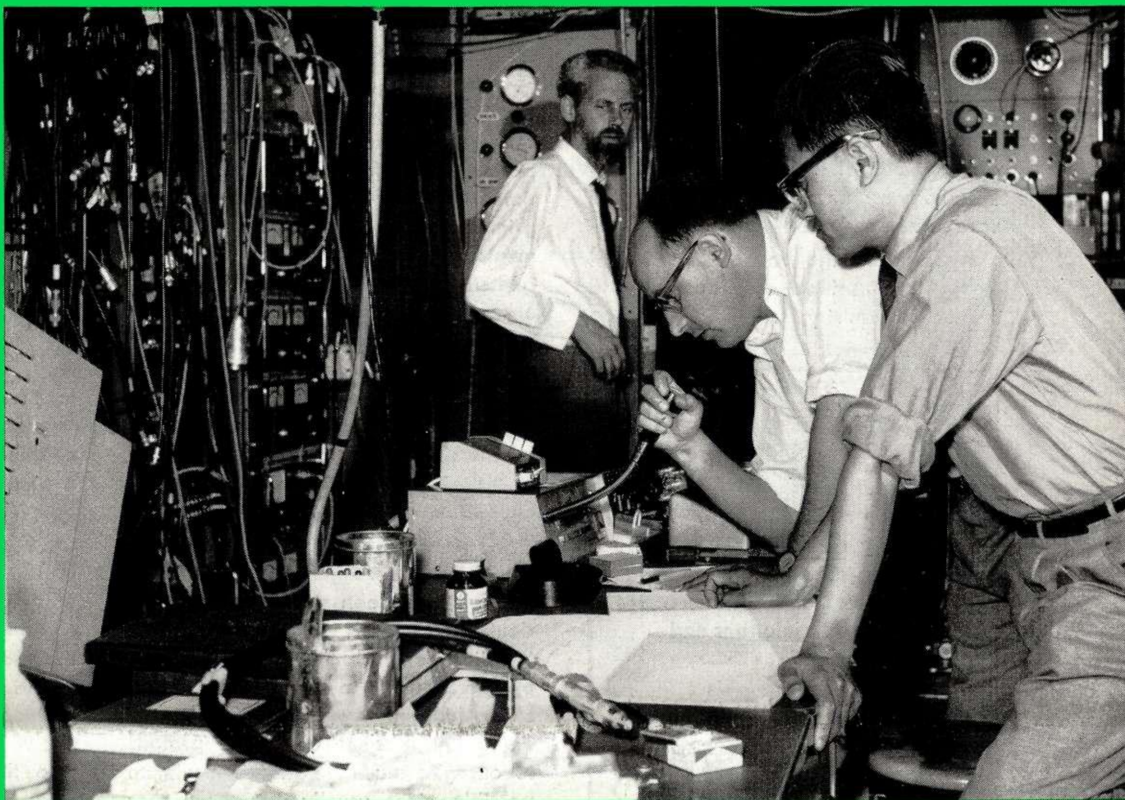
CERN COURIER



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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 (1.92 %), Belgium (3.78), Denmark (2.05), Federal Republic of Germany (22.47), France (18.34), Greece (0.60), Italy (10.65), Netherlands (3.87), Norway (1.46), Spain (3.36), Sweden (4.18), Switzerland (3.15), United Kingdom (24.17).
Contributions for 1963 total 92.5 million Swiss francs.

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

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

Last month at CERN

Although in July the holiday season meant that room could nearly always be found in the car parks, life proceeded very much as usual for those who remained in CERN.

Apart from the routine number of hours for machine development and nuclear chemistry, roughly half the running time of the **proton synchrotron** during July was spent with the external proton beam, for the 'neutrino experiment', and half with the internal beam, primarily for the two counter experiments in the East hall. These two — one studying the nature of the secondary particles from proton interactions in various targets, the other some new measurements on proton-proton interactions — both completed their machine runs. Several other experiments using counters and spark chambers were being set up, or shared the beam during these runs.

The proton-proton interaction experiment, which investigated the production of excited nucleon states (isobars) and deuterons, served to provide an interesting demonstration of the **flexibility of operation** of the synchrotron. Normally a high-energy accelerator like the PS is not used to accelerate protons to energies much below the maximum possible, since usually it is the higher energies that are most useful, lower-energy accelerators being used for lower-energy problems. For an experiment like this one, however, where the production of the isobars and deuterons changes in a systematic way with the incident energy, it is useful to be able to vary the energy of the incoming protons over as wide a range as possible. In this way, any errors that might be introduced by transferring the detecting apparatus to a lower-energy machine is avoided. Thus during the progress of this experiment in June and July the incident proton energy was varied right down to about 3 GeV. As a final proof of versatility, during one of the machine development periods the synchrotron was operated at 1 GeV, equal to the maximum energy of Europe's smallest (and first) synchrotron at Birmingham University, where, incidentally, many of CERN's accelerator engineers gained their initial experience.

The intensity of the synchrotron's **circulating beam** was further increased during the month, and the maximum recorded figure has now reached 8.5 x 10^{11} protons per pulse. The highest average for one 8-hour shift was 7.9 x 10^{11} protons/pulse and the average for the whole month just over 7.2 x 10^{11} protons/pulse.

In previous discussions of the fast ejection system now operating at the synchrotron, mention has been made of the **slow ejection equipment**, designed to extract the protons gradually from the circulating beam over a considerably longer time during each machine cycle, to suit experiments using electronic counters and spark chambers.

At the end of July, a further step was taken towards the provision of this facility. During the 2 1/2 normal maintenance days, the 'slow ejection magnet' and its electromechanical positioning equipment were completely installed in the vacuum box in straight-section no. 1 of the accelerator. This is the same box that contains the fast ejection magnet, but whereas the fast magnet is impelled into the beam path from below, the slow magnet moves in and out in a horizontal plane. Both systems have been carefully interlocked, so that they do not interfere with each other.

