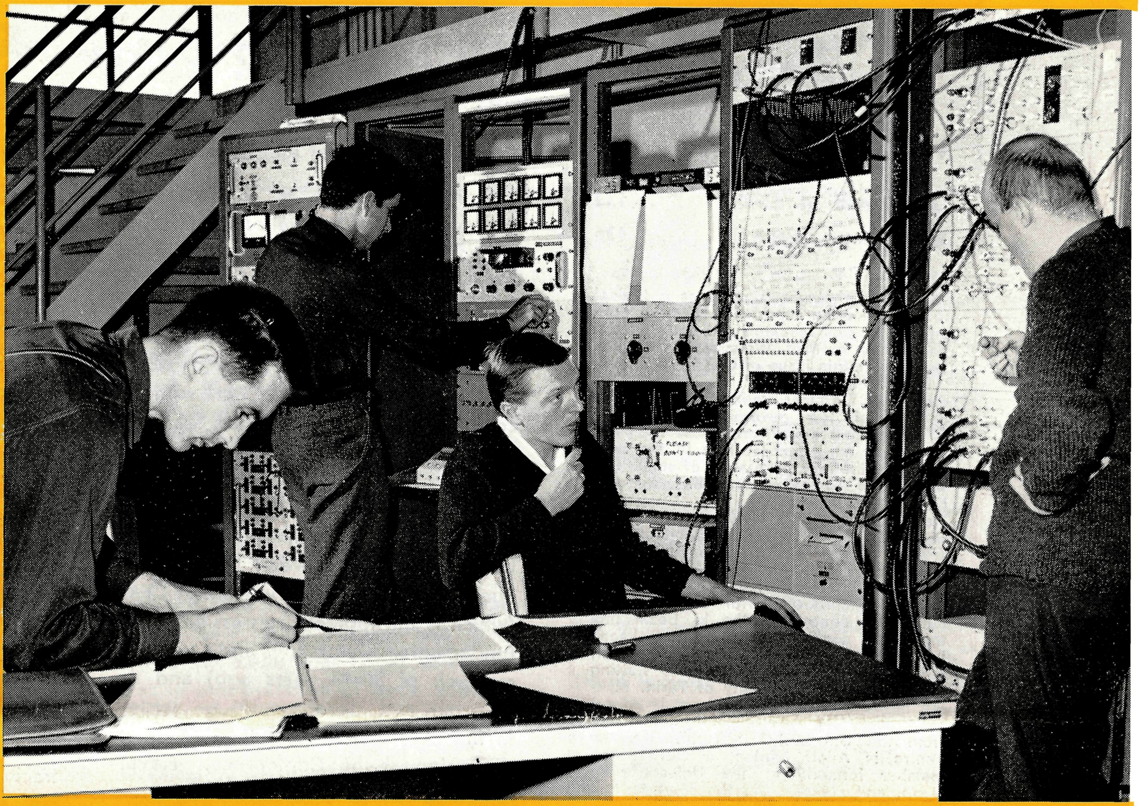
CERN COURIER



CERN/PI 194.10.64

10
VOL. 4
pp. 133-148

October 1964

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 (1.96%), Belgium (3.85), Denmark (2.09), Federal Republic of Germany (22.86), France (18.66), Greece (0.60), Italy (10.83), Netherlands (3.94), Norway (1.48), Spain (1.68), Sweden (4.25), Switzerland (3.20), United Kingdom (24.60).
Contributions for 1964 total 107.2 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

VOL. 4 OCTOBER 1964 NO. 10

The cover photograph provides a typical illustration of an important aspect of high-energy physics research and underlines a point made by Prof. Weisskopf in his talk reprinted in this issue of CERN COURIER. " High-energy physics ", he says, " aims directly at the most fundamental questions of the basic laws governing the structure of matter and the universe. It therefore must play an important role in the education of the new generation of scientists, who come to our universities in ever increasing numbers."
Here, four members of the team working with the Saclay/Ecole Polytechnique (Paris) 81-cm liquid-hydrogen bubble chamber are seen on the platform in the North experimental hall of the CERN proton synchrotron, with some of the equipment controlling the k_4 beam line that was constructed to direct kaons into the chamber. Giovanni Borreani, adjusting one of the controls, is visiting CERN from the University of Turin. Making notes on the table in front is Albert Werbrouck, an American physicist also from the University of Turin. In the centre is Adolf Minten, a CERN staff member formerly at the University of Bonn, and standing on the right is Philippe Briandet of the Ecole Polytechnique, Paris (who, incidentally, has recently returned from a 9-months' stay at the Joint Institute for Nuclear Research at Dubna, U.S.S.R.). The photographs taken by the bubble chamber, showing interactions of 700-MeV/c kaons in hydrogen, are being examined by groups in the Universities of Turin, Genoa, and Bari.

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.
The text of any article may be reprinted if credit is given to CERN COURIER. Copies of most illustrations are available to editors, without charge.
Advertisements are published on the sole responsibility of the advertisers.

Published by the
European Organization for Nuclear Research (CERN)

PUBLIC INFORMATION
Roger Anthoine

Editor :
Alec G. Hester

Assistant Editor :
Frédéric C. Maurer

CERN, 1211 Geneva 23, Switzerland
Tel. 41 98 11

Printed in Switzerland

Last month at CERN

3rd U.N. International conference on the peaceful uses of atomic energy

From 31 August to 9 September Geneva was the centre of attention of the whole world, on the occasion of the 3rd ' Atoms for Peace ' conference organized by the United Nations Organization and the International Atomic Energy Agency. Although many people automatically connected CERN with the conference, this Organization was not, in fact, involved directly at all, and members of the Public Information Office in particular spent a considerable amount of time explaining to enquirers the difference between high-energy nuclear research as carried out at CERN (which is the logical progression of the fundamental atomic and nuclear research of 30-40 years ago) and the research and development — largely in the field of nuclear power — under discussion at the Conference. Nevertheless, with so many scientists and journalists in Geneva, CERN could not avoid some degree of involvement. Apart from many individual visitors, two parties of conference participants and a party of journalists were received on different days for a tour of the laboratory and to hear an explanation of its work.

Vth International conference on nuclear photography

The Vth International conference on nuclear photography, which took place at CERN from 15 to 18 September, brought together nearby 150 people from about 20 countries in various parts of the world. Organized this time by CERN, the conference was the latest in a series started by Prof. P. Cuër, of the Department of Particle Physics at the Nuclear Research Centre of Strasbourg, in 1957. His intention was to provide a common meeting ground for the scientists using special ' nuclear ' photographic emulsions in their research and those in industry responsible for manufacturing them.

Nuclear emulsions are basically similar to those used for the film of an ordinary camera, but are usually much thicker and are specially prepared to record the tracks of nuclear particles. Each of these tracks shows up in the emulsion after development as a black line, or a series of black grains, and accurate measurements under a microscope can give information about the particle concerned and any interactions that have occurred.

