range of values than before. The system, which has been developed from the so-called 'stochastic' method of acceleration, gives a beam pulse on the target lasting for a much longer period of time than would be possible with simple operation of the synchro-cyclotron. In ordinary operation, protons start at the centre of the cyclotron and spiral outwards as they are accelerated, until they strike an internal target or are extracted from the machine. With the slow-extraction system, the



This photograph, taken inside the machine room of the 600-MeV synchro-cyclotron, shows the new inflector magnet installed at the beginning of the muon channel. On the right of the picture can be seen the thin metal 'meson window' of the accelerator, through which pions can leave the vacuum tank after their production in internal targets. To the left of the inflector magnet are the first six quadrupole magnetic lenses of the muon channel, which collects pions produced by one of the targets and focuses them in such a way that an enhanced proportion of the muons arising from their decay is retained in the form of a muon beam. Pierre Knöbel is working on one of the quadrupoles.

acceleration programme is stopped just before the protons reach the orbit that would bring them into the extraction channel, and the particles continue to circulate at constant speed. However, in this position they pass through an auxiliary hollow electrode which is connected to a programmed radio-frequency supply. Each peak of the radio-frequency voltage deflects some of the protons into an orbit of greater diameter, from where they are extracted as an external beam. Thus, instead of a short intense burst of external protons there is a train of less-intense pulses lasting for a much longer time, repeated 54 times a second according to the normal programme of the accelerator. The 'duty cycle', the fraction of time during which particles are actually present in the external beam, is greatly improved and a high accelerated-beam intensity (in terms of protons per pulse) can be used without saturating the counting equipment in the various experiments.

Installation and operation of the new system produced some unexpected difficulties, and for this and other reasons the beginning of the new experimental programme using the cyclotron had to be put back for two weeks (to the first week of March instead of the middle of February as originally planned). After the initial running, however, the performance of the extraction system was equal to that of the previous version and work is now continuing to explore the operation of the system more fully and to find the optimum conditions for various requirements.

The inspection, in conjunction with engineers from the manufacturers, of the magnet coils of the cyclotron proved to have more importance than previously imagined. Each of these coils is made up of a number of 'pancakes' and it was found that about half the connexions to the pancakes had become distorted as a result of the strong forces set up by temperature effects in the coils when the magnet current is varied. Relative movement of the pancakes had also led to considerable wear of the insulation.

A series of mechanical, magnetic and electrical measurements thus had to be carried out to determine the precise state of the coils. All the former rigid connexions were then replaced by flexible ones and repairs were made to the insulation so far as possible. As a result of these and other measures, it seems that the accelerator can continue to be operated with little danger of serious damage from a short-circuit in one of the coils.

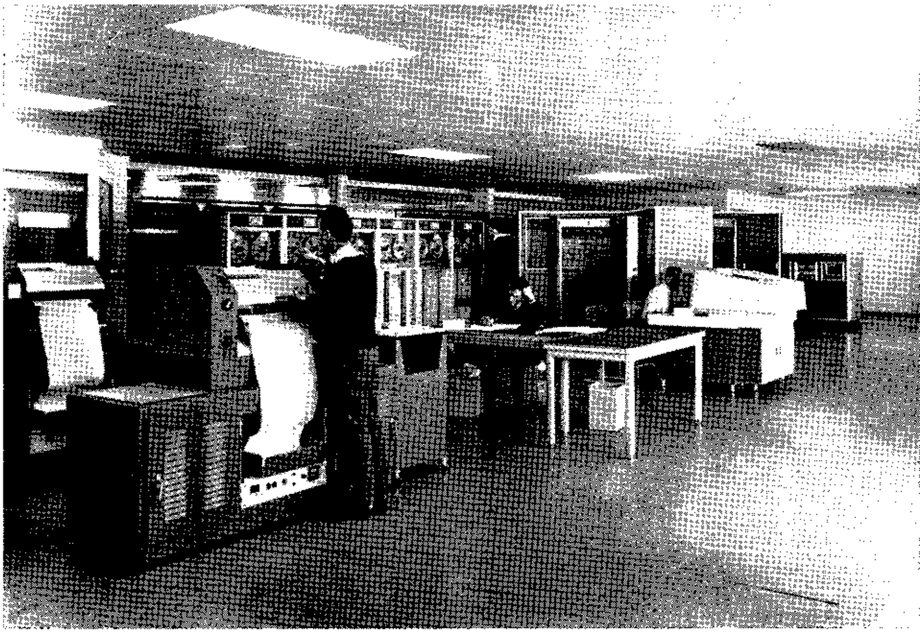
The magnitude of the work on the beam-transport systems and other apparatus for physics experiments can be gauged from such items as the inspection of the electrical and thermal cut-out systems on 8 bending magnets and 40 focusing magnets, improvement of the various supply couplings to the magnets, checking of about 1000 cables between the two experimental rooms, the machine hall, the control room and the counting rooms, and installation of some 15 km of new cable. The whole of the vacuum system for the accelerator, including the two diffusion pumps, three mechanical pumps and the 'booster' pump, was overhauled. A number of improvements of various kinds were made to the safety systems, concerning both operation of equipment and personnel safety. All the numerous electronic valves, screw connexions, switches, and so on were checked. Temporary measuring instruments that had been installed as the need arose were replaced by permanent apparatus. These form only a sample of the many jobs carried out, either as routine maintenance or to ameliorate the performance of the accelerator.

In addition, two of the accelerator's external beam lines were dismantled during the shut-down, for cleaning and overhaul of their components, and then reassembled. One of these was for the 70-MeV pion beam, the other the muon channel, both in the experimental hall known as the neutron room. When the muon channel was replaced a new inflector magnet was incorporated, designed to allow a variation of the energy of the pions entering the channel, and hence of the muons produced by their decay.

Physics with the 2-m chamber

After operating for the first time last December, the CERN 2-metre bubble chamber was successfully launched on its career as an experimental physics instrument on Thursday 18 March. From 12.30 p.m. on that day until 8.00 p.m. on Monday 22 March it operated in a beam of separated antiprotons, with momentum 5.7 GeV/c, taking 113 000 photographs for a CERN/Saclay collaboration. The photos showed an average of 20 antiproton tracks each. This run was followed by one from 4.30 p.m. on Tuesday 23 March to 6.00 a.m. on Sunday 28 March, during which 87 000 photographs were obtained, each showing about 13 positive kaons of momentum 5 GeV/c, for a Brussels/CERN collaboration. In each case the incident particles were provided by means of the new o_6 beam line, which is basically the same as the o_2 but with a branch near the end to take the beam to the 2-m chamber instead of to the 152-cm chamber ●

CERN's New Computer



General view of the new 6600 computer room at CERN. The computer itself is in the centre background, behind the control console. To the left of the computer are some of the tape units, and two of the high-speed printers can also be seen on the left of the picture. On the right, at the back, are the two disc files.

