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CERN COURIER

European Organization for Nuclear Research

The cover photograph was taken in the West Workshop and shows the completed assembly of an unusual wheel built up of seventeen scintillation counters. The wheel is part of the detection equipment in an experiment to examine the decay products of the negative xi particle. Of particular interest, is the rare decay giving an electron, which occurs about five times in ten thousand decays (the usual decay giving a pion). The wheel has to be very large (about 3 metres across) so that it will still catch the decay particles even though it is not right close to the target where the xi is produced but is preceeded by a gas Cherenkov counter, which distinguishes between an electron and a pion. (CERN/PI 56.8.67)

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Comment

At its meeting in June of this year, the CERN Council approved an agreement for the construction of a 20 cubic metre hydrogen bubble chamber to be used at the 28 GeV proton synchrotron. The detailed design study for this chamber was prepared by a group of experts from the Federal Republic of Germany, France and CERN ; Germany and France will participate in the project as equal partners with CERN. The finance is to be divided equally among the three partners and the whole project will be supervised by a steering committee with one representative from each party.

To increase the range of physics which can be covered by a chamber of this type, it is necessary to contain much larger volumes of liquid hydrogen than in the chambers now in operation. The new chamber will be 30 cubic metres in volume (20 cubic metres of which will be useful volume for particle interactions). All the related components, such as magnets, cameras, cooling, vacuum, controls and expansion system, have then to be designed to cope with this larger volume. No straightforward extension of conventional systems could meet the requirements without involving prohibitive costs.

A complete rethinking has been necessary ; many new ideas and many recent developments in technology have been incorporated. The design still imposes severe demands on various components — a superconducting magnet (larger than any yet constructed) to provide a magnetic field of 35 kg accurate to 3 % over the useful volume ; an intricate camera and optical system involving wide angle lenses, precisely constructed 'fish-eye' windows and possibly a compressed-air driving mechanism for the film ; an extensive cryogenics system to produce the low temperatures for the liquid hydrogen and for liquid helium which will cool the superconducting coils ; a novel arrangement of the expansion system probably with large epoxy resin components ; eventual computer-control of chamber operation... Meeting this design will be a stimulus to European industry in a wide variety of technologies.

Pursuing sub-nuclear physics often requires new approaches which impose exacting demands for instrumentation. It gives industry the opportunity to cut its teeth on new developments in technology by tackling specific projects. The benefit that this brings to industry is a bonus and not a justification for sub-nuclear physics in Europe, but it is worth recognizing that our field is one of those which force the rate of advance of European technology.

CERN, the European Organization for Nuclear Research, was established in 1954 to '... provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto'. It acts as a European centre and co-ordinator of research, theoretical and experimental, in the field of sub-nuclear physics. This branch of science is concerned with the fundamental questions of the basic laws governing the structure of matter. CERN is one of the world's leading Laboratories in this field.

The experimental programme is based mainly on the use of two proton accelerators — a 600 MeV synchro-cyclotron (SC) and a 28 GeV synchrotron (PS). At the latter machine, large intersecting storage rings (ISR), which will allow experiments with colliding proton beams to be carried out, are under construction. Scientists from many European Universities and national Laboratories as well as from CERN itself take part in the experiments and it is estimated that some 700 physicists outside CERN are provided with their research material in this way.

The Laboratory is situated at Meyrin, Canton of Geneva, Switzerland. The site covers approximately 80 ha about equally divided on either side of the frontier between France and Switzerland. The staff totals about 2300 people and, in addition, there are over 400 Fellows and Visiting Scientists.

There are thirteen member States participating in the work of CERN. The contributions to the cost of the basic programme, 172.4 million Swiss francs in 1967, are in proportion to their net national income. Supplementary programmes cover the construction of the intersecting storage rings and preliminary studies on a proposed 300 GeV proton synchrotron for Europe.

