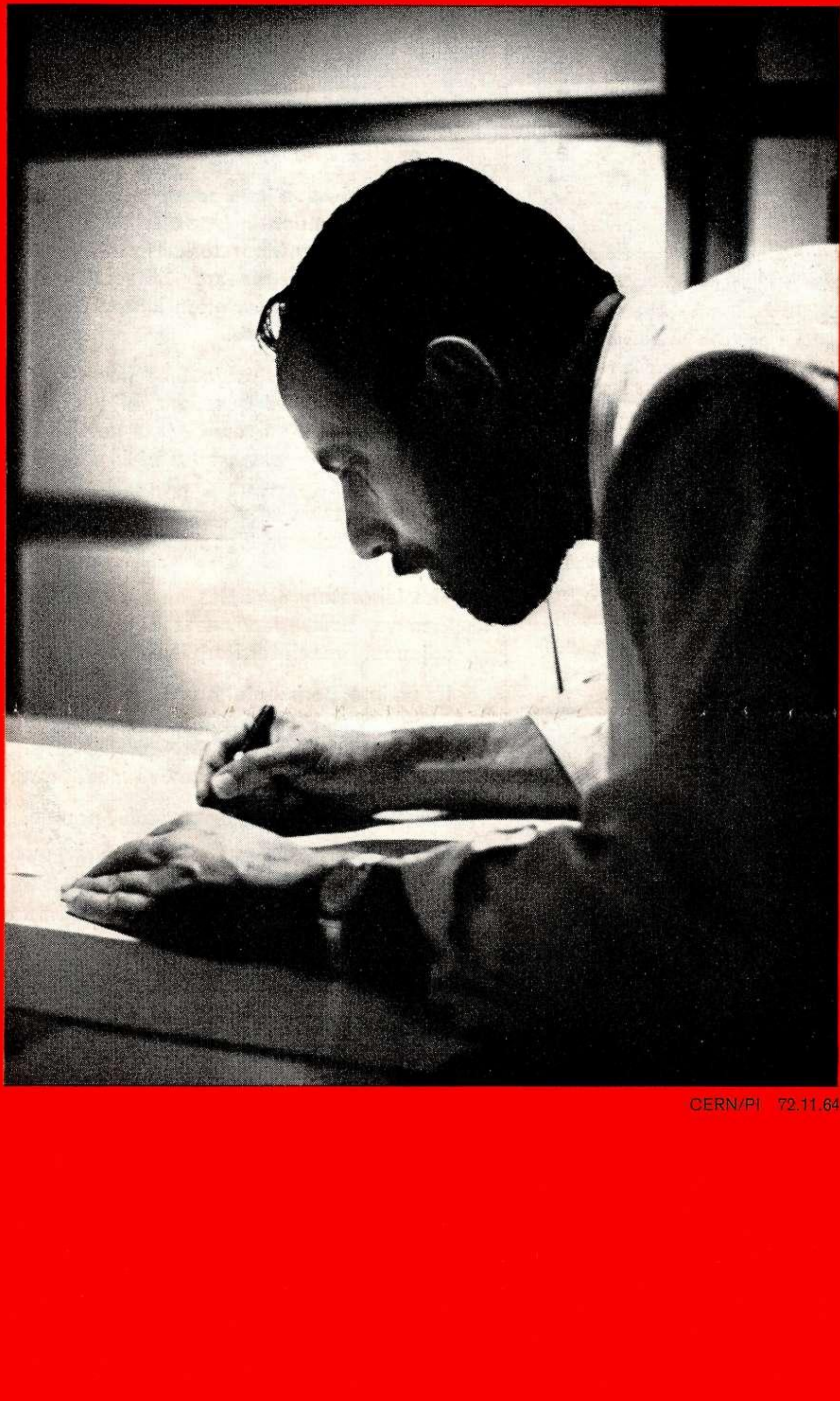
CERN COURIER



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The cover photograph, a study of concentration, shows one of the visiting scientists from the U.S.A. at CERN, Robert Tripp, inspecting the tracks of sub-nuclear particles as recorded by the cameras of a bubble chamber. The scanning table he is using is the prototype of a new design specially conceived to take film from CERN's 2-m bubble chamber. Among other refinements, the projection system uses overhead mirrors so that the image of the tracks, reproduced in their original length, can be inspected from all sides. A digitizing system for measuring the tracks can also be added, so that the table can be used in conjunction with a flying-spot digitizer for semi-automatic analysis of the data (HPD system). Great interest has been aroused by this design in many European laboratories and it is anticipated that the table will eventually be made available commercially by European industry.

CERN COURIER

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

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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 occupies an area of 41 hA (100 acres) at Meyrin, Canton of Geneva, Switzerland, next to the frontier with France. A similar area on adjacent French territory is expected to be taken over shortly.

Its main experimental equipment consists of two large particle accelerators:

— a 600-MeV synchro-cyclotron,
— a 28 000-MeV (or 28-GeV) proton synchrotron,

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

The CERN staff totals some 2000 people.

In addition to the scientists on the staff, there are nearly 300 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.

Thirteen Member States contribute to the cost of the Organization, in proportion to their net national income:

Austria (1.95%)	Italy (10.78%)
Belgium (3.83%)	Netherlands (3.92%)
Denmark (2.07%)	Norway (1.47%)
Federal Republic of Germany (22.74%)	Spain (2.18%)
	Sweden (4.23%)
France (18.57%)	Switzerland (3.19%)
Greece (0.60%)	United Kingdom (24.47%)

Poland, Turkey and Yugoslavia have the status of Observers.

The budget for 1965 amounts to 128 760 000 Swiss francs (= $29 800 000), calling for contributions from Member States totalling 126 400 000 Swiss francs (= $29 300 000).

A supplementary programme, financed by eleven states, covers design work on two possible future European projects in high-energy physics — intersecting storage rings for the 28-GeV accelerator at Meyrin and a 300-GeV accelerator to be built elsewhere ●

Last month at CERN

2-metre bubble chamber tested

The most exciting news at CERN during the last month of 1964 was of the successful testing of the 2-m liquid-hydrogen bubble chamber. At two minutes past midnight on the morning of Sunday 13 December, some five years of effort devoted to its design and construction were rewarded with the first track photograph, the final proof that all was well.

Various modifications and adjustments remain to be carried out and final tests still have to be made with the magnet energized, but within the next few months CERN expects to be able to conduct its first experiment with one of the two largest hydrogen bubble chambers in the world.

As most readers will know, a bubble chamber is a complex device, requiring the application of advanced engineering techniques, for detecting nuclear particles by means of the tracks of minute bubbles they leave in a 'super-heated' liquid. The heart of the new CERN chamber is a stainless-steel vessel, weighing 22 tons and containing 1650 litres (275 gallons) of liquid hydrogen, at a temperature of —247° C and under a pressure of about 6 atmospheres. The front and back walls of this vessel are optically clear glass windows, 200 cm wide, 60 cm high and 17 cm thick, enabling the hydrogen to be illuminated, by a flash tube and lens system, through one and photographed, by an array of four cameras, through the other. The whole massive equipment is enclosed in an electromagnet of overall dimensions 3.6 m × 6.5 m × 4.16 m high, weighing over 400 tons. The major part of the design was carried out at CERN but industrial firms in many of the Organization's Member States contributed to its construction.

A photograph of the completed equipment will be published in the February issue of *CERN COURIER*. A limited number of copies are also available of the engineering drawings showing the three main cross-sections of the chamber and magnet. However, the 'artist's impression' produced by Bernard Chamdru, of the Track Chambers Division, and distributed as a supplement to this issue, is thought by many people to give a rather more interesting picture of some of the details!

28th Session of CERN Council

On 15 and 16 December, delegates from CERN's 13 Member States met in Geneva for the 28th Session of the Council, under its President, Mr. J. H. Bannier.

In presenting the Progress Reports of the Divisions for the previous six months, Prof. V. F. Weisskopf was able to announce, among other things, the successful tests of the 2-m bubble chamber and also of the radiofrequency particle separator, which had been shown capable of separating kaons, from other particles in a beam, up to a momentum nearly twice as high as that previously obtainable.*

A total budget for 1965 of 128.76 million Swiss francs was approved, and eleven of the thirteen Member States also agreed to provide a further 5.7 million Swiss francs for the supplementary programme on new projects.

The chairman of the Scientific Policy Committee transmitted the Committee's recommendations for full support of a coherent programme for the development of high-energy physics in Europe, which includes various improvements to the present CERN proton synchrotron, as well as the construction of intersecting storage rings for this machine, and the creation of a new laboratory centred around a 300-GeV accelerator of the same basic type.

A fuller report of the Council Session will be included in our February issue.

Senior staff changes

The following appointments were made by the Council at its December session:

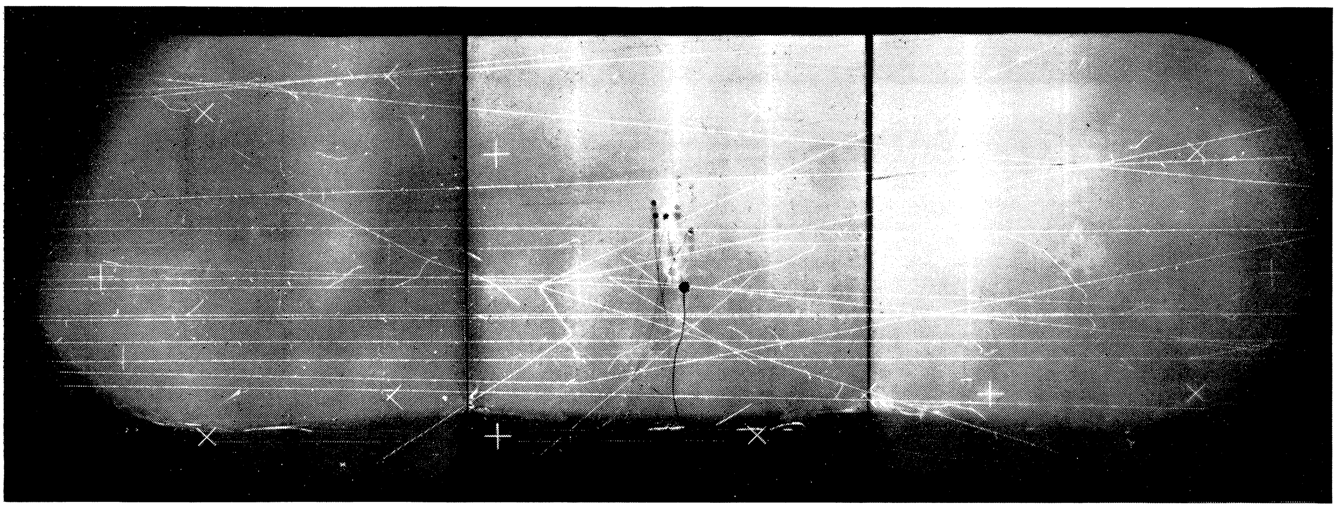
Dr. Pierre Germain as full-time Member of the Directorate, with responsibility for Technical Management, a position he has held part-time for the last two years while also Leader of the Proton Synchrotron Machine (MPS) Division;

Dr. Peter H. Standley as Leader of the MPS Division, in succession to Dr. Germain;

Prof. Wolfgang Paul as joint Leader of the Nuclear Physics Division, together with Prof. P. Preiswerk.

