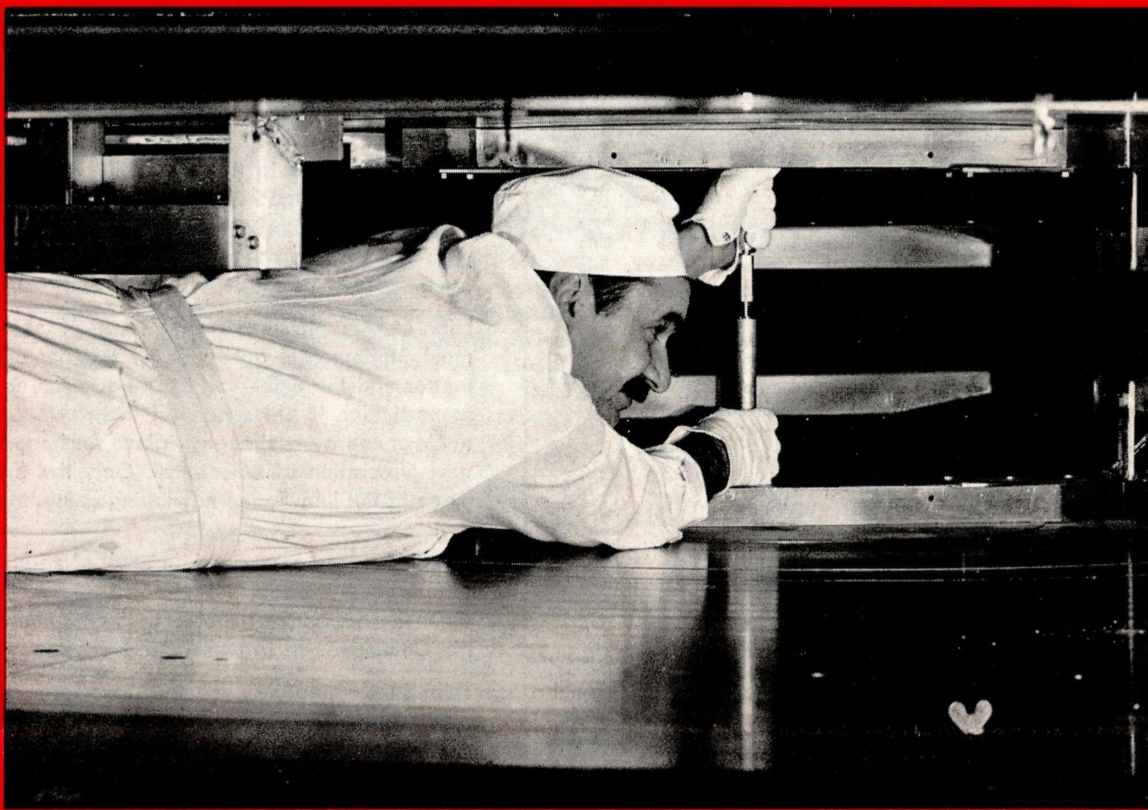
CERN COURIER



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CERN COURIER

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Contents

The cover photograph was taken during the Christmas shutdown of the 600 MeV synchro-cyclotron. It shows the centre of the machine as seen from the 'neutron platform'. The mechanic is mounting a fixture for drilling the holes used for fixing new ion source support contact fingers. The mouth of the dee can be seen behind the vertical clamp.

The main article in this issue of CERN COURIER is devoted to the improvements programme for the synchro-cyclotron.

The CERN COURIER is published monthly by CERN in English and in French editions. It is distributed free of charge to CERN employees, and others interested in the construction and use of particle accelerators or in the progress of nuclear physics in general.

Editor: Brian Southworth
Public Information Office,
CERN, 1211 Geneva 23, Switzerland.
Tel. (022) 41 98 11 / Telex: 2 25 48

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

In this Convention, the aims of the Organization are defined as follows:

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

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

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

The laboratory comprises an area of about 80 ha (200 acres), straddling an international frontier; 41 ha is on Swiss territory in Meyrin, Canton of Geneva (the seat of the Organization), and 39.5 ha on French territory, in the Communes of Prévessin and St.-Genis-Pouilly, Department of the Ain.

Two large particle accelerators form the basis of the experimental equipment:

- a 600 MeV synchro-cyclotron,
- a 28 GeV proton synchrotron,

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

The CERN staff totals about 2200 people.

In addition to the scientists on the staff, there are over 350 Fellows and Visiting Scientists, who stay at CERN, either individually or as members of visiting teams, for periods ranging from two months to two years. Although these Fellows and Visitors come mainly from universities and research institutes in the CERN Member States, they also include scientists from other countries. Furthermore, much of the experimental data obtained with the accelerators is distributed among participating laboratories for evaluation.

Thirteen Member States contribute to the cost of the basic programme of CERN in proportion to their net national income:

Austria (1.90 %)	Italy (11.24 %)
Belgium (3.56 %)	Netherlands (3.88 %)
Denmark (2.05 %)	Norway (1.41 %)
Federal Republic of Germany (23.30 %)	Spain (3.43 %)
	Sweden (4.02 %)
France (19.34 %)	Switzerland (3.11 %)
Greece (0.60 %)	United Kingdom (22.16 %)

Poland, Turkey and Yugoslavia have the status of Observer.

The 1966 budget for the basic programme amounts to 149 670 000 Swiss francs, calling for contributions from Member States totalling 145 860 000 Swiss francs.

Supplementary programmes, financed by twelve states, cover construction of intersecting storage rings for the 28 GeV accelerator at Meyrin and studies for a proposed 300 GeV accelerator that would be built elsewhere ●

31st Session of CERN Council

The Council met at CERN on 15 and 16 December 1965. Major decisions on the improvement programme for the existing installations and on the intersecting storage ring project were reported briefly in the January issue of the COURIER. This article amplifies the information concerning these decisions and in addition covers a review by Professor Weisskopf of the contribution of CERN to high energy physics during his five years as Director General.

Professor Weisskopf, making his last appearance before the Council as Director General of CERN, presented a review of the contribution of CERN and its collaborating Laboratories throughout Europe, to the progress of high energy physics. The following paragraphs are a condensed version of this review.

"About the beginning of 1960 a new wave of discoveries was breaking loose in high energy physics. It was realized that the elementary particles exist in many quantum states or 'resonances'. The existence of these quantum states has dominated high energy physics ever since and their systematic study has started a new discipline — the spectroscopy of elementary particles. We are by now aware of some underlying mechanism of which the detailed structure remains to be discovered and explored.

In addition to the field of 'strong interactions', which was opened up by the new spectroscopy, there are the 'weak interactions' and the 'electromagnetic interactions'. In 1960, the field of weak interactions was still absorbing the discovery of the violation of parity in 1957. This discovery has enabled the mechanism of the interaction to be formulated in a more systematic way and yielded relevant questions which may clarify the basis of these mysterious interactions. At the same time, the field of electrodynamics had an excellent theory of the interaction of charged particles with the radiation field. But the theory still faced fundamental problems such as the existence of two types of electron (the light and the heavy electron or muon), and the electromagnetic properties of the strongly interacting particles.

CERN contribution

I would like to present to you the contribution of CERN to the attack on these problems. The tables include some of the important research results from CERN or its European collaborators in the period from 1960-65. The results underlined were either obtained for the first time in Europe or more thoroughly investigated here than elsewhere.

1. 'New particles'

a) **Baryons**	b) **Mesons**
Antistates:	$f(0,2)$, $K^*(1/2,2)$
Ξ, $\bar{N}^*$, $\bar{Y}^*$	$E(0,?)$, $D(0,1)$
Excited states:	$A_1(1,1)$, $A_2(1,2)$
$Y^*(1,5/2)$ $Y^*(0,5/2)$	$C(??)$, (K^+K^+) $(?,?)$
$\Xi^*(1/2,?)$ $\Xi^*(?,?)$	properties of mesons

The experiments were of varied character, results coming largely from bubble chamber research but with important contributions from counter and spark chamber experiments. The importance of Europe's contribution to the discovery and classification of baryon and meson states can be roughly gauged from the number of papers published on the subject (although this says nothing about the quality of the papers). From 1960 to 1965 about 30 % were written by European groups even though CERN has really only been fully operative for the last two or three years.

In the last few years the study of the new spectroscopy of particles has led to some conclusions about certain symmetries (SU_3, SU_6 or U_{12}) to which the unknown underlying structure is subjected. The Theoretical Studies Division at CERN, which is in some ways the European nerve centre of theoretical studies in elementary particle physics, has participated actively in the classification of ideas regarding these new symmetries.

2. Strong interactions

a) **Theory**	b) **Experiment**
Regge poles	Shrinking of diffraction peak
Diffraction scattering	Quasi-elastic scattering
Pomeranchuk theorem	Total cross-sections
Peripheral model (meson exchange)	Peripheral processes
General field theory	Charge exchange collisions

All the collision processes which lead to the production of the excited quantum states are strong interaction processes. It was always the tendency among the physicists connected with CERN, to study these processes and their mechanism and not only the products.

