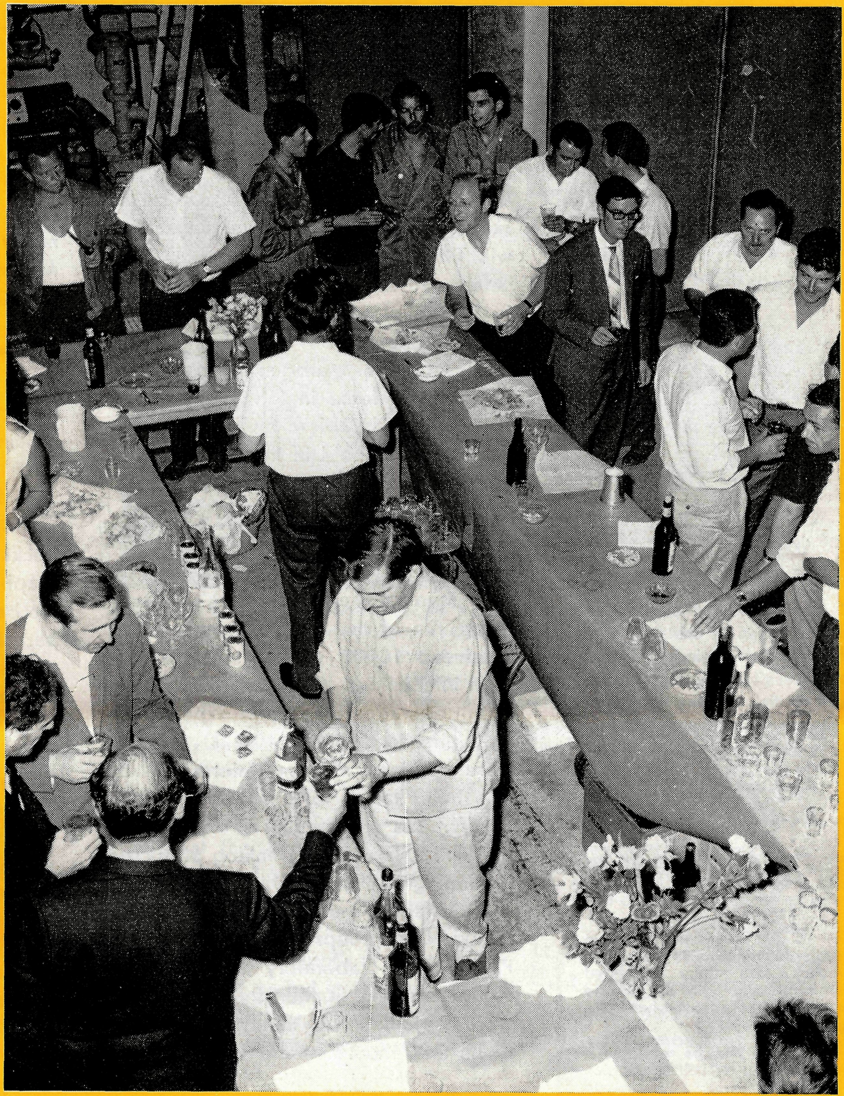
# CERN COURIER



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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.'**

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**The cover photograph** shows a minor result of a successful series of experiments with a new piece of equipment. At the end of the day on 27 July, one end of the East bubble-chamber building was cleared of construction equipment, the bottles and glasses were laid out, and people from many parts of CERN as well as the ' visitors ' from England gathered to toast the successful completion of the first run by the British National Hydrogen Bubble Chamber. For further information about the run, see under ' Last month at CERN ' on this page.

**CERN COURIER**

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# Last month at CERN

### ' HBC 152 ' finishes first run

On 27 July the group operating the British 152-cm hydrogen bubble chamber, and those who had been associated with its installation and use at CERN, celebrated the successful completion of its first run, with over a quarter of a million photographs to their credit. Because of the hydrogen safety regulations still in force in the ' British ' end of the East bubble-chamber building, the party was held in the ' CERN ' end, in the shadow of the big 200-cm chamber still under construction.

As mentioned in *CERN COURIER* last month, the first week's ' technical ' run of the 152-cm chamber also produced 10 000 pictures of positive-pion interactions. In the first two weeks of full operation for physics experiments (25 June to 5 July), 100 000 pictures were obtained showing interactions of negative kaons of momentum 5.08 GeV/c. This (experiment T 49) was for the ' $K^-$ collaboration ' linking physicists in Birmingham, Glasgow, London (Imperial College) and Oxford Universities as well as groups at the Rutherford High Energy Laboratory and the Max-Planck Institute in Munich. The kaons were obtained by means of the $o_2$ beam line, the 180-metre long arrangement of magnets, collimators and electrostatic separators specially designed by British physicists for use with the new chamber. An average of 15 kaons per pulse was obtained in the bubble chamber, with a ' contamination ' of 7 pions or muons.

In the third week (9 - 14 July) a further 40 000 pictures with $K^-$ at 5.08 GeV/c were obtained and the beam line was then readjusted to give positive kaons at 5 GeV/c for the T 55 experiment, in which groups at Cambridge (U.K.) and Brussels (Belgium) as well as at CERN are collaborating. On the evening before the visit of the British Press, a highly satisfied group of physicists celebrated a collection of 60 000 pictures, each showing about 15 kaons — 10 000 pictures more than they had asked for and including about twice as many interactions as they had expected. After a ten-hours rest to allow some emulsion and nuclear chemistry exposures in the $o_2$ beam, the run ended (15 - 19 July) with another 66 000 pictures for the T 49 experiment, this time using negative kaons at 6 GeV/c. At this energy the performance of the beam line surpassed all expectations and about 60 kaons were obtained at each accelerator pulse, with only a small contamination of other particles, (nearly all muons). This intensity would have given far too many tracks on the bubble-chamber photographs, even with the final magnet in the beam line to distribute the incoming particles across the whole field of view of the cameras. Hence the collimator apertures had to be closed down to reduce the flux again to about 15 kaons per pulse, with a spread in momentum about the mean value of only ± 0.3 %.

### Visit of British Press

On 15 July CERN was host to some two dozen journalists representing newspapers and technical publications in the United Kingdom. The main purpose of the visit, which was arranged by the Department of Scientific and Industrial Research and the CERN Public Information Office was to see the British 152-cm bubble chamber in operation, but advantage of the occasion was taken to obtain a more general view of the work that is done at CERN and the plans for the future.