CERN/PI 38.3.65

The Control Data 6600 Computer ordered by CERN in January 1964 has now arrived and been installed. This machine is the most powerful computer now available and thus will provide the Organization with a very valuable backing to its physics research programme*. The 6600 delivered to CERN is the third machine made by the company in this series, of which ten are on order. The two earlier machines were delivered to the Livermore Laboratory of the University of California and to the CDC Systems Science Division in Los Angeles.

As so often with new machines, and computers are no exception, certain delays have been encountered on the schedule originally planned, but the 6600 'hardware' has now been installed and all that remains is for the final 'software' (operating system) to be delivered. The computer was flown in to Geneva on Thursday 14 January and, the CERN transport section unloaded the plane and brought the whole machine to a temporary storage in the East experimental hall of the PS. There it stayed, on the trucks, until the Friday morning, when the task of unloading and unpacking it began. At the end of the day the computer was finally placed in the new computer room, and the assembly work was well under way.

The installation of the machine continued for the whole of the week-end following its delivery : all the cables were connected by the Monday morning and power was switched on. From that moment the team of engineers worked 24 hours per day commissioning the items of equipment and then, on the Thursday, the first Fortran programme was successfully compiled (converted into the language used by the machine itself). After that more and more programmes were run to find possible errors in the machine.

The programming for the computer at CERN will be done in CERN FORTRAN, which is a version of Fortran chosen to be compatible with many existing versions of the Fortran language. Programmes written at CERN may then be processed elsewhere with a minimum of complication, providing a necessary flexibility for the interchange of programmes and data between CERN and associated laboratories in the Member States (see *CERN COURIER*, vol. 4, p. 167, December 1964). The operating system of the computer is completely different from that of the IBM 7090 and has not yet been delivered to CERN. Until it is, all work that is processed on the 6600 has to be run under the more primitive Chippewa system*. When the CERN system, SIPROS, is delivered it will be modified by the Programming Section to include several other features, such as tape labelling and error procedures, before its general use can begin.

The new computing area has been designed to allow greater and easier access to the input/output parts of the computer. The computer room has been built alongside the old 7090 room and between it and the programmers' area is an 'in/out wall' which allows the incoming work to be passed to the card-reader operator and the results to be delivered back to the programmer through pigeon holes. As the new computer room is open to the old one the same height has had to be preserved, and at present the ventilation system supplies both machines. The electrical supplies, however, are entirely separate, with a new room for the motor-generator set alongside the old one. Later, when the 7090 is shut down and removed, the tape units for the 6600 will be moved into the area left vacant and the viewing passage provided for visitors will be continued so as to lead out through the existing 7090 entrance.

For those initiated in computer nomenclature, it is worth noting that the 6600 comprises 128 K of 60-bit central-memory words, with ten, effectively independent, peripheral processors of 4 K words each, these latter controlling all the data transfers in the whole system. There are 12 units for 1-inch magnetic tape and 4 for $^1/_2$-inch tape, two discs of 7 $^1/_2$ million 60-bit words each, three 1000 line/minute printers, a card reader, a card punch and a console. Compatibility with the existing 7090 is obtainable through the $^1/_2$-inch magnetic tapes, as they can be read by both machines. The whole computer, it is expected, will be capable of about 15 times the throughput provided by the CERN 7090, together with the possibility of much quicker input and turn around for the user and the connexion on-line of many devices such as the HPD, IEPs, spark-chamber experiments, typewriters and displays.

N.S.

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* See, for example, CERN COURIER, vol. 4, pp. 73-77, June 1964.

* An interim system arrived with the Fortran compiler on 5 April. It will be possible for CERN programmes to be processed on this system and thus to make the 6600 available for general use without waiting for the final system, SIPROS.

In defence of high-energy physics

by **Victor F. WEISSKOPF,** Director General of CERN

Early this year, a book with the title Nature of matter – purposes of high-energy physics **(BNL 888 (T-360), edited by L. C. L. Yuan, $1.75) was published by the Brookhaven National Laboratory, U.S.A. In it, thirty of the leading theoretical physicists in America and Europe give their views on the subject and discuss some of the problems and implications involved. Its aim is to provide a degree of communication between high-energy physicists, the scientific community as a whole, and the general public, by presenting a comprehensive basis for a better understanding of the fundamental importance and great depth of high-energy physics.**

One of the contributors to the book is Prof. V. F. Weisskopf, Professor at Massachusetts Institute of Technology and currently Director General of CERN, and what he writes is reproduced here by kind permission of the editor. Distinguishing two trends in the development of science in this century, the 'intensive' and the 'extensive', Prof. Weisskopf shows how these are nevertheless closely interconnected and argues strongly against neglecting 'intensive' research such as sub-nuclear physics just because it has little 'extensive' content. He then explains that recent work in sub-nuclear physics points the way to an understanding of questions such as: why are there only a few stable particles making up matter?, why do there appear to be four different kinds of interaction in the universe?, and how did the universe get into its present state? If the tempo of sub-nuclear research slowed down, these questions would remain unanswered, he says; any subsequent 'extensive' research depending on the answers for its exploitation would then be precluded.

Today the development of science has arrived at a critical stage. The cost of science in terms of money and manpower has reached a point where society is beginning to question its further uninhibited growth.

So far the cost of science has been negligibly small. All basic scientific activity ever undertaken from the times of Archimedes until today amounts, in terms of money expenditure, to less than ten days' output of the industrial world, an amount which is below the yearly increase of world production. This represents an impressive rate of return on a capital investment if one considers that almost all industrial production today is a consequence of basic scientific research. Still, it is true that the requirements of modern basic research are beginning to be substantial and a discussion becomes unavoidable of the importance of basic science and of the relative importance of its different branches.

Clearly, the main targets of attack are the most expensive branches which, in addition, have a certain flavour of 'uselessness', that is, high-energy physics and astronomy. Modern astronomy, however, has the advantage of being connected with 'space'; it therefore profits from the present emphasis on everything that is related to space science. Clearly, this emphasis is not exclusively based on arguments of scientific merit. High-energy physics or — as it should better be named — sub-nuclear physics no longer enjoys such extraneous support, after having ridden on the coat-tails of nuclear energy for a number of years.