Proton synchrotron

Because of the troubles of the preceding two weeks, the PS schedule was changed during the first part of December and from 9-14 December the previous



A 'life-size' (2-metres long) copy of this photograph was on display outside the Council room on the first day of the December meeting. It is one of the first to be taken with the 2-metre bubble chamber and shows particles travelling from right to left. One of these incident particles clearly interacts with a proton near the centre of the chamber.

counter experiments were continued, instead of the bubble-chamber runs originally planned. The latter then took place in the week before the Christmas shut-down.

Among the counter/spark-chamber experiments, the one investigating the parity of the negative xi (using the polarized-proton target described in last month's issue) took some 27 000 photographs. Its m_{4_3} beam line gave excellent results; providing 10 000 to 12 000 kaons in each pulse, using 60-70% of the internal proton beam (at 8×10^{11} protons per pulse) on target no. 1. Secondary particles for three other beams were also taken from this target. In the North Hall, the CERN/ Ivry group took 400 000 photographs in their investigation of pion and kaon scattering from a hydrogen target, at momenta of 2.8, 3.25 and 3.5 GeV/c. These photographs are being analysed by means of the automatic system employing the flying-spot digitizer 'Luciole' (*CERN COURIER*, vol. 4, p. 75, June 1964).

During this week, also, the 152-cm British bubble chamber continued to take pictures on a 'parasitic' basis, using some 10% of the beam directed on to target no 60 (by the rapid beam deflector) during the acceleration phase of the machine cycle. The 57 000 photographs obtained, of 10-GeV/c proton interactions in hydrogen, were shared among groups in Cambridge, Hamburg and Stockholm.

In the following week, most of the operating time of the o_2 beam line that feeds this chamber was devoted to tests of the radiofrequency separator system. These separators demand a very short (2-microsecond) burst on the internal target, which is produced by giving a 'kick' to the beam, by means of the kicker magnet normally used for the fast ejection. This kick causes the beam to oscillate slightly about its normal path, in such a way that it strikes the target after a further 1 2/3 circuits of the machine, that is, after travelling a distance of about 1000 metres. As may be imagined, the adjustment of such a system, and the co-ordination between its various components, is rather critical and in the time available it was not possible to get particles along the beam line and into the bubble chamber.* However, between tests the chamber obtained some 8000 photographs of 5 GeV/c positive pions, to add to earlier ones shared between groups in Bonn, Durham, Paris (Ecole Polytechnique), Nijmegen and Turin. The 81-cm Saclay/ Ecole Polytechnique chamber, at the same time, provided 90 000 photographs of negative kaons in hydrogen, with momenta between 800 and 1200 MeV/c, for CERN, Heidelberg and Saclay.

Nuclear Chemistry at the PS

Contained within the Nuclear Physics Division is a small group doing Nuclear Chemistry, that is, applying the techniques of chemistry to the solution of nuclear problems (see, for example, *CERN COURIER*, vol. 3, pp. 31-34, March 1963). Each week they have about 1½ hours of synchrotron machine time to themselves, when they irradiate their special targets for later analysis. As an example of the way in which this comparatively short time can be used, it is worth citing the exposures carried out in the first week of synchrotron running mentioned above.

Firstly, there was the exposure of three mica foils, each receiving just one pulse of the internal proton beam, as part of an investigation of the possible use of such foils for the study of fission cross-sections at high proton energies. For this purpose they are much less sensitive than nuclear emulsions to the background of protons.** These foils were sent to Naples for examination. Then an iron target was irradiated for 10 minutes. The lithium isotopes produced by the high-energy protons will be studied using a mass spectrometer at Orsay. A silver foil was irradiated for 30 minutes, for an investigation at CERN of the indium isotopes produced; and finally a uranium foil was given a 20 minute irradiation, the resulting radioactive bromine isotopes being isolated and separated in the CERN isotope separator, as part of a study of high-energy fission and fragmentation.

The following week, two exposures were made during the 'Nuclear Chemistry' period. A further mica target was irradiated for examination at CERN, and a 40-minute uranium irradiation was carried out, this time for the study of the iodine isotopes produced.

News in brief

Experiments at the synchro-cyclotron continued as usual during the month. Most of the time only the neutron room was in use, for experiments on positive pion decay and problems of nuclear structure, as well as the testing of various items of equipment for other investigations. At the beginning of the month a few shifts were taken up by the establishment of a shielding tunnel for the external proton beam, so that measurements of the scattered radiation intensity could be made by the Health Physics group.

Among the 'social' activities at CERN in December were the traditional Christmas parties for children of the staff and from local schools, held on the afternoons of 6 and 13 December, and a Christmas Ball arranged by the Staff Association, from 9.30 p.m. until 2.30 a.m. on 11/12 December. Following the Photo Club's annual exhibition in the last week of November, December produced an exhibition of paintings and handicrafts by the children of CERN staff; winning entries in the accompanying competition later joined those from other International Organizations in Geneva in an exhibition and sale, arranged in collaboration with the 'Intérêts de Genève', in aid of a local children's organization. On the evening of 10 December, Richard Morris, the Irish actor, gave his characterization 'Shakespeare and his time', illustrated with excerpts from the comedies and tragedies, and the following week the Music Club's second concert of the season brought the violinist Szymon Goldberg, accompanied by Gerard Hengeveld, to CERN ●

VISITS AND LECTURES ORGANIZED BY CERN

The European Organization for Nuclear Research, at Meyrin, Geneva, announces that in 1965, as in previous years, visits for groups will be organized on Saturdays. It is, however, stipulated that visits take place only by prior arrangement.

In addition, CERN puts at the disposal of schools, universities and societies the services of lecturers well qualified to explain its work or to present its recent achievements in the field of high-energy physics. Lectures can be given in English, French, German or Italian, and may be adapted to correspond to many different levels.

Further information is available from:

CERN
Public Information Office
1211 Geneva 23
Telephone:
(022) 41 98 11 / ext. 2788

*** On 25 January the full system was operated for the first time when the o_2 beam line, equipped with two radiofrequency separator cavities, provided a beam of negative kaons at a momentum of 10 GeV/c for the 152-cm hydrogen bubble chamber. The photographs obtained showed an average of seven kaons per picture with a contamination of other strongly interacting particles of only about 5-10%.**

** See **CERN COURIER**, vol. 4, p. 134, October 1964; a report of the first CERN tests has been issued as **CERN 64-49**.

CERN from May to November 1964

Progress reports of the Divisions

EXPERIMENTAL AND THEORETICAL PHYSICS

As stated by Prof. Weisskopf in his introduction to the reports, this period has seen the publication of a number of important results from both the experimental groups and the theoretical physicists, the Dubna Conference in August providing the platform for releasing many of them.

Taking electronics experiments at the synchrotron first, probably the most interesting results to readers of this periodical were those from the neutrino experiment, and these are summarized separately on pp. 8-9.

Protons still 'bounce' at high energies

Another experiment (to be more exact, series of experiments), that has been reported fairly regularly is that on proton-proton scattering. With the adoption of sonic spark chambers as detectors a study was undertaken of the scattering through very small angles, in the region where interference can be detected between the nuclear scattering and the Coulomb scattering due to the electric charge. Measurements were made of the angular distribution of the scattered protons in the angular range of about 0.1-1.0° (2-20mrad) and total cross-sections were evaluated, for incoming protons with momenta 10, 19 and 26 GeV/c. From the data obtained, it appears that the parameter known as the 'complex elastic scattering amplitude' has a substantial 'real' part, amounting to some 30-40% of its 'imaginary' part. This result, found also in recent experiments in other laboratories, though quite unexpected, shows that even at these high energies two colliding protons can still behave surprisingly like billiard balls. Measurements have since been done at CERN, using the same apparatus, on elastic proton scattering from the nuclei of deuterium, lithium-6, lithium-7, beryllium-9, copper and lead, using protons with a momentum of 19.3 GeV/c.

Einstein postulate confirmed directly

A short experiment using more or less standard fast electronic counters and timing equipment gave an accurate check of Einstein's second postulate of relativity, which states that the velocity of light and other electromagnetic radiation is independent of the velocity of the source emitting it. In effect, gamma rays were timed over an accurately measured distance of about 30 metres and their velocity was found to be the same as that normally accepted as the velocity of light (2.9978×10^8 m/s), to within one part in 10^4, even

The progress reports prepared by each Division of CERN for presentation to the Council in June and December of each year provide a valuable summary of the work of the Organization.

Since CERN is a scientific establishment, it is inevitable that the work of its scientists should be the most reported and the most well-known. The others, who provide the material and services without which this work could not be done, receive less recognition and, if they concern themselves with such thoughts, have to be content with the knowledge that their contribution has been of value. In some cases it is the whole Organization that plays this supporting role, and it is not at all uncommon for experimental results to be published by physicists at European universities following the analysis of particle tracks on bubble-chamber film or in nuclear emulsion obtained from CERN.