Much pioneering work in this direction was done at CERN and in Europe.

3. Weak interactions

a) Theory

- Cabibbo angle
- Symmetries
- CP violation (5th force)

b) Experiment

- Neutrino:
  - $\nu_e \neq \nu_\mu$
  - lepton conservation
  - $M_W > 2$ GeV
  - form factors
- Σ decay:
  - $(\Sigma - \Lambda)$ parity
  - e/μ ratio
  - $\Delta S / \Delta Q = 1$
- K^0 decay: $\Delta S / \Delta I = 1$
- Λ decay: C_V / C_A
- Ξ decay: $(\Delta I = 1/2)$
- π^+ decay: $(\pi^+ \to \pi^0)$
- K^0_2 decay: (energy dependence)
- μ capture in H
- μ decay (electron polarization)
- Precise measurement of universal weak charge.

The weak interactions have always been in the centre of interest at CERN. One of the first decisive experiments on the 600 MeV synchro-cyclotron in 1957 established the decay of the pion into electrons. The neutrino experiments have been very fruitful and currently, after the discovery of CP violation at Brookhaven, intensive research is underway on this problem.

4. Electromagnetic interactions

a) Pure interactions

- (g-2) experiment (muon magnetic moment)
- γ-ray absorption
- e^+ annihilation
- μ-e scattering
- Theoretical calculations

b) Electric hadron properties

- Λ magnetic moment
- π^0 lifetime
- $\pi^0 \to 3\gamma$
- Time-like form factor of proton

CERN is pioneering and is ahead of other Laboratories in the investigation of the riddle of the heavy and light electrons. We have also recently made an important contribution to knowledge of the electromagnetic structure of protons and mesons. The 'electric heart-beat', as it were, of the particle was measured and surprisingly proved a thousand times weaker than expected.

5. Nuclear structure

- Double hypernuclei
- Muonic X-rays (quadrupole moments)
- He_4 excited states
- Pion double-charge exchange
- Muon capture rates
- Theoretical studies

This research started late but is now in full swing, mainly on the synchro-cyclotron. Europe was always advanced in this field, both in theory and experiment, and at CERN we have a unique opportunity to apply high energy beams to these questions.

Four reasons

This review shows that CERN and the other European Laboratories are today in the forefront of nuclear and elementary particle physics. The results could have been more impressive; some of the recent sensational discoveries were made elsewhere. Nevertheless the work done in Europe is now on a level with that at other similar research centres.

There are, in my view, four reasons for this satisfactory state of affairs. The first is the quality of the people working at CERN. We have a devoted and enthusiastic group of collaborators, who cover a wide spectrum of abilities.

The second reason is the quality of our equipment and research facilities. The two accelerators are in excellent condition with an unusually high reliability of performance. Many new facilities have been brought into use as a result of a long-range development programme. Today we have well-functioning systems for fast and slow ejection allowing a much better exploitation of the beam. We have developed a very reliable set of electrostatic separators and recently put into use a radio-frequency separator, which was the first in the world to be exploited for experiments. CERN has constructed a heavy liquid bubble chamber which is at present the largest in the world, and a 2 m hydrogen chamber which was put into use a year ago and has worked faultlessly. For our data handling facilities, we acquired last year a new computer — the CDC 6600 — which should provide us with the most advanced computing devices for all our needs. Automatic scanning machines for track chamber pictures, the Hough-Powell Device and the Luciole Device, were conceived and developed at CERN. The HPD is now in use all over the world.

The third contributing factor to our work is the excellent support which we have received from the Member States: from the scientific community and from the governments, via the Council. The governments have looked at CERN as a centre of fundamental science in Europe, which must be kept going and blossoming, because Europe was the cradle of modern science and should remain in the forefront of it. We feel that CERN had always been a pet child of the governments; I am sure the reason for this sympathy and support is the fact that CERN is a symbol of European unity, and of successful international collaboration.

The fourth reason is perhaps the most important one: we were able here at CERN to develop an atmosphere favourable for research, a spirit of openness, of discussion between groups, a spirit which appreciated good ideas, a good experiment, a good result.

Because of these four reasons, CERN will go on producing excellent results. In fact, I am convinced that the real golden age of CERN lies ahead. CERN is now a mature institution; we have much more experience in doing things, in thinking about things, in acting together. Five years is a short time in the life of an institution and this development is bound to go on. I am convinced, therefore, that the scientific achievements of CERN and Europe will be more impressive in the future. This is why I am looking forward to Professor Gregory's report in 1970, and to the corresponding report of the Director General in 1975, when the storage rings and the new improvement programme will have been put into use. I am sure that they will be far more impressive that what I could tell you today."

Basic Programme

Council approved a budget of 149.67 million Swiss francs for the basic programme of CERN in the year 1966. The basic programme concerns the exploitation and development of the existing CERN installations. The considerable increase in the budget over that of 1965 marks the approval of the Council for the start of an improvement programme on the 28 GeV proton synchrotron. 6 million Swiss francs are allocated to this work in 1966.

The first stage of the PS improvement programme will run up to the end of 1968 and will include an increase in the repetition rate by a factor of 2 or 3 (involving a new magnet power supply); improved experimental facilities (such as a more intense neutrino beam, an on-line data handling installation, a large spark chamber, a long pulse r.f. separator); the heavy liquid bubble chamber 'Gargamelle', which will be constructed by France; and an extension of the experimental areas. The improvements will enable more complex experiments to be done and, in particular, using Gargamelle and the more intense beam of neutrinos, neutrino physics will be on a quantitative basis for the first time.

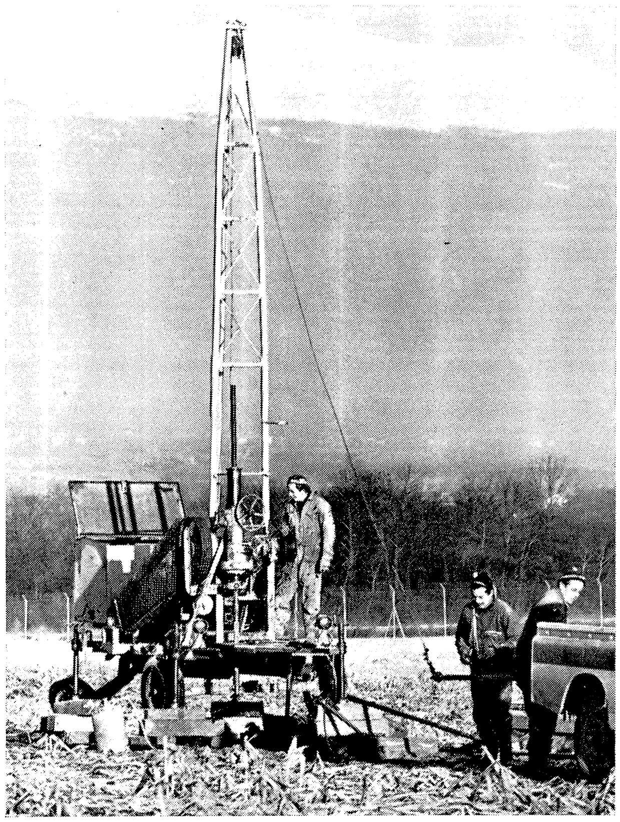
The second stage of the programme, planned for completion in 1970 and 1971, includes a very large hydrogen bubble chamber (volume of 25 m^3); a new 200 MeV injector (giving a 4 or 5 fold increase in intensity per pulse); and more advanced experimental facilities. This stage represents a further increase in quantity and quality for the PS and its surrounding facilities.

ISR Project

In addition to the basic programme, which comes under the terms of the original CERN Convention, there are two supplementary programmes. The first of these is the intersecting storage ring project. At the Council Session in June 1965 the project was approved in principle and in December all the Member States with the exception of Greece were able to announce that they were willing to participate. A budget of 21.7 million Swiss francs was voted for 1966.

The estimated cost for the full project, over the six years 1966-71, is 332 million Swiss francs. It covers the building of two intersecting storage rings which will be supplied with protons from the 28 GeV PS; two colliding beam halls; one 25 GeV experimental hall and all the necessary buildings, laboratories, workshops and other services (power and water supplies, cooling and control equipment, roads, etc.).

Professor Leprince-Ringuet spoke as Chairman of the Scientific Policy Committee urging the ISR project as 'sound and highly recommendable', providing the greatest degree of flexibility which it can be hoped to obtain with this kind of machine. The SPC advised that during the first months of the project, before large sums of money were committed, any possibility of improving the collision structures be pursued, so as to make the final version of the ISR the best conceivable within the limits of the site and the financial provisions.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A fourth boring being taken at the beginning of January' on the French half of the CERN site, as part of the geological survey for the ISR project.

At present, preliminary work is underway on the newly acquired French site. The area has been fenced off. Drainage works between the PS South Hall and the centrè of the ISR, and the first section of the service tunnel on the French site, connecting the main substation with the ISR, are under construction. Early in the summer of this year the major construction work will begin.