Nine of the ten sessions into which the conference was divided dealt with various aspects of the use of these emulsions. The opening session, however, was devoted to a fairly new, related subject, that of nuclear tracks in solid-state detectors. In the first part of this session, two papers were read on the detection of charged particles in large single crystals of silver chloride. Among recent advances it has been found that, under suitable conditions, tracks can be made visible in such crystals without any need for ' classical ' processing using developer, fixing baths, etc. One of the most interesting papers of the conference was then given by R.M. Walker (General Electric Research Laboratory, Schenectady, New York), who surveyed the characteristics and applications of solid-state detectors, such as mica, minerals, glasses and plastics. In such substances, it has been found that heavy charged particles leave a trail of radiation-damaged material (visible under an electron microscope) which can be enlarged by chemical etching to such a size that it is visible under an optical microscope. Almost every insulator that has been tried has been found to show such tracks after irradiation with fission fragments, although from the point of view of particle detection and measurement mica is the one that has been investigated most thoroughly. Its main advantage over photographic emulsions is that below a certain rate of energy loss there is no effect, so that the technique should be very useful for studying heavy particles in the presence of a much larger background of lighter particles. One of the more interesting possibilities has arisen from the discovery of tracks already existing in natural samples of mineral, from which the age of the sample can be determined. Ages of several hundred million years have been measured in this way.

Every so often a discovery made in the course of 'pure' research is found to have an immediate useful application in an entirely different field, and the work with particle tracks in plastic films has provided an example. By irradiating a thin film with a beam of heavy ions all having the same energy and then etching it, perfectly round holes of precisely determined equal size are formed. In this way thin plastic sieves with precisely controlled hole size and density can be made, for use in cytological or bacteriological research. Already experiments (in R.M. Walker's Laboratory) have shown that cells of diameter 10^{-3} mm can be easily separated from human blood, using a sieve with holes 6×10^{-4} mm in diameter, and other work is now in progress to provide a method of filtering free-floating cancer cells from the blood of persons harbouring malignant disease, as a means of diagnosis. There is also a possibility that a filter of this kind, with very small holes (obtained by etching for a shorter time), would be of use in virological research. It has already been shown that such filters are capable of separating sodium ions from lithium ions, thus opening up a series of possible applications in chemistry.

The rest of the conference was concerned with subjects more familiar to the users of nuclear emulsions, with many contributed papers covering detailed aspects of the work going on in various laboratories. These papers were presented in nine sessions, under the main headings :

- Latent image formation,
- Preparation of emulsions,
- Properties of emulsions,
- Processing of emulsions,
- Spurious scattering,
- Automation of measurements in emulsions,
- Measurements in emulsions,
- Range, ionization and multiple scattering parameters in emulsion,
- Applications of emulsions.

The earlier sessions were thus devoted more to the actual emulsions while the later ones were biased towards their use in experiments. Among the papers in the first group was a contribution from E. Klein and E. Moisar (Agfa-Gevaert Laboratories), which dealt with the fundamental aspects of growth and shape of photographic silver-halide crystals. Apart from its intrinsic interest this was of particular note because it underlined the mutual interaction between the 'pure' research of high-energy physics and cosmic rays and the 'applied' research and manufacture of nuclear emulsions. As the authors stated in their introduction : "the demands of particle physicists for special photographic emulsions... have caused the manufacturers to develop new emulsion-making techniques and furthermore to learn much about the actual mechanism of crystal growth".

In the session on parameters, further results were presented on two unresolved problems that could affect the precise interpretation of track measurements. Although it is well established that the ionization of a particle, as revealed by the number of 'blobs' per millimetre in the track, at first decreases with increasing velocity of the particle and then rises again after reaching a minimum, there is some controversy about the relationship between ionization and velocity at higher velocities. A number of experiments have indicated that the ionization becomes constant, but others have shown small variations from this 'plateau'. The measurements reported at the conference by F.R. Buskirk *et. al.*, (U.S. Naval Postgraduate School, Monterey, California), give further evidence for the plateau ; they were also interesting from another, more general, point of view since they were made on borrowed emulsion films that had been exposed to 16-GeV pions at CERN in 1960 and developed at Berkeley (California) a few days afterwards. Concerning the other problem, W.H. Barkas, *et. al.* (Lawrence Radiation Laboratory, Berkeley) presented evidence for a small difference in range between positive and negative pions (of energy 1.6 MeV) in emulsion. This supplements their previous measurements on the ranges of sigma hyperons* and indicates that separate calibrations of range against energy may be necessary for positive and negative particles.

Among the more interesting papers in the last session were those dealing with the use of emulsions for measurements of cosmic rays and the earth's radiation belts, by means of satellite and rocket flights. Results of particular interest for high-energy physics were those obtained at CERN and presented by Prof. E.H.S. Burhop (University College, London University), showing that the emulsion and spark-chamber techniques could be effectively combined.** There is hope that in this way positive information could be obtained about the presence of short-lived particles produced in neutrino interactions and about the unknown nuclear excitations that hamper the conclusive interpretation of such interactions in a bubble chamber.

The session on the automation of measurements produced further information on the work being done in this field in Europe, mostly under the auspices of the CERN Emulsion Experiments Committee.*** As with track chamber photographs, the accurate measurement of particle tracks in nuclear emulsions is tedious and time-consuming, and many ideas have been produced for relieving this situation. Some are fairly simple, involving only automatic recording and calculation of the measurements made with a microscope in the usual way. More ambitious

Continued on p. 143

* Mentioned in CERN COURIER, vol. 3, p. 99, August 1963.

** CERN COURIER, vol. 4, p. 86, July 1964.

*** CERN COURIER, vol. 4, p. 54, May 1964. Following the meeting at Amsterdam in April a Sub-committee for automation of microscope measurements in nuclear-emulsion physics was set up. This held its first meeting in Strasbourg on 24 June, and decided that its short-time programme should be limited to the completion of the digitized microscope on which M.A. Roberts is working at CERN. As an immediate measure, a questionnaire was circulated in August in an attempt to compile an inventory of all the different pieces of measuring equipment that have been built in laboratories all over the world, with the hope that they could be shared in suitable cases.

Whilst this issue was being prepared news came of the death in Bologna, on 29 September 1964, of Prof. **Antonio Stanghellini,** Professor of Theoretical Physics at the University of Bologna and member of CERN's Theoretical Studies Division since 1960. An appreciation of Prof. Stanghellini and his work for high-energy physics will be published in our November issue.

This is the second loss that CERN has sustained within a very short time. Not long before we had been shocked to learn of the death of **Anschy Biffiger,** on 19 July 1964, in a climbing accident. He had been at CERN for just over two years and was a popular and hard-working member of the group in the Track Chambers Division building the 2-m bubble chamber. Outside CERN, he was an experienced mountain guide and it was whilst leading a party on the Matterhorn that he was killed by a fall of rock.

Why pure science?