The six-monthly progress reports, together with the more comprehensive Annual Reports, however, provide the opportunity for each part of CERN to make its work known to the rest of the Organization and to the world outside.

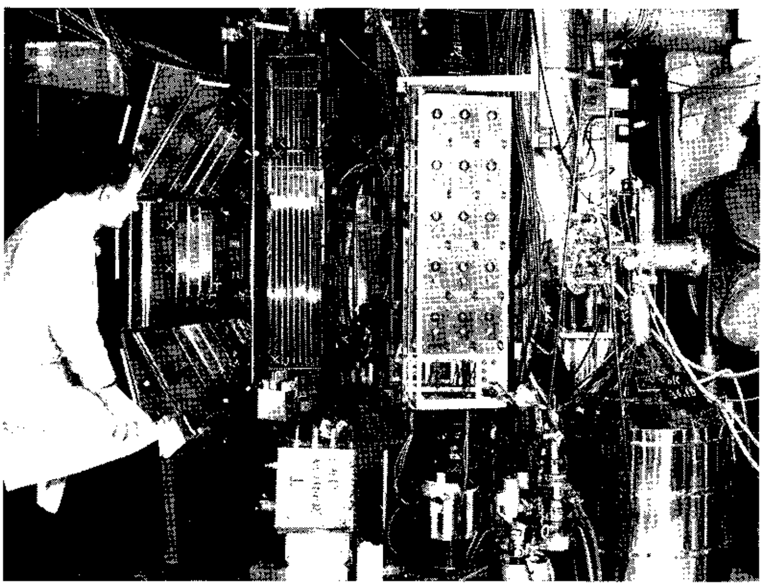
The accompanying account highlights some of the main points from the latest collection of reports, an 81-page typed document (CERN/560) presented to the Council in December. If there is still a bias towards the presentation of scientific and technical results, it is because it is here, rather than in the routine work going on all the time, that there is most likely to be something new. In addition, more attention has been paid to events that have not been reported in CERN COURIER as they took place.

though the neutral pions that emitted them were themselves moving with a velocity of 99.975% of that of light.

Experiments with spark chambers

A more refined analysis of the photographs from the experiment on the beta decay of the lambda particle ($\Lambda^0 \rightarrow p + e^- + \nu$) has almost been completed, about 130 examples of this rare process having been found in some 200 000 pictures. Normally the lambda decays into a proton and a pion or a neutron and a pion.

A visiting team from Saclay, which came complete with spark chambers, electronic equipment, etc, and



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As described in last month's CERN COURIER, the Saclay/CERN polarized-proton target is now in use for an experiment at the proton synchrotron on the parity of the negative xi hyperon. Here, practically all that can be seen of the cryostat is the end plate and the helium exhaust pipe, with the 50-litre helium flask on the right-hand side of the photograph. The end of the m_{4b} kaon beam line can also be seen on the right. In the centre there is a rack of digital signalling devices and to the left of these can be seen some of the spark chambers behind the target. Further left still are mirrors that enable more than one view of the spark-chamber gaps to be photographed.

FIGURES FROM THE PROGRESS REPORTS*
May to November 1964

— On 15 November, CERN personel numbered
1592 staff members,
412 supernumeraries,
70 fellows and research associates,
208 visitors and students,
2282 altogether.

— In the Nuclear Physics Division, out of a total of
187 staff members, there were
60 scientists, involved in experiments,
with, in addition
107 fellows and visiting scientists.

— The Theoretical Studies Division had
15 staff members, including
11 scientists or mathematicians
with, in addition
24 fellows and research associates,
9 visiting scientists from Member States,
15 visiting scientists from other countries.

— Total consumption of electricity in this period was
40 430 000 kWh,
with a maximum demand of
18 658 kW.

— The amount of water used for cooling was
2 273 000 m³.

— The proton synchrotron (PS) schedule devoted
3025 hours to experiments,
470 hours to development,
175 hours to special tests,
out of which breakdowns contributed a total loss of
245 hours.
Average beam intensity during experiments was
7.5×10^{11} protons per pulse,
with a best fortnightly average (220h) of
9.5×10^{11} protons per pulse,
and a highest recorded value of
1.1×10^{12} protons per pulse.
Total number of protons accelerated for experiments was
3 000 000 000 000 000 000 (3×10^{18}).

— PS facilities included
12 secondary beams of particles,
enabling runs to be carried out on
24 experiments,
with an average of
5 experiments simultaneously.

— The beam lines utilized
120 items of beam-transport equipment,
5 km of flexible electric cable,
1.2 km tubing for cooling water.

— In the k_4 beam of the PS North experimental hall, the 81-cm Saclay bubble chamber, filled with liquid hydrogen, took
300 000 photographs of antiprotons of momentum 1.2 GeV/c,
250 000 photographs of negative kaons of various momenta between 0.8 and 1.2 GeV/c;
and filled with liquid deuterium,
120 000 photographs of positive kaons at rest,
80 000 photographs of antiprotons at 0.6 GeV/c,
70 000 photographs of antiprotons at rest.

— In the o_2 beam of the PS East experimental hall, the 152-cm British bubble chamber, filled with liquid hydrogen, took
140 000 photographs of negative kaons at 5 GeV/c,
400 000 photographs of negative kaons at 6 GeV/c,
60 000 photographs of positive kaons at 5 GeV/c.

— The synchro-cyclotron (SC) schedule devoted
3713 hours to experiments,
141 hours to development,
with faults and repairs contributing a loss of
140 hours.

— The liquefying plants in CERN produced
78 000 litres liquid hydrogen,
1 300 litres liquid helium.
In the first ten months of 1964, CERN used
1 600 000 litres of liquid nitrogen,
about half of it for the 152-cm British bubble chamber.

— The Main workshop
worked 53 370 man-hours,
produced equipment valued at
1 085 000 Swiss francs,
sub-contracted work valued at
250 000 Swiss francs.

— The West workshop
worked 33 450 man-hours,
produced equipment valued at
609 700 Swiss francs,
sub-contracted work valued at
70 000 Swiss francs.

— The new Surface-treatment shop
worked 6920 man-hours,
produced equipment valued at
83 500 Swiss francs.

— The 7090 computer, working continuously, processed
350 jobs per day.

— The Programming Enquiry Office
answered 11 enquiries a day,
and added to the CERN programme library
28 new programmes.

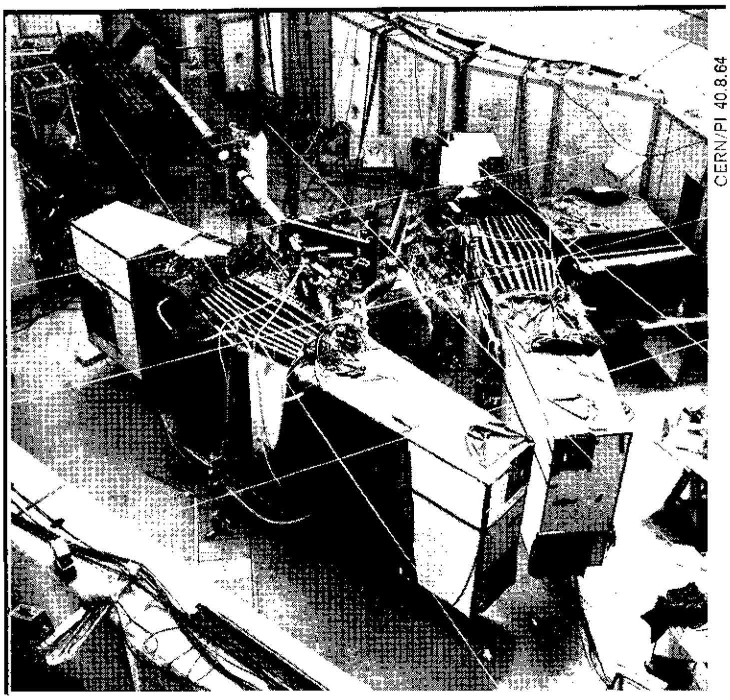
— Telephone calls averaged
38 000 per month.

— The Messenger service handled an average of
49 000 letters per month.

— CERN reports were distributed to
655 addresses
in 54 countries.

— Regular distribution of CERN COURIER reached
3050 copies in French,
2075 copies in English.

* For earlier figures see CERN COURIER, vol. 4, p. 92, July 1964.



A general view of the PAPLEP experiment, at the end of the m_{4a} beam line in the PS South hall. The detection apparatus for muon pairs consists essentially of two similar sets of spark chambers, scintillation counters and lead absorbers, each mounted on an arm that can be swung about the target on a turntable. Most clearly seen here are the range-measuring spark chambers, each with a dark box on either side to enable the sparks in the gaps to be photographed. On the target side of each of these chambers is the specially shaped lead absorber and there are other, smaller, spark chambers that cannot be seen. The white strings are alignment references.

technicians, has finished a run to study the so-called charge exchange—actually the transfer of electric charge from one particle to the other—in the scattering of negative pions on protons, as well as the production of neutral pions and eta mesons at low pion momentum (2.5 or 5.8 GeV/c). The pictures are now being analysed. The same kind of reaction, involving negative kaons instead of pions, has been studied in an experiment carried out by the CERN/ETH group using a large magnetic spark chamber. This apparatus consists basically of a set of spark chambers inside the magnet formerly used for the cloud chamber.

Various other experiments are still running. One of these, the 'missing-mass spectrometer' has been found to work successfully, giving interesting results in its more recent runs. Another, the experiment on the annihilation of antiprotons into muon pairs has shown (from a study of 7000 million antiprotons) that the cross-section for the process is not greater than 10^{-32} cm^2, or some million times less than that for other annihilation processes.

Theory seems right in emulsion experiment

Among experiments with emulsions, a collaboration between Bristol, CERN, Lausanne and Munich obtained a preliminary result for the magnetic moment of the lambda hyperon (0.54 ± 0.24 nucleon magnetons) that was consistent with the expected value although still not precise enough to show up any possible small discrepancy.