The slow ejection magnet is of the 'septum' type, with a length of about 1.8 metres and overall cross-section 10 cm x 15 cm. Before being installed, the whole system had completed some 250 000 cycles of test operation in a similar vacuum box in the South-hall extension, under normal operating conditions except that there was no proton beam or other radiation.

Back at CERN in July was Anselm Citron, physicist of the Nuclear Physics Division and present co-ordinator of experiments on the synchro-cyclotron, after a stay from 23 May to 20 June at the **Joint Institute for Nuclear Research** in Dubna, U.S.S.R. During his visit, the result of an invitation to a number of CERN physicists from Prof. D.I. Blockhintsev, Director of the Institute, he worked in the Laboratory of Nuclear Problems on the first stages of the installation of a muon beam at their 660-MeV synchro-cyclotron. His experience with the design and construction of the muon channel at the CERN synchrocyclotron was thus of particular use. He

Contents

The cover photograph was taken in the control area of the big spark-chamber assembly in use for the neutrino experiment, during the initial stages of a run during July. Of the three physicists in the picture, representative of more than a dozen working on this part of the experiment, only one is a CERN staff member — Frank Krienen, from the Netherlands, who is furthest from the camera. Max Reinharz, speaking into the microphone of the comunications set linking the experimental areas and the main control room of the synchrotron, is a research associate, from Austria, and Shuji Fukui is a Ford visiting scientist from Japan. An article on CERN fellows and visitors, and the way in which they join in the work of the Organization, begins on p. 101.

CERN COURIER

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also gave two lectures (in Russian) ; one at a general seminar, on the experiments already completed or now in progress at the CERN SC, the other more specialized, on muon focusing devices.

Apart from other Laboratories (equivalent to CERN Divisions) of the Institute, he visited the Lebedev Institute in Moscow, which has various electron accelerators, and the Physical Institute of the Armenian Academy of Sciences, in Erevan, where he saw the 7-GeV electron synchrotron under construction and some large-scale cosmic-ray experiments.

Both he and his wife were very cordially received everywhere, and apart from the scientific interest of the journey they were able to meet many people and see something of the everyday life of the country●

Slight corrections to the data on subnuclear particles published in our May issue have been shown to be necessary by a communication from physicists of the Lawrence Radiation Laboratory, Berkeley, U.S.A., in *Physical Review Letters* dated 1 July. This resolves an anomaly previously existing in the determination of the mass of the Σ^- hyperon and gives new values for both this mass and that of the Σ^0. The new values are 1197.6 ± 0.5 MeV and 1193.2 ± 0.7 MeV respectively. The previous anomaly was shown to be due to the fact that Σ^- particles slowing down in matter lose energy at a lower rate than Σ^+ particles of the same velocity.

Prof. A. H. Rosenfeld, of Berkeley, has also kindly pointed out to us that the **eta meson** occupies an anomalous position in table 2 of the listing in the May issue. Its short lifetime is due to decay by means of the 'electromagnetic' interaction and it is in fact stable against disintegration by the 'strong' interaction. Although it is among the newer particles to be discovered, transferring the eta meson from table 2 to table 1 would make the table headings more correct, an 'elementary' particle being interpreted as one which is stable against break-up via the strong interaction.

We hope to return to this subject later on, but meanwhile, readers of *CERN COURIER* will be interested to know that Prof. Rosenfeld is currently contributing a series of articles entitled 'An elementary (?) guide to the elementary (?) particles' in the Lawrence Radiation Laboratory's monthly journal *The Magnet*●

In Memory of Prof. Bakker

CERN/PI 163.7.63

At 12.30 a.m. on Thursday 25 July, members of CERN gathered in the library to remember our former Director-general, the late Prof. C. J. Bakker, and to witness the unveiling of a bust created — from memory — by one of us, Paul Theurillat, photolithographer in the Scientific Information Service.

There also were Mrs. Bakker, Mr. J. H. Bannier, Netherlands delegate and Vice-president of CERN Council, Mrs. Bannier, and Mrs. Dakin. The unveiling was performed by S. A. ff. Dakin, CERN's Directorate Member for Administration, deputizing for the Director-general, Prof. Weisskopf, who was unable after all to be present.

Mr. Dakin recalled Prof. Bakker as the chief of the few devoted men who built up the framework of the Organization, forming the living structure to express the ideals for which it was created :

'Very happily, he saw the synchro-cyclotron come into most successful operation, and the first of the many first-class research results to come from it, the harvest of so many years of his work, as Leader of the Synchro-cyclotron Group before CERN existed, as Director of the SC Division and as Director-general. We must be happy that he saw also the operation and the inauguration of the proton synchrotron.'

Continuing, Mr. Dakin reminded us that : 'Prof. Bakker saw CERN through the first of its growing pains, when the Member states had to be gradually, and painfully, convinced that the original estimates of our size and cost, drawn up with the innocence of people who were trying to do something that had never been done before, had proved grossly insufficient... CERN is now going through another such period ; without the work and effort which Prof. Bakker devoted to it a few years ago, CERN would now be barely alive enough to grow.'

Of the bust, Mr. Dakin said : 'It seems to be particularly fitting that (it) is the work of a member of the CERN staff... This makes it peculiarly a CERN family occasion, and it is good that this bust should be placed in the library, not in a public place, but in the very heart of CERN itself.'

Mr. Bannier, speaking, as he said, on behalf of Mrs. Bakker and her family, for himself, and as Netherlands representative on the Council, remembered Prof. Bakker firstly as a scientist, who had put all his enthusiasm into building up the scientific organization that is CERN. It was fitting that his image should be in the library, where all the results of CERN's work are stored in printed form and where inspiration for further progress is to be found.

But Prof. Bakker was also more than a scientist ; he had a scientist's vision for international co-operation and better understanding between peoples. From the very earliest days he had imagined, and worked for CERN not as just another important scientific institution, but as something of very great human value. It was good that in the future those who worked here, and those who came to CERN as visitors from all over the world, should find him here also as the spirit of the international co-operation that he had so much at heart●

Larger accelerators recommended for the U.S.A.