The intersecting storage rings will be a unique facility. It is the only project of its type, producing head-on collisions in two high energy proton beams, which is going ahead anywhere in the world. Its uniqueness leads to new and challenging technical problems (beam stacking in the ISR, very stringent vacuum conditions, improved detection methods) and will eventually allow the investigation of extremely high energy proton interactions which could reveal a new range of phenomena. Authorization for this new development at the CERN site contributes considerably towards ensuring the vitality of CERN in the coming years.

300 GeV accelerator

The second supplementary programme concerns the preparatory studies for a future very large accelerator which would be built elsewhere in Europe. A budget of 5.2 million Swiss francs was requested to enable this work to continue. Some Member States however considered that this figure was too high and that the proposed build up during 1966 implied a too early freezing of the design and too large commitments for 1967.

Professor Leprince-Ringuet said that the Scientific Policy Committee considered that it would be catastrophic for the future of CERN if the preparatory studies for the 300 GeV project were stopped. The working group would be broken up; it would be difficult to set up again and the breaking up would give the impression that the project was being abandoned for a fairly long time. This would have irreversible effects in many countries, which would revise the balance between national and international expenditure. The SPC was firmly of the opinion that the preparatory studies should continue.

It was agreed to continue the work for three months on the basis of a budget for 1966 of 4 million Swiss francs while the problem is being reconsidered by the Finance Committee.

Nine Member States offered a total of twenty-two sites for consideration as the location of the 300 GeV project. This has now been reduced to thirteen; Germany and Italy are putting forward more than one site and discussions will be started shortly with the authorities concerned to determine the order of preference. Site studies are now in progress. They include investigation of the site itself — geological, geotechnical and hydrogeological — and also investigation of local industrial potential, manpower availability, housing, etc. Council has requested an interim report on the site proposals at the June 1966 meeting and complete dossiers on the 8 or 10 remaining sites by June 1967. The President reminded the Delegates that a method for selecting the site remains to be established.

In addition to the site studies, preparatory work concerning the machine itself is underway on a small scale. It includes basic design studies for the accelerator. The European Committee on Future Accelerators, which under the Chairmanship of Professor Amaldi recommended the 300 GeV machine in its report of 1963, has been reconvened to discuss the technical and scientific problems connected with the project and to give guidance on the work to be done during preparatory studies.

And then there were thirteen —

The sites remaining under active consideration for the proposed 300 GeV machine are as follows:

Austria	**Göpfritz**
Belgium	**Focant**
Federal Republic of Germany	**Drensteinfurt**
	Ebersberg
	Reimsbach
	Sarrlouis
France	**Le Luc**
Italy	**Doberdo**
	Nardo
Norway	**Kongsvinger**
Spain	**El Escorial**
Sweden	**Uppsala**
United Kingdom	**Mundford**

There are also general layout studies and feasibility studies for accelerator components — linear accelerator improvements, magnet construction problems (experience is being gained from the models for the ISR), r.f. accelerating systems, induced activity and shielding problems, new control methods and survey techniques.

Serpukhov collaboration

Professor Weisskopf reminded the Council that the USSR would soon be completing their 70 GeV accelerator at Serpukhov, which would be for several years the highest energy accelerator in the world. The possibility of CERN collaboration at this research centre was being discussed and proposals as to the way in which co-operation could be achieved have been put forward to the USSR. The Council supported Professor Weisskopf's initiative.

The Session closed, as reported in the January issue of the COURIER (p. 3), with a farewell speech by the President to Professor Weisskopf after five years in office as Director General, and a welcome and an assurance of continued support for Professor Gregory, the new Director General.

CERN News

PS Breakdown

On the night of 8 February, a mechanical accident occurred on the main magnet power supply of the proton-synchrotron. The PS is shut down and the Experimental Planning Group is working out proposals for a new programme to compensate as far as possible for the loss of the experimental time which had been scheduled up to Easter.

* * *

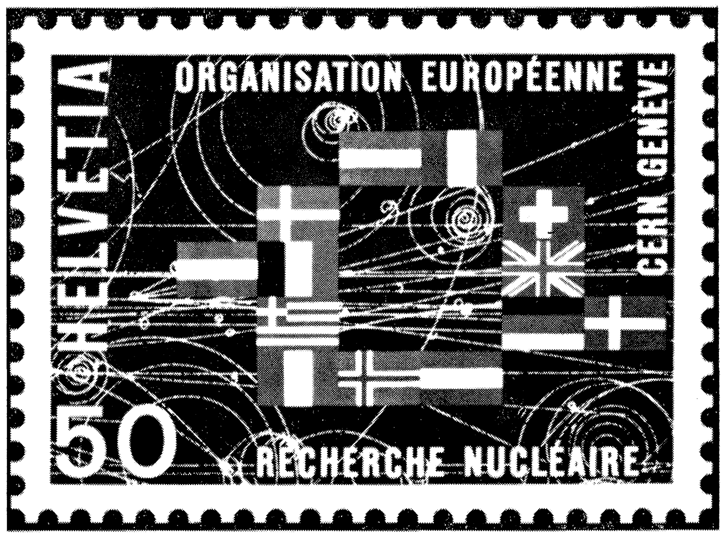
As the protons are accelerated in the synchrotron, they are held in their orbits of constant radius by a rising magnetic field in the hundred magnets of the synchrotron ring. This rising field is achieved by providing a pulse of power (which can be as high as 34 560 kW) to the magnets. To take such large surges of power direct from the Geneva electricity grid would produce fluctuations in the grid voltage at the repetition frequency of the machine and affect other users on the grid.

A power supply is therefore introduced between the grid and the magnets to smooth out the effect of the machine pulses. It does this by storing mechanical energy, in its rotating components, some of which is converted into electrical energy once every few seconds to pulse the magnets and the loss in energy is made up more gradually from the grid. The rotor of the power supply motor in fact weighs 5180 kg and revolves at about 3000 rev/min.

The accident occurred when a clamping band, which holds the rotor coils in position, fractured, possibly because of direct mechanical failure or because of a short circuit which caused sufficient local heating to melt the band. Due to the centrifugal force, the ends of the windings splayed out and hit the stator windings. Both sets of windings suffered extensive damage but no harm appears to have been caused to either the rotor or the stator laminations. Complete spare sets of the windings exist and the motor was immediately taken to the manufacturers to be rewound. It is estimated that the repairs will take three months and will cost about 90 000 Swiss francs.

The experimental time up to Easter has been lost. Fortunately however a six week shutdown was scheduled from Easter until 25 May, to install the new slow ejection system in the East Area, for a major rearrangement of beam lines in both the East and the South Area, and for work on the injector, which includes installation of a new ion source and pre-accelerator column and an improved inflector (see page 29). Some of this work has already started and every effort will be made to complete the shutdown by the time that the repaired magnet power supply is back in action.

A contract for a new PS magnet power supply was placed in the week preceeding the accident. It is a larger supply which will make possible a machine repetition rate 2 or 3 times higher than is available with the present supply. This gain in repetition rate is part of the PS improvement programme. A subsidiary reason for ordering the new supply is to have a spare available.



A black and white reproduction of the Swiss postage stamp issued in honour of CERN. The issue will continue for one month from 21 February.

CERN Stamp

On 21 February, the Swiss Postal Authorities (PTT) issued a 50 centime postage stamp in honour of CERN. The stamp is one of a series of three, the others being in honour of the International Union for the Preservation of Nature and its Resources (10 centime) and of the fiftieth anniversary of the Swiss Industrial Fair at Basle (20 centime).

The decision to issue the CERN stamp was taken in 1964 and five Swiss artists, including Marcel Bron from Site and Buildings Division, were selected to produce designs. The artists visited the Laboratory and were told the story of CERN and shown around the site. They each then presented two designs which were judged on 13 May 1965 by a committee under the Chairmanship of Dr. Tuason, Director General of the PTT, which included representatives of the Federal Commission of Fine Arts, the Commission of Applied Arts, and the Union of Swiss Philatelic Societies. Mr. G. H. Hampton, Directorate Member for Administration, Mr. R. Anthoine, Head of Public Information Office and Mr. J. Baudeloque from the CERN Philatelic Committee were present from CERN.

The selected design, by Mr. H. Kümpel from Zürich, shows the flags of the thirteen Member States of CERN superimposed on a bubble chamber photograph. The flags are arranged to represent roughly the outline of the Swiss border.