Intensive and extensive

Looking at the development of science in the twentieth century one can distinguish two trends, which I will call 'intensive' and 'extensive' research, lacking a better terminology. In short: intensive research goes for the fundamental laws, extensive research goes for the explanation of phenomena in terms of known fundamental laws. As always, distinctions of this kind are not unambiguous, but they are clear in most cases. Solid-state physics, plasma physics, and perhaps also biology, are extensive. High-energy physics and a good part of nuclear physics are intensive.

There is always much less intensive research going on than extensive. Once new fundamental laws are discovered, a large and ever-increasing activity begins in order to apply the discoveries to hitherto unexplained phenomena.

Thus, there are two dimensions to basic research. The frontier of science extends all along a long line from the newest and most modern intensive research, over the extensive research which was recently spawned by the intensive research of yesterday, to the broad and well developed web of extensive research activites based on intensive research of past decades.

One can easily distinguish four important steps of intensive research during this century: electrodynamics and relativity, quantum theory of the atom, nuclear physics and recently sub-nuclear physics. The extensive dimensions of electrodynamics, relativity and quantum theory reach very far today and are constantly expanding. Nuclear physics has already a large extensive part in the detailed studies of nuclear structure and in its astrophysical applications. Sub-nuclear physics is still mostly intensive in its character.

Sub-nuclear research at the frontier

Each part of this scientific frontier is of importance. It would be most dangerous to neglect some parts relative to others. It is often argued that sub-nuclear physics should be given less support because this field leads to very little extensive research, because it attracts too large a proportion of clever scientists, and because the cost per scientist is much higher than in many other parts of the scientific frontier. These reasons, however, are inherent in the fact that sub-nuclear research is at the frontier of intensive research.

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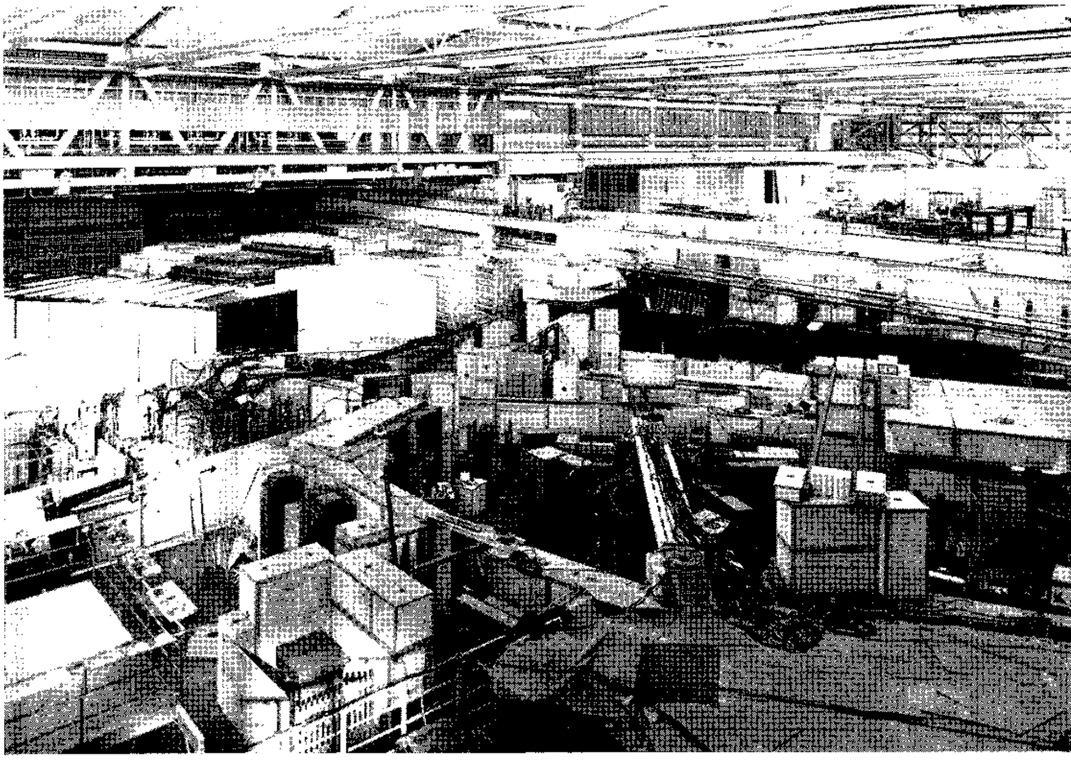


Today's nuclear physics laboratory is very different from that of a generation ago, and this view of part of the South experimental hall of the CERN proton synchrotron is typical. In a certain sense, the plasticine, string and sealing wax of Rutherford and his students can still be found, but to them has been added, as the physicists' basic equipment, such things as concrete shielding blocks, electronic boxes, and cloth, cardboard and wood to keep the light out of spark-chamber viewing systems. In the nearest enclosure, under the cable bridge, is the equipment for the 'Paplep' experiment; further back and to the left is the 'missing-mass spectrometer', with its counting and control systems in another enclosure on the extreme left; behind this is the shielding complex for the neutrino experiment, including the bubble-chamber and spark-chamber block-houses; to the right again, under the black curtains, is the apparatus for the experiment on the K-nought-two decay. In the background on the right is the bridge over the accelerator, connecting with the North experimental hall.

Obviously, the most advanced part of intensive research has yet very little bearing upon the understanding of other phenomena, and therefore its extensive component is small. After all, one is at the very beginning of understanding what is going on at the sub-nuclear frontier itself. Clearly, the same situation existed at earlier periods when other fundamental discoveries were at the frontier of science. Faraday did not know that electricity is the basis of the structure of matter; when the first steps were made towards an understanding of atomic spectra, nobody knew that this would lead to a complete understanding of chemical reactions. Thus the extensive effect of sub-nuclear physics is not yet visible, but even today it seems already probable that sub-nuclear phenomena are important for the understanding of the recently discovered galactic explosions.

The frontier of intensive research has always attracted a certain group of very clever scientists. To work in an uncharted field, to discover new laws of nature and completely new types of phenomena, is a great lure for a scientist. One is placed at the spearhead of a great and successful tradition ranging from Galileo, Newton, Maxwell to Einstein, Bohr, Dirac and Heisenberg. It is improbable, however, that this field should in fact ever deprive other fields of science of skilled manpower. It is by its very nature a limited field. Competition is heavy, success is rare and depends more often than not on luck and opportunity. Many of the best scientific brains avoid this field because of the narrow choice of activities.