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

This is the text of a talk given by Prof. Weisskopf during the 'Journées nationales des hautes énergies', organized by the 'Institut interuniversitaire des sciences nucléaires' and the 'Société belge de physique' in Brussels last April (as mentioned in CERN COURIER *vol. 4, p. 55, May 1964). It is, in effect, an answer to the question of its title and shows the importance of continued research in the field of high-energy physics, in spite of the increasing cost. Discussing the development of modern physics in our century, Prof. Weisskopf tells how the discovery of the atom, the formulation of the quantum theory, and investigations of the atomic nucleus have revolutionized our knowledge of science and its applications in many fields, particularly those of chemistry, electricity and biology, and led to the growing technology of nuclear power. He then briefly describes the present state of the next stage of this research, the investigation of the nuclear constituents, which is known as 'high-energy' or 'particle' physics and whose future development may have equally revolutionary consequences. Considering the need for particle accelerators producing still higher energies, Prof. Weisskopf mentions the possible link between this work and recent astronomical discoveries, and then goes on to discuss the cost of high-energy physics and pure research in general, a cost which is still not so high, particularly in relation to other expenditure, as one might believe. Finally, he points to an instructive parallel between industrial growth and interest in basic science and concludes that it is fundamental research that sets the standards of scientific thought and creates the intellectual climate in which our civilization flourishes.*

Science is playing an ever-increasing role in our culture, in our life and in the economy of the world. Yet at the same time its results are becoming, for the layman, increasingly abstract and apparently further removed from everyday life. Astronomy is dealing with cosmic cataclysms billions of light-years away; physics with nuclear particles which exist only a billionth * of a second ; biology with macro-molecules containing billions of atoms in specific sequences. Meanwhile, the pursuit of pure science is becoming more and more expensive. The astronomers want huge new radio-telescopes in order to look at strange objects at the edge of the universe ; probers of outer space want ever more expensive gadgets for the exploration of realms far removed from us ; physicists want more money in order to find out more about the innermost structure of the atomic nucleus. The amounts of money earmarked for pure science are of the order of a billion dollars a year, and the citizen has a right to ask the question : why pure science ?

It is our aim here to defend one special kind of pure science : the physics of elementary particles, the branch of physics that looks for the fundamental constituents of matter. It is a very expensive branch; it needs those huge accelerators known under the name of cyclotrons or synchrotrons, machines of enormous dimensions and cost. The largest existing machines are in the Brookhaven National Laboratory on Long Island near New York and at the laboratories of the European Organization for Nuclear Research (CERN) in Geneva. These accelerators produce beams of protons with an energy of about 30 billion electronvolts, and cost about 30 million dollars each. They are already considered obsolete and will soon be replaced by machines of about ten times that size.

Any intelligent discussion of the impact of pure science in our society must be based upon knowledge of the development of modern physics in our century and of the role of the study of elementary particles in the history of science in general.

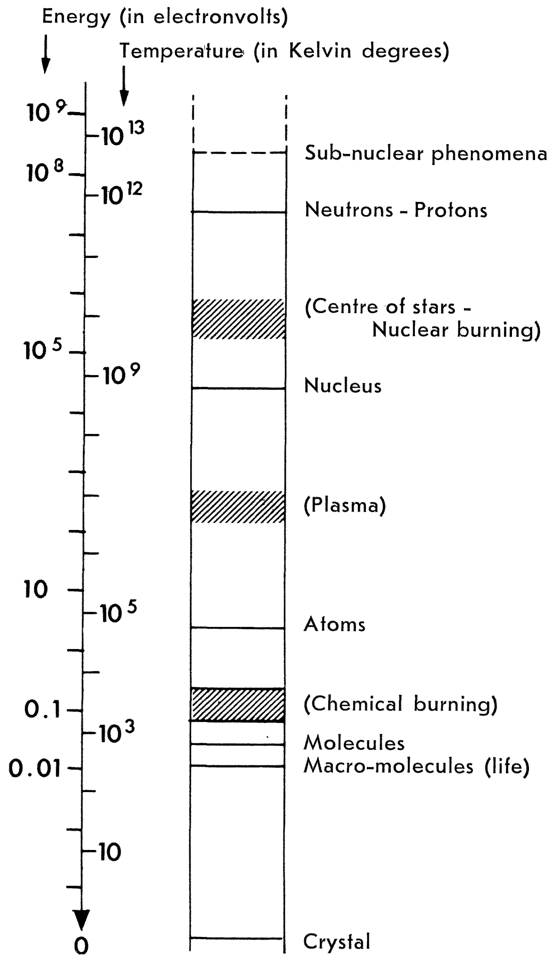
Natural science is centuries old. Physics, the most advanced of the sciences, has developed considerably since its beginning. Broadly speaking, one can say that physics in the eighteenth century was essentially mechanics. It gave us the steam engine and other mechanical devices. The nineteenth century was the age of electricity and its well-known technical applications. The twentieth century is the age of atomic research. The development of this research has been so rapid that it is often difficult to see the whole picture in perspective. This lack of perspective explains perhaps why high-energy physics is often misunderstood. In order to try to see the problem more clearly, we shall divide the development of atomic research into three parts.

* 'Billion' is used here in its American sense of 'thousand million'.

The atom and the quantum theory

Today everyone knows that the atom consists of a very small but solid atomic nucleus with electrons revolving around it. The first step in atomic research was to recognize the existence of the outer electron shell and to study its laws. The essential advance which made this possible was the conception of quantum theory. It was recognized that there is a basic stability in certain characteristic configurations of the electron shell which endow the atoms with their specific properties ; this stability allows the atom to change energy only in well-defined quantum steps. These quantum properties of atomic electron configurations were found to be intimately connected with the wave nature of electrons. In fact, the properties of the electron shell could all be explained and predicted by considering the combinations and the interplay of characteristic electronic wave patterns, which follow from the quantum theory of electron waves. It is hardly too much to say that it was the quantum theory that gave us the key to the understanding of most of the phenomena which surround us on earth, and therefore also the tools to control them.

One cannot exaggerate the importance of the quantum theory and of the discoveries to which it led. From a philosophical point of view, it can be said that the knowledge of what goes on in the electron shell of the atom gave us a basis for the understanding of chemistry, that is a basis for the understanding of the constitution of all the substances which make up the



The successively greater energies (or higher temperatures) associated with successively smaller constituents of matter can be seen from this ' quantum ladder '. The horizontal lines represent stable states of matter which, generally speaking, can in each case be changed only by the application of higher energies. The shaded portions show the intermediate regions where energy transfers take place. Knowledge of atomic structure has given a deeper understanding of chemical processes ; the discovery of the nucleus and of neutrons and protons has led to the practical applications of nuclear energy, and further investigations should lead to a better understanding of the interactions involved. Perhaps, above the top of this ladder, there are new ' fundamental particles ' that may explain the sub-nuclear phenomena now being studied in the world's high-energy laboratories.

world that surrounds us — metals, solid bodies, gases and fluids. It has also enabled us to understand electrical phenomena, the relation of matter with light, the colours of things and the emission and absorption of radiation. It also led to an understanding of production of energy by fire, electricity and chemical processes. The knowledge of the electron shell has also given us the key to the understanding of biology. It is very probable that the problems of heredity, of biological differentiation and of evolution are all connected with the question of the quantum nature of molecular structure.

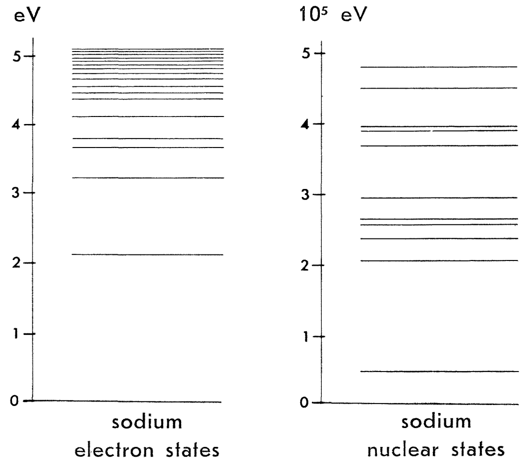
From a practical point of view, it is certain that every industrial activity today is affected in one way or another by atomic science ; modern production of power is based on a thorough analysis of the underlying atomic processes. Electronics, the science of communication, could not exist without a knowledge of the quantum nature of electron motion. Modern metallurgy makes use of the quantum structure of metals and the production of plastic materials would be impossible without modern quantum chemistry. The understanding of the electron structure of the atom gave us the means of control of our terrestrial environment.