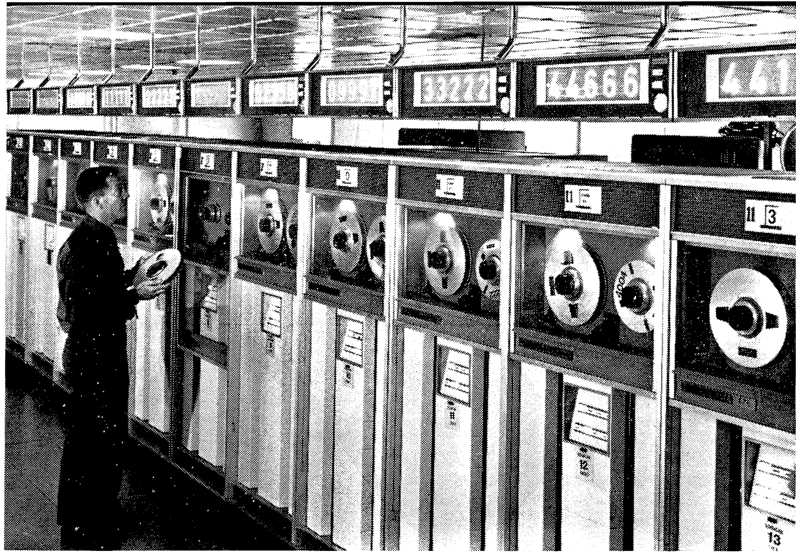
On the date of issue of the stamp, the CERN Philatelic Committee organized a distribution of envelopes, illustrated on the same European and nuclear themes, carrying the stamp postmarked at the CERN post-office. Enclosed in each envelope was a leaflet showing an aerial view of the CERN site and giving some information on the European Organization for Nuclear Research. The Philatelic Committee also organized an exhibition of stamps at CERN from 21-28 February. The exhibition, which attracted several groups of philatelists from outside CERN, was in three sections — one devoted to CERN history, from the collection of Mr. Pen of Chambéry; the second devoted to stamps on the theme of atomic and nuclear physics from the collection of Mr. Gase and the third to the theme of Europe from the collection of Mr. Baudeloque.

For one day each week for the next six months, the normal franking machine in the CERN post-office will not be in use and the CERN stamp will be used instead for mail going outside Switzerland.

Among the Immortals

On 13 January, Professor Leprince-Ringuet, Chairman of the Scientific Policy Committee, was elected to the Académie Française. Membership of

Professor Leprince-Ringuet (on the right) was elected to the 'Académie Française' in January. He is seen here, in conversation with Professor Perrin (left) and Professor Gentner, both delegates to the December 1965 Council meeting, at the Dinner given by the Council in honour of the departing Director General, Professor Weisskopf.



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The 'tape unit reel number display system' of the 6600 computer, mounted over the tape units. This display system was developed at CERN and installed in October 1965. It serves to inform the operator of the number of the reel required on the unit for processing, by a programme which is executing under the SIPROS operating system.

the Académie is regarded as one of the highest honours in France and the Académiciens are known as 'Les Immortels'. The Académie is limited to 40 members at any one time; Professor Leprince-Ringuet takes the place left vacant on the death of General Weygand.

Louis Leprince-Ringuet was born in 1901 at Alès (Gard). In 1925, he joined the Laboratory of the famous French scientist Maurice de Broglie where he worked on the artificial transmutation of elements, and on neutron and cosmic ray research. He led several research teams in cosmic ray physics and in the 1950s was in charge of a Wilson cloud chamber installation on the Pic de Midi where some of the first studies of the properties of mesons and hyperons were made. (Among the physicists who worked with him during that time were Professor Gregory, now Director General of CERN, and Professor Peyrou, now Head of Track Chambers Division.)

From 1936, Professor Leprince-Ringuet has lectured at the Ecole Polytechnique and in 1949 joined the Académie des Sciences. He was also named Professor of Nuclear Physics at the Collège de France in 1959 on the death of Professor F. Joliot.

He has been active in the development of CERN since 1952. He was involved particularly in bubble chamber projects, for example, the 1 metre heavy liquid bubble chamber of the Ecole Polytechnique. For the last two years he has been Chairman of the Scientific Policy Committee which makes recommendations to the CERN Council on major items of scientific policy. Professor Leprince-Ringuet spoke on behalf of the SPC, at the December 1965 Council Meeting, on the CERN basic programme, the ISR project and the 300 GeV machine studies (see page 25).

CDC 6600

On 20 and 21 January, the third meeting of users of the CDC 6000 computer series was held at CERN. The meetings are known as VIM meetings (roman numerals, VI = six ; M = thousand). Their purpose is to serve as a forum of 6000 series users which can make collective recommendations to the manufacturer concerning desirable features for the existing computers and concerning future systems. They also serve to bring about some collaboration on programming.

Representatives from the various centres using, or planning to use, computers in the 6000 series attended the meeting. Fifteen CDC 6600's have now been ordered - mainly for centres in the USA but with two 6600s and one 6400 for Europe. CDC are currently working on a 6800 system, which will have a potential speed four times higher than the 6600, and this new computer is expected to be ready around mid-1968.

The CERN CDC 6600 is in operation round the clock, 13 hours being computing time fully absorbed by CERN computing requirements. The rest of the time is divided between system development (5½ hours), engineering (4 hours) and development work for such devices as HPD and Luciole, etc.

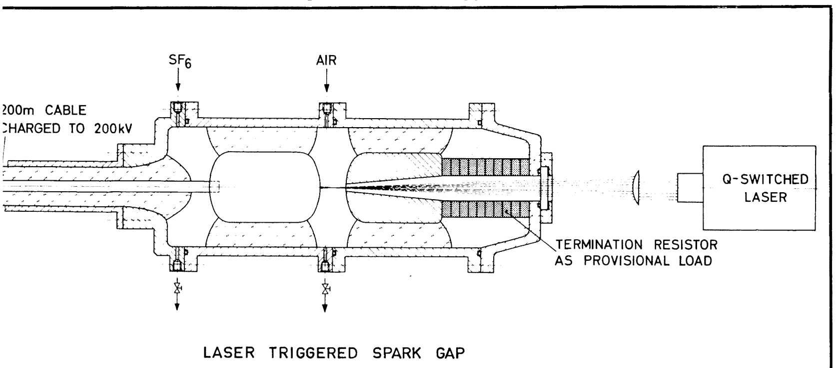
The time-sharing system, SIPROS, is a monitoring program which supervises the progress of the work fed to the computer, organizing the sequence of operation so that use is made of the computer's multi-processing capabilities. It enables many programs to pass through the computer at the same time instead of being run one after the other as at present. A version of SIPROS developed at CERN is now undergoing production testing in order to prove it for full scale operation.

Attempts are being made to establish a thorough system of checks as a permanent feature of the maintenance procedures to prevent a recurrence of the troubles which put the computer out of action in November 1965. As a result of the overhaul done at that time the computer hardware (the central processer, the memory, the peripheral processer, the data channels, etc.) is now working considerably better. Also at that time, a CDC 3400 computer was brought to CERN to provide some on-site computing facilities while the 6600 received attention. It is still being used and will probably stay at CERN until the time-sharing system is in full and reliable operation on the big computer.

Lasers at CERN

It has been known for some time that it should be possible to trigger high voltage spark gaps by means of laser beams. Experiments at CERN and elsewhere have confirmed this, and lasers are likely to be widely used for this purpose in the future.

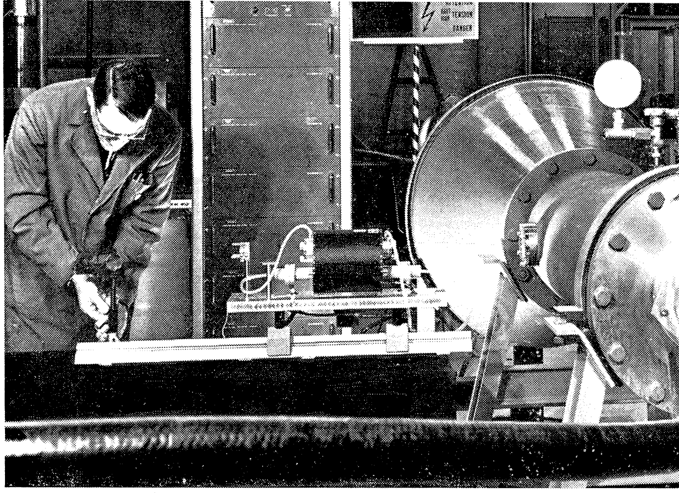
A diagram of a laser triggered spark gap to switch a 200 kV supply.



A conventional method of switching-on high voltage equipment for a short pulse is by means of a three electrode spark gap. One electrode is triggered to cause ionisation in the gap, which then fires between the other two electrodes to convey the required high voltage to the component concerned. This three electrode device is relatively complicated and presents more and more difficulties the higher the working voltage, as the trigger circuit itself is on a high voltage level. These difficulties are completely removed if the intense beam of light from a laser is used to cause the ionisation in the gap. The trigger circuit is then completely isolated from the high voltage components.

The photograph at the top of page 29, shows a laser being used with a 600 kV pulse generator which is under construction for the study of pulsed separators. These separators may turn out to be of interest for some special beams of short lived particles.

A laser spark gap is also under consideration for switching of a 200 kV supply to a kicker magnet on the PS, which is a component in the system for fast ejection of one or more proton bunches from the synchrotron. The particular requirements of this switching process are that it should have low 'jitter' and be capable of high repetition rates. A research contract was placed in January to investigate the extent to which a laser triggered system will meet these requirements. If it proves possible to use the laser system it will have important advantages such as basic simplicity, even for simultaneous switching of several gaps, improved synchronisation and greater reliability.



