AN INTERNATIONAL LABORATORY FOR NUCLEAR RESEARCH

ON July 1, a Convention was signed in Paris for the establishment of a European Organization for Nuclear Research. Representatives of twelve European nations took part in the ceremony, and the Convention will take effect when the signatures have been ratified by the Governments of Switzerland, the host country, and six other nations. In the words of the Convention, the purpose of the Organization is to "Provide for co-operation 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 experimental and theoretical work shall be published or otherwise made generally available". This achievement has been brought about through the initiative of Unesco, which, at its general conference in Florence in 1950, instructed its director-general "To assist and encourage the formation and organization of regional research centres and laboratories in order to increase and make more fruitful the international co-operation of scientists in search for new knowledge in fields where the effort of any one country in the region is insufficient for the task".

During an initial survey, the particular need appeared for joint action in nuclear research among European countries, for the modern equipment required is often very costly. Although work with cosmic rays is relatively inexpensive to carry out and is extremely fruitful in results, its role is to make a preliminary survey of the high-energy field. Many important findings which are made by it can only be followed up if high intensities of high-energy particles are available. These high intensities can be produced in a perfectly controllable manner with modern high-energy particle accelerators, but these are extremely costly and may be quite beyond the resources of many countries.

The European Council for Nuclear Research (C.E.R.N.) was therefore established in May 1952, to work out plans for co-operation in this field. One of the Council's first acts was to arrange an international scientific conference in Copenhagen during June 1952. Many eminent nuclear physicists were present, including a number working in the field of cosmic rays. The state of knowledge at that date was examined in order to obtain guidance upon the main problems requiring further investigation. After the conference, four study-groups were set up by the Council. The first was to consider the design of a 600-MeV. synchrocyclotron, the second the design of a proton synchrotron for energies greater than 10 GeV., the third was to concern itself with theoretical studies of interest to the Council and the promotion of other forms of co-operation in nuclear physics, and the fourth was to work out plans for a laboratory.

The 600-MeV. synchrocyclotron was chosen because as a machine it is relatively straightforward to design and build, and yet when completed it will provide a laboratory source of mesons and high-energy protons for European physicists who have not had previous access to them. It should be practical to complete this machine in a few years, and much in advance of the time likely to be required to build the proton synchrotron. In the course of its development it will provide experience in running a co-operative research programme with a project the technical problems of which are relatively straightforward. When it is completed, physicists will, in the course of its use, become familiar with the techniques necessary when working with high-energy particles, and so should be ready to make full use of the big machine with the minimum of delay when it is completed.

The proton synchrotron is in an entirely different category, for an energy greater than 10 GeV. is well beyond that of the biggest machine now being built in the United States, and so when completed it should make available new fields of work only investigated previously by workers with cosmic rays.

The basic programme now envisaged for the Organization is the construction and organization of an international laboratory for research on high-energy particles, including work on cosmic rays, and the organization and sponsoring of international co-operation in nuclear research including co-operation outside the laboratory.

The laboratory will be located at Geneva, Switzerland, on ground offered by the Government of that Canton. The site is approximately 600 metres square and adjoins French territory about three miles north-west of the town. The main tools of the laboratory will be the two high-energy particle accelerators which have been studied.

The design of the synchrocyclotron is already well advanced, and its construction can be started quickly once the Organization is established. The machine will be used for neutron and proton studies up to 600 MeV., meson studies up to 300 MeV., radiochemistry, and possibly production of more than one π meson in some nuclear collisions. The cyclotron magnet will have a pole diameter of 5 metres and will weigh 2,500 tons. It will be excited by two coils weighing 180 tons with a power consumption of 700 kW. to give a magnetic field at the centre of 20,500 oersteds. Between the poles will be mounted a stainless-steel vacuum chamber containing the accelerating electrodes. The machine is primarily designed to accelerate protons; but provision will probably also be made for the acceleration of deuterons and α-particles. For protons, the radio-frequency at the start of the acceleration will be 31 Mc./s. and the frequency change required will be 2 to 1. The frequency repetition-rate will be 50 cycles per second. Considerable attention has been given to the experimental facilities to be provided with this machine. Collimated beams of protons, neutrons and mesons will be available. There will be one experimental room for neutron and π-meson studies. Neutrons of energies up to 600 MeV. will be available at an estimated flux of approximately 10^5/cm.^{2}/sec., and the energy of the π-mesons will be up to 350 MeV. with an estimated flux of 10^2/cm.^{2}/sec. In a second experimental room, the extracted proton beam will be available with a maximum energy of approximately 550 MeV. and a flux of 10^7/cm.^{2}/sec.; π^+ mesons will also be available in this room up to an energy of about 200 MeV., again with a flux of approximately 10^2/cm.^{2}/sec. Thick shielding walls will separate both experimental rooms from the cyclotron.