The basic force which keeps the electrons together in the atom — and which, therefore, is responsible for the atom's quantum structure — is of an electrical nature. This force is the power of attraction between the atomic nucleus and the electrons which surround it. The atomic nucleus plays the part of a solid charged core at the centre of the atom. The internal properties of the atomic nucleus need not be known to understand the atomic phenomena which we have mentioned so far.

The nucleus of the atom

This brings us to the second period of atomic research, concerned with the nucleus. To understand the significance of this second step it is necessary to keep in mind a basic law of nature, a quantum law, which states that the smaller the object being studied, the higher must be the energy used to penetrate into that object. This law, which is far more fundamental than it may sound when formulated in these terms, means that, for the study of atomic phenomena as we observe them in our environment, the structure of the nucleus itself is not important since, at the energies usually found on earth — for example, when we strike a match or light a fire — the nucleus is not involved : it merely remains the charged core of the atom. Physicists could approach the investigation of the structure of the nucleus only when sufficiently high energies became available to enable them to penetrate into the realm of very small dimensions. Such energies range from a hundred thousand to millions of electronvolts ; they are larger by far than the energies which atoms are usually exposed to on earth. One might have obtained energies of this magnitude from radioactivity as supplied by nature, but the really systematic development of nuclear research only became possible when artificial particle accelerators of this energy level could be built. This took place in the early thirties. It then became possible to discover the structure of the nucleus and it was found that nuclei are composed of particles, namely protons and neutrons. What was even more important was the fact that there exists a new kind of force keeping these two constituent parts together. This nuclear force is a new discovery ; it is different from the force of gravitation and from the electromagnetic force, which were already known. A new physical force was thus identified. The investigation of the structure of the nucleus proceeded as instruments became available. It became clear that the laws of quantum mechanics which govern the electron shell are also the laws of nuclear structure, if allowance is made for the fact that the motion of electrons is governed by the new nuclear force instead of electric forces. It was a great success for the quantum theory that it should also be applicable to the nuclear world.

Let us once more try to describe the significance of this second phase of atomic research from a philosophical and a practical point of view. The philosophical significance (if the term may be used in this context) lies in the discovery of a new force in nature, and a new world of phenomena. The latter includes nuclear reactions, the transmutation of a nucleus of one element into one of another, the excited states of a nucleus whose study has led to nuclear spectroscopy analogous to atomic spectroscopy. It also includes



This diagram shows, on the left, the various quantum states of the sodium atom and, on the right, those of the sodium nucleus. In each case the states are represented by horizontal lines, and the energy of each state is given by the vertical scale, in electronvolts for the atom and in units of a hundred-thousand electronvolts for the nucleus. Future discoveries may one day lead to a similar drawing (on a still larger energy scale) for the nucleons contained in this and all other atomic nuclei.

radioactive phenomena, artificial radioactivity, fission and fusion. Furthermore, it was found that nuclear processes are responsible for the energy production in the sun and in the stars. The age-old question of where the sun gets its power from was solved. There is a nuclear fire burning in the centre of stars such as our sun, in which hydrogen is burned to helium, much in the same way as carbon is burned into carbon dioxide in the ordinary chemical fire ; only here we are facing nuclear reactions instead of chemical ones, for which the energy turnover is a hundred-thousand times larger. Moreover, the study of nuclear processes led to an understanding of the history of the universe. It could be shown that the elements were formed in the centre of stars and in star explosions. The history of matter could be traced from an original hydrogen cloud to its present forms.

The practical side of all this is well known. We know that, contrary to all expectations, nuclear physics has not remained an esoteric pure science but that it has eminently practical applications. In nuclear reactors, the fission of the nucleus has been turned into an outstandingly productive source of energy. It warrants the hope that the nuclear fusion process, which takes place in the stars, will also some day find a practical application. Furthermore, artificial radioactivity, which was a consequence of this development, has opened up a whole new field in medicine and in science as a whole, from biology to metallurgy.

Nucleons in the nucleus

Now for the third stage of development. The nucleus consists of protons and neutrons. What do these elementary particles consist of ? What is their structure ? Because of the law already mentioned above, it is necessary to use substantially higher energies in order to penetrate into the structure of these particles. One can get a glimpse of the structure of these particles only if energies a thousand times higher than those required in the second stage are available. Consequently, it is necessary now to have machines, or natural energy sources, which give us thousands of millions of electronvolts. There is a natural source of energy of this order of magnitude — cosmic radiation. But cosmic radiation, like natural radioactivity in earlier days, is too dispersed and too difficult to control to be useful as a systematic tool of research. Accelerator techniques, on the other hand, have been developed to such an extent that they can provide thousands of millions of electronvolts, and we now have accelerators of this energy capable of accelerating particles up to 10, 25 and 30 billion electronvolts. From a technical point of view there seems to be no reason why one should not be able to build accelerators producing a hundred-thousand million or one million million electronvolts.

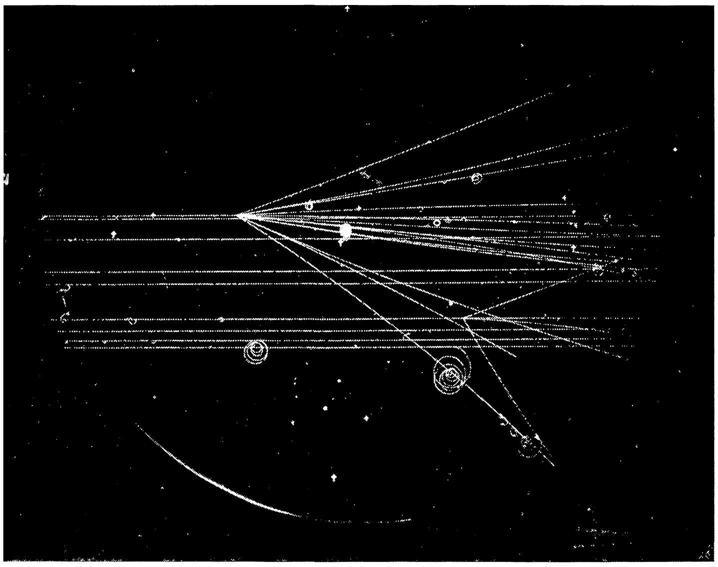
What is the outcome of this third stage of research ? One cannot furnish a systematic description of it as for the first and second stage, because we are still at the beginning of this third period. We are still unable to formulate the results in a simple way ; we cannot as yet assess their full philosophical and practical significance. Nevertheless, it seems obvious that, from the 'philosophical' point of view as we understand it, some very great perspectives are opening up. We are beginning to understand the real nature of this new force, the nuclear force, which acts between protons and neutrons. We are faced with entirely new phenomena and are perhaps approaching what might be called the primeval history of matter. We are now approaching the problem of the fundamental structure of matter. Perhaps such research will produce answers to the major questions that are still unanswered : the expansion of the universe, gravitation, the origin of matter. We cannot, at this stage, speak of practical applications ; they are still remote. All we can offer at the moment is a description of phenomena — not a systematic classification, certainly not yet an explanation or a formulation. The phenomena which we can describe may be divided, somewhat arbitrarily, into four groups.