In the U.S.A. a panel of scientists, convened by the President's Science Advisory Committee and the General Advisory Committee of the Atomic Energy Commission, has made a number of recommendations for the development of high-energy physics there. Foremost among the panel's specific proposals is the building of a 200-GeV proton synchrotron by the Lawrence Radiation Laboratory, Berkeley. Also included are the construction of storage rings for the alternating-gradient synchrotron at the Brookhaven National Laboratory, the initiation of a design study for a proton synchrotron of 600 - 1000 GeV, also at Brookhaven, and the construction by the Midwestern Universities Research Association (MURA) of a very high-intensity accelerator.

On the question of a joint U.S.A. - U.S.S.R. accelerator project the panel is of the opinion that 'a jointly constructed and managed high-energy accelerator... would be a major "breakthrough" in regard to the amount of information exchanged between the two sides'. At the present time, however, accelerators of the sizes now contemplated (200 - 300 GeV) are considered to be within the capabilities of more than one group, and such accelerators are needed on both sides of the Atlantic.

The panel members see 'considerable merit' in joint coordination and planning, and in fact some preliminary discussions on those lines are now going on. As mentioned before in *CERN COURIER* (May 1963, p. 62), representatives of the U.S.A. and U.S.S.R. were invited to take part in the discussions of the European committee for future accelerators. (*The Magnet*, Berkeley, June)

The Princeton-Pennsylvania Accelerator

An announcement on 15 April by the U.S. Atomic Energy Commission and the Universities of Pennsylvania and Princeton gave the news that the Princeton-Pennsylvania Accelerator had produced its first beam at full energy. This machine, a synchrotron which accelerates protons to an energy of 3 GeV, is unique in having a much higher pulse repetition rate than similar accelerators at that energy. Instead of one burst of protons every few seconds, it will supply 19 per second, thus increasing the rate of output of secondary particles by a large amount. It is intended that the accelerator should be used primarily for the production of pions and kaons, for experiments designed to search more deeply into the properties of these 'particles' which seem to play a key role as the 'glue' holding the atomic nucleus together.

A later announcement said that work was beginning on an extension to the experimental area around the accelerator, in order to accomodate an external beam. At the moment, the protons are not extracted from the accelerator and the secondary particles are produced from internal targets. The initial project, which is located at Princeton University's Forrestal Research Centre, cost 12 million dollars (nearly 52 million Swiss francs) ; the extensions will cost a little over 8 million dollars more.

80-inch bubble-chamber in operation at Brookhaven

At 12.30 p.m. on Sunday 2 June, the first photograph was obtained of a nuclear interaction in the newly completed 80-inch liquid-hydrogen bubble chamber at Brookhaven National Laboratory, U.S.A. Essentially the same size as the one under construction at CERN (a length of 202 cm against the CERN chamber's 200 cm), this is now the world's largest bubble chamber in operation. It is housed in a building adjacent to the 33-GeV AGS (alternating-gradient synchrotron), and beams of secondary particles from targets inside the synchrotron are guided to it by a system of magnets, in much the same way as they will be guided to the CERN chamber, (and before then to the British national chamber) in the East area of the proton synchrotron.

The Brookhaven chamber, together with the building to house it, a power station to provide electricity for its magnet, the hydrogen storage area, refrigerator and safety sphere, and other associated equipment, cost about 6 million dollars (26 million Swiss francs) and took about four years to design and construct.

(*Bulletin Board*, Brookhaven, 11 June)

International centre for theoretical physics

At a meeting of the Board of Governors of the International Atomic Energy Agency held on 14 June a decision was taken to establish an international centre for theoretical physics in the first half of 1964. The centre will be located at Trieste, in Italy.

It was agreed that the centre should be established on a provisional basis and its work should be evaluated so that the Board, after two years, could decide upon the future direction of its activities. A further evaluation should be made to enable the Board to determine if it would be desirable to move the centre to a 'developing' country after four years.

The question af an international centre for theoretical physics under I.A.E.A.'s auspices has been discussed by the General Conference and the Board since September 1960 and a series of studies have been made with the assistance of eminent theoretical physicists from many countries ; these studies have concerned both the principle of the value of such a centre, its scope and direction, and the best location, in view of the many generous offers received for concrete assistance. Such offers have been made by Italy, Pakistan, Denmark, Austria and Turkey. The main support has come from the developing countries.

The Italian Government has offered to construct a new building for the centre and housing facilities for the staff and the fellows ; it has further offered a cash contribution of 250 000 dollars per year for five years, staff services and fellowships. I.A.E.A. will contribute fellowships and professorships to an annual value not exceeding 55 000 dollars for four years and additional annual contributions not to exceed a total of 110 000 dollars in the same period●

(*I.A.E.A.*)

CERN FELLOWS AND VISITORS

— Profile of a programme

by **R. W. PENNEY,** General Administration Division

As mentioned in last month's report on the 24th Session of CERN Council, recent discussion of ways in which the smaller Member states of the Organization might obtain more benefit from their membership has included suggestions for increasing the opportunities available for fellows and other 'visitors' who stay at Meyrin for relatively short periods.

This article describes the Fellowship and Visitor Programme as it is at present, detailing the various headings under which the visitors come and indicating the methods by which they are chosen. The way in which their work is integrated into the general scientific activity of CERN is discussed briefly.

As an example of the international character of high-energy physics, last December's issue of *CERN COURIER* mentioned one of the papers presented to the 1962 International conference. The contributors to this paper included 9 CERN scientists — 5 staff members and 4 Fellows or Visitors — coming from 8 countries in all. This example also illustrates the significant contribution to the CERN research effort made by members of our Fellowship and Visitor Programme ; in fact, out of some 260 physicists at present working directly on research in CERN, about 190 are Fellows or Visitors. Applied physicists, engineers and technicians add about another 80 to this last total.