Large hydrogen bubble chamber

A description of the large hydrogen bubble chamber for the CERN proton synchrotron

Early in 1965, European physicists working with bubble chambers, and the CERN Scientific Policy Committee studied the future requirements of this experimental technique. They emphasized the very important role of these detectors in particle physics research and recommended that the present generation of bubble chambers should be succeeded by two chambers of large volume — a hydrogen chamber and a heavy liquid chamber. German and French Laboratories who, like CERN, had considerable experience in bubble chamber construction expressed great interest in these projects.

At its meeting on 25 March 1965, the CERN Council decided to participate in the project for a large heavy liquid chamber, called 'Gargamelle', which was under consideration in France and recommended that a study group, with experts from Germany, France and CERN, be set up to prepare a detailed proposal for a very large hydrogen chamber. During the Summer of 1965, experts from Germany and France joined the team at the Track Chamber Division in CERN and, last November, they presented a report to the Scientific Policy Committee. The project was approved at the Council meeting in June 1967.

The large hydrogen chamber is part of the second stage of the improvements programme for the CERN proton synchrotron. The programme is designed to improve the performance of the machine itself and to provide advanced experimental equipment for use at the machine. The first stage is already being implemented and is scheduled for completion in 1968. It will increase the repetition rate of the synchrotron by a factor of 2 to 3 in order to obtain a higher intensity of accelerated protons per unit of time. A large new power supply for the main magnet ring and additional radio-frequency accelerating cavities are being constructed. Another important feature of this first stage is the improved facilities for experiments with neutrinos (see CERN COURIER, vol. 6, page 211) including the heavy liquid bubble chamber, 'Gargamelle', which is at an advanced stage of construction in France. The second stage, covering approximately the years 1968 to 1971, includes two major proposals. One is the construction of a new injector of higher energy (see CERN COURIER, vol. 6, page 63); a study group on this project will present its report soon. The other is the construction of a large hydrogen bubble chamber.

Physics with bubble chambers

Over the past ten years, bubble chambers have played a very important role in the investigation of interactions between elementary particles. Their contributions have included — the discovery of new particles and many of the unstable resonances and the measurement of their properties, such as mass, spin, parity and lifetime; the investigation of two-body interactions; the study of weak interactions including the first quantitative results on neutrino interactions. The bubble chamber technique has the following features: it records all the charged products of the interaction and makes visible the tracks of these particles even in the immediate vicinity of the interaction; it makes possible very accurate measurements of momentum and direction; it records all information in an unbiased way (since it cannot be triggered to select only a particular type of event); it detects unstable secondary particles.

The technique has been particularly appropriate for a central Laboratory such as CERN intended to serve Universities throughout Europe. The photographs taken on the bubble chambers at CERN are distributed widely for analysis by the groups participating in the experiments. From January 1960 to September 1966, more than 15 million photographs were analysed, 80 % at national centres and 20 % at CERN.

There is a growing demand to participate in bubble chamber experiments and a growing capacity in national centres for the analysis of bubble chamber photographs. The developments in this field, being implemented or proposed at CERN, are intended to meet the growing demand, incorporate the technical developments of recent years, increase the field of research which the chambers can cover and improve the quality of the research which can be carried out.

There are two types of chamber in operation at present — the heavy liquid chamber and the hydrogen chamber. (Chambers filled with helium, which have useful but restricted applications are not discussed.) The heavy liquid type is usually filled with propane or one of the freons and, because of the high density of these liquids they are used particularly in experiments where it is important to detect neutral particles (such as neutral pions and neutrons) and gamma rays. These leave no track themselves but their path-lengths in heavy liquids are often sufficiently short for them to produce, within the volume of the chamber, charged particles (such as electron-positron pairs from gammas) by means of which they can be measured. These chambers suffer from having a complicated target (the nucleus of the heavy liquid) and the tracks give momenta and directions with limited precision because of high Coulomb scattering of the charged particles by the nuclei, which have high charge.

The hydrogen chambers have the simplest possible target (a single proton at the nucleus of the hydrogen atom) and Coulomb scattering is much less of a problem. Also, when filled with deuterium, they provide the nearest approach to a free neutron target. However, the path-lengths of neutrons and gammas are long and, with the existing chambers, the investigation of events involving the production of neutral pions which decay into gammas is restricted. Thus, most experiments to date have been carried out at energies below 10 GeV, since the chambers are not sufficiently large to detect the neutral particles which are produced in larger proportions at higher energies. Neither can the present chambers be used efficiently for neutrino experiments since their target volume is too small to give an adequate event rate.