The use of a laser to trigger a 600 kV supply for the study of pulsed separators. A continuous 600 kV generator is connected to a heavy screened cable (running along the bottom of the photograph) and discharged through a spark gap, triggered by a short pulse from a laser beam. The laser (centre of photograph) is being aligned with the window of the spark gap chamber.

Multi-turn injection

At the end of December 1965, multi-turn injection was achieved for the first time on the PS. Injection was continued for three turns with a beam pulse 20 μs long from the injector. The increase in PS intensity was about 25 %, so that the year ended with a flourish of 10^{12} particles per pulse which had eluded the machine since the July shutdown. Multi-turn injection will now be in regular use.

Although the 500 keV preaccelerator and the 50 MeV linac are usually considered together as the injector of the PS, the term 'injection' applies specifically to the process of feeding the 50 MeV protons into the magnet ring. This has been done by providing a pulse of particles just under 7 μs long from the injector; the particles are bent into their orbit in the ring by an electrostatic inflector. Injection continues until the first injected particles have travelled once round the ring and reach the inflector again. Thus the PS is filled with particles for one turn and the process is called single-turn injection.

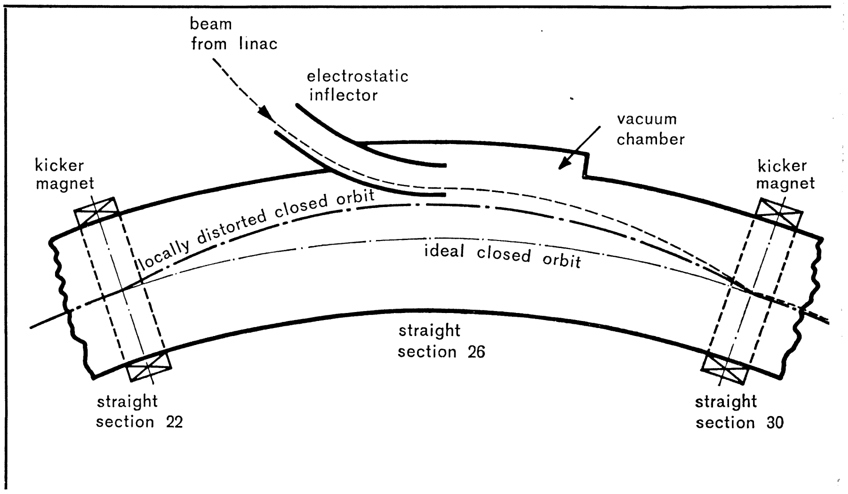
To increase the PS intensity, efforts have previously been concentrated on increasing the number of protons in the one injected turn. While waiting for significant advances to be made here, attention has turned towards 'multi-turn' injection. Injection for three turns requires a pulse 20 μs long from the injector which involves a longer pulse from the proton source and introduces serious 'beam loading' problems in the preaccelerator and, especially, the linac. An intense particle beam causes an important load on the stored energy of the accelerating field and causes voltages to drop; this is aggravated by lengthening the beam pulse.

Also, the injection process itself of more than one turn is complicated. The protons of the first injected turn, after being bent by the electrostatic inflector, in straight section 26, and the kicker magnet, in straight section 30, will travel on their orbits dictated by the energy of the protons and the strength of the magnetic field. However they do not travel exactly on a circle (the ideal 'closed orbit') but oscillate about it (betatron oscillations). When the second and subsequent turns are injected, unless something special is done, the newly introduced protons and those already circulating will approach the kicker magnet in very different directions. The deflection introduced at the magnet would then cause one or other group of protons (depending upon whether the magnet was left on or switched off) to be bent so that they would hit the walls of the vacuum chamber and be lost.

To prevent this and to ensure that virtually all the particles lie within what is known as the 'acceptance' of the PS, the closed orbit is locally distorted near the inflector (see figure) so that the orbiting protons and the newly injected protons approach the kicker magnet from roughly the same direction (the turns separated by only the thickness of the lip of the inflector or 'septum'). The local distortion is introduced by an additional kicker magnet in straight section 22 and the kicker magnet in straight section 30 (half a betatron wavelength away) cancels the distortion.

The problems were gradually overcome during the past year. Further improvements to the linac beam and a new inflector tank are planned for 1966, and should result in still better exploitation of multi-turn injection.

A schematic diagram of the multi-turn injection process.



Improvements at the Synchro-cyclotron

Over the past three years, an improvements programme for the CERN 600 MeV synchro-cyclotron has been evolved. The aim of the improvements is to adapt the machine and its associated experimental facilities to the growing needs of the physics research using the machine. This article is based mainly on a Seminar given at CERN by Dr. G. Brianti, Head of the SC Machine Division, and Dr. E. G. Michaelis, Deputy Head of the Division.

The synchro-cyclotron started operation in August 1957 and has been in full use for physics since then. Inevitably, with the coming into operation of the 28 GeV synchrotron, the machine and its work has been somewhat overshadowed by its larger partner. However over the past few years the demand for machine time on the SC has been increasing and the SC physics programme has been revitalized by the introduction of two new fields of research — nuclear structure and radio-chemistry.

The work of the SC can be considered under the following headings:

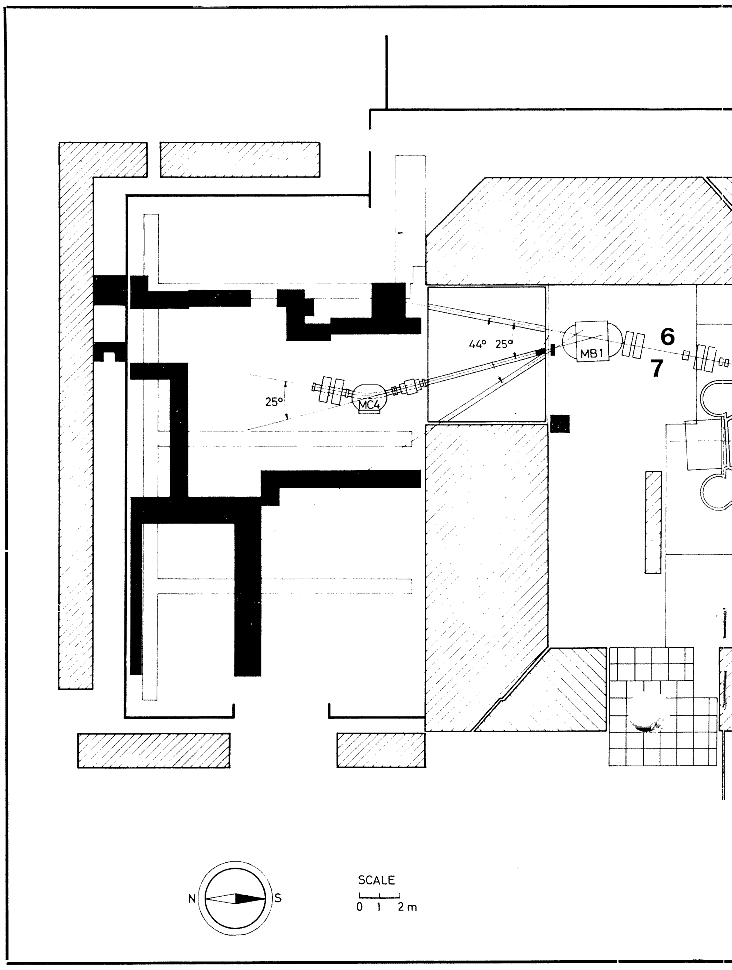
Elementary Particle Physics: Pion, muon, neutron and proton beams can be used for elementary particle physics experiments at energies of a few hundred MeV. In particular major contributions to pion and muon physics have been made using the SC.

Nuclear Structure Physics: In the last year, a vigorous programme of research in this field has been established on the SC using protons, pions and muons as tools to investigate particular features of nuclei.

Radio-chemistry: A new project (called ISOLDE — isotopic separator on-line development) has emerged over the past year. It is concerned with the separation and identification of short-lived isotopes of a variety of elements, which are produced under bombardment of stable nuclei by high energy protons.

The SC is also useful for testing, economically, equipment destined for the overcrowded PS programme.

To meet the requirements of this work it has been decided to develop the performance of the SC until some 'natural' limit is reached. This implies realizing the full research potential of the existing machine without major transformations (with the possible exception of a rebuilding of the r.f. system). The natural limit which will probably dictate the optimum machine performance is the acceptable level of induced radioactivity. This activity is created by the absorption of accelerated



particles in certain parts of the machine. If an internal beam of over 10 μA could be reached in the SC, it might well produce a level of activity in machine components which would make it very difficult to handle them (for modifications, adjustments etc.) in a reasonable time.