The high cost of sub-nuclear physics comes from the fact that it deals with new phenomena which were not previously observed. Sub-nuclear physics requires the study of matter under new conditions. As science progresses, these conditions become increasingly different from normal conditions on earth. Nuclear physics deals with intrastellar conditions and sub-nuclear physics submits matter to even more abnormal conditions. Obviously, it becomes increasingly expensive to create increasingly abnormal environments in a laboratory.

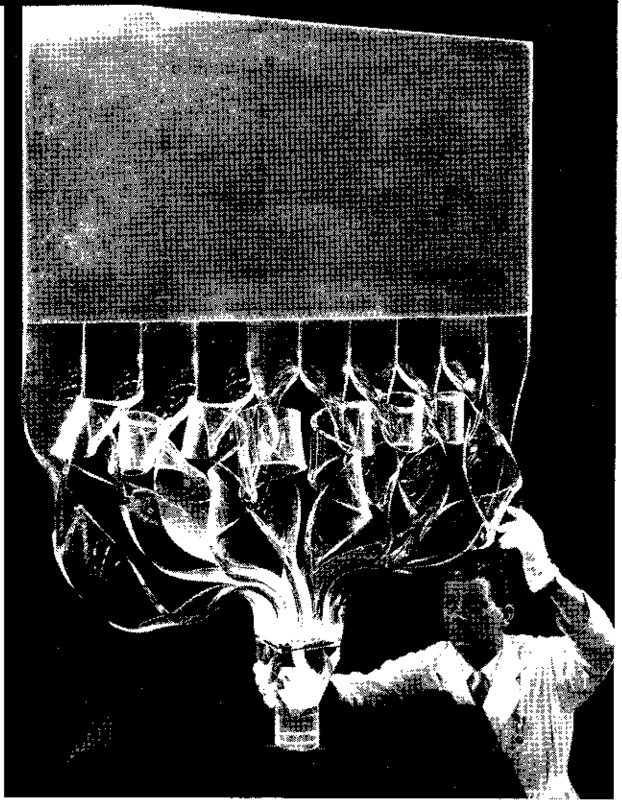
A new world of phenomena

There is today a clear danger that the alleged narrowness and the high cost of sub-nuclear physics will, in fact, retard its development compared to other fields at the scientific frontier. Already the *Physical Review* shows a stronger increase in the number of solid-state-physics papers compared to nuclear-physics papers. This occurs just at a time when sub-nuclear physics begins to reveal the existence of a new world of phenomena within the nucleons. We see today the birth of a third spectroscopy compiling the excited quantum states not of atomic systems or of atomic nuclei, but of the nucleon itself. We find today the first indications of regularities in these level schemes, which will soon lead to an insight into the structure within the nucleon. This insight is bound to bring us nearer to the understanding of some of the most fundamental unsolved questions. Let us list three groups of such questions:

Today we understand the behaviour of matter on the basis of the interaction of atomic nuclei and electrons. But the basic question remains: why is it that the proton, the neutron and the electron are the elementary particles that make up matter under terrestrial conditions? Why are these particles, together with the light quantum and the neutrino, the most stable forms in a long series of particles including the hyperons, the numerous bosons and the heavy electrons? These questions concern the basis of everything scientific. As long as they are not answered, the structure of any form of matter remains essentially not understood. The great triumph of quantum theory was the explanation of the characteristic properties of the elements on the basis of the recognition that the field of a given electric charge admits only certain well-defined quantum states of the electron. This idea is fundamental to all atomic physics, chemistry and molecular biology. However, it is valid only because of the existence of identical electrons and protons with fixed and well defined charges and masses. In fact, quantum theory does not really explain the existence of characteristic intrinsic properties of each element; it deduces it from another unexplained set of facts: the existence of a small number of elementary particles with their own characteristic intrinsic properties. Hence, the basic problem which underlies all physical sciences, that of the structure of matter, is still unsolved. It is precisely that problem which is attacked by sub-nuclear physics.

Another fundamental set of questions is connected with the problem of the different types of interaction between material particles. Physics has solved the problem of unifying a large number of interactions, such as electric and magnetic forces, chemical forces, cohesional forces, capillary forces, etc., all of which are reducible to the quantum effects of electric attraction between nuclei and electrons. But there is still no connexion seen between nuclear, electromagnetic, gravitational and weak interactions. Hence, the task of a consistent understanding of nature has only begun and is in need of further development. It is again mainly sub-nuclear physics which attacks these problems; theoretical research in relativity theory and astronomical research into the structure of the universe will contribute to the solution.

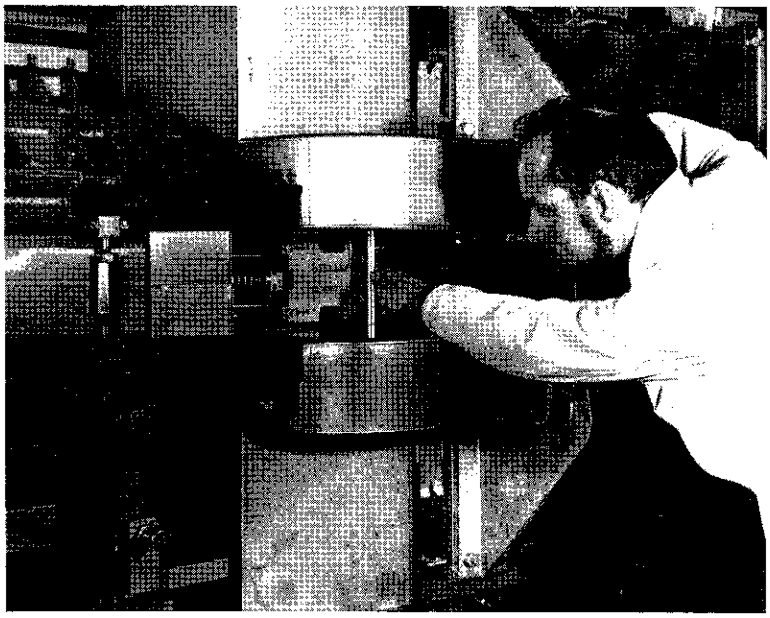
Finally, the same three fields of research are about to tackle the problems of the history of the universe. The question of the origin of matter can already be discussed on scientific grounds. So far, rational ideas are developed only concerning the element formation from a gas of protons and electrons. But the problem of the origin of this gas begins to acquire some scientific aspects with the discovery of matter under extreme conditions of high energy at the centres of galaxies. These phenomena are obviously connected with the interactions of particles at very high energy, as studied in sub-nuclear physics.