The study group considered the scientific, technical and financial aspects of various systems to overcome the present limitations. They concluded that a hydrogen bubble chamber as large as is technically and financially feasible would be the best solution for future physics in this field. (It is significant that the same conclusion was reached by scientists in the USA and USSR. It has been decided to build a 12 foot chamber at Argonne and a 7 foot chamber, as a model for a 14 foot chamber, at Brookhaven. A design group is working on a 5 metre chamber at Dubna.) Such a chamber will accept more incoming particles to provide more events per picture, increase the range of momenta of particle beams which can usefully be used, improve the accuracy of measurements on charged particles of high momenta, improve the studies of multiple particle events, improve the identification of neutral particles and provide an acceptable neutrino event rate.

Technical developments

The bubble chambers at present in use were conceived about ten years ago. Since then, there have been major developments in some of the important technologies involved in their construction.

i) Progress in the development of superconducting magnets makes it possible to use a much higher magnetic field. This is significant since the precision of the momentum measurements is directly proportional to the strength of the magnetic field. Using conventional techniques the operating costs become prohibitive for magnets producing fields in excess of about 25 kG. With the new superconducting alloys, fields up to about 70 kG can be envisaged, with relatively very low power consumption for cooling the magnet to maintain the operating temperature of 4° K (—269° C). No superconducting magnet of the size proposed for the new chamber has yet been built, but no insurmountable problems are foreseen in extending the present progress to fulfill the design.

ii) The idea of bright-field illumination systems using 'Scotchlite' has overcome the problem that no simple dark-field system can be devised for very large chambers. In the dark-field system, incorporated in almost all the existing chambers, the bubbles produced along the tracks of charged particles become visible as they scatter some light from the flash-tubes towards the cameras. They appear therefore, as white tracks on a black background. These systems involve very large windows and condenser lenses and to extend them to the size of the proposed chamber would be feasible but extremely expensive.

Scotchlite consists of a layer of small spherical beads embedded in a transparent plastic. Its significant property is that it reflects light (up to angles of incidence of about 60°) in the direction of the incident ray. If, then, the chamber is illuminated from the camera side the photograph shows a bright background against which the bubbles appear as dark spots, because the light scattered by the bubbles no longer reaches the cameras.

The problems of diffraction are more acute with bright-field illumination. Whereas with the dark-field system, the loss of contrast because of diffraction can be compensated to some extent by simply increasing the intensity of the light, with the bright-field system the bubbles have to be allowed to grow to larger sizes before being photographed. In the conventional chambers operating at 26° K, bubbles are photographed after about 1 ms when they are about 300 microns in diameter; in the proposed chamber they will need to grow to about 700 microns with a growth time of about 4 ms, unless the chamber is operated at lower temperature. Some precision in the momentum measurements will be lost because of the larger bubble size and because the bubbles may drift during the longer growth time. However it is anticipated that this will be more than compensated by having a much higher magnetic field and by being able to measure longer tracks.

iii) The developments in optics enable wide-angle lenses to be used. In present chambers, the cameras are set well back from the useful volume; the new lenses can be brought closer to the volume to be photographed. However, in order to avoid too complicated wide-angle lens systems and also to avoid strange looking, distorted pictures which would be difficult to scan, a compromise solution has been chosen — setting the lenses some way back from the useful volume and accepting some 'useless hydrogen' (though nowhere near as much as would be necessary with standard lenses, unless a very large window is used).

iv) The experience gained with the existing chambers has been an important factor in making the large volume of liquid hydrogen involved in the proposed chamber acceptable. The cryogenic and safety aspects of handling these large volumes no longer seem as daunting as they did five years ago. On this point, (and on many others) the proposed chamber will be an important step towards the realization of the enormous chambers which can be envisaged, presuming that the bubble chamber technique still retains its usefulness, in association with the proposed 300 GeV accelerator.