Before looking at the programme as a whole, it may be of interest to know what different kinds of 'Visitors', using the term in its generality, there are at CERN.

In no kind of status order we have :

1. Fellows : these are typically young graduates from the Member states of CERN who have probably obtained a doctoral or equivalent degree. They come to CERN for one, two or occasionally three years to gain experience, usually by working either with one of the experimental research groups, or with the Theory Division, or on problems connected with machine and apparatus development. They are paid by CERN and candidates are suggested by the Member states' delegations, who in most cases delegate this task to a national scientific panel.

2. Research Associates : these can be regarded as senior Fellows, having some years of experience and positive results to their credit. For them the emphasis is on collaboration in the work of CERN rather than on learning and formal training. They are nominated and supported in the same way as Fellows.

The Fellows and Research Associates together represent the 'CERN Fellowship Programme', which at present includes some 65 physicists.

3. Guest Professors : these are outstanding scientists of international status who come to CERN for varying periods and who can provide a real stimulus to the CERN research programme. One has only to mention names such as Lee, Yang, Salam, and Panofsky, to appreciate the part played by this group.

4. Visiting Scientists :

a) From Member states : these include individual visitors, not falling into the Fellowship category, but doing some specified work in the Organization, usually connected with the programmes of their home laboratories. There are 122 such visitors in CERN at present. They may be wholly or partly paid by CERN or fully supported by their home institutions. However, most of the visitors from Member states belong to the various visiting teams or groups working on specific projects of their own or, more often, combining with CERN staff on joint projects. At present we have 7 teams from Britain, France and Italy, while others from the Federal Republic of Germany, the Netherlands, Norway and Switzerland have worked at CERN in the past.

b) From Non-member states : A grant from the Ford Foundation enables CERN to invite some 20 visitors each year. Unfortunately, these funds will not be available for more than another year or two and the number of future visitors from this source will have to be restricted. There is also a growing number of visitors now coming to CERN with independent support, either on sabbatical leave, through the U.S. National Science

Some of the members of Prof. Lagarrigue's Group, from the École Polytechnique in Paris, photographed during dismantling of their 1-m heavy-liquid bubble chamber in the East experimental hall at CERN, in preparation for the modifications now being carried out. Physicist Xavier Sauteron takes a look while technicians Roland Vaschy (nearest camera) and Henry Querel work on part of the expansion system of the bubble chamber, situated inside the heavy steel electromagnet.

CERN/PI 117.6.63

and Guggenheim Foundations or the International Atomic Energy Agency Fellowship programmes, on various exchange programmes with, at present, Brookhaven (U.S.A.), Dubna (U.S.S.R.) and the Weizmann Institute (Israel), or simply paid for by their institutes.

It is the presence of these visitors which really underlines the internationality of CERN and which is so effectively forging world-wide links with other centres of high-energy physics. The visits to CERN of young scientists from some countries — Poland and Japan are good examples — have already produced remarkable results in the development of interest in high-energy physics in their countries. The presence of visitors from Argentina, Australia, Brazil, Canada, Czechoslovakia, India, Israel, Japan, Lebanon, Pakistan, Poland, Rumania, Syria, Turkey, U.S.A., U.S.S.R. and Yugoslavia — the list is not exhaustive — shows that at least in one activity the countries of the world can work together in harmony and to good purpose.

5. Vacation Students : each year now, some 70 European university students spend from 2 to 4 months in CERN, usually during the summer vacation. The aim of this scheme is essentially educational, although these visitors also provide a useful helping hand during the holiday months. The present scheme is only in its second year but it is already clear that it has caused a great deal of interest among European universities, and one hopes that several of our guests will be seen again in CERN after they have graduated.

The following table shows more clearly where the visitors at present in CERN come from :

CERN FELLOWS AND VISITORS (as at 1.8.63)

Member states

	Fellows	Res. Ass.	Visitors	
			Individual	Team
Austria	6	1	–	–
Belgium	1	1	1	–
Denmark	2	2	2	–
France	5	5	24	31
Germany	3	1	10	–
Greece	1	1	1	–
Italy	1	5	13	9
Netherlands	3	2	–	–
Norway	3	3	–	–
Spain	4	1	3	–
Sweden	–	2	1	–
Switzerland	2	2	14	–
United Kingdom	7	1	22	26

Non-member states

	Ford	Others		Ford	Others
Brazil	–	1	Japan	1	–
Canada	–	1	Pakistan	2	–
China	1	–	Poland	5	–
Czechoslovakia	–	1	Rumania	–	2
Hungary	–	2	U.S.A.	11	20
India	1	1	U.S.S.R.	–	2
Israel	–	2			

The demand to come to CERN as a scientific visitor grows continually, and it has become necessary to apply a rather strict system of selection. We are glad to accept either individual applications or nominations from countries or institutes, but the Director-general alone can take the final decision to invite a Fellow or Visitor. Many factors have to be taken into account; notably whether accommodation and facilities are available and whether the visit would be of benefit to CERN, to the visitor himself and to his institute. These sometimes difficult considerations are handled by two CERN advisory committees, the Fellowship Committee which meets twice a year, and the Visiting Scientist Committee which meets three or four times a year. Both committees include all the interested CERN Division Leaders and members of the Directorate and at present both are under the chairmanship of Prof. L. Van Hove. The Nuclear Physics Research Committee considers requests for national teams to work at CERN according to the possibilities of the Organization's scientific programme.

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Not all the Visitors at CERN are scientists. Seen in this picture is Noria Christophoridou, Librarian of the Greek Atomic Energy Commission, who has been sent by her Government to CERN for a year, to widen her experience of library and documentation services. When the photograph was taken she was providing information to Kurt Gottfried, a CERN Visiting Scientist from Harvard University, U.S.A., who is spending a year with CERN's Theory Division.