This construction in transparent plastic, displayed by Leslie Thornhill, could well form part of an exhibition of modern sculpture, but it is in reality part of a new scintillation detector for the 'missing-mass spectrometer'. The rectangular part at the top is a sheet of plastic scintillator and the remainder is a complex system of light pipes to transmit light from the scintillator, where it occurs as a flash produced by an incident nuclear particle, to the photomultiplier that detects and records it. Each of the ten plastic strips is 1.2 m long, so that the time taken for light to travel along any one of them is the same. The curves were designed so that the light remains trapped inside each strip, and in use a layer of black tape also prevents external light from entering. The manufacture of this device, in the West workshop at CERN, was a complex operation of bending and glueing, after initial polishing of all the surfaces to a very high degree of perfection, the slightest scratch on the surface of the plastic contributing to a decrease in accuracy of the finished detector.

One broad front

We are facing today a situation where it is threatened that all this promising research will be slowed down by constrained financial support of high-energy physics. And this constraint is based, partially at least, on a claim that the aim of this field is narrow and restricted. The three above-mentioned groups of unsolved questions should be sufficient to invalidate this claim. It is granted that further progress, say, in biology or in solid-state physics is possible without any further research into the sub-nuclear field. But let there be no doubt that the style of the scientific community would change its character if the frontier of intensive research were hampered. It would subtly change towards over-emphasis on extensive research, and this would harm all fields of science. A spirit would be fostered, different from the one which created modern science, if basic questions that can be



Since its completion at the end of 1959 the CERN PS has been the object of numerous improvements to increase its efficiency, flexibility of use and ease of operation. One of the latest of these is a new quadrupole focusing magnet, shown here being adjusted by Joseph Guillet between the coils of one of the ring magnets of the accelerator. Designed and constructed in the PS Division, this lens is one of 50 which control the spread of the beam immediately after its injection into the synchrotron. At this energy, they replace the 20 much larger quadrupoles of more conventional design, one of which is seen on the left of the photograph.

News from abroad

U. S. A.

Policy for high-energy physics approved by the President

A booklet published in February for the U.S. Joint Committee on Atomic Energy* included the text of the Atomic Energy Commission's proposals for the development of high-energy physics in America, covering the period 1965-1981, which have been submitted to Congress by President Johnson.

Among the specific plans presented are those for the construction of a 200-GeV proton synchrotron, to be completed before 1974, conversion of the Brookhaven AGS to a high-intensity machine, improvements at the Argonne ZGS, the construction of a high-energy electron-positron storage ring at the 20-GeV Stanford linear accelerator, the early construction of two or three large hydrogen bubble chambers, increased support for university high-energy physics groups, and intensive design studies for a proton accelerator of 600 to 1000 GeV energy to come into operation in 1980, with provision for the possible future addition of storage rings.

It is hoped to give further details of this report in the next issue of *CERN COURIER.*

World's first experiment with colliding beams

Spectacular news came from Stanford University (U.S.A.) in March, when it was announced that on 1 February 1965 two electron beams travelling in opposite directions in a pair of intersecting storage rings had at last been made to collide.

The electrons in each beam had an energy of 300 MeV, so that when two of them met head-on their colliding energy was 600 MeV, equivalent to that of a 360 GeV electron hitting a stationary target.

This success, by a team of physicists from Stanford and Princeton Universities, marks the climax of six years of intensive work, the last three of which were years of frustrating problems that sometimes threatened to defeat the whole programme. During the last year in particular, after beams had been successfully stored in the rings, attempts to make them collide resulted in failure, except with relatively weak beams. Repercussions of this frustration were felt at CERN, where doubts were thrown on the feasibility of operating the proton storage rings proposed for the PS, in spite of the confident assurance by the designers that the unexplained electron effects were unlikely to occur to the same extent with the more energetic and less dense proton beams. The new results reflect an improvement of colliding beam operation to an extent that the collection of experimental data on the collision interactions could be started.

The Stanford storage rings are fed from the 'Mark III' linear accelerator, and electrons have been stored in the rings for periods as long as 35 hours. The beam current in each ring is about 0.03 ampères. One of the main experiments now proposed is a new, more severe test of the theory of quantum electrodynamics, made possible by the higher available energy which enables one to investigate 'objects' of smaller size.

F. R. of GERMANY - DESY

Accelerator running regularly

News from the 'Deutsches Elektronen-Synchrotron' (DESY) at Hamburg (Federal Republic of Germany) in March was that the accelerator was running on a regular weekly schedule of 96 hours, from 11 p.m. each Monday to 11 p.m. Friday. About 50% of the time was being used for experimental physics (with counters and a bubble chamber) and about 30% for experiments and development work with the accelerator itself, some 20% still being lost because of technical difficulties.

This machine, as well as the similar one (Cambridge Electron Accelerator) in the U.S.A., produces the world's

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* 'High-energy physics programm: report on national policy and background information', Washington, U.S. Government Printing Office, 55 cents.

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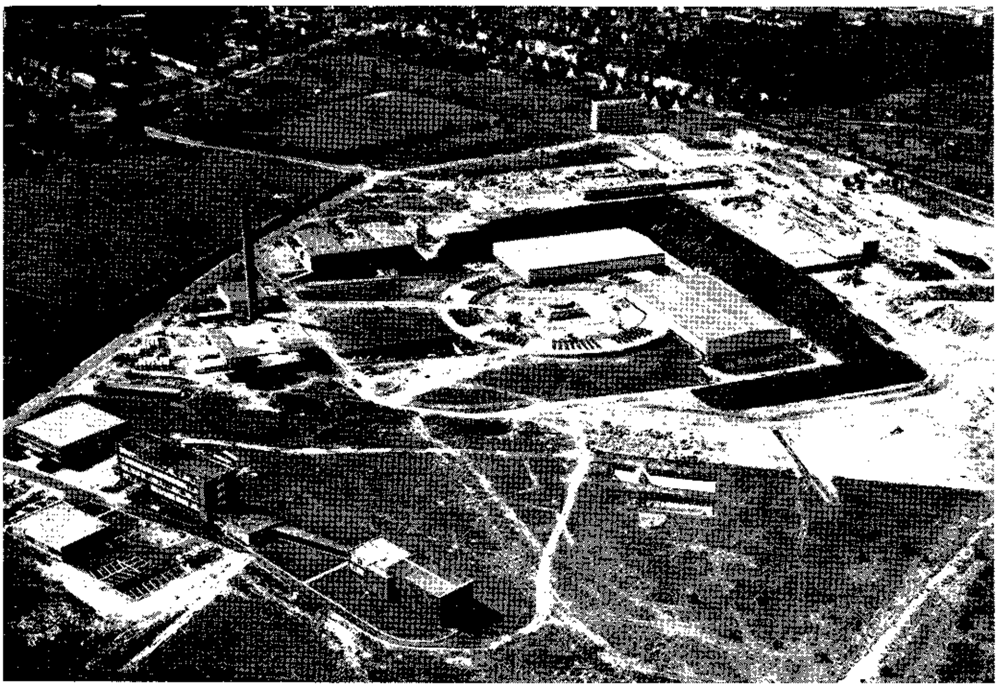
answered are left unanswered or are neglected by lack of attention. The questions remain, they cannot be overlooked.