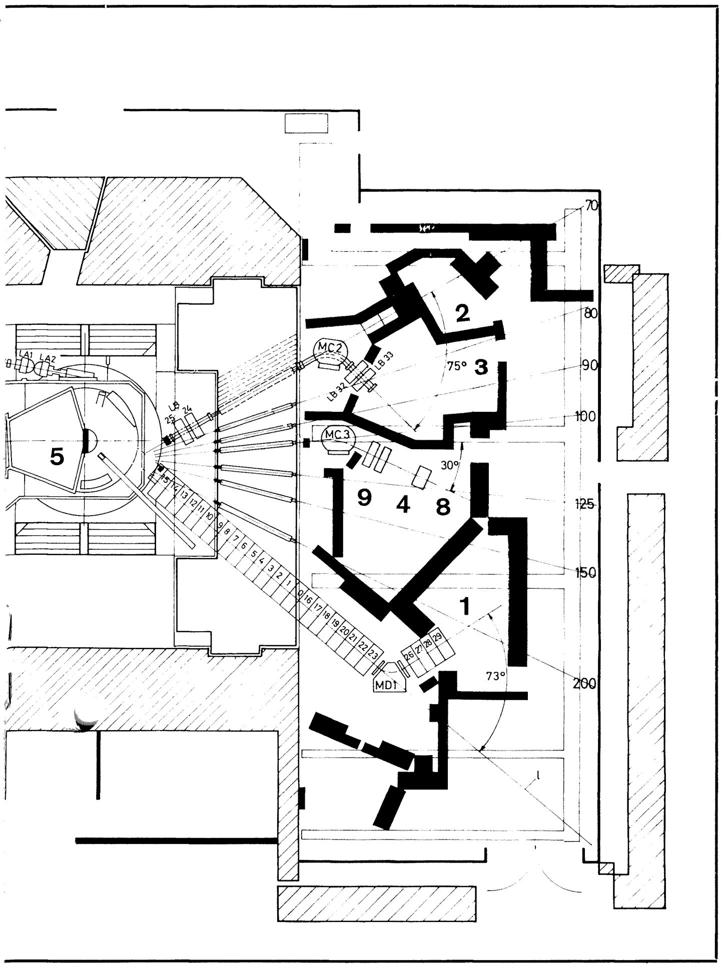
The programme can be considered in three parts — internal beam; beam extraction; meson beams and external proton beams.

Internal Beam

An increase in the intensity of the internal beam (the number of protons accelerated per second) could be achieved by increasing the number of protons accelerated in each pulse and by increasing the pulse repetition rate. The first stage of the improvements programme is concentrated on achieving more protons per pulse.

It is well known that most of the beam loss in synchro-cyclotrons occurs in the central region — the region in the immediate vicinity of the ion source where the first few orbits of the protons occur. The behaviour of the beam in this region under the influence of space charge forces and electrical and magnetic fields is very complex and has to be investigated mainly experimentally.

Three tools are being prepared or are in use to try to understand and overcome the existing limitations:



A diagram of the synchro-cyclotron and its experimental halls. The numbers 1 to 9 represent a situation in November 1965 when nine users were set up around the machine in a single week. Seven of them were experimental groups of whom two or three were operating at a time. This is an indication of the extent to which parallel running has been developed on the synchro-cyclotron.

i) An ion source rig (see photograph on page 32) has been set up, with a magnet and vacuum chamber, where it will be possible to test full scale ion sources of the types which are interesting for synchro-cyclotrons.

ii) An electrolytic tank will enable the first analytical studies of the complicated field configurations in the region of the ion source to be made.

iii) A central region model is being completed. This is a miniature synchro-cyclotron capable of accelerating protons up to an energy of 20 MeV, i.e. well beyond the energy where the central region phenomena are occurring.

These three devices, especially the model, will enable longterm studies to be carried out which would not be possible on the SC itself, where the physics programme allows comparatively little time for machine development work and activation prevents easy manipulations.

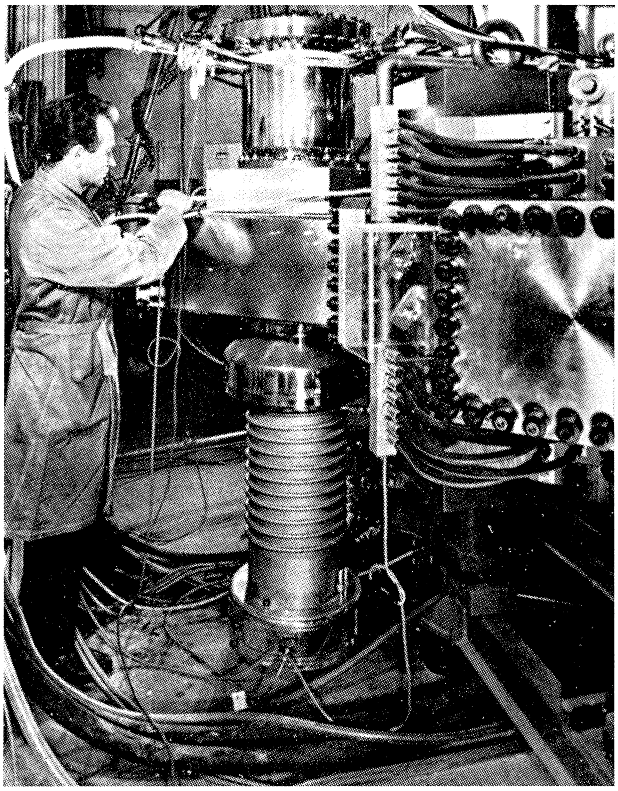
One of the most interesting possibilities, which will be tested initially on the model, is to use a new type of ion source — a 'hot-cathode' hooded arc source instead of the 'cold-cathode' Penning type in use at present. This new source has attracted attention at various laboratories, in particular it has been used on the 160 MeV synchro-cyclotron at Orsay where, with the same internal beam as previously, it resulted in an improvement from 8 to 20 % in extraction efficiency and also in a reduction in the energy spread of the external beam from 2 to 0.4 %. This source injects protons into the machine in the median plane along well defined orbits. It results in a better beam quality with smaller vertical and horizontal oscillations. This question of beam quality is of importance in view of increasing not only the beam intensity but also the beam extraction efficiency.

Unfortunately this new source cannot be simply exchanged for the existing one. It requires modifications to the 'dee' electrode configuration, namely, lip extensions protruding towards the median plane and towards the ion source at the centre of the machine. (See diagram on page 32.) Also the r.f. system, which provides the accelerating voltages, would be required to supply a higher initial voltage and a faster rate of change of frequency. Studies are underway to see how far the present r.f. system can be developed and it seems possible to improve the initial voltage from 5 kV to 10 or 12 kV with suitable increased rate of change of frequency.

It is hoped that this first stage of the improvement programme will result in a rather more intense beam of better optical quality. The ultimate performance at this stage will probably be limited by the extent to which it will be possible to develop the existing r.f. system. If a new r.f. system is built as a second stage of improvement, much more substantial gains will be possible. The repetition rate of the SC could be increased and the initial voltage and rate of change of frequency increased still higher. The advantages and disadvantages of both mechanical (rotating condenser) and electrical modulators for a new system are being examined.

Beam Extraction

The present system of proton beam extraction follows the classical Le Couteur scheme; it involves a regenerator (a device which creates large oscillations in the paths of the protons passing through it so that they move out of their stable orbits) followed by a magnetic channel to guide the particles out of the machine. The system gives pulses 200 μs long of about 5×10^{11} protons per second when used as fast extraction (about 5 % of the beam is extracted) and pulses in 'saw-tooth' form at 500 Hz of about 3×10^{11} protons per second when used as slow extraction (3 % of the beam extracted).



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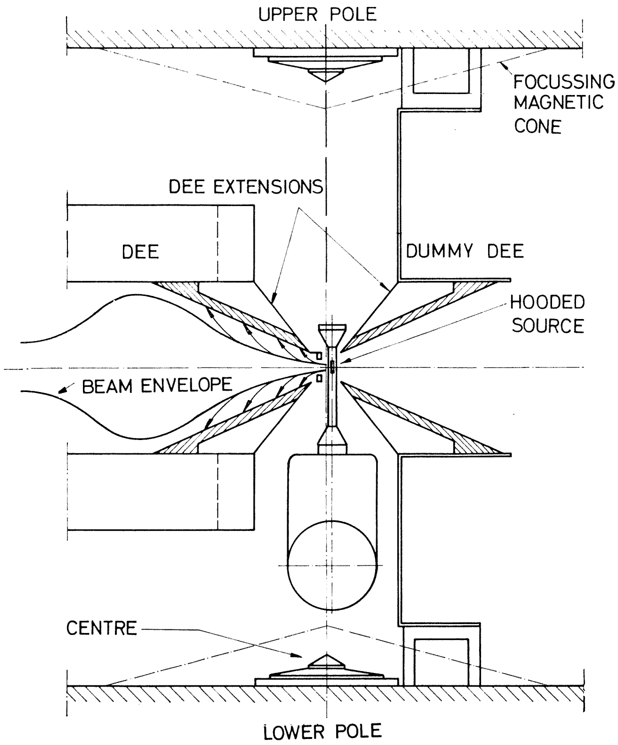
The ion source rig which will enable various types of ion source to be tested, to examine their possibilities for use in the synchro-cyclotron.