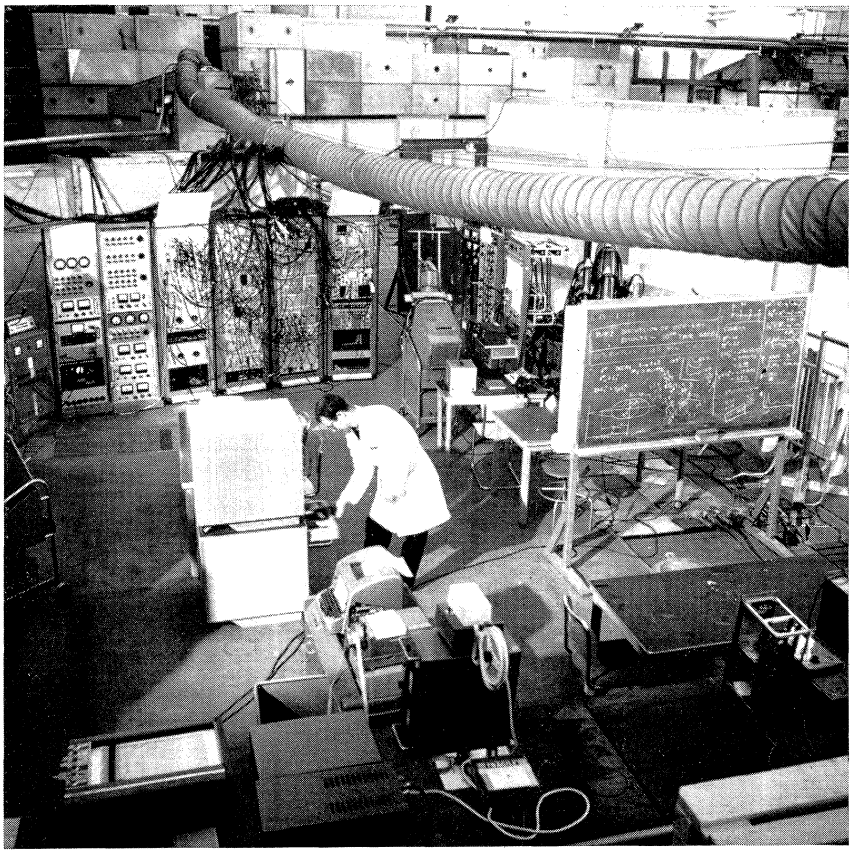
After Prof. Preiswerk, Leader of CERN's Nuclear Physics Division, had welcomed the visitors in the Council Chamber, Prof. C.C. Butler gave an introductory talk on ' What is CERN and where does the BNBC fit into its work ? '

Prof. Butler, who is Head of the Physics Department at Imperial College, London University, began by saying that his audience might find it a little strange to be told about CERN by someone who was also a visitor, but that this was in fact an example of the principle of CERN, as an organization which belonged to all the physicists engaged in high-energy physics research in its Member States. The United Kingdom contributed nearly a quarter of CERN's financial resources, and British physicists could very proudly feel that they owned a quarter of the Laboratory. They could use the facilities of CERN, paid for out of its normal budget, and they could also bring to CERN equipment wholly financed from their own resources. This was the case with the British bubble chamber which the journalists had come to Geneva to see. During their visit they would also see the 81-cm French bubble chamber, which had been at CERN for some years and which had been used not only by the French physicists in charge of it but also for the well-being of European physics as a whole. At Imperial College, for instance, the physicists had analysed very many pictures that had come from the French chamber, just as in return they would send pictures from the British chamber to France and other countries.

Prof. Butler went on to describe the 28-GeV proton synchrotron and its operation, and the purpose of 'fundamental-particle' or 'high-energy' research, before describing the way in which the use of bubble chambers has developed in Europe. He then explained the way in which a bubble chamber works, with particular reference to the design of the British chamber. Finally he talked about the $o_2$ beam line — 'the most sophisticated of its kind in the world' — which conveys particles of the right kind, at the right energy and in the required numbers from the accelerator to the bubble chamber.

After the traditional view of CERN and its surroundings from the roof of the Administration building, the visitors were taken to the East bubble-chamber building. There, as well as being given an explanation of the British chamber and its various controls, they were able actually to look into the liquid hydrogen to see the spray of tracks formed every two seconds as the accelerator was pulsed and the chamber expanded. Then, in the Data Handling laboratories, they were shown some of the photographs being inspected on the new scanning table developed for use with the CERN 2-metre bubble chamber and how the tracks were measured on a 'IEP'.

After lunch the programme began with a visit to the main control room of the proton synchrotron and the visitors' platform in the South hall, followed by a look at the 81-cm bubble-chamber, also in operation, in the North hall. Then came a climb to the upper gallery of the East experimental hall, to view the entire length of the $o_2$ beam line. The visit ended in the laboratories of the Accelerator Research Division, where the electron storage-ring model was presented and explained, and refreshments proved very welcome at the end of a day in which the weather had been more suited to sunbathing than to inspecting a scientific laboratory.



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**Part of the equipment enclosure for the missing-mass spectrometer experiment in the South experimental hall of the proton synchrotron at CERN. In the foreground can be seen the paper-tape punch and electronic typewriter which are operated from the Mercury computer in the Data Handling laboratories ; to their left is an automatic graph plotter also operated by the computer. This equipment allows the physicists to keep a constant watch on the progress of the experiment. The long flexible tube provides ventilation in the area of the hydrogen target and the target can be watched by means of the television receiver seen on the table behind the blackboard.**

### Experiments at the PS

As mentioned above, during the first fortnight of synchrotron operation the **British and French bubble chambers** were in use together. **Emulsion** exposures were made in the $a_8$ beam for trials of the E11a experiment on the magnetic moment of the positive sigma hyperon, and whilst the 152-cm chamber was out of action for some hours during the early part of its run the opportunity was taken to expose two emulsion stacks to about 2 million antiprotons, for the benefit of several French laboratories. (This was in addition to an exposure to kaons which took place later in the run.)

The complex system of spark chambers in the $d_{15}$ beam line was removed during the month, following completion of the experiment on the peripheral production of gamma rays. The beam line was then modified to $d_{17}$ for the experiment designed to carry out a systematic investigation of the unstable mesons (or meson 'resonances'), using the **'missing-mass spectrometer'.** This apparatus, which, incidentally, is of particular interest from the point of view of the development of experimental techniques at CERN, had been moved from the synchro-cyclotron to the South hall of the PS during May. It uses a hydrogen target, together with a collection of sonic spark chambers and scintillation counters to detect the incoming and outgoing particles. The electrical signals from the detection system are registered by electronic scalers, which translate them into numbers, ready for recording (in an electrically coded form) on magnetic tape. The numerical data is also transmitted over a cable, 1.2 km long, to the 'Mercury' computer, which carries out various calculations and transmits the results back to the physicists at the PS. This allows a constant check to be kept on the functioning of the apparatus and, more particularly, on the results being obtained. The progress of the experiment is in fact determined by the kind of results that it gives. This is the first time that an experiment has been carried out at the PS 'on-line' to a computer.

The $d_{17}$ beam line itself is also of note, since its first element is a new **'thin' magnetic lens** of the 'split-pole' type *, specially developed for use in regions of the target area where space is limited. This type of lens, evolved after extensive investigations using 'model' techniques, employs a novel combination of a split pole having sections of different heights with three separate excitation windings, to achieve the required accuracy and value of field gradient. It is only 50 cm wide, compared to 117 cm for the standard quadrupole with the same aperture (20 cm) and similar performance, and 1.5 metres long.

In the second fortnight of synchrotron operation, six different **counter experiments** were in various stages of operation round the machine. These included the missing-mass spectrometer, as well as the well-established **PAPLEP** and **proton-proton scattering** experiments, which are continuing to gather data.

In the South hall, considerable progress was made with the assembly of the apparatus for the experiment (S 30) to determine the **rate of decay of the rho meson into a pion and a gamma ray,** relative to its decay into two pions. The apparatus to detect the decay products includes a number of spark chambers arranged around the liquid-hydrogen target, and an optical system to enable the sparks to be photographed. Looked at from one side, the plates of all the spark chambers are perpendicular to the plane of a large vertically placed lens. The action of the lens is such that objects viewed through it from the focal point appear to be in line with each other if they are in fact on a line parallel to the lens axis. The camera placed at the focal point thus 'sees' straight along each spark-chamber gap. On either side of the spark chambers, two vertical glass plates have been set up. These have identical grids of fiducial mark engraved on them, and the plates are accurately aligned so that the marks define a set of imaginary lines parallel to the axis of the lens. Thus, with the camera accurately positioned, the two sets of fiducial marks appear superimposed on the photographs and provide a reference grid against which the position and direction of each set of sparks can be measured. Mounted immediately above the lens is an identical one which forms part of a similar optical system, with the addition of a large plane mirror mounted, at 45° to the horizontal, above the spark chambers. This allows the chambers to be photographed from a vertical viewpoint. A three-dimensional reconstruction of the path of each decay particle is then obtained by combining the measurements from the two photographs of each interaction.