This different spirit will do most harm in the education of young scientists. The study of science is based upon a burning interest in fundamental problems. The attitude of students would be perverted if they were not constantly aware of a lively quest for the solution of the basic problems of science. Even the scientist who will devote his life to purely extensive research must be aware of the existence and the spirit of intensive research. The reason is that, even in the most extensive research, at every step there is always an intensive component: at each unsolved problem one must go back to some fundamental idea, one must try to see more of the essence of the problem. This is an attitude which can be fostered and maintained only if intensive and extensive research have an equal standing in the scientific community. There is one broad front in science and each part of it must be pushed forward with full vigour.

We find strong support today for space technology, which may allow us to explore the unknown parts of the solar system. Exploration of the unknown was always a strong component of human endeavour in our modern civilization. But it must go together, as it always did, with another equally strong component: the explanation of the unknown in whatever form it faces us.

In the beginning of the 16th century, when the scientific era began, Magellan performed the first trip around the earth. But also in the same period Copernicus published his work on the motion of the planets ●



Aerial view of the DESY Laboratory, at the time of the inauguration of the electron synchrotron last November. The shape of the accelerator (which is 2.5 m underground) can be seen clearly in the centre of the picture, with the main control room at the centre of the ring and two large experimental halls tangential to it. In the left foreground are the buildings of the II Institute for Experimental Physics of the University of Hamburg.

highest energy electrons. It is now just over a year since the first accelerated beam was obtained*, and the intensity at the present maximum energy of 6 GeV is about 2×10^{10} electrons per pulse. At the usual operating energy of 4-5 GeV, the intensity is 10^{11} electrons per pulse, or more (corresponding to an instantaneous beam current of about 20 mA). With a repetition rate of 50 pulses per second, this means that the number of electrons normally delivered by the machine is 5×10^{12} per second.

The accelerator was officially inaugurated on 12 November last, by the Federal Republic's Minister for Scientific Research, Hans Lenz, at a ceremony attended by some 400 guests from all parts of the world, including a number from CERN. Like the CERN PS, DESY is a circular machine, using the strong-focusing principle of magnetic guidance for the accelerated particles. The ring has a diameter of 100 metres (half that of the CERN PS) and there are 48 magnets with 16 acceleration cavities. Electrons are injected from a 40-MeV linear accelerator. The cost, altogether 110 million DM, was met largely by the city of Hamburg (17 million) and the Federal Republic (83 million), but a timely gift of 10 million DM from the Volkswagen Foundation also enabled a delay in the completion of the accelerator to be avoided. The head of the DESY Laboratory is Prof. Willibald Jentschke, who was born and educated in Vienna and worked for some years after the war in the U.S.A., before returning to Europe to become Director of the Physics Departement of the University of Hamburg with which DESY is associated. Prof. Jentschke is also a Member of CERN's Scientific Policy Committee and a Delegate of Germany to the Council.

Liquid-hydrogen bubble chamber

A day or two before the inauguration of the accelerator, the first photographs were obtained with the Laboratory's 80-cm liquid-hydrogen bubble chamber, and the first 'production' run began in February, in an experiment on the interaction of high-energy gamma rays with protons. This chamber is a particularly striking example of the 'team work' of high-energy physics, as it was projected by a joint group of physicists from Institutes in Aachen, Bonn, Hamburg, Heidelberg and Munich and built by a mixed team of German and French physicists and technicians at the French centre of Saclay. Among the physicists associated with the use of the chamber for experiments are a number who were previously at CERN.

The design of the chamber follows closely that of the 81-cm Saclay chamber at CERN, with a hydrogen volume of 128 litres (an oval cylinder 80 cm × 40 cm × 40 cm deep), but the cycling time is much faster. Taking pictures at the rate of two per second, the instrument consumes film at the rate of 1 km per hour. Shortly before its first run began, the chamber was officially inaugurated, on 18 February 1965, by Prof. F. Perrin, High Commissioner for Atomic Energy in France, who is also a Member of CERN's Scientific Policy Committee and a Delegate to the Council.

U.K. - RUTHERFORD LAB.

Accident to Nimrod

At about 11 p.m. on the night of Sunday 21 February a serious mechanical accident occurred on the power supply for the magnet of the 7-GeV proton synchrotron 'Nimrod'. As a result, operation of the accelerator and its already overcrowded physics programme has been brought to a halt.

As with other synchrotrons, the magnetic field rises to a maximum and falls again with each pulse of the accelerator, and the corresponding surges of current

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* See, for example, CERN COURIER, vol. 4, p. 78, June 1964.

are too large for the magnet coils to be fed directly from the public electricity supply. Instead, at Nimrod, a twin motor-alternator-flywheel set mounted on one long shaft is used as a 'buffer' between the supply and the magnet. The two motors are driven from the supply, the alternators provide (through rectifiers) the magnet current, and the flywheels increase the rotating mass and help to store energy between each pulse. Although the whole system rotates continuously at about 1000 revolutions per minute it slows down by about 4% when current flows into the magnet and speeds up again when current flows back at the end of each pulse.

The rotor of each alternator is of 'salient-pole' design, with six poles running the length of the machine (over 3 metres) and keyed into the rotor body by a dove-tail joint. As a result of the tremendous stresses set up by the alternate slowing down and speeding up, every 2 seconds or less, of the system, one of these dove-tail joints fractured, allowing the end plate to move outwards under centrifugal force and to tear into the surrounding stator.

It is estimated that the alternator will take about eight months to repair. There is a chance that the accelerator will be able to run with the remaining alternator during this time, with a repetition rate of one pulse every 5 or 6 seconds instead of every 2 seconds, but this will depend on the results of detailed investigations into the cause of the failure, and elimination of the possibility that a similar accident could occur again. At the time of writing (end of March) the results of these investigations were still unknown.

Before the breakdown, the accelerator had been running well, with beam currents of around 1.5×10^{12} protons per pulse as routine.