These various Fellows and Visitors play a vital role in the scientific activity of CERN. Details of their collaboration in CERN could fill several editions of *CERN COURIER*, but the programme has also a more general purpose that cannot be too strongly emphasized. This can be summarized in the words of the CERN Convention as ' the promotion of contacts between, and the interchange of scientists, the dissemination of information and the provision of advanced training for research workers ' and 'collaboration with... national research institutions '.

With these aims in mind, the need for mobility among scientists becomes clear. The problem of keeping the right balance between short - term and long - term workers stems directly from this need and, in a very large measure, the solution is automatically provided by the Fellowship and Visitor Programmes with their annual turnover of some 200 physicists and engineers. The integration of the short-term Visitors with the longer-term CERN staff, who change at the rate of about 10 a year, provides the right kind of balance inside the Laboratory, and, moreover, it is a balance that can be fairly easily adjusted from time to time. It also means that the Visitor can take a full interest in the work of CERN, can contribute to it from his recent experience outside CERN, and at the end of his stay can take back to his home institute an up-to-date view of what is happening in CERN●

1963 International Conference on

Sector-focused Cyclotrons and Meson Factories

CERN, 23-26 April, 1963

a review by P.M. LAPOSTOLLE, Leader, Synchro-Cyclotron Machine Division
and E.G. MICHAELIS, Synchro-Cyclotron Machine Division

To those accustomed to thinking of a 28-GeV proton synchrotron as a normal particle accelerator and who consider only machines of 300 GeV and above as exciting, it may seem a little surprising to find a renewed and lively interest in the field of machines of lower energy. Yet progress in the field of cyclotrons has been no less spectacular than in the design of giant machines: while the energy of synchrotrons has increased tenfold in the last ten years, present-day cyclotrons have internal beam currents which are a hundred times larger than those available around ten years ago.

Progress in this field was reviewed at a conference held at CERN in April of this year, and the following paragraphs give a short summary of the proceedings.

SECTOR-FOCUSED CYCLOTRONS

Since the invention of the principle of cyclic acceleration by Lawrence in 1931, cyclic accelerators have undergone a remarkable development, which has led from the first 50-keV model to the present-day giant synchrotrons and the even larger machines now being planned.

At the base of Lawrence's discovery lay the realization that the orbital frequency of an ion circulating in a uniform magnetic field is independent of the energy of the ion, so long as this is small compared to its rest-mass energy (that is, the energy corresponding to its mass at rest). An accelerating voltage of a suitable resonant frequency, applied to the dee-electrodes of a simple cyclotron, therefore accelerates ions at all radii until this 'resonance condition' breaks down on account of the relativistic increase of the mass of the accelerated particles.

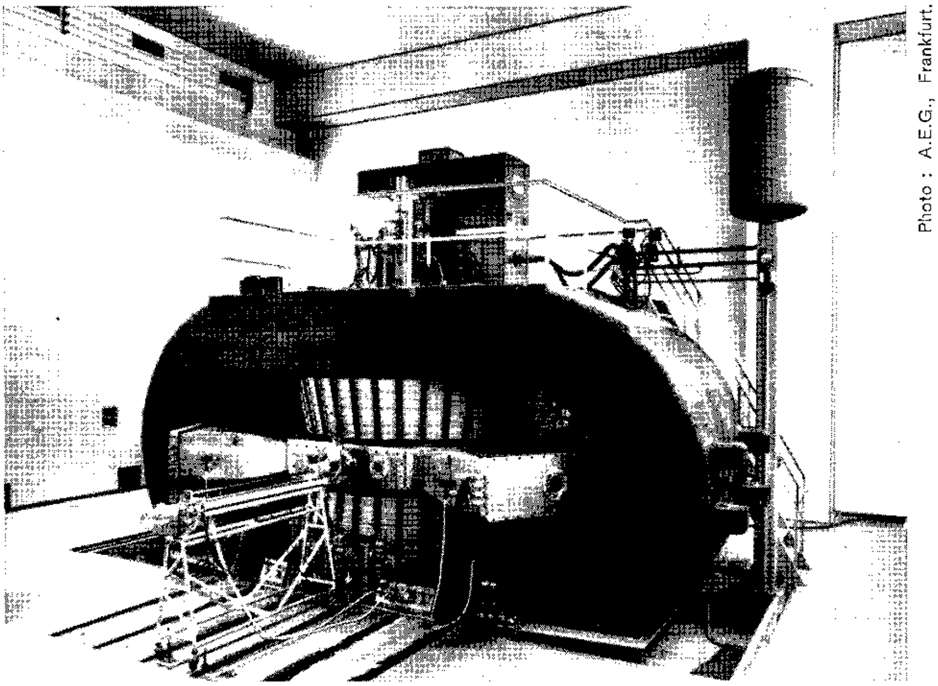
This mass increase limited the energy of conventional proton cyclotrons to about 20 MeV. The limitation was overcome by the invention of the frequency-modulated 'synchro-cyclotron', where the frequency of the accelerating voltage is varied in time, but since the resonance condition can now only be met, at any instant, for ions of a given energy, these machines give an intermittent output. A limited bunch of ions is accelerated by following the frequency-modulation cycle, but ions outside this bunch cannot be accelerated at the same time. The success of the synchro-cyclotron in reaching higher energies is thus achieved at a great loss of beam current.

Even before the development of the synchro-cyclotron, L. H. Thomas showed a way in which the limit set by the relativistic mass increase could be passed without frequency modulation. One can match the increasing mass of the ions at greater energies by a magnetic field increasing with radius, but such a field defocuses the ions and they are quickly lost. Thomas proposed to overcome this defocusing effect by the introduction of sectors of high and low field, and indicated that it was possible by this means to pass to higher energies while maintaining a constant frequency. However, little note was taken of this idea of sector-focused cyclotrons, and it was eclipsed by the success of the synchro-cyclotron until the demand for higher beam currents and the more detailed study of focusing conditions undertaken for the alternating-gradient machines led to a renewed interest in sector focusing in the early 1950s.