Plans for the proton synchrotron are not so far advanced. The target energy for it has been set at not less than 10 GeV.; but it seems from the design study that 20 GeV. or higher will be achieved. Confidence that a proton synchrotron for this energy region can be built has been obtained from the success with which other large proton synchrotrons such as the Brookhaven cosmotron have been operated, as well as from the design study which has been in progress for the past year. This study was upon a machine to use the alternating-gradient focusing principle announced by Courant, Livingston and Snyder in 1952 [1]. In any synchrotron the particles being accelerated perform vertical and radial oscillations within the annular vacuum chamber. The amplitude of these oscillations determines the required cross-section of the annulus and hence the size and cost of the magnet providing the guiding and focusing field. With a conventional machine, this magnetic field is made to fall off approximately linearly with radius, so that $\frac{\partial H}{\partial r} = -n\frac{H_0}{r_0}$, where n is a constant such that $0 < n < 1$, H is the field at radius r, and H_0 is the field at the particular radius r_0. When the condition $0 < n < 1$ holds, the particles being accelerated are acted upon by relatively weak focusing forces in both vertical and radial directions. In an alternating-gradient focusing machine, it is proposed to construct the magnet in a number of sectors and to make $|n| \gg 1$ with positive and negative values in alternate sectors. The forces acting upon the particles will then be strongly defocusing in the radial direction and strongly focusing in the vertical direction for sectors with positive values of n and vice versa. Courant *et al.* showed that the net effect upon particles passing around a machine constructed in this way would be a strong focusing action in both directions. This offered the possibility of achieving a reduction in both the vertical and radial dimensions of the aperture simultaneously.

The new principle has required a very careful design study, for as well as its important advantage, it also has inherent in it certain definite limitations which have had to be understood, and which will have to be taken into account in designing the machine. The limitations arise from the fact that the strongly focused particles are made to perform oscillations of small wave-length. These oscillations are very sensitive to small irregularities in the magnetic field whether they are due to mechanical or electrical causes, and consequently dangerous resonances can occur. The design study has had to take into account the practical considerations of achievable accuracies in constructing various parts of the machine, and determine how much advantage can be taken of the alternating-gradient focusing principle, that is, what should be the value of n. The relative importance of variations in each of the main design parameters has been worked out, and several possible designs obtained for machines of 30 GeV. energy with apertures less than $\pm$ 10 cm. and n's in the region of 100–1,000. A magnet weight of less than 10,000 tons seems practical with a manufacturing tolerance on the position of the equilibrium orbit of 0·020 in. However, more information is required upon the mechanical and magnetic tolerances achievable in the manufacture and measurement of magnets with various values of n and different apertures before a final choice of parameters can be made. Investigations are being carried out to obtain this information. Other problems in connexion with the machine, such as the design of the radio-frequency system and of the injector, are also being studied. It will be one of the major tasks of the new laboratory in its initial stages to complete this study and, with the help of industry, carry through its development and construction. It is estimated it will take six years to build, requiring a total staff of about a hundred scientists, draughtsmen and technicians, and will cost approximately 55 million Swiss francs. The plans for this machine envisage it being installed in a trench-type building below ground, with a thick roof over the trench to provide protection for the staff and reduce radiation in the main laboratory buildings to an acceptable level.

To make full use of the possibilities offered by these two accelerators, it will be necessary to gather together staff with specialist knowledge in several different fields. The present plans envisage a strong theoretical group which will work in Copenhagen for some time to come. It will carry out fundamental studies and take part in the planning and interpretation of the experimental work. A chemical department will be required for radiochemistry and to provide any analytical techniques required; and specialists in electronics and instrumentation for the design of experimental apparatus, and a central drawing office and workshop, will be necessary, in addition to the staff of nuclear physicists.

The architectural planning of the laboratory is well advanced. The main features of the accelerator buildings are entirely determined by their physical characteristics and functional requirements. For the laboratory it is proposed to construct single-story buildings with basements, which should allow great flexibility in detail, facilitate movements between laboratories and reduce radiation interference between different experimental installations. A unit method of construction is to be adopted, and careful attention has been given to the mode of distribution of services and the method of construction of partition walls to allow great flexibility in the internal arrangements. Present plans are for a main building with a total floor area of about 5,000 sq. m. available for the use of the scientific and technical staff; 2,500 sq. m. for lecture rooms, restaurant and administration, and a main workshop of 1,000 sq. m. floor area.

The construction of all the buildings and the arrangements of the site are expected to take three years and to cost about 23 million Swiss francs. The cost of all the activities, including construction and installation, during the first seven years is estimated at 120 million Swiss francs. The funds will be provided by the member States on a relative scale based on their average net national incomes; but no one State will pay more than 25 per cent of the total.

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[1] Courant, E. D., Livingston, M. S., and Snyder, H. S., *Phys. Rev.*, 88, 1190 (1952).