The lenses are made of 'plexiglas', with a diameter of 1.4 metres and a focal length of 10.5 metres. The special tools to shape and polish them, as well as the lenses themselves, were produced in CERN. Each of the four reference plates is about 235 cm wide and 200 cm high, with a thickness of 1.6 cm, and the fiducial marks (engraved at CERN also) form a square grid with 100-mm spacing, each point being positioned to about 0.01 mm. The mirror is in two parts, each 1 m x 2.5 m x 25 mm thick, aluminized on the front surface. To ensure accurate results, all these heavy components had to be aligned with a high degree of precision. The whole apparatus is enclosed in a light-proof wooden structure some 14 m long, 3 m wide and 4 m high, and all that can be seen (apart from the usual impressive array of electronic equipment along the side) is the $q_3$ beam line entering at one end and the two cameras projecting at the other.

In the East hall, the $d_{16}$ beam was used by the group from Saclay investigating **'charge-exchange'** reactions of pions, while the monitor beam for the $o_2$ beam was used for a novel, short experiment to check the **second postulate of relativity theory** — that the velocity of electromagnetic waves is independent of the velocity of the source emitting them.

### On - line computer

Previously, another step towards automatic processing of experimental data was made on 19 June, when the Nuclear Physics Division took delivery of the major components of its **SDS 920 computer.** Compared to the CDC 6600 now on order for CERN, or even its present IBM 7090, this is a small machine, but it is also intended to serve a completely different purpose. The whole computer, with its auxiliary equipment, will be set up as a self-contained unit inside a small mobile hut, so that it can be transported to any of the experimental halls and 'built-in' to any desired set of electronic detection equipment.

Its first use is expected to be in conjunction with the sonic spark chambers of the proton-proton scattering experiment in the East hall of the proton synchrotron. Here, individual protons are tracked to and from the target by means of the spark-chamber array. In each chamber the noise from the spark takes different times to reach each of the four microphones placed around its edge and, as with the missing-mass spectrometer, these times are given numerical form by scalers in conjunction with an oscillator, each scaler counting the number of oscillations between the high-voltage pulsing of the chamber and the arrival of the sound at its particular microphone. After each proton has passed through the apparatus the readings of all the scalers, together with other relevant data in numerical form, will be fed automatically into the computer, the programming of which will cause suitable checks for consistency to be carried out. Between accelerator bursts the accepted information will be transferred from the computer on to magnetic tape and the tapes will afterwards be taken to the large central computer for complete analysis. Because the computer can accept information much faster than it can be stored on magnetic tape, it will be possible to record the behaviour of about ten protons in each accelerator burst, instead of that of a single one, which is all that can be done at present.

This computer indicates clearly the rapid development that has taken place in computer techniques (both design and use) in the past few years. The central computing unit occupies a cabinet some 165 cm high x 125 cm wide x 64 cm deep, and weighs 600 kg, making it easily transportable. Yet in computing speed and scope it is comparable to CERN's 'Mercury' computer, only six years old, whose racks line the wall of a large room (as seen on the left-hand side of the photo on p. 76 of the June issue of *CERN COURIER*), and which was sufficient for the whole laboratory for some years after its installation. The SDS 920 was manufactured by Scientific Data Services Inc., of Santa Monica, California, and supplied through the French firm 'Compagnie Européenne de Calculateurs Industriels et Scientifiques'. Its cost, with peripheral equipment, was about 600 000 Swiss francs ●

* Report CERN 64-5.

# Financing high-energy physics

by **M.G.N. HINE**, Directorate Member for Applied Physics

**In the July issue of CERN COURIER a report was given of the discussion on the future of high-energy physics held at the last meeting of Council. Basic to the problems involved is the question of expense, and in this article Dr. M.G.N. Hine presents some of the main reasons for the argument that, even with the present plans for the development of this fundamental science in Europe, the cost is not prohibitive.**

**Starting from a classification of the different kinds of research and development that are usually grouped under one heading, he describes how certain fields of study have become basic to all others and how important these are for continued cultural and industrial development.**

**The limitations on the future growth of basic research are then discussed, from the points of view of finance and available manpower, and it is concluded that over the next ten years the cost could be multiplied by six and the number of scientists by three, without exceeding any real limits. The article concludes with a short review of the main proposals for future high-energy physics in Europe.**

**This is a revised version of the talk that Dr. Hine gave to representatives of the technical and scientific press during their visit to CERN on 19 May 1964.**

## Introduction

How much money should go towards high-energy physics in 1974? Governments in Europe and in America have to face this question in the next year or two, in view of plans in both continents to start constructing soon very large accelerators for use from that date onwards.

The question brings up a host of others. How much should be spent on science as a whole? What are the proper relations between pure and applied science, between teaching and research, between universities and specialized institutes, between local, national and international laboratories? Why are some sciences more expensive than others and how should this affect policy? How far do questions of economic and military interest or national prestige distort the purely cultural needs of countries for development of science?

There is considerable confusion, often of an elementary kind, in political and even in government advisory circles on these questions; this leads, for example, to spokesmen quoting the figures for the total national expenditure on Research and Development — mainly the cost of aircraft prototypes and of development of nuclear technology — when questioned about the emigration of university biologists.

Some classification of the different kinds of scientific research is necessary, showing what they do, how they work, and who benefits, before any rational basis for allocation of resources or policy for future growth can be considered.

## Classification of scientific work

Science in the mind of governments covers Research and Development (R & D), but this should be split down further, as in the table overleaf, which gives a very schematic list of activities in which science plays an important role as such and which are relevant to the present-day state of industry and of science.

In this list, development and applied research at present take about 90 % of the money and the great majority of qualified scientists in advanced countries. The results are not primarily scientific knowledge but objects or techniques for making objects; the programmes are determined by specific industrial or military needs, and claims for money must be judged in terms of these needs and by the success of those involved in satisfying them.

Since development and applied research take nearly all the money and have objectives and techniques quite different to those of basic research, the total for R & D is a bad index of how well basic science is being supported; conversely, large changes could be made in the support of basic science while scarcely affecting the total bill.

The division of basic research into fundamental and non-fundamental is a comparatively recent development and one of some importance in understanding the place of high-energy physics in science as a whole.

The idea that all matter is governed by a few universal fundamental laws is an old one, but up to the end of the 19th century, and even later, there was nothing resembling a common and complete set of laws underlying all the usual scientific disciplines. From the start, Newton's laws of motion and gravitational forces were admittedly universal, but in addition each science used its own basic ideas and quantities, such as 'heat', 'electric fluids' or 'fields', 'ether', 'light', chemical 'forces' and 'activities', 'vital forces' and other specifically biological entities. It was not possible to connect these concepts in a single framework, nor was it clear in which science would be found the key concepts underlying the rest. All the conventional branches of science that had passed the purely classificatory stage could rightly be considered as equally fundamental.