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A diagram of the dee extensions which will be needed if the hot-cathode, hooded arc source is used on the synchro-cyclotron. The extensions provide the required field in the central region of the machine, to ensure that the proton beam gains enough energy on its first turn to clear the vertical tube of the source.

The improvement in beam quality expected from the central region modifications should bring an increase in the extraction efficiency (as happened at Orsay mentioned above). Further improvements under consideration involve changing the extraction system altogether. An ironless extraction channel would replace the magnetic one, while a kicker coil would replace the regenerator for fast extraction. It is calculated that, for fast extraction, efficiencies up to 50 % could be obtained with pulse lengths of 1 - 2 μs. Prototypes of the extraction channel and the kicker coil have been made and successfully tested.

Before adopting this new scheme however, it is important to know its performance under slow extraction conditions (which is in fact the predominant requirement at present in the use of the machine). Computer programs are being prepared to calculate the expected behaviour when a thin scattering target or even the regenerator replaces the fast kicker coil.

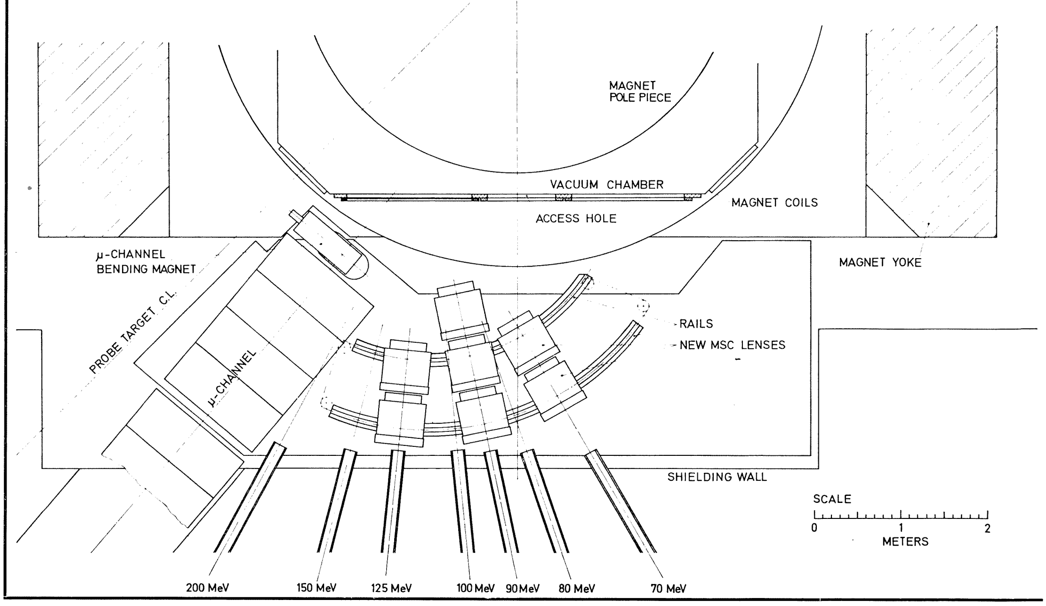
SC Beams

Provision of better beam facilities for experiments around the SC has to attempt to balance several conflicting requirements. At present the emphasis is on compatibility of several beams so that experiments can run in parallel; two or three experiments can run at the same time using the same internal target. In addition the beam is sometimes shared between internal and external targets (targets inside the accelerator itself and targets in the experimental halls). In one week of November 1965, for example, nine experiments were set up around the machine to receive beams and two or three were usually running at the same time. (See diagram on pages 30 and 31.)

Recently however, there has been increasing interest in variable momentum beams so that experimental equipment set up in one position can investigate a range of beam momenta or receive, for example, both positive and negative pions from an internal target. Nuclear structure experiments are particularly interested in this last facility.

In planning the beam line facilities to meet the present requirements and those forseeable for the next few years, some balance has to be stuck between compatibility and flexibility. A new system has been evolved to provide either an increased number of improved parallel, fixed momentum beams (compatibility), or two variable momentum, fixed path beams (flexibility). Change over from one to the other will take about one day and therefore will not seriously interrupt the machine running.

For the compatible beams, in the past, frequent changes of magnet lens position followed by optimisation were necessary as one or other of the beams became 'main user'. This will be simplified by having the lenses mounted on a common circular rail system so that the changes can be effected by motor driven chain, followed by remote control adjustement of position and direction. New magnet lenses will be used which, though smaller in overall dimensions, have a larger (25 cm instead of 20 cm) beam aperture. This is expected to give an increase of about 20 % in pion intensities. A third magnet lens can be added to one of the beams which could raise the increase in intensity to between 40 and 50 %. Installation of this new arrangement will take place during a shutdown scheduled for May 1966.



The new lens system on the neutron room side of the machine. The diagram illustrates the scheme for moving the magnet lenses quickly on rails from one beam channel to another and shows how an additional lens can be added to one of the channels.

SIS/R/12219

An increase in the diameter of the beam pipes is under consideration, since this could lead to a considerable increase in pion beam intensity, but it would involve major rebuilding of the shielding wall through which the pipes pass, and this could not be done before 1967.

The two flexible beams are the muon channel and the so-called MSS beam (after its designers Meunier, Spighel and Stroot) which was installed during the Christmas shutdown. Each channel can provide beams whose momentum can be selected over a wide range by a suitable choice of the internal target position and the conditions of injection into the channel. The MSS channel will be a high resolution facility; the muon channel, as well as providing the muons for which it was originally designed, will provide more intense beams of pions in a wider momentum band.

Underground Tunnel

So far the discussion of the improvements in SC beam facilities has been concentrated on the secondary beams of pions and muons from internal targets coming into the experimental area known as the 'neutron hall'. On the opposite side of the machine is the second experimental area, known as the 'proton hall', where the proton beam itself is extracted. Even using extreme care in beam alignment and with elaborate and inconvenient shielding precautions (a concrete tunnel constructed along the entire length of the beam which prevents any other experiments using the proton hall), the radiation produced by the full intensity external proton beam restricts its use to less than 10 % of the available machine time. If there is a considerable increase in proton beam intensity, as a result of the SC improvements discussed above, the situation will become even worse.

A radical solution has been imposed by the requirement of the ISOLDE project for use of the extracted beam for 600 hours per year. The solution involves directing the beam underground by means of a vertical bending magnet as it leaves the SC. It can then be steered through the SC foundations by magnet lenses, into a beam tunnel whose roof is five metres underground. This removes the radiation problem; the scheme is technical feasible and the cost of the tunnel itself (not including the extra beam transport equipment etc.) is comparable to the heavy concrete shielding which has been used above ground.

It is hoped that construction of the tunnel can be carried out during the shutdown beginning in May and that construction of the underground laboratory for the ISOLDE project can be completed by the end of 1966. Experiments could start early in 1967.

The proton hall will then be free for other experiments involving low intensity beams (of the order of 10^8 particles per second or less as opposed to the full intensity extracted beam of over 10^{11} protons per second) which would help to relieve the congestion in the neutron hall.

A list of some of the experiments performed at the 600 MeV synchro-cyclotron in 1965:

Capture of negative pions in light nuclei; study of n-p correlations
Studies of μ-mesic X rays
μ-capture in gaseous hydrogen; investigation of the diffusion of μp in hydrogen gas
Scattering of 600 MeV protons on a polarized target
Study of the reaction $Li^6(\pi^+, 2p)\alpha$
Search for the decay $\pi^0 \to 3\gamma$
Production of charged pions by proton bombardment of nuclei
Scattering of 600 MeV polarized protons by carbon
Various biological irradiations using 600 MeV protons.

Conclusion

It is hoped that by implementing the successive stages of this programme of improvements, the synchrocyclotron will continue to play the important role which it has assumed in the field of intermediate energy physics (involving particle energies of a few hundred MeV).

The suitabilily of the SC for nuclear structure and radiochemistry research in addition to particle physics, provides a new incentive to improve and adapt the machine to some 'natural limit' and thus make full use of all its potentialities.

BOOKS

Physics of nuclear kinetics, by G. Robert Keepin (Reading, Mass., Addison-Wesley Publishing Co. Inc., 1965 ; $ 12.50).

Let us firstly clear up the only criticism of this excellent book, and that is of its highly misleading title. The book is, in fact, concerned with neutron-induced fission and in particular those aspects of the process that enable the author to deal in the second half of the book with the subject of the kinetic behaviour of nuclear reactors. Whilst the book is intended principally for reactor physicists and engineers, it contains a substantial amount that is of interest to the physicist studying neutron-induced fission as such (always of course within the energy range of neutrons present in a nuclear reactor).