Excited states from bubble photographs

From the analysis of photographs taken with the 81-cm Saclay/Ecole Polytechnique bubble chamber, collaborations between groups inside and outside CERN have made a number of new discoveries, mainly concerning resonances and excited states.

Further study of the C^0 resonance ($K\pi\pi$), discovered at CERN early in 1964, has established that it decays via the $K^*\pi$ channel as well as by the $K\varrho$ — that is, it disintegrates first into an excited state of the kaon and a pion, or into an ordinary kaon and a rho meson. A resonance in the $K^*\pi$ system, having isotopic spin 3/2 and mass 1270 MeV, has also been found in photos of the annihilation of antiprotons at 3 GeV/c, but it is not yet clear whether this is the C^0 or a different state. Important results have also been obtained on the system of two kaons, one charged, one neutral.

The $K\pi\pi$ resonance mentioned above has also been found in interactions of positive kaons in the liquid hydrogen of the bubble chamber. In addition a $K\pi$ resonance with a mass of 725 MeV (the Kappa meson) has been found, serving to confirm a previous discovery at Berkeley which had afterwards been doubted. Indications have also been found for a resonant state combining two positive kaons. This would be particularly interesting if it were confirmed, since it involves not only a double charge but, particularly, a strangeness number of +2, which has hardly been studied up to now.

In an experiment with positive pions at 8 GeV/c it has been possible to apply strict kinematic analysis for the first time at such energies. This has led to the discovery that the collisions are predominantly 'peripheral' and proved that very often the initial reaction gives only two particles (which rapidly decay into a number of others).

The interaction of negative pions of momentum 16 GeV/c in the Ecole Polytechnique heavy-liquid bubble chamber has provided confirmation of the phenomenon of 'diffraction dissociation', in which the pion gives the appearance of changing into three pions in the field of a nucleon. These three pions are in the form of the resonance called A_1, recently found at CERN and elsewhere. The absence in this reaction of a similar resonance, A_2, also recently discovered, indicates that the spin and parity of the A_1 is either 1^+ or 2^-.

Nuclear physics at the SC

At the synchro-cyclotron, besides the continuation of work on the properties and interactions of pions, several experiments were devoted to problems of nuclear structure. . The introduction of advanced techniques, particularly current-measuring chambers (cover picture of September *CERN COURIER)* and Cherenkov counters with high discrimination between particles, has opened new ways to the investigation of nuclear energy levels.

Preliminary measurements of the inelastic scattering of negative pions from nuclei of low mass have revealed new gamma-ray energies arising from transitions between levels. In collaboration with the Orsay laboratory (France), the experiment using current-measuring chambers found evidence for an exited state of helium-4. The process of 'double charge exchange', in which an incident negative pion is transformed to an outgoing positive one, has been observed in helium, lithium, beryllium and carbon, but a special search for the 'tetraneutron' (four neutrons combined) and hydrogen-7 (1 proton plus 6 neutrons) showed these to be very rare, if they exist at all.

Results of the CERN neutrino experiments, 19

At the present time it is believed that there are essentially four basic forces in nature, motivating the gravitational, weak, electromagnetic and strong interactions respectively, in order of increasing strength.[1] The weak interaction is typified by the 'beta' radioactive decay of an atomic nucleus, which is nothing more than the transformation (or 'decay') of a neutron into a proton, with the emission of an electron (or beta particle, in the nomenclature of radioactivity). In order to account for the results obtained in studies of these reactions, W. Pauli postulated in 1933 that a second particle, the neutrino[2], was emitted at the same time as the electron. Such a particle would have no electric charge and no mass, but could nonetheless carry energy (like a photon, the 'particle' of light). Not being subject to strong or electromagnetic interactions, it would interact extremely rarely with other matter; if the earth were solid iron a low-energy neutrino passing through it would stand less than one chance in a hundred million of being lost by an interaction[3]. Indeed it was not until 1957 that Reines and Cowan succeeded in proving the existence of the neutrino by detecting just such rare interactions. A particle that carries off energy from nuclear processes and only rarely gives it ι which have only recently begun to be conside

Following the discovery of the pion in 1948 decays to a muon, and at one time it was decay. It is of supreme importance in the f whether there are two kinds of neutrino or (experiments on the interactions of the ne valuable because they provide a way of stud no strong or electromagnetic interactions. I from almost non-existent happenings, neutrino like developing into a fairly distinct branch of

Regular readers of CERN COURIER will recall that, after an initial failure in 1961 due primarily to the lack of an incident beam of sufficiently high intensity, a large-scale experiment on neutrinos was begun at CERN in June 1963. Its aims were essentially threefold:[4]

— to verify with more precision the conclusion of the Brookhaven experiment in 1962, that there are two different kinds of neutrino,
— to gain new information on weak-interaction processes and, in particular,
— to search for the intermediate boson, known as the W particle, postulated as the 'carrier' of the weak force by analogy with the mesons that 'carry' the strong force.

Preliminary results were announced at the Sienna conference in October 1963,[5] and at meetings in Hamburg and Brookhaven. Before committing themselves to final statements on the existence of the W, however, the physicists waited for the results of more accurate calibration experiments and further experimental runs, under slightly different conditions, that were carried out from February to May 1964. Sufficient progress had been made by August for the results to be presented at a special 'neutrino' session of the Dubna conference, afterwards summarized in a 'rapporteur's talk' by Prof. G. Bernardini, and in October and November three papers were published in *Physics Letters*[6].

Essentially two independent experiments have been carried out, one by the bubble-chamber group, the other by the spark-chamber group, but their results are complementary and are more easily summarized as a whole. The conclusions can perhaps be best understood as the answers to seven questions, in the way that Prof. Bernardini presented them in a talk at CERN in November.

1. If the theory of the Universal Fermi Interaction is true, are the electron neutrino and the muon neutrino two different particles; if so to what extent might it still be possible for them to be interchangeable?

   Answer: Definitely two different particles, any mixing being less than 1%. The results also indicate that the Universal Fermi Interaction holds up to transverse momentum transfers of at least 1 GeV/c.

2. Is there a 'neutrino flip', in the sense that a kaon decaying directly to a muon may produce simultaneously an electron neutrino rather than a muon neutrino?

   Answer: No. In any event not more than 10% of the kaons decaying in this way could produce an electron neutrino.

3. Do 'neutral currents' exist in weak interactions? For example, if the weak interaction is due to the mediation of a particle could this particle have no electric charge, making possible a scattering such as $\nu + p \rightarrow \nu + p$ in addition to the normal reaction $\nu + n \rightarrow \mu^- + p$?

   Answer: No, any possible neutral current being less than 3% of the charged currents.

4. Are strange particles produced in neutrino interactions, and if so can they appear singly, or always in pairs by 'associated production'? This forms a test for the $\Delta S = \Delta Q$ rule (that the strangeness can only change by the same number of units as the charge of the heavy particle in a weak interaction).

   Answer: They are produced at the higher neutrino energies, perhaps at a greater rate than previously expected and probably only in pairs, though the total number of events seen is still low. The $\Delta S = \Delta Q$ rule

Theoretical ideas—and hard calculations

Although the theoretical physicists continued to work on strong interactions, particularly the study of SU_3 symmetry and peripheral collisions, major interest shifted to the implications of the Brookhaven experiment showing the 2π decay of the K^0_2 meson (*CERN COURIER*, vol. 4, p. 118, September 1964). Proposals were made for a specific mechanism for the 'CP' violation that may be responsible for the abnormal decay, as well as for a possible alternative explanation of the observed effect, namely the existence of a new long-range force generated by the stars and galaxies surrounding us. Much work was devoted to exploring the theoretical possibilites of these suggestions, as well as others made elsewhere, and to the working out of their experimental implications.

Further work on weak interactions dealt with a scheme incorporating intermediate bosons into the framework of SU_3 symmetry and with the production of nucleonic and mesonic excited states in neutrino-induced reactions. A thorough review was made of the present experimental evidence concerning the coupling constants involved in muon capture, revealing good agreement with the values expected theoretically.

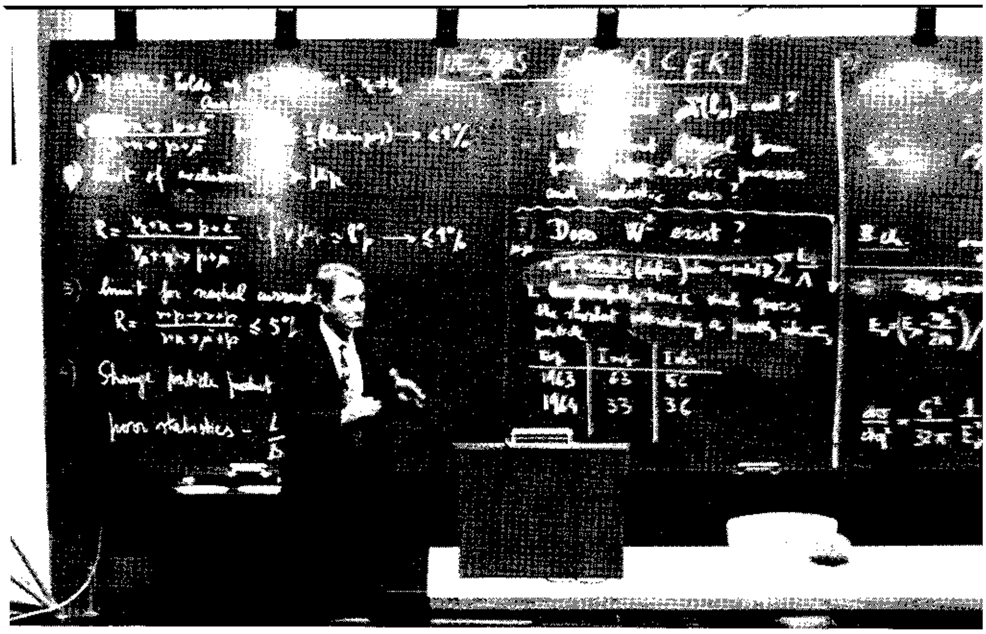
In strong interactions, large-angle scattering was studied from two aspects — the 'statistical' model and the 'analyticity properties of the amplitude'. The latter approach was also applied to the scattering between two pions, giving the remarkable result that the strength of the interaction was limited by analyticity in an absolute way, depending only on the pion mass.