The triumph of 19th-century and early 20th-century science was the discovery of such a framework of fundamental laws in the quantum theory of electrons, atoms and radiation, and the special theory of relativity, which apparently are adequate in principle to explain the whole of chemistry, physical chemistry, electromagnetism, the bulk and atomic properties of matter

| Activity | Objective | Technique | Beneficiaries |
|---|---|---|---|
| Development | Construction of prototypes for industrial production | Use of established principles and procedures of engineering, physics, chemistry, etc. | The consuming public ; the military |
| Applied Research | Development of technology; solution of particular industrial problems | Use of established principles and procedures of engineering, physics, chemistry, etc. | Industry ; the military ; applied scientific and engineering knowledge |
| Basic Research<br>a) non-fundamental | Study of the behaviour of matter in complicated forms obeying established fundamental laws of nature | Application of established fundamental natural laws to explain already known or newly discovered phenomena | Scientific knowledge ; industrial research and development ; human culture and industry via higher education |
| b) fundamental | Discovery of fundamental laws describing space, time, matter, energy and how they interact | Research into the behaviour of matter in forms not *a priori* explicable by established laws | Other sciences : human culture and industry via higher education |

in many forms — solids, liquids, gases, ionized plasmas — and many aspects of biology. The recent successes in molecular biology show in a spectacular way how these basic physical laws of behaviour of electrons and atoms are removing the barrier between living and dead matter in the same way that Wöhler's discovery of the synthesis of urea removed the barrier between organic and inorganic chemistry.

All these branches of science, then, have ceased to be fundamental, in the sense that the result of an important piece of research is not 'I have discovered a new law of Nature' but 'I have discovered how the quantum theory explains so and so'. This does not diminish the importance or the difficulty or the beauty of work in these fields, neither does it remove the need for experimental investigation, since nature is still infinitely complicated and surprising even if explicable ; it does, however, mean that they are no longer self-sufficient for their theoretical basis, and that the central 'life-line' of science, the succession of Galileo - Newton - Faraday - Maxwell - Einstein - Rutherford - Bohr, to quote only a sample of names, is today concentrated in a rather smaller range of fundamental sciences than before.

In order to explore the validity of conventional electromagnetic and quantum theory, to isolate the fundamental building blocks of matter and to continue the attack on the nature of space, time and gravitation, research must be directed to studying matter under more extreme conditions than in the non-fundamental sciences, where we have good reason to believe that these laws and concepts hold with very good accuracy.

We must explore the fields of extremely large distances, times, masses and energies, that is, by astronomy, cosmology and gravitational theory, and of extremely short times and distances and the particles which we find there. This latter field is that of elementary-particle physics, where perhaps even our present quantum theory, which overthrew conventional causality, may in its turn be proved inadequate.*

Research of this kind is apparently far from everyday life — just as were Faraday's researches into electromagnetism in their day — but it is here that we can most likely expect the next discoveries that will not just add to scientific knowledge, but revolutionize human thought and culture.

For this reason, these fundamental branches of science have a special position in any overall plan for the scientific development of a community : by their nature they will always tend to attract the very best scientific brains to the laboratories and countries where they flourish, and they provide the intellectual roots from which the other basic sciences and industry must be fed, if they are to grow healthily in the long term. A country or continent that pretends to a culture of its own, and is not merely a parasite on others, can neglect sciences like oceanography or optics and lose only the industrial advantages that come from a supply of people trained in these specialities, since the knowledge discovered elsewhere will still be available if wanted : to drop out of the fundamental sciences is to commit a slow but certain intellectual suicide.

This shows up clearly in current developments in higher education. The basic scientific knowledge used in industry changes rapidly : engineers have had to add a good knowledge of micro-wave, solid-state, nuclear and plasma physics to their normal intellectual equipment since the last war and have to face relearning their profession several times during their working life. It is now essential that all scientists and engineers should be properly taught basic physics at university by forward-looking teachers who keep up to date by being involved in advanced research. The number of teachers and research workers at universities must increase in future and they must be given access to the necessary equipment for the basic research that is their function. Thus the proper support of basic research is one of the unavoidable overhead charges of our civilization, though one which, luckily, pays for itself many times over if the value to society of the knowledge and the trained manpower it produces is set against its immediate cost.

* One subject for science has not been mentioned so far : the relation and interaction between mind and matter. Perhaps what we call 'mind' is merely a name for the indescribably complicated way in which a brain works according to the ordinary laws of physics and chemistry ; perhaps not, and then this interaction should also be classified as the subject for a fundamental science. So far, psychology has not really got past the stage of description and classification, so today the question cannot be answered.

A few other subjects like molecular biology or theoretical chemistry are not, in the sense of this paper, fundamental, since they do not question the ordinary quantum theory of atoms. They are, however, in the position of supplying basic concepts to a whole range of fields of non-fundamental research, and so have an intermediate position in this analysis.

In assessing what are reasonable national resources to allocate to basic research and how they should be divided, several points are of importance.

Firstly, basic research is by its nature not aimed at short-term problems, and success or failure cannot be judged by whether industrialists are interested or not in the results.

Secondly, second-rate research is a waste of money and men. There is usually a certain significant minimum of support necessary to keep a branch of science in a healthily growing state ; if this cannot be provided it would be better to stop the work entirely.

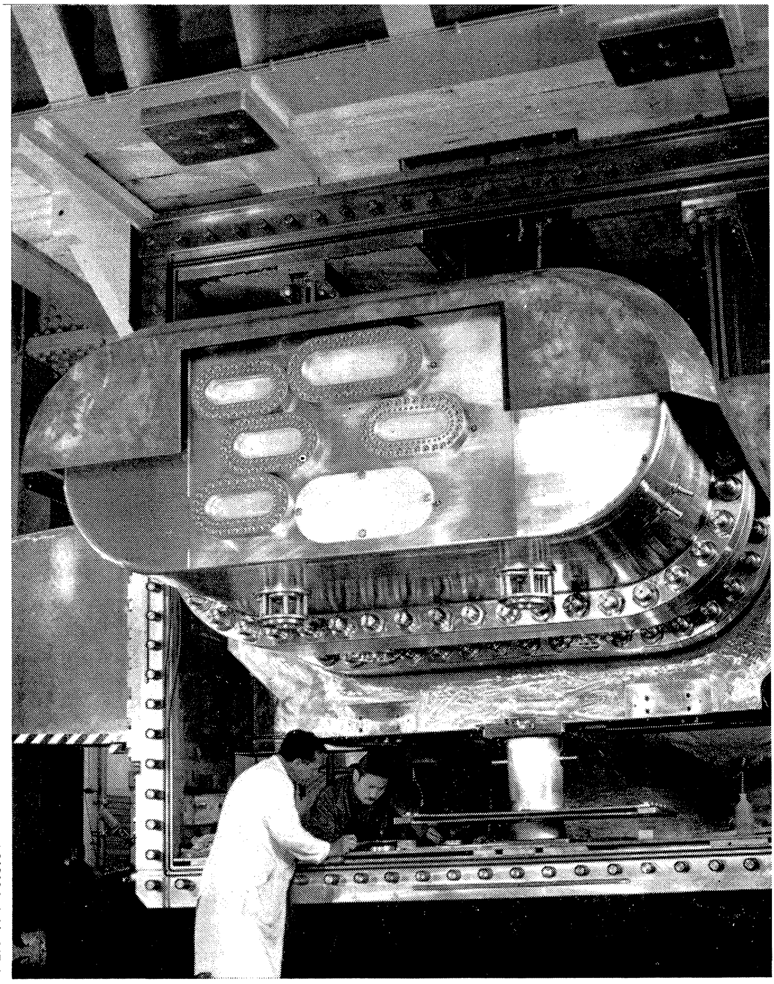
Thirdly, in considering financial support, it must be realized that just because fundamental research deals with matter in extreme states of energy, distance, etc., the equipment necessary is more complicated and the technical staff larger than those needed by the man who can still ' do it himself '. This extra and increasing cost per physicist in fundamental research must not weigh too heavily in the scales when comparing subjects. After all, all sciences are more expensive than Greek literature. The important choice to be made in planning science is the division of manpower, not the division of money ; a sound plan will provide enough money to allow for at least the ' significant minimum ' number of scientists working in the front line in all branches that are to be supported at all, regardless of whether one branch then gets three or ten times as much money as another.