Among the experiments recently completed, two are perhaps of particular interest. One of these used a polarized-proton target, of a somewhat different design to the one at CERN, to measure the parity of some of the 'resonances' obtained in the scattering of pions by protons. The other was an investigation of the decay of the K^0_2 meson into two pions, using sonic spark chambers as detectors and kaons with an energy less than that used at CERN but still higher than that used at Brookhaven. Like the CERN physicists, the group that carried out this experiment obtained almost exactly the same number of decays (relative to other charged modes), as in the original Brookhaven experiment, serving to underline the fact that the effect, whatever it is, that violates the CP-invariance rule is independent of the energy of the kaons.

U. S. S. R. - DUBNA

New Director of the Laboratory

An interchange of positions has taken place at the Joint Institute for Nuclear Research (J.I.N.R.) at Dubna (U.S.S.R.), where Prof. Dimitry I. Blokhintsev has given up his post as Director of the Institute to become head of its Laboratory of Theoretical Physics and Prof. Nikolai N. Bogolyubov, formerly head of the Laboratory of

Theoretical Physics, has been appointed Director of the Institute.

Prof. Blokhintsev had been Director since the founding of the Institute in 1956. Before then he worked at the Physics Institute of the U.S.S.R. Academy of Sciences and directed the construction of the first nuclear power plant, put into operation in the Soviet Union in 1954, although his interests are primarily in the field of theoretical physics. He was made professor in the University of Moscow in 1936, at the age of 28, and has contributed especially to the theories of phosphorescence, fluorescence and semi-conductors.

Prof. Bogolyubov had led the Laboratory of Theoretical Physics since 1956, as well as being in charge of the Department of Theoretical Physics of the V. A. Stehlov Mathematics Institute of the U.S.S.R. Academy of Sciences. Previously he was chairman of other Departments in the Academy of Sciences as well as at the Universities of Moscow and Kiev. He is a theoretical physicist who has made many contributions to the subject, often of a basic nature, particularly in the fields of analysis, function theory, differential equations, theory of vibration, theory of stability and quantum field theory.

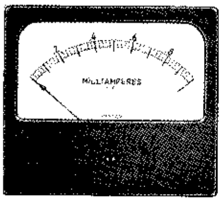
Both physicists are well known also outside Russia and Prof. Bogolyubov, like CERN's Director General Prof. V. F. Weisskopf, has participated in the 'Pugwash' movement, of science and world affairs, for many years.

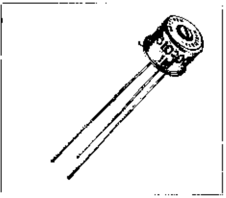
10-GeV accelerator operation

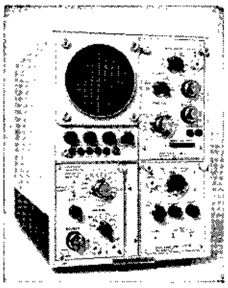
In a seminar given at CERN on 23 March, Dr. J. V. Chuvilo, Deputy Director of the Laboratory for High Energy Physics at J.I.N.R., gave an outline of the experimental facilities and experiments in progress round the 10-GeV synchrophasotron (synchrotron). The accelerator gives an internal proton beam of intensity 1.2×10^{11} protons/pulse, with a repetition rate of 1 pulse every 9 seconds at the highest energy. Instead of the 14-day cycle used at the CERN PS, the synchrophasotron has a more complex schedule of 57 days: 12 on, 2 off; 12 on, 2 off; 21 on, 8 off. With one long shut-down of about a month, there are about 5000 hours of running time available for physics experiments each year.

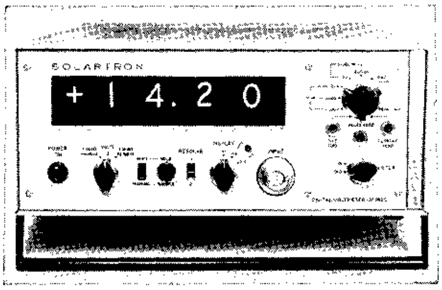
The accelerator has two experimental halls, and among the experiments recently completed or currently in progress are bubble-chamber runs on particle 'resonances', using incident pions; pion-proton and proton-proton scattering, with emulsions, spark-chambers or a cloud chamber as detectors; and investigations on the various 'normal' decay modes of the K^0_2 meson. As at CERN, some of these experiments are carried out by visiting teams from the universities of the Institute's member states.

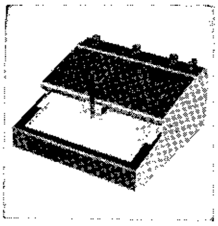
In addition to a 40-cm liquid-hydrogen bubble chamber, the Institute now has a 1-metre hydrogen chamber, on which the first tests were carried out last December. This chamber, which is housed in a separate building some way from the accelerator, is now being prepared for its first experiment, in a beam of negative pions. The Institute also has a xenon bubble chamber, 55 cm × 27 cm × 18 cm, a 1-metre propane chamber, and a 2-metre propane chamber (volume 220 cm × 70 cm × 40 cm), though the latter is not yet fully operational ●

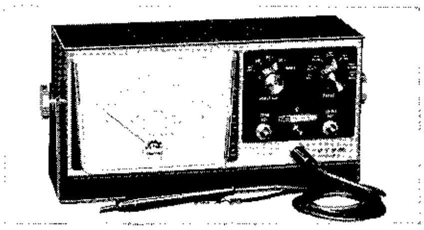












CERN **has vacancies for**

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to work in the data handling and computing aspects of high-energy nuclear physics experiments. The laboratory has recently installed a CDC 6600 computer. This fast time-sharing computer with 131-thousand-word memory, the first of its kind in Europe, will be the basis of a considerable development in experimental data-handling techniques and general computing work of the laboratory. The Organization invites applications for the following vacancies:

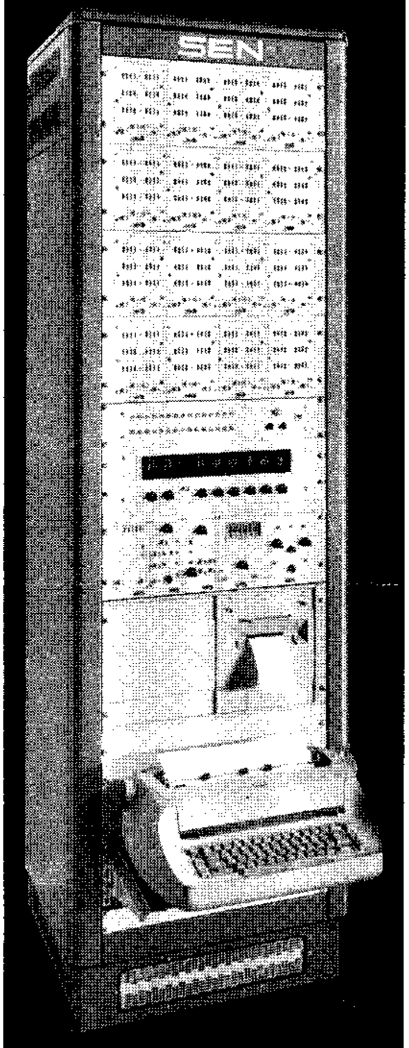
1. **Experimental Physicists** wishing to assist in the development of automatic data-analysis systems and their application to high-energy physics experiments. These systems include the use of advanced techniques such as computer-controlled flying spot digitizers for film measurement and on-line connection of experimental equipment to digital computers. Previous experience in this field is desirable but not essential.