Considerable efforts were devoted to the study of various problems in field theories of both the 'non-renormalizable' and 'renormalizable' types.

3 and 1964

again also has many implications in cosmological theory in any detail.

ɾas found that a neutrino is also produced when the pion ıught that this neutrino was the same as the one in beta ıulation of theories of weak-interaction processes to know one, but proof could only be obtained by means of inos themselves. Such experiments are also extremely g the weak interaction by means of a probe that itself has pite of the great difficulty of obtaining significant results :periments have thus become of great importance and look, clear and sub-nuclear physics.



Questions and answers on the neutrino experiments, as displayed and explained by Prof. G. Bernardini during the CERN Thursday afternoon seminar on 19 November.

CERN/PI 495b.11.64

seems to be at least 80% true (though in any case, former doubts as to its validity[7] have now been largely dispersed by more recent experimental evidence).

5. Is the 'muon' lepton number conserved in these reactions, in the same way as the electron number; for example, is it certain that a neutrino (particle) can only interact 'elastically' with a neutron to produce a proton and a negative muon (particle) and never with a proton to give a neutron and a positive muon (antiparticle)?

   Answer: Yes, at least to within 2%.

6. What is the value of the 'axial-vector form factor'? This is one of the terms that appears in the equation describing the weak interaction theoretically.

   Answer: The same as that of another term, the vector form factor, plus or minus 25%, again for all values of the momentum transfer up to 1 GeV/c. This is the first time that this factor has been measured.

7. Is there an intermediate boson?

   Answer: We don't know. In the spark chambers, many events were found that looked at first sight to be due to the decay of such a particle, but careful calibration, the consideration of all possible other causes and, before the 1964 run, changes to the apparatus to make identification of the particle tracks more certain, all led to the final conclusion that there was not yet any proof for its existence. From three possible cases of a muon-electron pair in the spark chamber and one in the bubble chamber, with no certain case of a muon-muon pair in either, it can be inferred that if the boson exists it has a mass greater than about 1.8 GeV/c^2, depending to some extent on the theoretical assumptions made. It now seems unlikely that the W-particle, even if it exists, can be produced with present-day accelerators ●

1. A fifth force, much weaker than gravity, has recently been postulated, but experiments to search for it are not yet complete.
2. Strictly speaking, the particle accompanying a negative electron is nowadays regarded as an antineutrino.
3. For neutrinos of high energy, however, such as those investigated at CERN, the probability is about 1 in 10 000.
4. The background to the CERN neutrino experiments was given in an article by G. von Dardel in **CERN COURIER**, vol. 4, pp. 29-33, March 1964. Unfortunately it has not been possible to publish the other two talks referred to there.
5. See **CERN COURIER**, vol. 3, p. 126, October 1963.
6. Neutrino interactions in the CERN heavy-liquid bubble chamber, by M. M. Block, H. Burmeister, D. C. Cundy, B. Eiben, C. Franzinetti, J. Keren, R. Møllerud, G. Myatt, M. Nikolic, A. Orkin-Lecourtois, M. Paty, D. H. Perkins, C. A. Ramm, K. Schultze, H. Sletten, K. Soop, R. Stump, W. Venus and H. Yoshiki; **Physics Letters**, vol. 12, pp. 281-285, 1st October 1964.
   Spark-chamber study of high-energy neutrino interactions, by J. K. Bienlein, A. Böhm, G. von Dardel, H. Faissner, F. Ferrero, J.-M. Gaillard, H. J. Gerber, B. Hahn, V. Kaftanov, F. Krienen, M. Reinharz, R. A. Salmeron, P. G. Seiler, A. Staude, J. Stein and H. J. Steiner; **Physics Letters**, vol. 13, pp. 80-86, 1st November 1964.
   Search for intermediate-boson production in high-energy neutrino interactions, by G. Bernardini, J. K. Bienlein, G. von Dardel, H. Faissner, F. Ferrero, J.-M. Gaillard, H. J. Gerber, B. Hahn, V. Kaftanov, F. Krienen, C. Manfredotti, M. Reinharz and R. A. Salmeron; **Physics Letters**, vol. 13, pp. 86-91, 1st November 1964.
7. See for example, **CERN COURIER**, vol. 2, no. 8, p. 9, August 1962.

Dealing with interactions at lower energies — in the field of nuclear physics—, earlier work on the 'optical' model for pion interactions (pion optical potential) has been extended in various directions. Pion absorption, leading to specific nuclear states, has been investigated, and the study of quadrupole effects in mesic atoms (having muons in place of one or more electrons) was pursued.

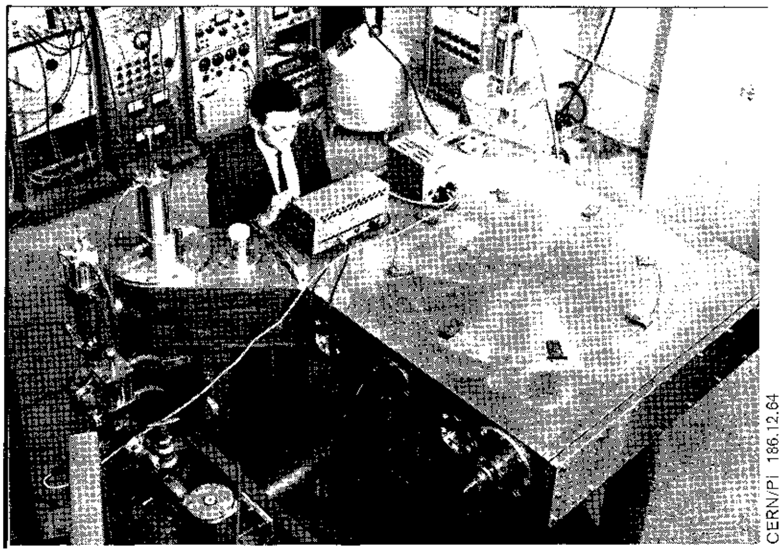
TECHNICAL PROGRESS

On the technical side, the main news items of the half-year were the achievement of 10^{12} protons/pulse at the synchrotron, the successful completion and testing of the 2-m bubble chamber, the tests of the radio-frequency separators, and the operation of the Saclay/CERN polarized-proton target. Apart from these events, work went on steadily in many sectors, aimed generally at faster electronic systems, more compact magnets and other equipment, better utilization of the accelerators, greater safety, and so on. The items dealt with below are only a sample.

Four targets at once

During this period, the simultaneous, or consecutive, operation of up to four targets in any beam pulse became standard practice at the proton synchrotron. Even the external proton beam has been incorporated into these target programmes. Much progress was also made with the components and other preparations for the ejected beams in the East hall.

A new column for the pre-accelerator (taking protons from the ion source to the linear accelerator of the PS), incorporating titanium electrodes fabricated at CERN, was successfully tested with 500 kV over a length of only 2.5 cm.



CERN/PI 186.12.64

To study in more detail the behaviour of the protons in the central region of the synchro-cyclotron, an accurate model has been designed and is nearing completion. In this photograph the vacuum tank can be seen during preliminary tests with the radiofrequency accelerating system. The magnet for the model cyclotron is ready for use, and the whole assembly will be transferred in the first part of 1965 to a new building under construction near the present synchro-cyclotron laboratories.

Rejuvenating the SC

Some of the major parts of the synchro-cyclotron, now over seven years' old, are beginning to show their age and much work was necessary to prepare for extensive overhauls during the shut-down in January 1965.

At the same time, various improvements are underway, including a new slow-extraction system for the external beam. Local shielding on the roof of the machine hall has been reinforced and heavy barytes-concrete beams have been constructed to cover the external beam, so that it can be used more often without exceeding the permitted radiation dose to surrounding areas. Remote-handling devices are being developed to cope with the increased radiation levels in the interior of the accelerator. On a more operational level, systematic studies of pion production in various targets are being carried out to see if present beams can be improved.

The biggest effort, however, has been concentrated on the testing and installation of a model that is to be used for exact studies of the phenomena occurring in the critical central region of a synchro-cyclotron.

100 000 000 cycles per second

Electronics experiments at the PS have been able to benefit, in one way or another, from more advanced equipment and more intense beams. Developments in the system of nucleonic 'modules'—the interchangeable units of electronics counting and recording equipment—have enabled units handling frequencies of 100 Mc/s to be used successfully in experiments.

Tests have been carried out on a new kind of Cherenkov counter (known as a DISC counter), invented at CERN, which can distinguish between pions and muons up to the highest energies obtainable in the PS secondary beams. It has an overall resolution for the velocity of charged particles of 1 part in 200 000.

By using more than one photomultiplier, together with fast electronic systems, it has been found possible to locate fairly accurately the position of the scintillation flash in a large sheet of plastic scintillator (following the same principles as the sonic spark chamber but with light instead of the much slower sound waves). With a combination of several counters, the trajectory of a particle can be measured to within 2 cm and its time of flight to within 0.2 nanosecond (2×10^{-10} s).

Much work has been done towards the greater use of computers 'on-line', and the SDS 920 computer has been used in the proton-proton scattering experiment since last September. This experiment essentially involves the following of individual protons to and from the scattering target, using sonic spark chambers, and up to a dozen such protons can now be recorded in each machine burst. Indeed, in two days' running time after installing the computer, data on 100 000 scattering events were obtained.

More antiprotons

The high-intensity separated-beam line, m_4, one branch of which is used for the PAPLEP experiment on rare antiproton annihilations and the other for the xi-parity experiment, came into full use during the period under review. It normally provides 50 000 antiprotons (momentum 2.3 GeV/c) or 20 000 negative kaons (1.8 GeV/c) per pulse (per 10^{12} accelerated protons). This is by far the most intense beam of its kind in existence.