## Past and possible future growth of science

The remorseless growth of science is not a new phenomenon : statistics on the number of scientists, number of scientific journals, number of publications, all show remarkably steady exponential growth over the past 250 years. During this time, the number of scientific papers has doubled regularly every 10 years, the number of science graduates and the number of scientific journals every 15 years, and the number of important physicists every 20 years. Over this long period the total growth has been by a factor of 10 000 - 100 000 or even more.

As for money, the total budgets for research and development in advanced countries since the war have been doubling about every 5 years, that is at about 15 % per annum, and the amounts for basic research have grown in many cases even faster. Even before the war, the growth of expenditure was in the region of 10 % per annum, keeping pace at least with the growing number of scientists.

This phenomenon of steady exponential growth is characteristic of a naturally expanding population with enough food. Apparently in the past the number of people becoming scientists has been proportional to the number already working and teaching, and their absolute number and cost have been so small that there has been effectively an infinite supply of potential scientists and of money to draw from.



CERN/PI 70.6.64

**An example of the kind of apparatus needed to detect and study the properties of atomic particles only 0.000 000 000 000 01 cm in diameter. This photograph shows the camera side of the safety cold tank of the CERN 2-m liquid-hydrogen bubble chamber, during pressure and vacuum tests last June. Covering the top part of the tank is part of the copper heat-radiation shield, and below the tank can be seen the pedestal that prevents pendulum oscillations of the chamber during each expansion of the liquid inside.**

It is obvious that this process cannot go on for ever ; if it did, research and development would be costing more than the whole national income by the year 2000. The growth must slow down, and governments feel more and more strongly that they, who provide most of the money, should have a hand in the slowing-down process.

How far away is a natural slowing-down point ; what, in fact, is the factor that will start to pinch soonest ? Two suggest themselves, namely money and manpower ; a third, that the growth rate of the previous centuries might decrease by itself because science suddenly became uninteresting, is not really conceivable.

If the real cost of basic research is compared with its value, it will be seen that the limit point just due to money is a long way away :

— broadly speaking, the cost of basic research has been growing for decades at about 10 % per annum, or more ;
— the total cost of all these past years, that is, the total cost of basic scientific knowledge since Galileo is then, as a simple piece of calculus, about ten times the current year's expenditure ;
— this year's expenditure on basic science is some 0.2 % to 0.3 % of the gross national product of the advanced countries ;

— ten times this is 2-3 %, that is, less than one year's growth in the gross national product.

Conclusion : the whole of scientific knowledge on which Western civilization is based, and which is the essential key to industrial and social progress, has cost *less than one year's growth in the production it has made possible*. It would be difficult to think of a better way of investing money. To increase the amount spent on basic science by a factor even as large as ten over the next ten years, would mean that the national product available for other purposes would increase by 48 % instead of 50 %, (assuming it continues to grow at 4 % per annum) ignoring completely the extra increase in production which this scientific surge would produce.

There is thus no *objective* limit from the side of money to continuing for twenty years or more the present rate of growth of support for basic research, if it is given the priority its importance warrants over the many other small but growing items in the national budget. This contrasts with the case of development which, being more closely linked with industrial production and already consuming 2-3 % of national resources, could not be increased tenfold without financial and other effects of first magnitude.

A limitation from manpower is likely to appear sooner. The total numbers of scientists employed in Europe and in the U.S.A. are about equal, although Europe has 1.6 times the population of the U.S.A. and is therefore a considerable way behind the present U.S. level of selection and use of the available scientific brain power. Official forecasts (OECD) suggest that in both continents the numbers of scientists will probably nearly double in the next ten years, continuing the past trend. The problem is how far this process can go while still maintaining the quality of the scientists produced. Data on the intrinsic ability of the population suggest that a large increase in the number of scientists of *average* ability is still possible if secondary education and selection are improved, but that the proportion of first-rate men now passed over is smaller, especially in the U.S.A. This is not such a serious limit as it seems, since modern science requires teams, of which some members can without disadvantage be only average compared with the leading spirits. Particularly is this true for those branches of science, including high-energy physics, where the nature of the work forces one to use equipment on the industrial scale.

Bearing in mind again that basic research and university teaching occupy only a small fraction of the scientifically trained population, these considerations suggest that, as with money, neither the overall scientific manpower nor the number of first-rate scientists available need be objective limits in Europe to the continuation of present growth rates for basic science for at least ten or, with some slowing down, twenty years. Since manpower seems to be the more critical factor, planning should aim at division of manpower into a healthy pattern, followed by appropriate allocations of money.

To put it in simple figures : an increase by 1.5 in the number of scientists and by 3 in the amount of money for basic research would only bring Europe into the *same* position as the U.S.A. is *now*, both in the fraction of the population engaged in science, and in the amount of money spent per scientist. These two figures could then be doubled in the next 10-15 years, according to

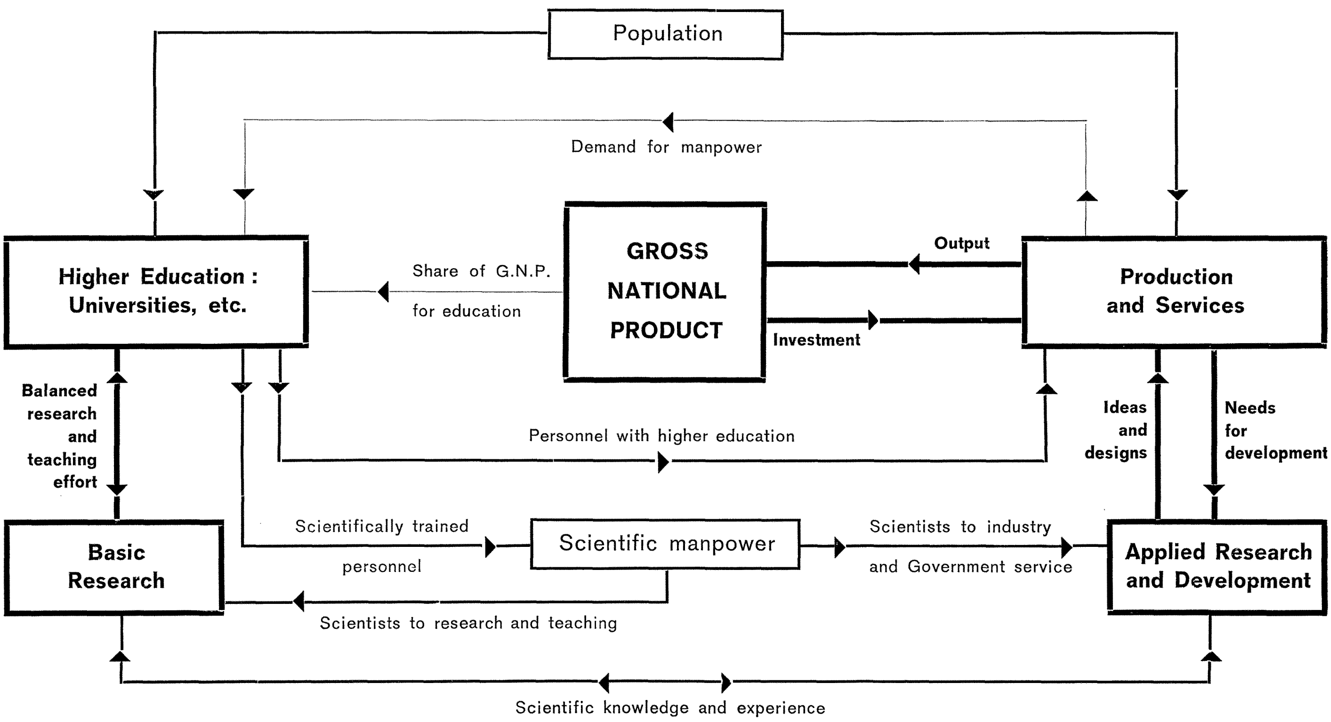



**Diagram illustrating the main logical and causal connexions (as distinct from those usually accepted) between the Gross National Product of a country, its industrial and other production, its universities and its research effort. The G.N.P. is closely tied to production, which in turn is both strongly dependent on and mainly responsible for 'applied research' and 'development'. 'Basic research' is a function of the universities and allied bodies (whose number and size need not depend on the G.N.P.) and an integral part of higher education. Note the absence of direct links between the G.N.P. and basic research, either logically or because of the amounts of money involved. — This is not the case for development, where a certain balance between the total development effort and the size of industry (and hence of the G.N.P.) seems natural and where the cost (2 - 3 % of the G.N.P.) may be an effective constraint.**