The design

Some of the major features of the proposed chamber are described; reference to figure 1 and figure 2 may help in understanding the design. Within the scope of a general article full details of each component cannot be covered and, in particular, cryogenics, vacuum systems, power supplies, controls and safety systems, all of which are important to the project are not described.

Hydrogen chamber

The volume of hydrogen to be contained is about 30 m³ of which 20 m³ will be 'useful', (where interactions can take place within the region of good magnetic field and within the field of view of the cameras). This compares with a useful volume of less than 1 m³ in the existing 2 m chamber at CERN. To accommodate such a large volume it is necessary, for reasons of mechanical strength and economy, to move away from the 'bath-tub' configuration which is most frequently used for conventional chambers. The chosen design is a cylinder 3.5 m in diameter, with the useful volume 2 m high (1 m above and below the plane of the incoming beam). Above that, the cylinder tapers to a domed shape adding about another metre in height. The axis of the cylinder is vertical which gives the easiest arrangement of other components (optics, expansion system, etc.). The walls of the cylindrical part of the vessel are 45 mm thick with thin stainless steel windows 30 cm high where the beam particles enter and secondary particles emerge. Since a chamber of this size could not easily be moved from one beam-line to another, a wide window is needed to accommodate beams coming from different angles. Also, with a wide window the incoming particles can be spread over the useful volume so that an increased

Figure 1: An artist's drawing of the design of the hydrogen chamber. The arrow in the chamber shows the direction of the incoming beam.
The location of the cameras, magnet coils, piston, separation disc and magnetic screen can be seen.