The first group is concerned with nuclear force quanta. We are now trying to discover what the nuclear force is. It is in many respects very different from the electromagnetic force, but it is interesting to see that it has some points in common with it. Just as there are quanta of light, the quanta of electromagnetic force, there are also quanta of nuclear force. They have been found and are called mesons. Their properties, the way in which they are emitted and absorbed and allied matters, now lie at the centre of our research. By making high-energy particles strike a target we can observe the consequent radiation of nuclear force from the target.

The second group of phenomena concerns the higher, excited states of the 'nucleons', as we call the protons and neutrons. When protons and neutrons are subjected to very high energies, they pass into states of higher energy, remain there for some time and then return to their ground state, like atoms. In doing this they emit a characteristic radiation which in most cases is not light but is mesonic radiation. We may, in this connection, speak of a third spectroscopy — the first being atomic and molecular, the second nuclear, and the third that of the nucleons or elementary particles — that is, the systematic study of the excited states of protons and neutrons.

The third category of phenomena in high-energy physics is connected with antimatter. By using the high energies now at our disposal it is possible to make matter out of nothing — to turn energy into matter. In the course of these transmutations it has become apparent that matter can only be produced together with antimatter. Antimatter does not differ from matter in any respect except that its pattern is reversed. The nuclei are negative instead of positive, the electrons are positive instead of negative ; all the constants, including the nuclear-force constants, are reversed. The picture as a whole is not very different from that of ordinary matter. But what is interesting is that antimatter and matter are produced together from energy and that when brought together antimatter and matter turn back into energy and mostly energy of a very special kind, namely nuclear-force quanta. Today's largest accelerators are providing us with beams of pure antimatter with which we can perform very interesting experiments in order to study the process of the transformation of matter into energy.

One of the most interesting fields of research, which concerns the fourth category of phenomena, promises much for the future. It is the field of weak interactions. Weak interactions are known to us through radioactivity. The usual radioactive decay, the beta decay, is the best-known example of a so-called weak interaction. It is a process which takes place in the nucleus, whereby a neutron is transformed into a proton and in so doing releases an electron and a so-called neutrino, that mysterious particle without charge or mass. Many such weak interactions have been found, not only those of radioactive decay but also more complicated ones. All seem to have a similar character. They are the interactions of electrons and neutrinos with neutrons and protons. It has been found that these electrons and neutrinos may, in some ways, be linked together and indeed may only be two different forms of the same particle, the so-called lepton. Furthermore, we have discovered that there is a heavy electron, known as the muon, which differs from the ordinary electron exclusively by its mass but is short-lived and decays into the ordinary electron. None of these phenomena is yet quite clear, and we may be faced here with a new force. Besides gravitation, electricity and the nuclear force, there may perhaps be this fourth force of nature, and this investigation is naturally the centre of interest. The two largest accelerators are now equipped with neutrino beams of high intensity. In 1962, in Brookhaven, it was established with the aid of such a beam that there are two kinds of neutrinos. We may discover the quantum of this new force, thus opening up very great perspectives in our study of nature.


CERN/SIS 12016

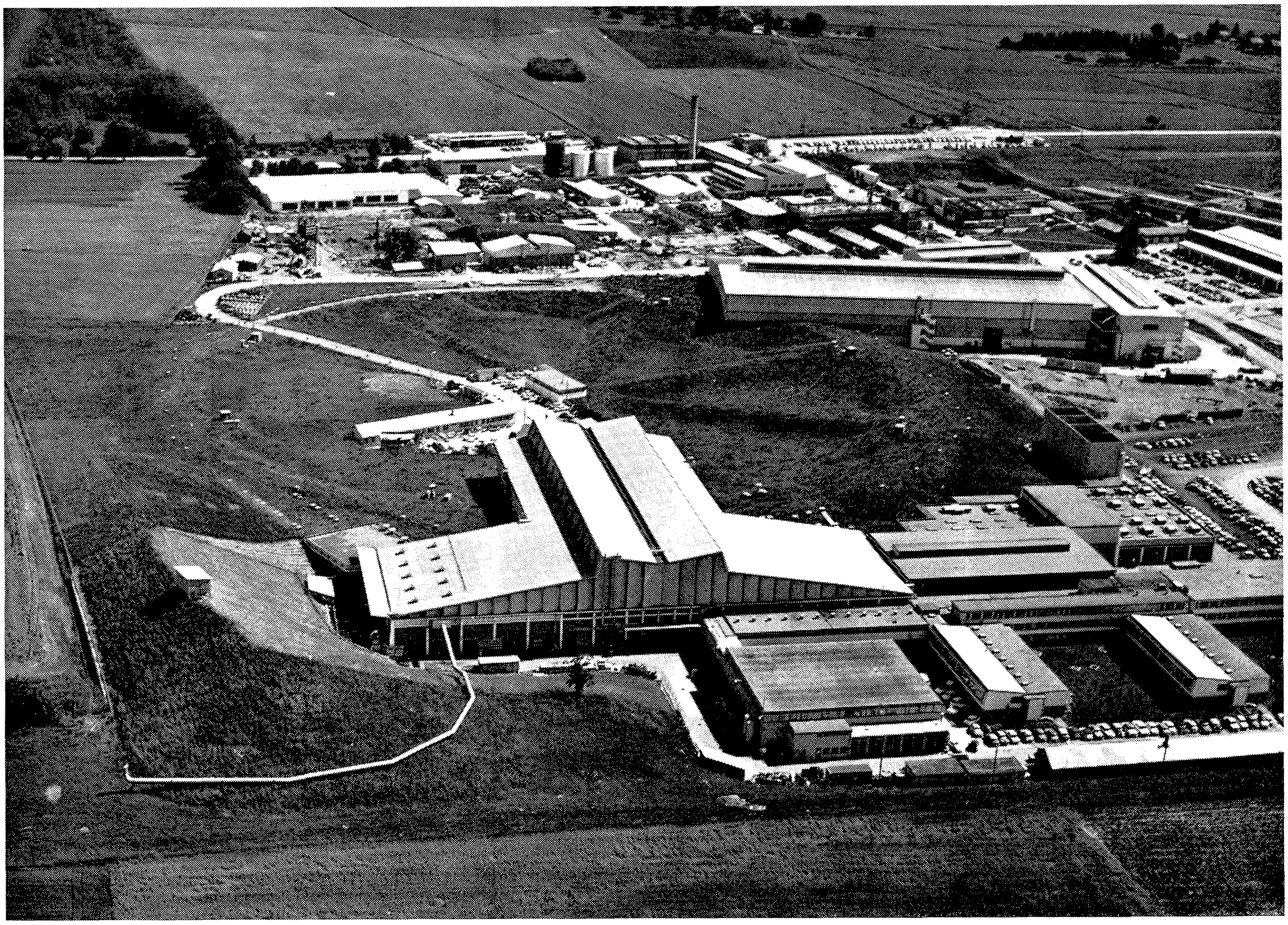
Although the particles investigated at CERN are far too small ever to be seen as such, their tracks can be made visible in various ways. This photo, taken with a liquid-hydrogen bubble chamber, shows protons travelling from left to right. Two of them have interacted with protons of the hydrogen, producing many pions, or particles of the nuclear force.

This is the briefest outline of some of the phenomena which appear in the third and latest phase of atomic research. It is clear that we are at the very beginning of this development, which is going to be most extensive. After all, the field is relatively new — the large accelerators have only been available for about ten or twelve years. Moreover, although these machines are described as 'large', they are not really large enough for the study of the phenomena in question. The energy now available, about thirty billion electronvolts, is just enough to produce the excited states of the nucleons and just enough to produce nuclear force quanta ; for the weak-interaction experiments it is close to the lower limit. The energies at our disposal are simply too small to probe into these very short distances. Accelerators of much higher energy will have to be built before really striking progress can be achieved in this new field.