present estimates, leading to a potential increase of 3 in scientific numbers and 6 in money by, say, 1975, without exceeding real, as opposed to conventional limits.

### Plans for high-energy physics in Europe

In 1963, about 350 million Swiss francs were spent in Europe on high-energy physics : 100 million Swiss francs directly in CERN and 250 million Swiss francs in national laboratories, including about 40 million Swiss francs used by national groups collaborating with CERN and perhaps 80 million francs on accelerator construction. In that year, two new national accelerators were completed (Nimrod, with 8 GeV protons and DESY, with 6 GeV electrons). These machines will be able to handle a considerable volume of research, together equivalent perhaps to CERN in total effort and budget. The European laboratories already existing amount to another half CERN in capacity.

Allowing for a moderate expansion (about 10 % per annum, in real terms, in the CERN budget), this leads in 1973 to a total of 750 million Swiss francs per year, double the present level. This would probably be capable of supporting 1.5 - 2 times the present number of high-energy physicists, and would allow construction of one or two more national machines.

By the standards for judging growth and expenditure suggested above, this is a very modest programme. It hardly matches the likely growth in numbers of people wishing to work in this most fundamental basic science and asks for less than half the growth in money of the past decade.

It does not, however, make adequate long-term provision for the future. In 1963, a Committee of leading European high-energy physicists under Prof. E. Amaldi studied the long-term problem, and proposed that two new European machines should be built as a 'Summit programme' to balance the 'Base of the pyramid' composed of the national laboratories dealing more directly with universities.

One machine, the smaller, is not an accelerator, but a pair of intersecting storage rings for the CERN proton synchrotron, in which 28-GeV protons will circulate continuously in opposite directions, with paths that cross in 8 places. At these points, the protons will collide, with a total energy of 56 GeV compared with the 7 GeV which is all that can be obtained when a proton from the proton synchrotron itself hits a stationary target nucleus. In fact the energy in the collision of the two beams is as great as would be obtained from a conventional accelerator of 1700 GeV. The intensity of collisions is not very high, and only proton-proton collisions can be observed; however, this device provides a remarkable window through which to look into the future of very-high-energy physics, long before any conventional accelerator will be built to do this work. It will cost only about 5 % of such an accelerator, and in fact its construction will add only one third to the normal CERN budget for about 5 years until 1970, if the CERN Council authorizes it.

The other, or principal, summit project is a proton synchrotron ten times as large as the CERN PS. Including a new site and laboratory to go with it, it would cost about 1600 million Swiss francs, with an annual budget during construction of about 250 million Swiss francs. To undertake this project would then double the cost of international physics over that of CERN, storage rings included, but Europe would have

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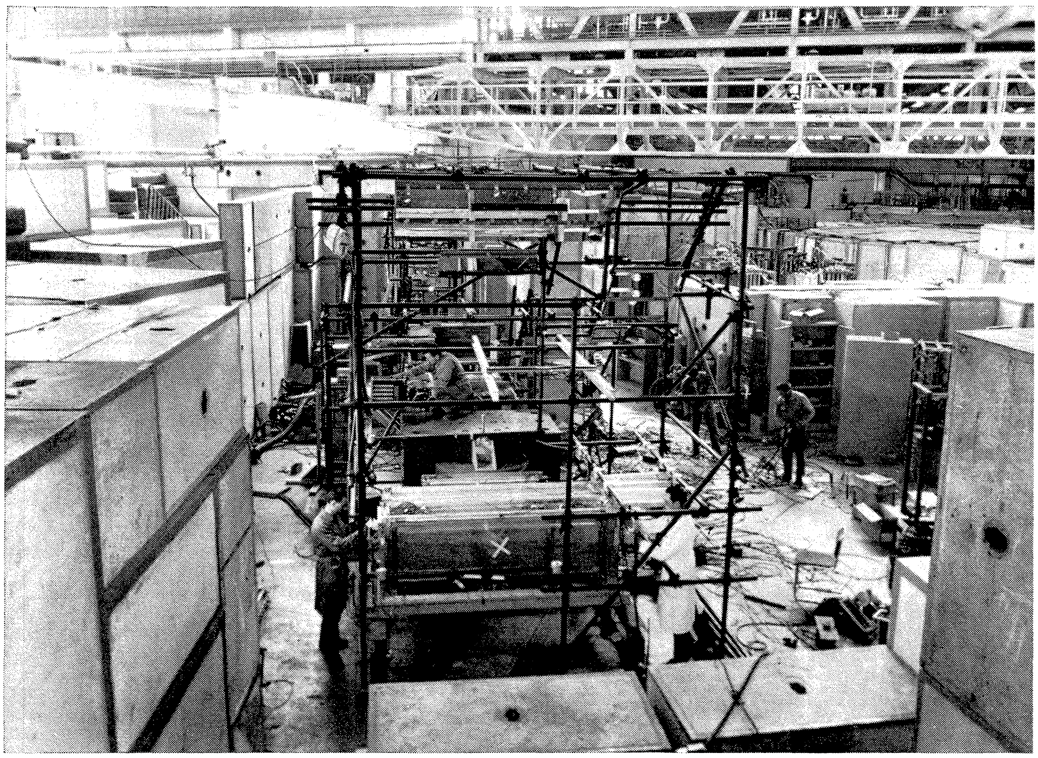
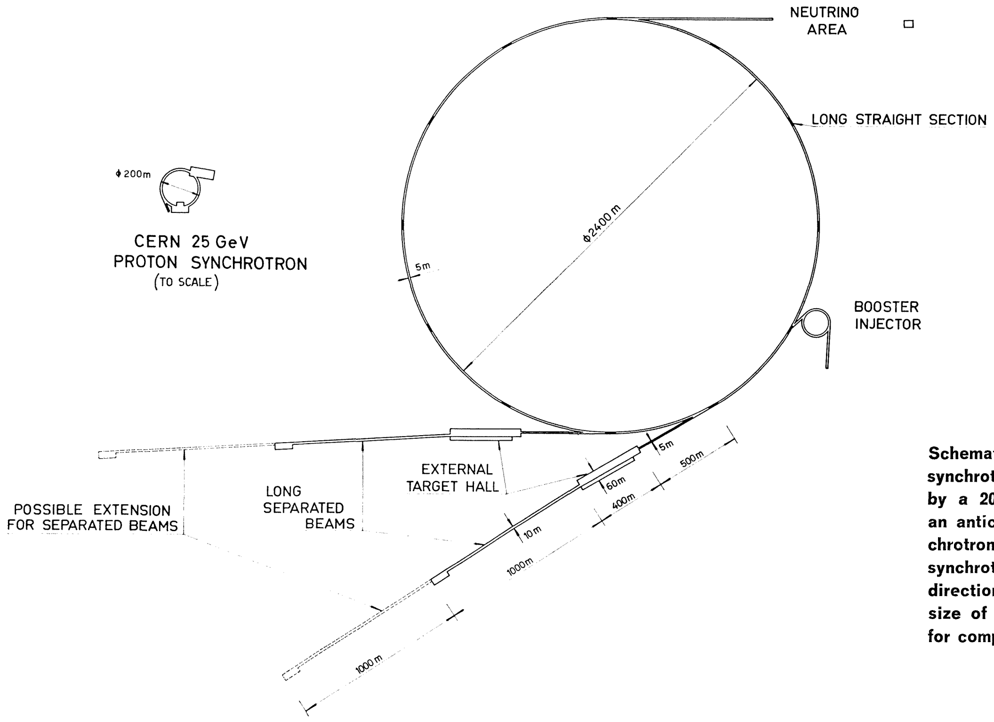