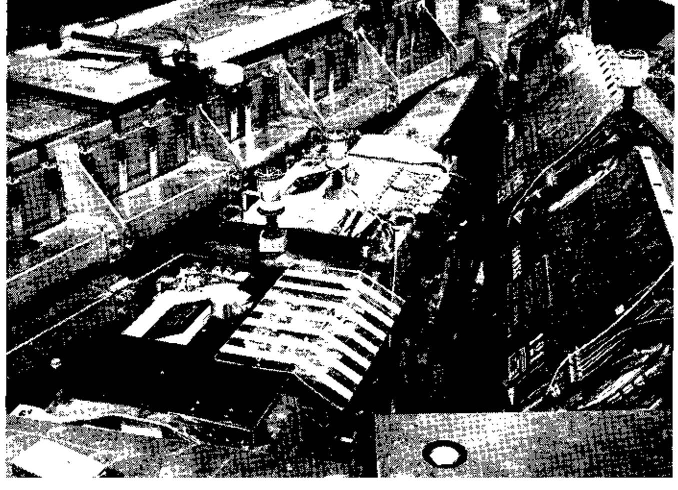
Sorting out the secondary particles

Higher electric fields in the electrostatic separators, and hence 'purer' separated beams, are foreshadowed by the development of electrodes coated with alumina, following a systematic study at CERN of different types of electrodes. A 3-m separator equipped with the new electrodes withstood 810 kV across a 9-cm gap, with only a few sparks per hour — a performance noticably better than that formerly obtained with stainless-steel electrodes. This separator was installed in the k_4 beam line in November.

Looking further ahead, CERN's microwave particle separator was also tested satisfactorily towards the end of the year. In its first separation tests, a beam of positive kaons of momentum 10 GeV/c was produced,

Secondary particles produced by the impact of accelerated protons on the targets in the synchrotron tend to be carried forward by the momentum of the incoming particles, and it is therefore of considerable importance for high-intensity secondary beams to collect particles from as near to the original proton direction as possible. This creates particular problems when more than one beam is to be obtained from one target; the target region becomes very crowded with equipment, and recourse has to be had to specially designed items. For CERN's record-breaking m_4 beam, the first magnet of the beam line is actually inside the target box, while the next two are special focusing quadrupoles of large aperture and reduced overall dimensions (see CERN COURIER, vol. 4, p. 71, June 1964). They are seen here between one of the accelerator ring magnets (on the left) and two normal quadrupoles of the q_3 beam line.

CERN/PI 128.6.64



with about equal numbers of wanted and unwanted particles. Improvements in the setting up of the whole system were expected to produce a much better separation, but difficulties in producing the required short pulse of protons on the PS target made it impossible to complete the tests. If all goes well, however, CERN will soon have a separated-kaon beam at nearly twice the energy obtainable anywhere else.

In parallel with the construction of the 2-m bubble chamber, new and improved methods of dealing with bubble-chamber film have been developed. The prototype scanning table for the 2-m chamber, for instance, has proved very satisfactory in use; the assembly of eight more is well under way and several laboratories in Member States have expressed interest in the design, which has many new features.

HPD scanning bubble-chamber films

The mechanical flying-spot digitizer, known usually as the HPD, has now successfully analysed its first sample of bubble-chamber pictures. Scanning and rough measurement on 'Milady' digitized tables was done at the rate of about 5 events per hour, while 54 events an hour were handled in the purely automatic part of the system, the HPD itself. The machine measures the amount of ionization produced along the tracks as well as their direction and length. Photographs from the experiment using the magnetic spark chamber are also being analysed by this machine. Luciole, the cathode-ray-tube flying-spot digitizer, was used extensively to provide test data for the development of programmes and a detailed comparison was carried out with a set of spark-chamber photographs, measured by hand in the normal way and fully automatically by this apparatus. At that time, some small discrepancies remained, due primarily to difficulties of calibration.

CESAR stores electrons

CESAR, the CERN electron storage and accumulation ring, is now in full use for investigations into the behaviour and operation of storage rings. Systematic measurements of beam 'stacking' are in progress, to study the efficiency as a function of the mode of stacking, the number of pulses stacked and the various parameters of the programme for the radiofrequency system that expands the orbit of each pulse injected into the ring. Up to 100 pulses and up to 20 mA of current have been stacked successfully, and measurements of the stacking efficiency are in progress. Voltage stability of the twin-beam Van de Graaff accelerator that supplies the input electrons has been improved by bringing into operation an automatic feedback system functioning on the second beam. For the time being, the pressure in the vacuum chamber remains rather higher that planned, at 2×10^{9} torr, although this is still a thousand times lower than normal accelerator values. An improvement of a factor of five is expected to follow a bake-out of the vacuum chamber planned to take place in March.

200 000 volts in 0.000 000 002 second

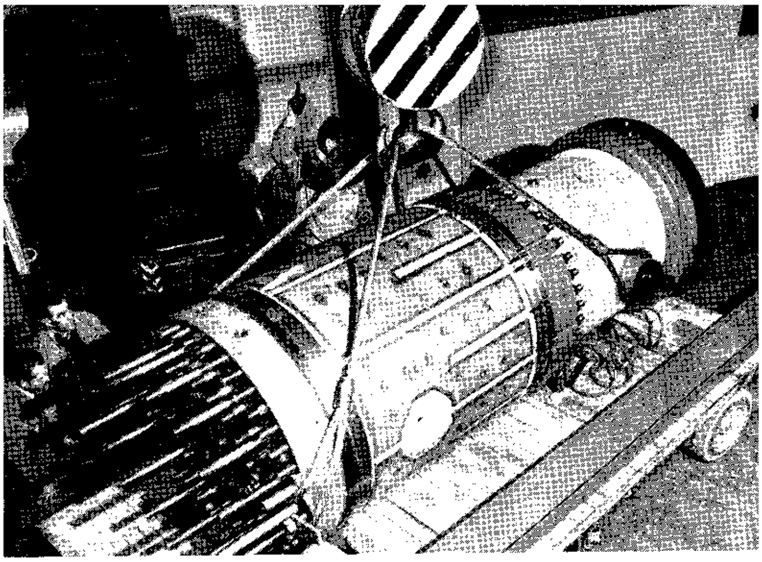
In another study aimed at providing equipment for the next steps in high-energy physics research, a high-voltage pulse generator providing an extremely sharp pulse has been built, to operate a 'three-dimensional', wide-gap spark chamber. This new development, in which the sparks are arrested before they can travel far between the plates of the gap, produces a track of light along the path of a particle, similar to the trail of bubbles in a bubble chamber. Although the track is not quite so well defined, there is the great advantage that the chamber can be triggered by external counters so that only the interactions of interest are photographed. The pulse generator, suitable for a chamber 10 cm high and 10 cm deep, gives 200 kV with a rise and fall time of about 2 nanoseconds. To measure these characteristics a special transmission line had also to be designed and constructed.

GENERAL PROGRESS

Behind the achievements of the scientists and engineers lies the work of many people who contribute in one way or another to the functioning of the Organization. Much of this work is inevitably of a routine nature and not much more can be reported in the way of 'progress' than the fact that it was done efficiently, or perhaps more efficiently than before. In some cases, however, the results are more obvious, as the few examples that follow will help to show.

Mass production ruled out

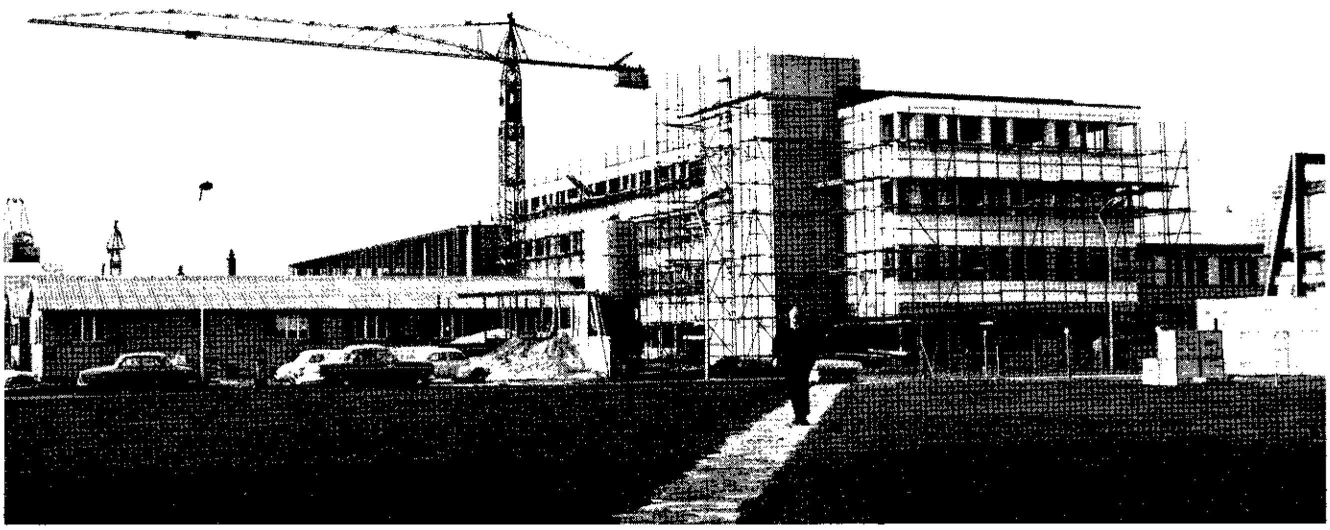
Closely concerned with the experiments and technical advances are the staff of the workshops, both centralized and Divisional, who manufacture so much special equipment, usually of unique design, often to very fine tolerances, and in many cases of unusual material. For example, in the second half of 1964 the Main Workshop produced the major part of the expansion system for the new 2-m bubble chamber (only one of many items altogether for that piece of equipment), specially shaped magnetic 'shims', 'plexiglas' frames for spark chambers, two large plano-convex lenses, with a diameter of 1.4 m and a radius of curvature of 5 m, also in 'plexiglas', engraved glass plates to provide reference marks for alignment, and many other



CERN/PI 259.12.64

The CERN heavy-liquid bubble chamber was converted into an instrument more than twice as large during the second half of 1964. This photograph shows the new chamber body, together with the extension (on the far end) that constitutes the camera support and safety shield, at the start of its lift back into the magnet, previously replaced in the 'neutrino' block-house. The new chamber holds 1130 litres of liquid (propane or freon), instead of the previous 500 litres, and provides a 'fiducial' volume of 660 l instead of 220 l. It also has a more effective temperature-control system and various other improvements. To accomodate the lengthened chamber, the magnet was extended by 20 cm and three more pairs of coils were added. Tests have shown that the magnet still provides the same field, having a value of some 27 000 gauss, with a power consumption of 4.5 MW.