The next step

In fact physicists in all countries are currently discussing what kind of accelerators should be constructed in the future. As pointed out before, from the technical point of view, there seems to be no immediate limit to the energy that can be reached. The largest machines today are the 33-GeV Brookhaven accelerator (GeV, or BeV in the U.S.A., is an abbreviation for a billion electronvolts) and the 28-GeV CERN machine ; a Russian machine of 70 GeV is being built and will probably be ready in two or three years. European physicists, after a very full discussion, have proposed that a machine of about 300 GeV should be constructed. Such a machine — which would be about ten times larger than present ones — would put us in a better position to study many of the problems mentioned here and to produce the phenomena more completely than we can with our present instruments.

Moreover, European physicists propose to build an extension to the CERN machine. This extension would consist of so-called storage rings. These would really constitute a second machine placed beside the existing one and into which the beam could be directed and stored. The beam will be injected in two directions, once round one way and the next time round the other way ; it would be possible, at chosen places on these rings, to let the two beams collide and thus not only to double the energy, as one might reckon at first, but to increase it by a factor of about 50 ; those who understand the theory of relativity will see why. Of course, the number of lucky hits one can expect when two beams collide is not very high because the beams are highly rarified matter. Nevertheless, it would be possible to make a certain number of experiments at a very high energy.



CERN/PI 44.6.64

The proton synchrotron at CERN, which accelerates protons to an energy of 28 thousand million electronvolts, for investigating the structure and properties of fundamental particles. Looking rather like a giant cartwheel partially buried under the earth, this machine has a mean diameter of 200 metres. In the centre foreground are the North and South experimental halls, with the adjoining laboratories, offices, and equipment buildings ; on the other side of the ring the East experimental hall leads off tangentially to the bubble-chamber building. Other CERN buildings can be seen in the background.

The American programme is much more ambitious than the European one. American scientists are thinking in terms of a 600 to 800-GeV machine and also of machines of lower energies, in particular an accelerator of 200 GeV. Ways and means are being discussed not only to reach higher energies but also greater beam intensities. If all these proposals are put into effect, a tremendous step forward will have been made in this field of physics which is the most fundamental of all.

One might now ask : is there any real sense in building ever larger machines ? Shall we ever come to an end ? We are now in the third phase of atomic physics and perhaps we shall again discover particles of particles so that we shall have to build accelerators of yet higher energies to investigate the structure of those particles of particles. And every time the machines cost more. Is there an end to this process ? That is a very difficult question to answer. Perhaps the time to stop is when the field will cease to be interesting. If we are very clever and very lucky, the discoveries made with the present machines and with the next 'generation' of machines may enable us to discover a basic law of nature to explain all phenomena. Then probably, yet another generation of accelerators will be needed to prove that conclusion. If we understand everything, the field will lose its interest : it will be closed. On the other hand, we may never be able to understand everything. In that case two possibilities would arise : either we continue to find new phenomena connected with nature and the history of nature and with our place in the universe — this would be interesting, and we probably ought then to be prepared to go further and further still ; or no new phenomena of significance appear, and this would be uninteresting. Nature so far has never been uninteresting ; in fact, recent astronomical studies have revealed the existence of galaxies in which tremendous explosions are taking place, whose energy is many million times higher than any ordinary nuclear process could explain. It would not be surprising if these phenomena are connected with the newly discovered world of mesons and excited nucleons. Such problems come close to the essential issues connected with the evolution of the universe, with the fundamental structure of space, time and matter, and with the question " why is matter what it is ? " The answers to these questions are already coming into sight today ; perhaps they will do so more clearly in the next few decades.

The cost of pure research

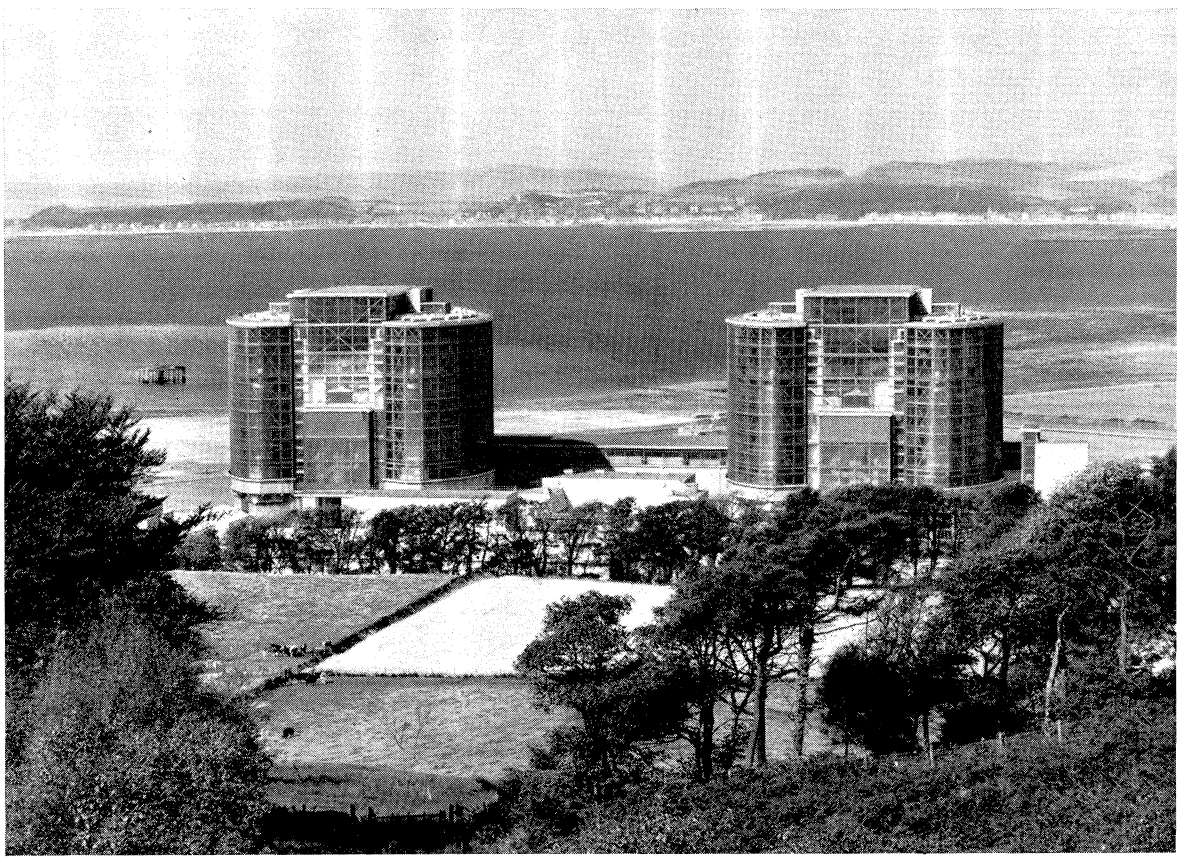
The practical side of the question is, of course, the question of money. Should a government be responsible for spending so much money on such a pursuit ? Why devote money to fundamental research ? There is a story about Faraday in 1800, just after he had made his first electrical experiments. It so happened that a member of the government visited him and asked what was the point of all the things he was doing. Faraday answered : " I do not know, but I am sure that your successors will some day levy a tax on it ". It is probable that the same thing will happen one day with today's fundamental research. It is useless to speculate on the way in which mesons and neutrinos can be used in practice. This is not how things work. Basic and fundamental ideas are not those which have practical applications. Faraday's experiments led to Maxwell's equations and the application of these theories then produced the electrical industry. The ideas and methods which develop from fundamental discoveries — which indeed are derived from them — are the elements which bring about technical progress.