**Another aspect of the large-scale nature of fundamental-particle research is shown in this view of the South experimental hall of the proton synchrotron. It was taken during dismantling of the spark-chamber experiment designed to investigate the production of high-energy gamma rays in the 'peripheral' collisions of high-energy pions with protons in a hydrogen target. The gamma rays were investigated indirectly by means of a 'pair spectrometer' and the whole detection system included 11 spark chambers, of which the largest were 2 m wide and 80 cm high and weighed about 1 ton. The chambers were photographed with a single camera by means of a complex array of 57 carefully aligned mirrors, some of which can be seen still on the scaffolding. The array also included 2 large bending magnets and occupied a total length of about 20 metres ; during the experiment it was completely covered in to exclude all external light. Pairs of electrons (one positive, one negative) created by the gamma rays gave tracks in the spark chambers, and subsequent measurements on the photographs (of which 100 000 were obtained) give the location of each track to within a fraction of a millimetre.**




**Schematic design of a possible 300-GeV proton synchrotron. The protons are accelerated first by a 200-MeV linear accelerator and then (in an anticlockwise orbit) by a 6-GeV proton synchrotron before being injected into the main synchrotron, where they travel in a clockwise direction and are accelerated to 300 GeV. The size of the present CERN synchrotron is given for comparison.**

an accelerator of world class, equal to if not better than what is proposed also in the U.S.A., which should last for fifteen years thereafter, being large and powerful enough to match the future growth of fundamental physics during that time.

The total annual cost of the assumed national programmes and the new 'Summit programme' would be about 1100 million Swiss francs by 1973, that is, a factor of 3 increase over present rates ten years from now. Again, judged by the previous criteria, this is not out of step with a minimum growth for total European science, and will not take a higher proportion of European scientific manpower than at present.

The scientific case for Europe's continuing forcefully in high-energy physics is overwhelming; the equipment needed is technically feasible ; the scientific manpower needed will be available ; the money is trivial. Only conservatism or timidity will stop it ●

## BEAMS AND BEAM LINES

At CERN, among those who work with the accelerators, the word 'beam' has been in use for many years with two complementary meanings :

(a) a stream of particles travelling along a more-or-less well defined path ;

(b) the collection of apparatus (or 'beam-transport system') that brings this about.

The primary circulating beam of protons in either of the accelerators provides an obvious example of the use of the word in its first sense ; another example is given by a phrase such as "emulsion stacks were exposed to a beam of $K^-$ mesons". The second sense (the more confusing one to the uninitiated) is seen in a statement like "the $o_2$ beam includes three electrostatic separators".

Although to the expert it is obvious what is meant in any particular case, those less familiar with the use of accelerators must often find statements difficult to visualize. Fortunately, a way out has been given by the Rutherford High Energy Laboratory in England, where the distinction is made between a 'beam' and what they have called a 'beam line'.

This distinction will in future be used in *CERN COURIER*, where the following definitions can now be understood :

**Beam :**
a stream of nuclear particles (protons, pions, kaons, etc.) travelling along a well-defined path under the influence of a beam-transport (or beam-guiding) system comprising collimators, bending and focusing magnets, particle separators, etc.

**Beam line :**
the path along which the beam travels and, by extension, the collection of beam-guiding apparatus in position along that path.

Among the various kinds of beam are the following:

**Primary beam :**
the particles (normally protons) circulating inside the accelerator ; usually called the 'internal beam' at the synchro-cyclotron.

**Ejected beam :**
primary beam travelling outside the proton synchrotron after being acted upon by the 'fast-ejection' or 'slow-ejection' apparatus ; at the SC, usually called the 'external beam'.

**Secondary beam :**
particles produced by the interaction of the primary beam in a target and gathered into a beam by means of the equipment in a beam line.

**Separated beam :**
secondary beam providing a high proportion of particles of one kind, the degree of separation depending on the particle concerned, momentum spread allowable, absolute flux, etc.

# BOOKS

**Vom Radiothor zur Uranspaltung. Eine wissenschaftliche Selbstbiographie** (From radiothorium to uranium fission — a scientific autobiography), by Otto Hahn (Brunswick, Friedr. Vieweg und Sohn, 1962 ; DM. 22.50), is really divided into two parts. The first, occupying some 155 pages, is the 'scientific autobiography' itself, the second, 47 pages, contains reprints of three papers by Hahn and his collaborators :

— Nachweis der Entstehung aktiver Ba-isotope aus U und Th durch Neutronenbestrahlung (*Naturwiss.*, **27** (6), 1939),
— Einiges über die experimentelle Entwirrung der bei der Spaltung des U auftretenden Elemente (*Abh. preuss. Akad. Wiss.*, Nr. 3, 1942),
— Die chemische Abscheidung der bei der Spaltung des U entstehenden Elemente (*Abh. preuss. Akad. Wiss.*, Nr. 12, 1944).

The general content of the book is well summed up by the title, and the reader will not find very many personal impressions, anecdotes, etc. There are few things or events that constitute 'la petite histoire'. Most of them concern the earlier periods in London and Montreal, and these sections of the book are, in that respect, much more interesting. The reader gets a fairly good picture of life and research in those days, the people present at the laboratory, embarrassing situations due to all-too-literal translations, and so on. Much more weight is given here to the general background, and Hahn's scientific work is only occasionally mentioned.

Soon, however, in progressing through the book, the situation is reversed. Dealing with the period 1913 - 1944 at the Kaiser Wilhelm Institute, the emphasis is laid upon his work ; personal impressions and his immediate co-workers are only briefly mentioned. Here one would, for instance, be interested to read more about the last difficult years at the Institute. This part of the book is thus much less interesting, and rather dry. But, according to Hahn's own introduction the author has promised a later biography where more weight will be given to his 'personal souvenirs'.

A few photographs illustrate the text. The printing and presentation of the book are good, and the price is not too high.

**B. E.**

**Radioactive isotopes in instrumentation and control,** by N. N. Shumilovskii and L. V. Mel'ttser (Oxford, Pergamon Press Ltd., 1964 ; 70 s.), is a volume in the series of *International monographs on nuclear energy*, produced by Pergamon Press.

The book deals with an application of radioisotopes which at present is comparatively unknown, except to specialists. It gives an excellent introductory description of the possible uses of radioisotopes in the automation of production processes.

As an introduction there is a very elementary treatment of the different types of nuclear radiations and their detection, including a discussion of various electronic circuits. This section ends with a very careful treatment of the errors that arise in measurements of this type.

Many different kinds of measurements using radioisotopes are discussed, most of them in the fields of chemical and metallurgical industries. Among them are measurement and control of thickness of foils and surface layers, control of liquid levels in containers, flow measurements of liquids and gases, and analysis of reaction mixtures. The theory of each type of measurement is given, and different possible instrumental systems are described.