Work on sector-focused machines began to be reported in 1956, for example at the CERN Symposium on high-energy accelerators of that year. Since then, progress has been extremely rapid. About a dozen machines of this type are now in operation and many others are being planned. Initially the energy region chosen was the gap between conventional cyclotrons and about 100 MeV; now also meson-producing machines of energies up to 800 MeV are being studied. The radial sectors proposed by Thomas have taken more picturesque forms, the so-called 'spiral ridge' being found more efficient in many applications.

THE CERN CONFERENCE

Since 1956 there have been three international conferences devoted essentially to sector-focused cyclotrons. The latest of these, at CERN during 23-26 April, occurred at a propitious moment. At the preceding meeting, held in Los Angeles in 1962, much of the material presented still concerned the theory or design of these machines. This year there was far more emphasis on experience and performance, six machines having been commissioned during the past twelve months and those completed earlier being now in full operation. One day of the conference was therefore devoted to the experience gained with the new machines, another to their use in physics research and the physics problems involved in their design and operation. A third day was reserved for new developments in theory and design, while the so-called 'meson



The relativistic isochronous cyclotron at the Nuclear Research Centre at Karlsruhe (Germany). It uses six equally spaced accelerating gaps, which form part of a system of three quarter-wave resonators. Two of these resonators can be seen projecting from the central vacuum box placed between the poles of the magnet. The magnet itself weighs 280 tons, the pole faces are 225 cm in diameter and are divided into six equal radial sectors : three 'hills' and three 'valleys'. A current of more than 200 μA of deuterons at the design energy of 55 MeV has already been obtained.

factories' formed the subject of the last day of the conference.

Operating experience

The most striking impression of the reports on experience in operation was that of the ease with which these machines had been brought into service and with which they reached their design specifications. This was emphasized by Prof. R.S. Livingston (Oak Ridge), who gave the introductory survey paper, and by succeeding speakers from Berkeley, Los Angeles, Karlsruhe, Ann Arbor, Eindhoven and other centres. This does not mean that such machines are easy to design or to make, but proves that the great effort made in their design and construction has paid handsomely. This effort involved not only many theoretical studies, supported by extensive computations, but also novel methods of field measurement and their direct use by electronic computers, as well as the design of sophisticated accelerating systems and new devices for beam extraction.

Internal beams of 50 μA are commonly achieved, compared with 1-2 μA in synchro-cyclotrons, and values as high as 500 μA have been obtained.

Since only a single accelerating frequency is required for a given condition of the machine, it is comparatively easy to vary this frequency and the magnetic field in such a way as to change the maximum energy, or to use a machine for the acceleration of particles other than the conventional protons. Many sector-focused machines are designed to be able to accelerate also deuterons, alpha particles or even heavier ions. This gives them a hitherto unattainable degree of flexibility. Moreover, the change-over from one working condition to another can usually be performed reliably and reproducibly by setting parameters to nominal values ; no lengthy tuning procedures seem to be required.

The extraction of the internal circulating beam has been one of the great problems of synchro-cyclotrons. To bring five per cent. of the internal beam out of the machine was an achievement, and to extract fifteen per cent. has been considered as sensational. In sector-focused machines it is found that the field-variations around the circumference actually aid the extraction, which is further helped by the small dimensions of the beam due to the excellent focusing conditions, by the high energy gain per turn and the resulting large separation between turns, and by instabilities which occur in some designs. By exploiting some or all of these factors, extraction efficiencies of 30 - 40 % have been achieved. The electron model of a high-energy machine at Oak Ridge has in fact yielded an extraction efficiency of 85 %.

Progress in beam extraction has eased the problem of machine activation, which has become a major headache in cyclotron design and utilization. This activation is caused by the fact that many of the accelerated particles strike internal parts of the machine and interact with the nuclei of the constructional material. The nuclides resulting from such interactions are frequently radioactive and give rise to alpha, beta and gamma radiations long after the machine itself has been stopped. Work at CERN, reported to the conference, has shown how these effects can be minimized by a suitable choice of materials, but it is evident that the best solution of the activation problem consists in bringing all the accelerated particles out of the machine. Even two years ago such a remedy would have been Utopian ; now the high extraction efficiencies achieved in sector-focused machines make it seem a practicable proposition.

An exciting prospect in cyclotron design was opened at the Los Angeles conference by a report from Boulder, Colorado, showing that it was possible to accelerate negative hydrogen ions in a cyclotron. The acceleration of negative ions had previously been performed only in electrostatic machines, for example in the 'tandem Van de Graaff'. There the advantage of negative-ion acceleration, followed by conversion of the H^- ion into an H^+ ion by the removal of its two electrons, is that the same accelerating potential is used twice, and the particle energy attainable may be doubled. In a cyclotron there is no such advantage, but negative-ion acceleration provides a very neat and complete solution to the extraction problem. Cyclotrons are necessarily constructed in such a way as to retain the particles they accelerate until the end of the acceleration process. To change this condition into one in which the bulk of the beam is ejected is difficult and requires one or several of the artifices mentioned earlier. But if the sign of the charge of the accelerated particle is reversed the problem solves itself, for particles of opposite charge are immediately deflected out of the machine. Negative-ion acceleration with subsequent reversal of charge not only provides the means of extracting the accelerated beam at full energy ; one can equally well think of extracting several beams at different energies from the same machine by converting ions from negative to neutral or positive at different radii.

The CERN conference illustrated the progress which has been made in this new field. Both the possibilities and the limitations of negative-ion acceleration are now much better understood. Dr. B. T. Wright (University of California, Los Angeles), who had already analysed this method of operation in 1957, gave results of recent experimental work and showed that it should be possible to accelerate a beam of 1 μA of H^- ions to about 45 MeV in the UCLA sector-focused machine. A team under Prof. J. R. Richardson at Los Angeles is studying the application of negative-ion acceleration in a much larger machine of the 'meson-factory' type, capable of yielding high currents.