Expenditure on pure research is very difficult to estimate. Pure research means research that bears no relation to any kind of applications : for instance, transistor or reactor research is not pure research. Pure research is the fundamental research described above ; it also includes basic biological research, astronomical research or research into the structure of different forms of matter, such as solids, liquids or plasma. Today the totality of pure research, not only high-energy physics, absorbs about one-third of one per cent of the gross national product in America and almost as much in both France and England. One-third of one per cent of the gross national product is a small fraction ; today it represents about $ 2000 million in the U.S.A. and about $ 1000 million in Western Europe. This is less than 10 % of the yearly growth of the gross national product. It is interesting to contemplate that the total expense for basic science from Galileo to the present time is not more than the increase of the world's production in one year. In ten years, the gross national income is bound to increase by 40 per cent or more. The percentage devoted to pure research is also going to increase, since the number of scientists grows steadily and the scientific methods are getting more involved and more complicated. One should therefore expect at least twice as much money to be spent on pure research in ten years than now.

High-energy physics is a relatively new part of basic physics which is now in a state of rapid development, in particular in Europe, where there was a slow and inactive period in the years after the war. It 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 therefore must play an important role in the education of the new generation of scientists, who come to our universities in ever-increasing numbers. The scientists working in high-energy physics cannot help the fact that their instruments are more expensive than the means of research in most other fields of basic science. They are, after all, investigating matter under most unusual circumstances. Is it then asking too much if the physicists request a substantial increase in financial support for this field of activity ?

The cost of high-energy physics is in fact not as high as one might believe. Western Europe spent in 1963 about $ 80 million in this field, and the United States about $ 200 million. The new research instruments, if they are ever built, will be more expensive. For instance, a 300-GeV machine would cost about $ 300 million altogether, while expenditure would be spread over roughly ten years, the time necessary for its construction. Assuming that the plans for new machines are approved, that these machines are built, and that ancillary equipment to exploit them and to train physicists in the universities is available, what would the yearly expenditure be when the programme is in full swing ? At the beginning, expenses are naturally less and then they reach a kind of plateau. At this plateau stage, in about ten years from now, the European plans would require about $ 250 million and the American plans about $ 500 million per year. This

Photo: The General Electric Co. Ltd. of England, No. 64-1034



The fundamental science of thirty years' ago has led, among other things, to the modern industries dealing with nuclear power and the applications of radioisotopes. Illustrating the former is this nuclear power station in Scotland, completed this year and at present the largest in the world. It has a power output of over 320 000 kW, and instead of burning 73 000 tons of coal each month it needs only 10 tons of uranium fuel.

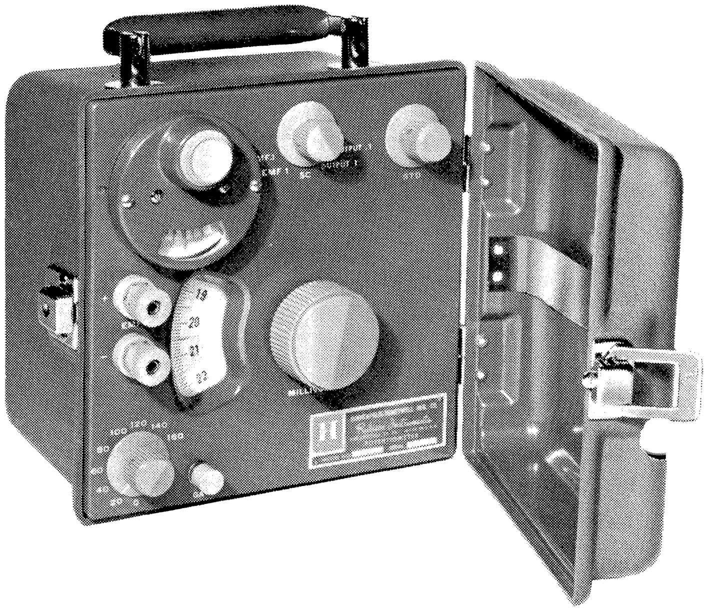
rate of expenditure for high-energy physics would amount to not more than twelve per cent of the expected total expense for pure research, a percentage that does not seem extravagant.

Basic science and industrial growth

When studying the development of industrial nations, one cannot fail to make the following observations : in the first half of the nineteenth century, England was the great industrial nation and, at the same time, England produced the great names in fundamental research : Maxwell, Young, Faraday, etc. Then, in the second half of the nineteenth century and at the beginning of the twentieth, Germany began to play a leading part. It is then that one finds a galaxy of German physicists : Helmholtz, Nernst, Röntgen, Planck, Sommerfeld, Heisenberg, etc. Later in the twentieth century, as America became the leading industrial nation, fundamental science blossomed out in America. Fermi, Oppenheimer, Lawrence, Rabi, McMillan, Alvarez, Schwinger, Feynman are only a few names illustrating this. There is a clear connection: where there is industrial growth there is basic science, and where there is basic science there is industrial growth.

The value of fundamental research does not lie only in the ideas it produces. There is more to it. It affects the whole intellectual life of a nation by determining its way of thinking and the standards by which actions and intellectual production are judged. If science is highly regarded and if the importance of being concerned with the most up-to-date problems of fundamental research is recognized, then a spiritual climate is created which influences all other activities. An atmosphere of creativity is established which penetrates to every cultural frontier. Applied sciences and technology are forced to adjust themselves to the highest intellectual standards which are developed in the basic sciences. This influence works in many ways : some fundamental-research students go into industry ; the techniques which are applied to meet the stringent requirements of fundamental research serve to create new technological methods. The short-time technique that was developed in high-energy physics deserves to be recalled. The style, the scale and the level of scientific and technical work are determined in pure research ; that is what attracts productive people and what brings productive scientists to those countries where science is at its highest level. This is why so many good scientists have moved to America from Europe in the recent decades.

Fundamental research sets the standards of modern scientific thought ; it creates the intellectual climate in which our modern civilization flourishes. It pumps the lifeblood of ideas and inventiveness not only into the technological laboratories and factories, but into every cultural activity of our time. The case for generous support for pure and fundamental science is as simple as that. A small part only of a nation's total income is needed to keep fundamental research in full swing. It would be wrong to try to save a fraction of this small part if such savings weakened the most vital and active part of our intellectual life, the part which we all should regard with pride as one of the highest achievements of our century ●



Last month at CERN (cont.)

schemes aim at completely automatic track following and measurement. At the conference, papers on both approaches were presented, the second being typified by the report of M. J. Duff (University College, London University). He and his co-workers have produced apparatus which enables the microscope to follow tracks through the nuclear emulsion, at a speed of up to 7.5 mm per min. and with an accuracy of 10^{-3} mm in any of the three co-ordinates. More interestingly, they have developed an electronic logical control circuit by means of which every function of the microscope (for example, 'move stage left', 'focus') can be initiated simply by applying an electric voltage to the appropriate terminal. The ideal at which they are aiming is completely automatic scanning of a prescribed volume of emulsion, looking for tracks satisfying certain requirements and following them until they stop or leave the emulsion, at the same time recording appropriate measurements in a form suitable for computation.