CERN/PI 165.11.64



One of the largest buildings currently under construction on the CERN site is this new laboratory (no. 13) for Track Chambers Division, linking laboratories 11 and 12 and the TC workshop, opposite the synchro-cyclotron. The barracks that at present house many members of the Division can be seen on the left of the picture and visible above them is part of the equipment assembly hall of the new building. The new building will be ready for occupation at the end of January.

things. Among work undertaken by the West Workshop was the manufacture of high-precision targets, a large-aperture 'kicker' magnet, spark chambers, Cherenkov counters, prototype liquid-nitrogen traps, items in titanium and 'inox', a liquid-helium target with inox windows, and so on. It is estimated that a third of the time of this shop is devoted to 'difficult' items. Although their new building was only ready for occupation in November, the staff of the Surface-treatment Shop were already producing such items as electroformed hollow conductors for ejection magnets.

Less open land

All over the site people were at work putting up new buildings, extending and altering old ones, and reshaping the land in between. Constructions finished in this period were the extensions to the Nuclear Physics Apparatus building, the Accelerator Research laboratories and what is now their annexe (formerly the only AR laboratory), and the Main Workshop. Work still in progress included that on the laboratory (no. 13), hall and sub-station for Track Chambers Division, the workshop and hall for the cyclotron model, garages and offices for Site and Buildings Division, offices and hall for the General Safety Group, the Surface-treatment Shop, constructions for fast-ejected beams in the East area, extensions to the computer building, a new workshop for the Proton Synchrotron Machine Division, and extensions to laboratory no. 4.

With so much new building going on, the appearance of parts of the site has suffered, but plans are now being made to improve those areas that are at present virtually devoid of vegetation. This is in addition to the routine care by CERN's four gardeners of the many lawns, trees and gardens already established.

Electronic book-keeping

The growing reliance on electronic computers for the performance of large numbers of routine calculations has now spread to the Finance Division, which took delivery of an NCR 390 computer last July. From the beginning of 1965 all calculations concerning salaries are being made with this machine, and book-keeping generally will be transferred progressively later in the year. Plans are also being made for the eventual recording of all the various stores transactions and accounts by means of CERN's new CDC 6600 central computer. This in fact is only one of a number of 'non-scientific' uses envisaged for the computer, and a special study group has been set up to look into long-term developments ●

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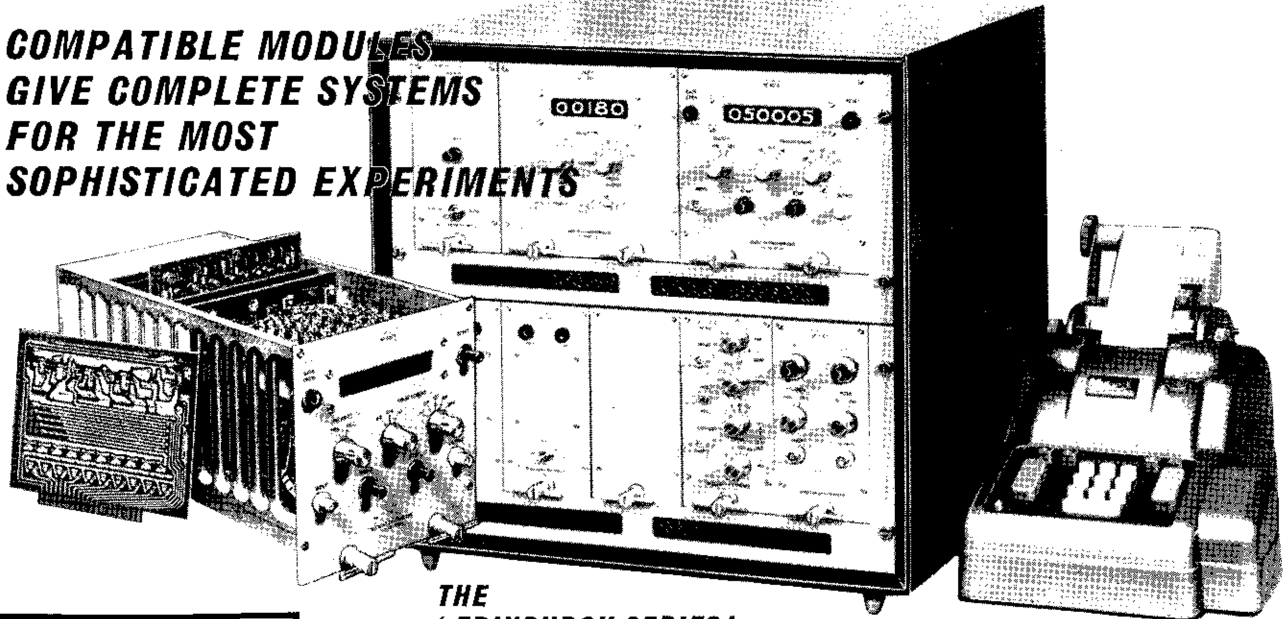

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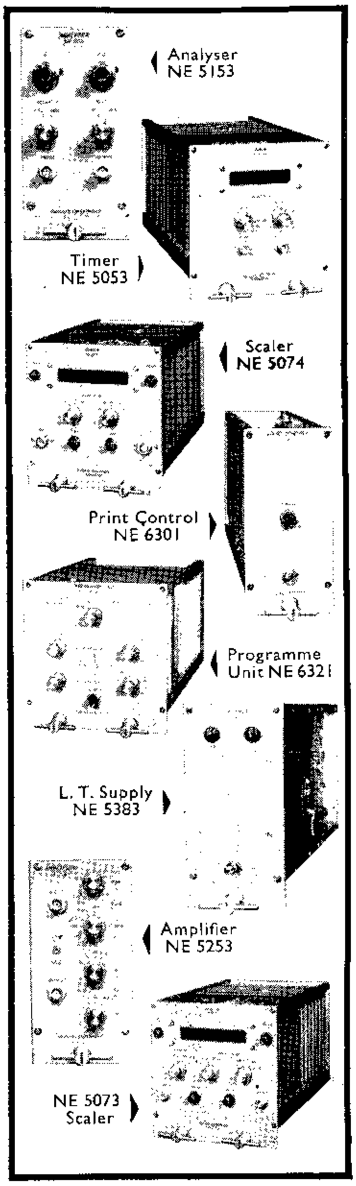

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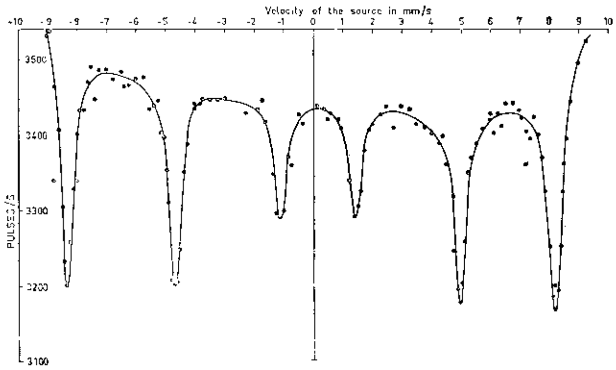

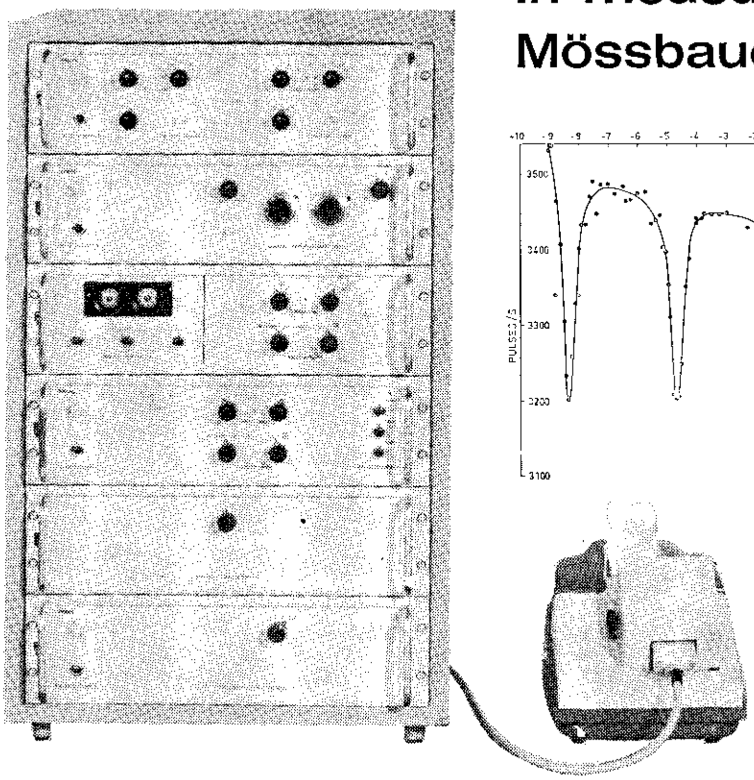

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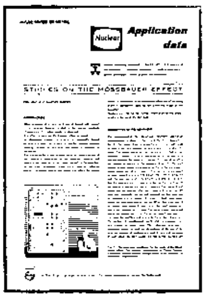

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COMMUNIQUE FROM THE WELFARE SECTION

CERN staff frequently have problems connected with the schooling and further education of their children. It has been found, after an enquiry, that solutions to these problems have often proved difficult in the past or unsatisfactory.