The possibility of accelerating beams of polarized particles in cyclotrons has been investigated in the past few years and results of progress in this field were reported by Drs. J. Thirion (Saclay) and L. Dick (CERN). Dr. Lee C. Teng (Argonne) gave an account of a theoretical study of the problems of polarized-ion acceleration in sector-focused cyclotrons, where the more intricate structure may lead to depolarizing effects. He showed how these effects could be minimized or avoided and concluded that the acceleration of polarized particles in the new machines should be feasible.

Physics research

The availability of sector-focused machines of proved reliability, capable of providing a variety of interesting experimental possibilities, has naturally aroused the enthusiasm of nuclear physicists. Dr. A. Zucker (Oak Ridge) outlined different lines of research in which these machines might be of especial value, for example in the study of different types of nuclear model or the more detailed features of nuclei, and pointed out how the requirements of such researches could be met. He also presented some experimental results already achieved with sector-focused machines at Berkeley and Los Angeles, to illustrate their potentialities.

Prof. G. Bernardini (Rome) made an eloquent plea for high-current machines of the meson-producing type, which could do much of the work now performed with larger accelerators. He thought the more modest scale of sector-focused machines of particular value to the scientist, and illustrated his remarks by spirited excursions into the realms of philosophy and some of the more personal aspects of the history of Florence in the Renaissance.

General problems of the experimental layouts required for the new machines were considered by Prof. E. Kelly (Berkeley), while scientists from other laboratories gave accounts of more detailed aspects of beams and other facilities. Prof. J. P. Blaser (E.T.H., Zurich) discussed recent progress in the study of shielding and activation problems created by the intense beams which are becoming available. Dr. M. Barbier (CERN) illustrated how the requirements of radiation safety would have to be met by the design of new devices such as target shields and special beam catchers.

Developments in theory and design

The accounts of theoretical work performed during the past year showed that after the solution of the general problems of stability, attention is now being directed to the central region and to beam extraction. The two fields are closely dependent on one another, for the high beam quality required for efficient extraction can only be furnished by a well-designed injection system at the centre. Detailed mathematical studies of the central region and of ejection systems have recently been performed, particularly at Michigan State University and by a team at the Philips Laboratories, Eindhoven.

Progress in the construction of new machines and novel design features were reported from Milan, Orsay, Grenoble and Michigan. From Oak Ridge came a description of a new extraction system consisting of a length of slotted coaxial cable, and from Berkeley an account of their experience in making a reliable high-voltage deflector, which has led to advances in the production of high electric fields.

Meson factories

The discussions on meson factories went rather beyond the framework set by sector-focused cyclotrons, for while these machines are undoubtedly strong candidates for the role of high-current accelerators in the energy range of 400 to 800 MeV, other types of machine such as the linear accelerator or the fixed-field alternating-gradient (FFAG) machine have to be considered.

The merits of different kinds of cyclic accelerator were compared by Prof. J. R. Richardson (Los Angeles).

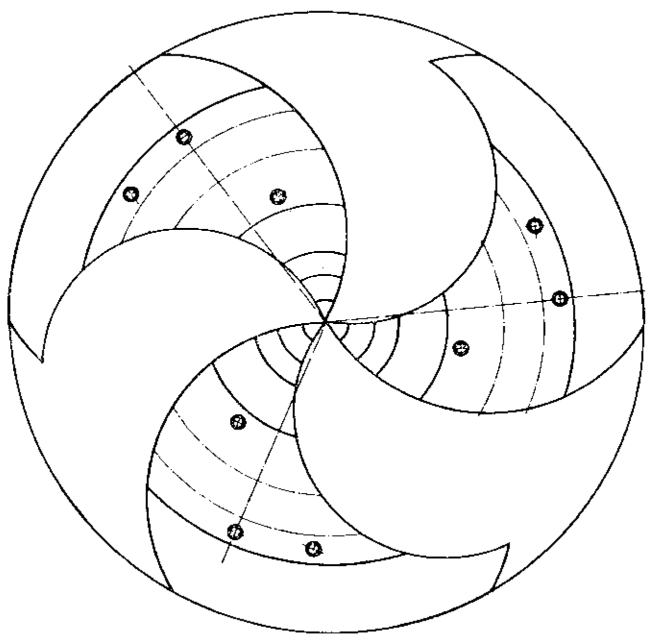


Diagram : Philips Research Laboratories, Eindhoven.

Diagram of the 'spiral-ridge' pole segments of a two-particle fixed-energy AVF cyclotron designed by Philips Research Laboratories, Eindhoven (Netherlands). The pole diameter is 140 cm and the machine will accelerate protons to 27 MeV or deteurons to 16 MeV.

He considered the effect of various design parameters on the characteristics of such machines as instruments for high-energy physics research. Apart from the requirement of intense and high-quality pi-meson beams, which is the essential characteristic of a meson factory, there are many other relevant factors such as cost, possibility of varying the energy, production of simultaneous beams of different particles or energies, duty factor, ease of extraction of the internal beam, and the associated question of induced activity. Prof. Richardson showed that in these respects the sector-focused cyclotron was probably superior to other types of machine, and that its usefulness would be increased if it were constructed for negative-ion acceleration, even though this is initially somewhat more costly. However, he pointed out that synchro-cyclotrons were capable of further development and that the FFAG accelerator also remained a serious competitor in the field.

The various linear-accelerator projects were examined by Dr. G. H. Stafford (N.I.R.N.S.). Linear accelerators possess the great advantage that there are no extraction or activation problems. Beam energy and intensity can be varied and the acceleration of polarized particles has proved practicable. On the other hand such machines have a poor duty factor, giving relatively intense beams for a small fraction of the time only. From the point of view of many, though not all, applications in physics this is a distinct drawback. The importance of the limitation will, however, diminish as more powerful valves become available for the radiofrequency supply, and many disappear altogether if projects for superconducting linear accelerators, now under study, prove to be practicable.