The first half of the book deals in detail with the observed results of fission, namely the energy, mass, and charge distributions of the products, the properties of the prompt and delayed neutrons and gamma rays, and the nature of the fission-product decay chains that lead to delayed neutron emission. Full descriptions are given of the experimental techniques necessary for these observations, and the resulting data are carefully evaluated. In somewhat less detail, these results are compared with theoretical predictions and the more important discrepancies between experiment and theory are discussed. Because of the similar effects on the kinetic behaviour of nuclear reactors of delayed neutrons and neutrons produced by the action of fission-product gamma rays on deuterium and beryllium, the latter processes are also discussed in detail.

The rest of the book is firmly the province of the reactor technologist, who will find a very complete account of nuclear reactor kinetics theory and topics such as the experimental determination of reactor kinetics parameters, reactor noise analysis, reactor transfer function and their implications for reactor stability.

One of the incidental impressions left by this book derives from the description of the fascinating and somewhat hair-raising series of experiments carried out at Los Alamos on remotely controlled metal spheres (12-20 cm in diameter) of each of the major fissile species — 'the world's smallest chain-reacting assemblies'. Amongst the experiments performed have been the assembly of these spheres into the 'above-prompt-critical' region, and the experiments are a fine example of the work of experimentalists who, having faith in their own calculations, have gone ahead and obtained a wealth of high-quality information.

Dr. Keeping's book is well written, and well produced. The reference lists are exhaustive and completely up-to-date.

C. R. Symons

Classical charged particles — Foundations of their theory, by F. Rohrlich (Reading, Mass., Addison-Wesley Publishing Co. Inc., 1965 ; $ 12.50).

As the author says in his preface, 'despite the great efforts of such men as Lorentz, Abraham, Poincaré, and more recently Dirac', the classical theory of charged particles 'is usually regarded as a lost cause'. The author feels, however, that 'with the present state of our knowledge we are able to look back at this theory, to put it in its right perspective, and, above all, to complete the unfinished work of the past'. He therefore has a well-defined programme ; moreover, his aim, in which he succeeds, is to convince us that this chapter of physics, though unappreciated, is coherent and attractive.

The book begins with two very short chapters : in the first, the author explains the role of theory in physics by analysing certain common terms such as 'domain of validity', 'scientific prediction' and 'scientific explanation'; he defines the relationship between various theories ; this heralds the fact that in the rest of the book there is constant reference to the quantum theories associated with the subject. The second chapter gives, in the space of 18 pages, the history of the main contributions to the subject under review. This makes the reader want to go on.

In chapter III the foundations of classical mechanics (Newtonian and relativistic) are viewed in connexion with the Euclidean, Galilean and Lorentz invariance groups. The principle of equivalence is carefully studied, together with its most recent experimental tests. A brief glimpse at the field of general relativity is followed by a thorough discussion of Mach's principle and of causality. The last seven pages of this chapter deal with conservation laws and should be read by all physicists*.

Chapter IV (46 pages) is devoted to a long study of the covariant and non-covariant forms of the Maxwell-Lorentz field. Naturally, one finds the invariant functions D, D_a, D_r, D_p, which are used to obtain the different potentials (retarded, advanced...). The derivation of the Maxwell equations from a Lagrangian is then shown, and how to form the energy-momentum tensor. Finally Lorentz and gauge invariance are studied. This chapter may well discourage the uninitiated reader on account of its abstract nature, but it is essential to read it in order to understand what follows. After the first 75 pages the reader may well be rather spoilt, but 'physics without tears' is a utopian dream and it is preferable to make necessary effort ; the gulf between the classical theory of charged particles and quantum electrodynamics will be bridged without difficulty. It should be mentioned here that the book contains a great many exercises which the author has inserted at appropriate points.

Chapter V (18 pages) deals briefly with electromagnetic radiation and studies the case of radiation in a synchrotron.

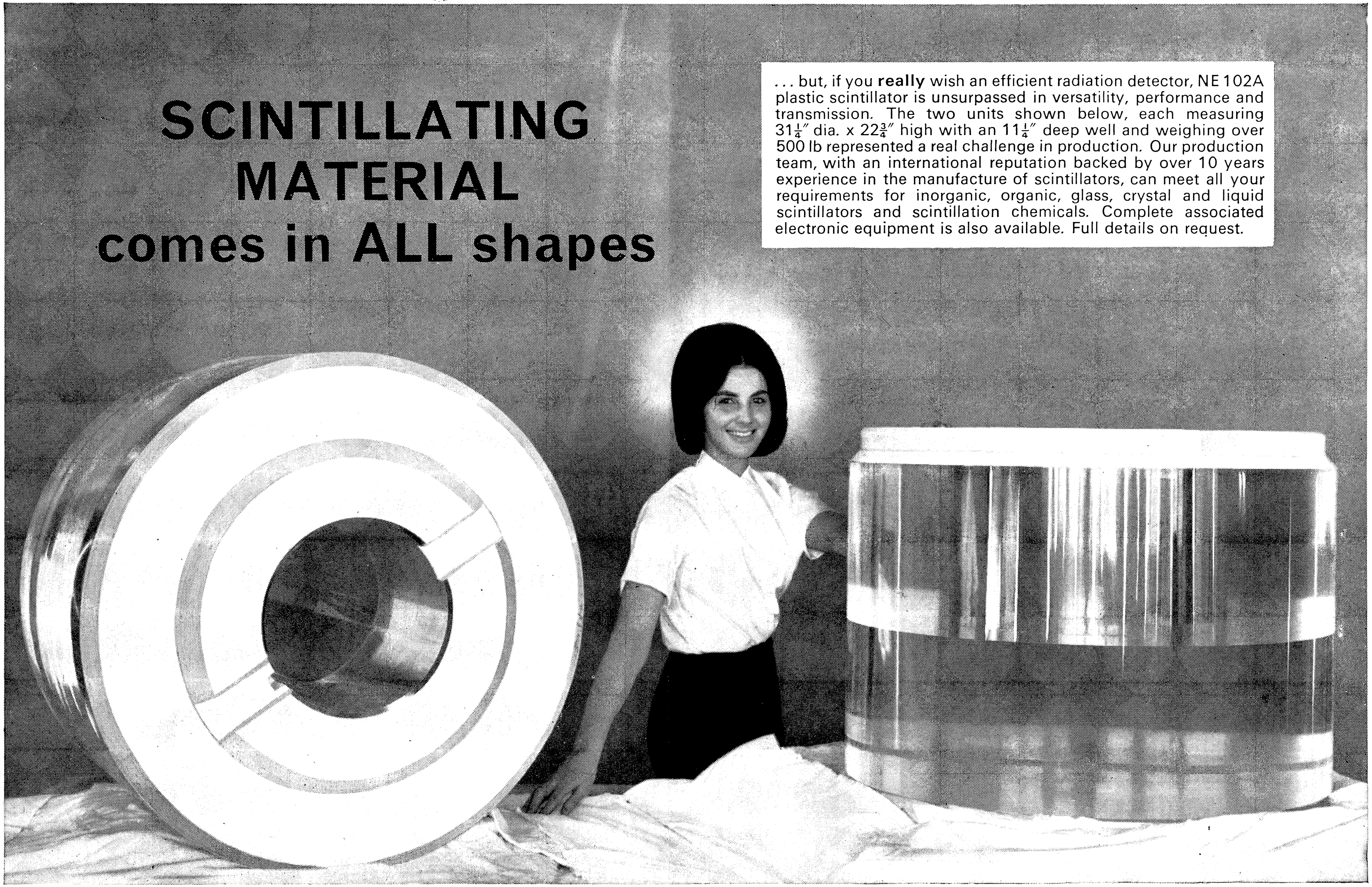
Chapters VI and VIII are devoted to a close study of charged-particle dynamics. In my opinion, this is the most interesting part of the book ; on the other hand, the part dealing with polarized particles (3 pages) seems to be rather sketchy.

The originality of the book is emphasized by the comparison made in its last two chapters between the theory it presents and corresponding quantum theories, on the one hand, and other kinds of field, on the other. Subjects such as charge conjugation and time reversal are studied. The book contains two most appropriate appendices on space-time in special relativity and in general relativity, and two detailed indexes.

This is a book that may be put beside Jackson's *Classical Electrodynamics*, since it covers different ground. It will be read with interest (and fairly quickly) by those who have studied quantum electrodynamics without taking the time to read 'the classics', and will give them a more intuitive grasp of certain problems, such as normalization. It will also serve those who wish to enter the quantum world with a solid classical background. Whoever reads it will have no regrets : this is an excellent book.

H. B.

* How many physicists are familiar with the conservation of currents or of energy-momentum, yet do not realize that they are both derived from Emmy Noether's theorem ?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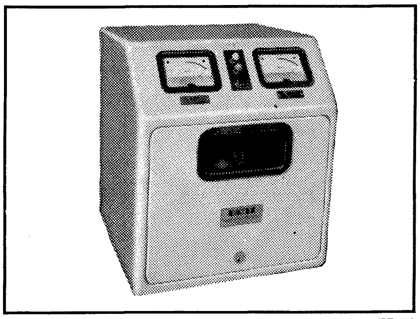

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