2. **Scientific Programmers.** Applied physicists and mathematicians wishing to work on the preparation of computer programmes for the analysis of data from high-energy experiments. Assignments may vary from team work for the development of large-volume data-analysis systems for bubble-chamber and spark-chamber experiments, using on-line flying-spot digitizers and similar techniques, to individual work assisting in the analysis of the results of a specific experiment.

3. **Systems Programmers** with several years experience on large-scale scientific computing equipment. The work will involve development of systems programmes (operating systems, compilers and assemblers) required for the CDC 6600.

Candidates (who must be nationals of CERN Member States) are invited to write for an application form, quoting reference CC/65/4 a to:

Personnel Division, CERN, 1211 Geneva 23, Switzerland



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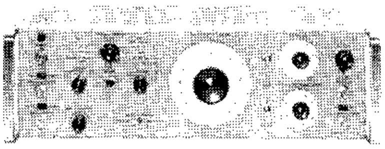

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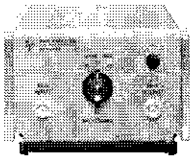

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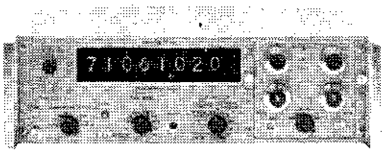

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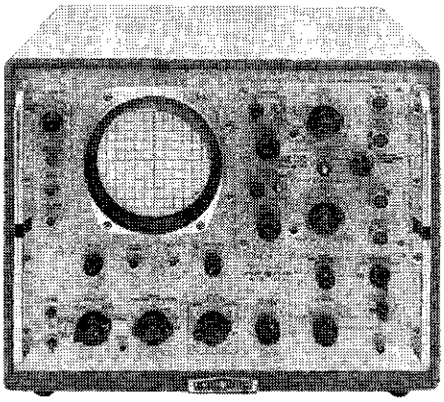

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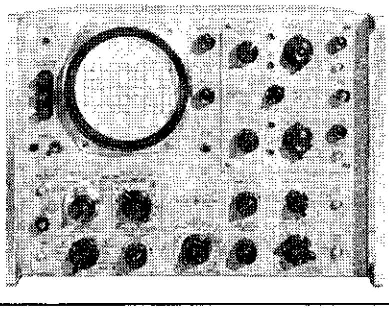

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PR 11/65
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Plaidoyer pour la physique subnucléaire

"Depuis Archimède jusqu'à présent, les sciences fondamentales ont coûté moins que 10 jours de production industrielle mondiale d'aujourd'hui" déclare le Professeur V.F. WEISSKOPF dans le numéro d'avril de "COURRIER CERN".*)

L'article que signe le Directeur général du CERN présente un plaidoyer pour la physique des hautes énergies. Il constitue un chapitre d'un ouvrage**) par lequel 30 théoriciens américains et européens communiquent, tant à l'ensemble de la communauté scientifique qu'au grand public, l'importance primordiale d'une science située à la pointe du savoir humain.

A une époque où le coût de la science en termes d'argent et de main d'oeuvre atteint un niveau tel que l'on envisage une réglementation de son développement, il est en effet opportun de considérer l'importance relative des diverses disciplines scientifiques.

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*) "COURRIER CERN", Vol.5, no.4, Avril 1965

**) "Nature of matter - Purposes of high energy physics"
$ 1.75/L.C.L. YUAN Editeur; publié par BROOKHAVEN NATIONAL LABORATORY, N.Y., U.S.A.

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PR 11/65
3-5-1965

In defence of high-energy physics

"All basic scientific activity ever undertaken from the time of Archimedes until today amounts, in terms of money expenditure, to less than ten days' output of the industrial world", according to an article by Professor V.F. WEISSKOPF in the April issue of CERN COURIER.*)

The article is a defence of high-energy (or sub-nuclear) physics by the Director General of CERN. It has been taken from a book, published early this year,**) in which thirty American and European theoretical physicists have given their views, for both the scientific community as a whole and the general public, on the fundamental importance of a science that pushes at the frontiers of human knowledge.

At a time when the cost of science in terms of money and manpower has reached a level such that its further uninhibited growth is beginning to be questioned, it is opportune to consider the relative importance of the various branches of research.

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*) "CERN COURIER", Vol. 5, no. 4, April 1965

**) "Nature of matter - purposes of high-energy physics", edited by L.C.L. YUAN, published by BROOKHAVEN NATIONAL LABORATORY, N.Y., U.S.A., $ 1.75

Sciences inductives et déductives.

Le Professeur WEISSKOPF distingue deux catégories de sciences contemporaines: "inductives" et "déductives". Les premières sont dirigées vers la découverte de lois fondamentales, les secondes vers l'explication de phénomènes en fonction des lois fondamentales connues. La physique subnucléaire, l'astronomie et une bonne partie de la physique nucléaire sont des sciences inductives; la physique des plasmas, celle de l'état solide, la biologie peut-être, sont des sciences déductives.

Sciences inductives et déductives sont étroitement liées, constate l'auteur, qui combat vigoureusement la tendance à négliger, par exemple, la physique subnucléaire, pour la seule raison qu'elle est peu déductive. Il explique ensuite que de récènts travaux effectués dans ce domaine ouvrent la voie à une explication des questions telles que : pourquoi la matière n'est-elle constituée que de quelques particules stables ? pourquoi semble-t-il y avoir quatre types différents d'interactions dans l'univers ? comment l'univers en est-il arrivé à son état actuel ?

Si le rythme de la recherche subnucléaire venait à se ralentir, ces questions resteraient sans réponse, dit-il, et toute recherche déductive ultérieure dépendant de ces réponses pour son exploitation, deviendrait alors impossible.