Of the detailed designs discussed, a few may be mentioned. The E.T.H. at Zurich is working on a two-stage accelerator, consisting of a sector-focused cyclotron of about 70 MeV, which injects a beam into a ring-shaped machine consisting of eight magnet units separated by field-free drift spaces. There the protons are further accelerated to about 500 MeV. Such a machine has many advantages over a conventional cyclotron on account of its open structure, which not only provides better accessibility but also overcomes some problems of beam instability. Dr. F. M. Russell (N.I.R.N.S. and Oak Ridge) proposed a 'separated-orbit cyclotron' or 'beehive' accelerator. This consists of a coiled-up linear machine whose turns of increasing radius are at different levels. (In view of the fact that bees in the neighbourhood of Geneva appear to be living in rectangular boxes the term 'crinoline accelerator' is proposed for local use.) Each quasi-circular turn of the machine has its separate guiding field, but the accelerating cavities, placed on meridians of the structure, serve all levels at once. Although this design is very intricate and probably costly, it avoids many difficulties besetting conventional machines.

Dr. R. P. Haddock (Los Angeles) discussed a machine for the acceleration of muons, which would open a new field in the realm of accelerators.

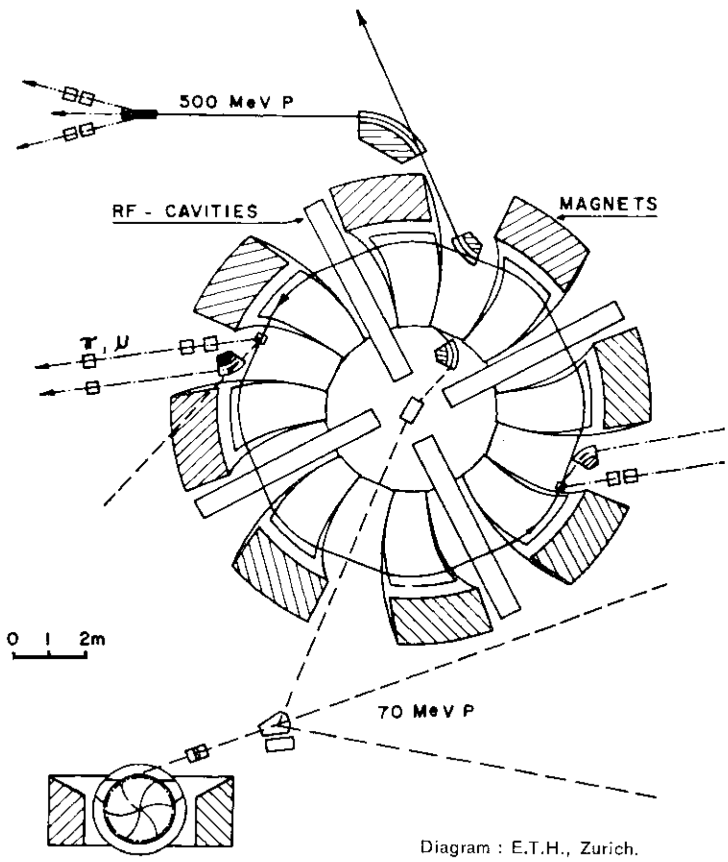


Diagram : E.T.H., Zurich.

Schematic layout of the proposed 500-MeV isochronous cyclotron for E.T.H., Zurich (Switzerland). This would have eight separate magnets, forming a ring, and four accelerating gaps. Protons would be injected at 70 MeV from the isochronous cyclotron shown at the lower left and accelerated to just over 500 MeV. External beams of protons, pions or muons would be available.

CONCLUSIONS

In view of the success of the sector-focused machines, one feels that the time when accelerators were built according to rough computations or approximate considerations is now past. Present day computers offer the possibility of studying not only linear but non-linear problems in detail, and the ease with which the complex sector-focused machines have been brought into operation proves the value of the theoretical and numerical work which preceded their design and construction. These machines have also provided engineers and technicians with intricate problems in the design of magnetic fields and of acceleration and extraction systems.

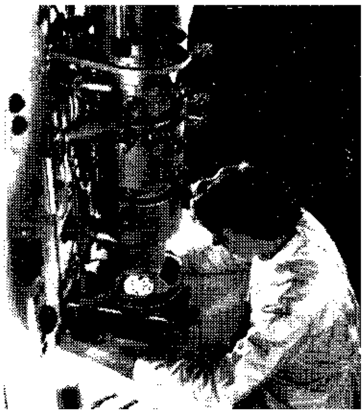
In optimal beam intensities there is a gap between currents of the order of 100 μA, which are best achieved with cyclotrons, and 10 to 100 mA, for which linear accelerators are most suitable. Here new solutions, such as the separated-orbit cyclotron or the cryogenic linac, may come into their own. The conference showed that past successes had not led the designers to rest on their laurels, but that there are many new ideas which will no doubt be pursued with enthusiasm and ingenuity.

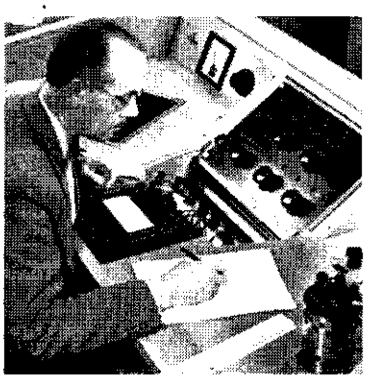
PROCEEDINGS

The Proceedings of the conference were edited by F. T. Howard (Oak Ridge) and N. Vogt Nilsen (CERN), helped by a team of scientific secretaries. They were typed for offset reproduction by a team working under Mme. A. Martin, and printing was begun on 29 May. Thanks to an all-out effort of the CERN Scientific Information Service, the first 500 copies were dispatched on 19 July. It is hoped that the Proceedings will form a useful compendium on sector-focused machines for some time to come●

SIEMENS
INSTRUMENTATION

A versatile range of manufacture





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