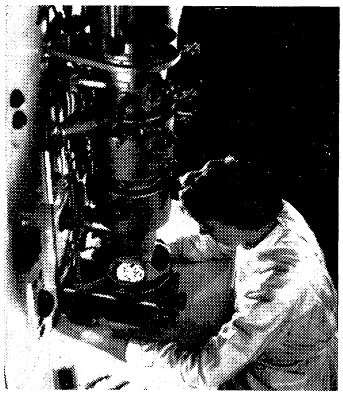
Experiments at the PS

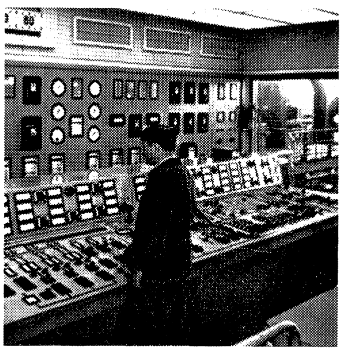
Since the last report in *CERN COURIER* (August) ten main physics experiments, using counters and spark chambers, bubble chambers, or emulsions, have been progressing at various times at the proton synchrotron, as well as exposures for nuclear chemistry and various beam tests. After being comparatively low during the first fortnight of August (on average, 'only' 7.3 × 10^{11} protons per pulse !) the beam intensity regained its new high value in the second fortnight and a record average of 9.5 × 10^{11} protons per pulse was achieved for that period. The accelerator is now running regularly with intensities of this order, and the temporary 'multiply by two' signs on the digital display meters have been replaced by a range switch enabling the current to be indicated up to 999 × 10^{10} protons per pulse instead of 99.9 × 10^{10} as formerly.

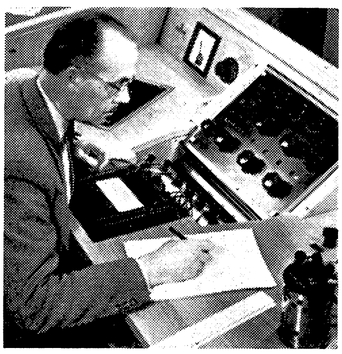
In the early part of August the long d_{17} pion beam line in the South experimental hall was further extended, this portion being known as d_{17a}. The **charge-exchange** experiment using a similar pion beam in the East hall finished its run at the beginning of September, after three days during which many different energies, between 10 and 20 GeV, were asked for from the PS operators.

During the first fortnight in September, in fact, a large number of short experiments were carried out, involving frequent changes of operating conditions and hence a greater load than usual on the operators. Seven different targets were in use altogether, as well as the fast-ejection system, set sometimes to give one bunch of protons in the external beam, sometimes all twenty. The single bunch was used for tests of the radiation 'background' in connexion with the planned new experiment on the magnetic moment of the muon ; the full ejected beam was used for two short test runs of equipment. Another short run checked the use of the fast kicker magnet of the ejection system (without the ejection magnet) to produce a short pulse on the internal target for the o_2 beam, in connexion with later tests of the radiofrequency particle separator.

In the second fortnight of September the two **liquid-hydrogen bubble chambers** were again in operation together. The 81-cm Saclay/Ecole Polytechnique (Paris) chamber gave 50 000 photographs of stopped antiprotons, 30 000 photographs of slow antiprotons and 30 000 photographs of stopped positive kaons, all in deuterium (heavy hydrogen). The 152-cm British chamber collected 108 000 good pictures of 6-GeV/c negative kaons in hydrogen ●







Staff Vacancies

at CERN

Applications are invited from citizens of CERN Member States to fill vacancies in various parts of the Organization.

There are vacancies in the three following main groups for :

— **Graduate physicists, mathematicians and engineers** with post-university experience in techniques such as computer programming, data handling, electronics, vacuum, electro-magnets, radiofrequency, high voltages, electron optics and pulses.

— **Qualified technicians** to help physicists and engineers in the performance of work in the branches mentioned above.

— **Secretarial staff.** There are excellent career opportunities for younger persons who already possess a good working knowledge of English and French and who have typing and / or general office experience.

CERN offers attractive salaries, generous leave, and substantial special allowances and benefits.

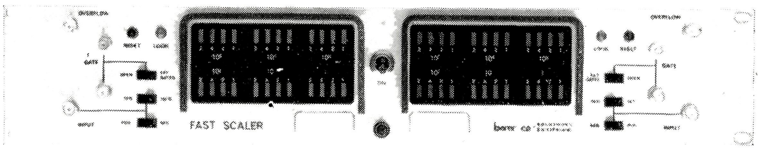
Present staff members are invited to bring this notice to the attention of suitable potential candidates.

Application forms may be obtained from

Personnel Division (CC/64/9), CERN, Geneva 23, Switzerland

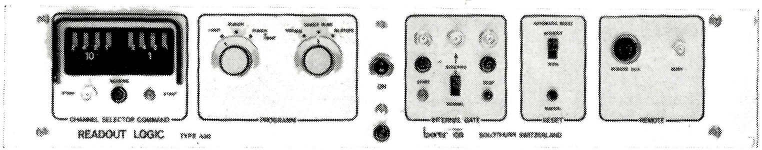
The Borer + Co Scaling and Readout System Now quickly available

These are some modules of our outstanding automatic scaling and readout system



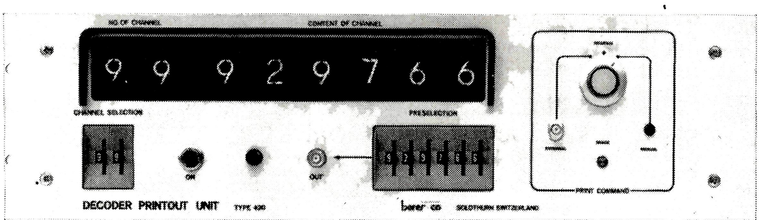
Fast Double Scaler Type 400

Double scaler with incorporated readout facility and power supply.
Counting rates up to 40 Mc/s.
Gating and coincidence input.



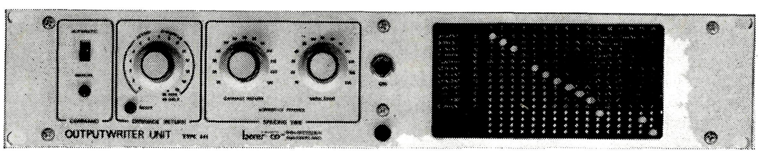
Readout Logic Type 430

Readout logic controlling automatic data collection via a printer, a tape punch or an electrical typewriter for up to 98 channels.



Decoder Printout Unit Type 420

Decoder printout unit for displaying and preselecting the content of a reference channel. During automatic readout all channel contents are indicated subsequently. Any one information may be shown be depressing an associated push button.



Output Writer Unit Type 441

Output writer unit for a very versatile programmation of the data output by an electrical typewriter. The unit may be adapted to other applications.

ELECTRONIC borer + co - SOLOTHURN SWITZERLAND

Borer + Co — 4500 Solothurn — Heidenhubelstrasse 24
Telephone (065) 2 85 45. Cables: Borelectronic. Telex: 34228

Our system of scaling and automatic readout was developed from a basic design of CERN's electronics group.