The book can be recommended especially to those planing chemical plants, because it enables the chemist to look into a field with which he is less familiar. There can be no doubt that isotope instrumentation has a future in the automatic control of industrial processes.

**Gunnar Sørensen**

**The Cavendish Laboratory,** by Egon Larson (London, Edmund Ward, 1962 ; 16 s.) is a difficult book to review. It is not a bad book ; many people will no doubt find it entertaining, even instructive ; many will like the journalistic style in which it is written. Yet... It should have been so much better. The author, it appears, has interviewed many of the scientists who worked in this world-famous physics laboratory in the University of Cambridge during and after the great years of J. J. Thomson and Ernest Rutherford, he has studied the history of the laboratory, he has read some of the scientific papers and other publications that have come from there since its foundation in 1871. From this he has distilled a series of anecdotes of the personalities who have led, or worked in the Cavendish, strung on the framework of historical advance and successive scientific discoveries.

We learn of the founding of the laboratory, at a cost of £ 8450, paid for personally by the then Chancellor of the University, the Duke of Devonshire, whose family name of Cavendish gave the laboratory its title. The first professor, James Clerk Maxwell, was brought from retirement at the age of forty, the second, Lord Rayleigh, left his dairy farm and his private laboratory to take over the still young research centre in 1879. Under their successive guidance the new practice of training students in experimental work was steadily developed, and the foundations were laid for the next holder of the chair, J. J. Thomson, who was professor from 1884 until 1919 and afterwards retained a strong interest until his death at the age of 84 in 1940. Gradually the work of the laboratory became concentrated on atomic and then nuclear phenomena, so that during the '20 s and '30 s, under Rutherford's leadership, the Cavendish led the world in experimental work in this field. Rutherford's death in 1937, followed by the war, and the advances of nuclear physics towards higher and higher energies demanding ever more costly equipment, seemed to many to spell the 'end' of the Cavendish. This was a misconception, because in fact the laboratory was not meant just for nuclear physics and, as the book shows, there has been only a shift of emphasis. In the fields of radio-astronomy and molecular biology in particular, the Cavendish tradition is being fully maintained.

Every now and again in the course of his narrative the author has attempted to explain the scientific ideas or discoveries that have given the Cavendish Laboratory its reputation, and it is here that the weaknesses of the book begin to show through. Many of his descriptions are obscure and some of them, on the isotopes of uranium for example, are just incorrect. Again, perhaps in an attempt to show that scientists are human after all, a good deal of attention is paid to the personal idiosyncracies of some of the people who have worked at the Cavendish and to the lighter sides of the laborary's social activities. It is true that Chadwick is quoted as saying that his discovery of the neutron in 1932 was the culmination of years of hard and sometimes tedious work by many men, but this is not the general impression that one is left with. Perhaps this is not the author's fault ; maybe this is the way the laboratory and its world-changing discoveries look to a non-scientific outsider — not very serious, slightly magical, and studded with brilliant and famous men. Probably only someone who has worked there can tell the true story of the Cavendish Laboratory.

**A.G.H.**

Maybe in this century of scientific revolution the fertile minds of scientists and engineers coin too many new words and phrases, and those who feel that the existing vocabulary suffers from this peaceful invasion take up arms in its defence in various ways, from circumlocutions to the complete outlawing of anything they consider intelligible only to the initiated.

Multilanguage technical dictionaries are obviously of great use to translators as reference books. They offer in addition, however, to the layman and often also to the professional scientist or engineer, a discreet means of acquiring or passing on knowledge. None of these works can hope to be complete, as is shown by the number in existence ; their merit, therefore, lies in the usefulness and aptness in a given field of the individual words and phrases they select.

The **Dictionary of nuclear physics and technology**, by Ralf Sube (Berlin, VEB Verlag Technik, 1961 ; English edition : Oxford, Pergamon Press Ltd., 1962) deals with the subjects of its title in four languages : English, German, French and Russian.

The book has four indexed sections, one for each language, each containing 15 063 terms or expressions from 'A-battery' to 'Zygote'. Each entry has a reference number, by which it can readily be identified in the English section or in the other volumes that the publisher intends to produce later. A short addendum gives brief equivalents in Russian and German of the locations and names of nuclear installations, like Dubna and Saclay. In this list, however, CERN is conspicuous by its absence.

No matter, this large 1600-page volume provides a valuable tool for anyone who has to work in several languages and who does not wish — or is unable — to master the numerous branches of science and, above all, engineering to which the book is devoted.

**R.A.**

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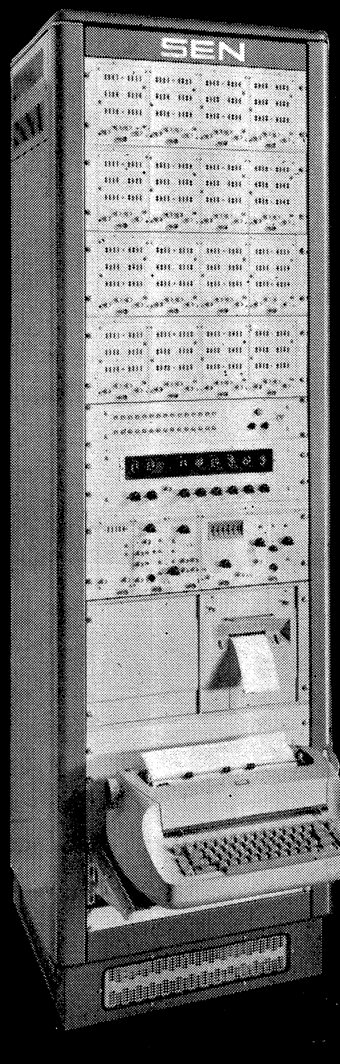


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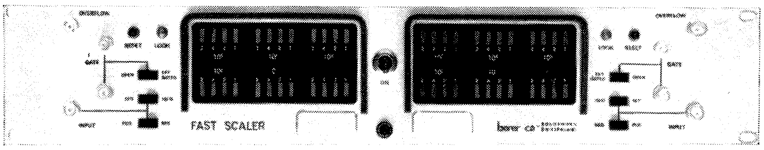


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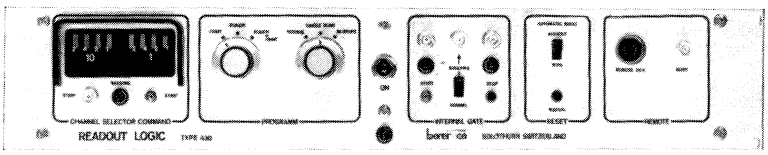


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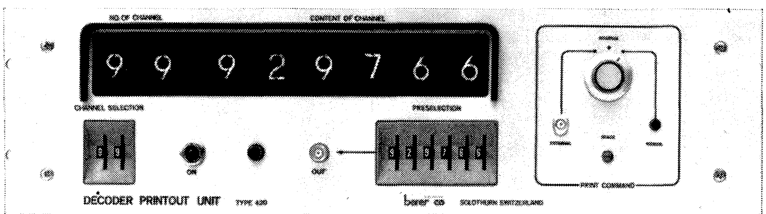


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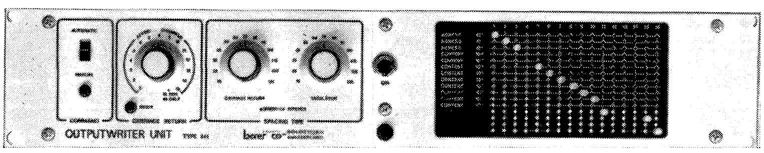


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