The CERN Welfare section has therefore secured the services, whenever required, of a careers advisor and a member of the teaching profession, both of whom co-operate with the "Office Cantonal de la Formation Professionnelle" and "Service de l'Orientation Professionnelle" (Cantonal Office for Vocational Training and the Service for Vocational Guidance). These two persons will endeavour to find the best solutions to any problems put to them. Their advice may be sought on the following matters :

- Conditions for admission to the various schools in Geneva;
- Validity abroad of diplomas obtained in Geneva and vice versa;
- Teaching syllabus in various schools;
- Private schools;
- Possibilities for vocational training (apprenticeships, etc.) in Switzerland;
- Possibilities of practising a profession or carrying on a trade abroad after training in Switzerland, and vice versa.

All persons wishing to avail themselves of this service should apply to Miss Kiss-Borlase, Information and Welcome Service, Telephone : 2226, Office R-048, Laboratory 4.

We should be grateful if you would pass on this information.

February 1965.

Réf. : PE/WE/41/PZ.

COMMUNIQUE DE LA SECTION DES AFFAIRES SOCIALES

Des problèmes relatifs à la scolarité et à la formation professionnelle des enfants des fonctionnaires internationaux se posent régulièrement au CERN. A la suite d'un sondage, il s'est avéré que certaines difficultés étaient résolues difficilement ou d'une façon peu satisfaisante.

C'est pourquoi la Section des Affaires Sociales du CERN s'est assuré les services, sur demande, d'un orienteur professionnel et d'un enseignant collaborant l'un et l'autre avec l'Office cantonal de la Formation Professionnelle et le Service de l'Orientation Professionnelle. Ces deux personnes seront chargées de trouver la solution la plus favorable aux divers problèmes qui pourraient être posés.

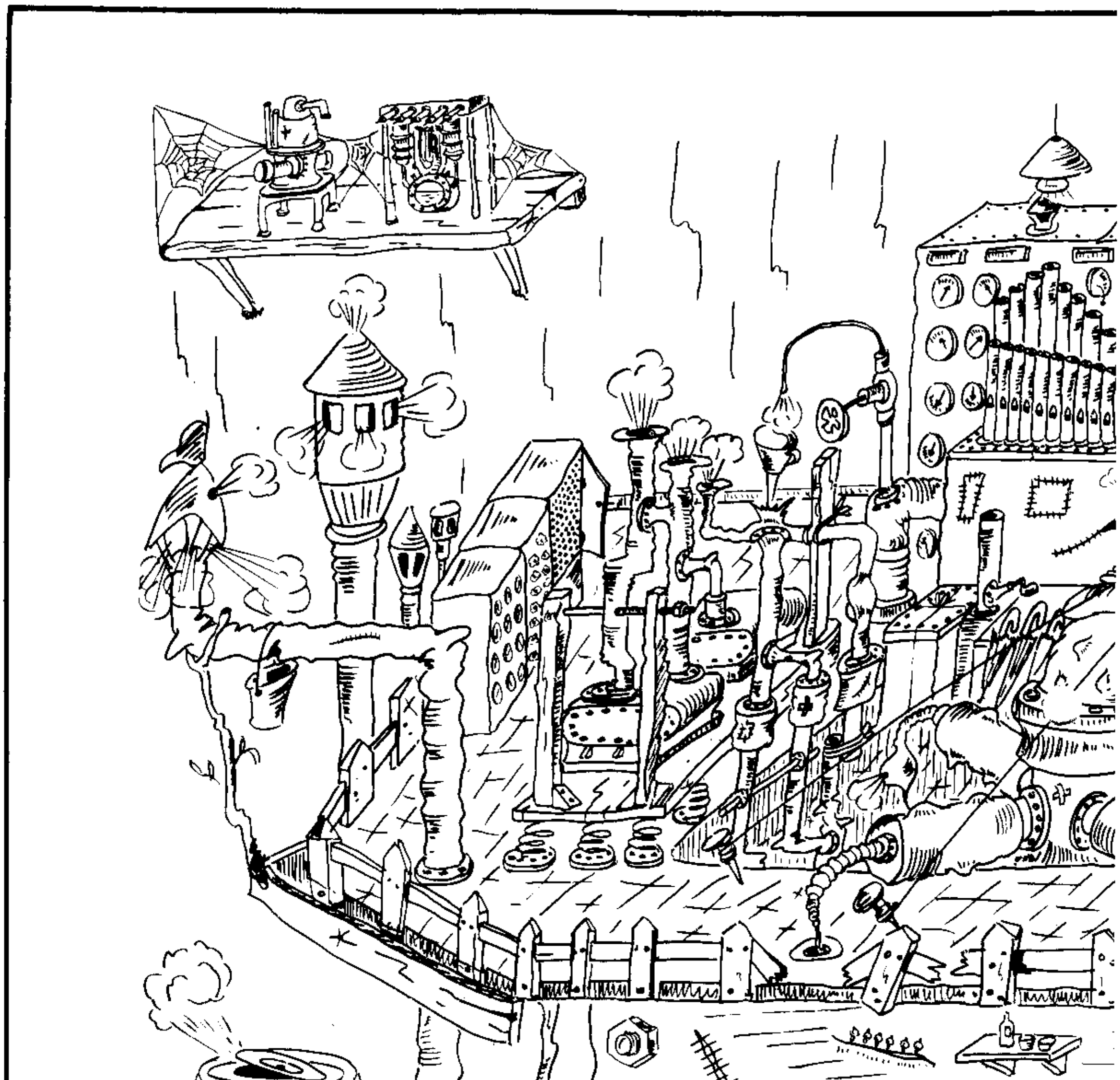
Leurs conseils pourront être sollicités dans les domaines suivants :

- Conditions d'admission dans les différentes écoles de Genève
- Validité à l'étranger des diplômes obtenus à Genève et vice versa
- Programme d'enseignement des différentes écoles
- Problème des écoles privées
- Possibilités d'acquérir une formation professionnelle (apprentissage, etc...) en Suisse
- Possibilités d'exercer à l'étranger après un apprentissage en Suisse et vice versa.

Toutes les personnes intéressées par ce communiqué peuvent s'adresser à Mlle Kiss-Borlase du Service de renseignements et d'accueil, interne 2226, bureau No R-048, Lab. 4.

Nous vous remercions de favoriser la bonne diffusion de cette information.

Février 1965.



'Artist's impression' of the CERN

«Conception artistique» de la chambre à b

Supplement to
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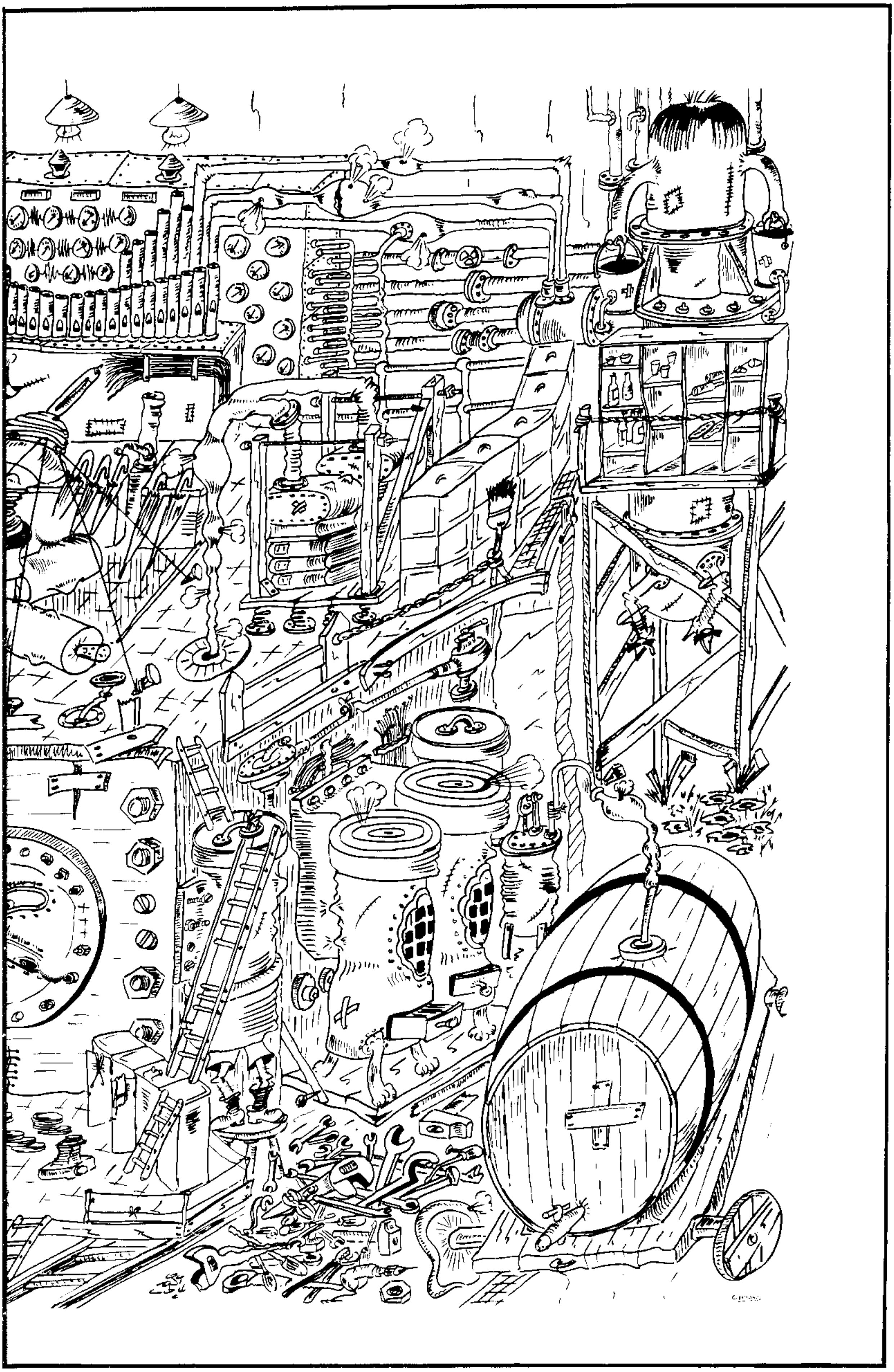

B. CHAMDRU (TC)

metre liquid-hydrogen bubble chamber.

les de 2 mètres à hydrogène liquide du CERN.

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