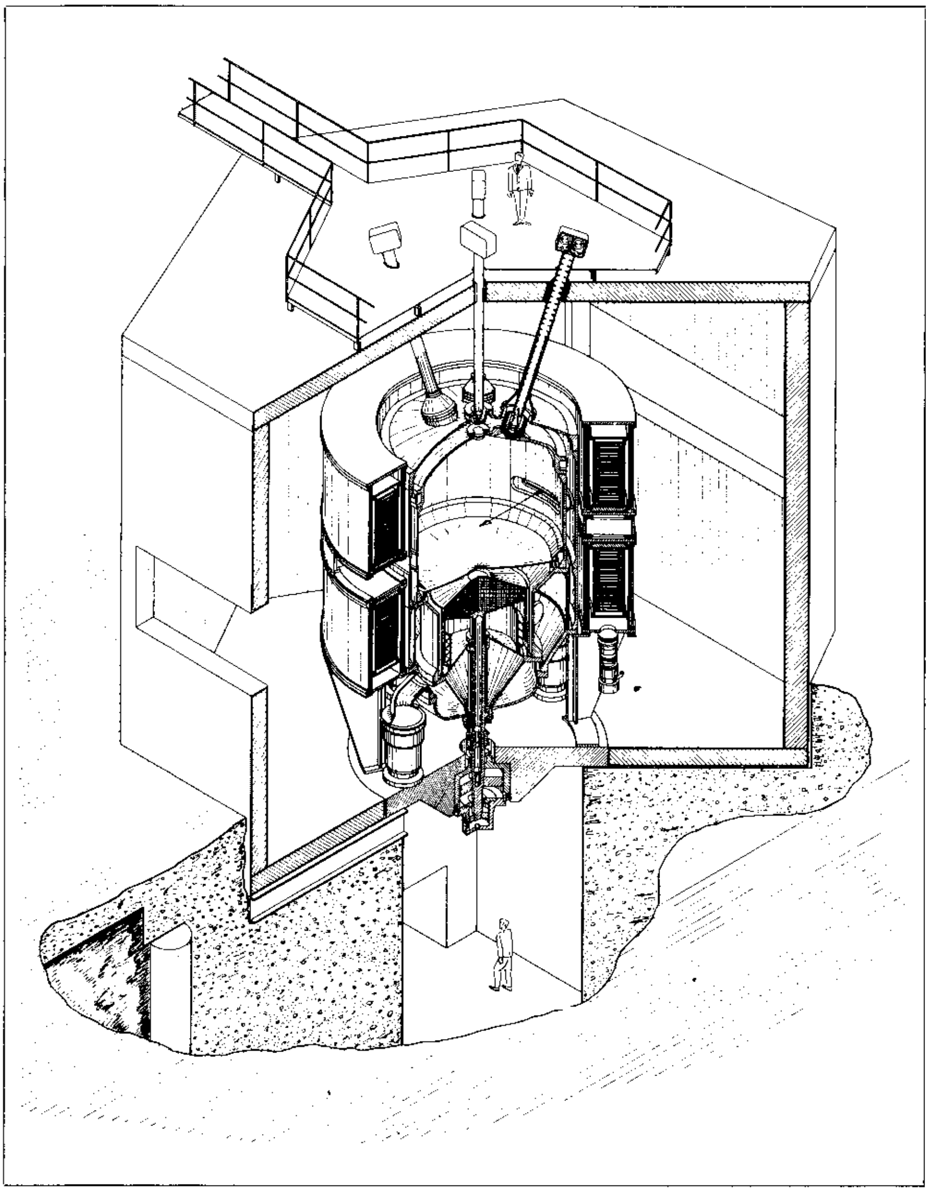

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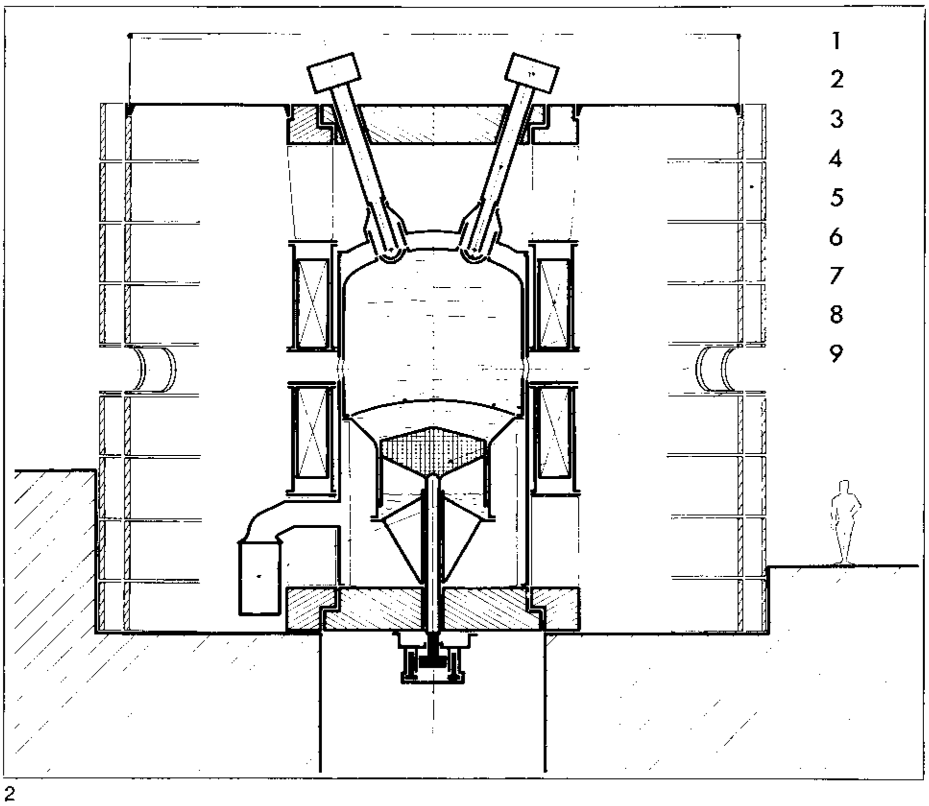
Figure 2: A cross-section showing the general assembly of the chamber. The positions of the various components are as follows —
1 one of the four cameras
2 film transport system
3 'fish-eye' windows
4 magnetic shielding around the chamber
5 upper superconducting coil
6 separation disc of the expansion
7 Scotchlite covering walls and disc
8 expansion piston system
9 vacuum pump



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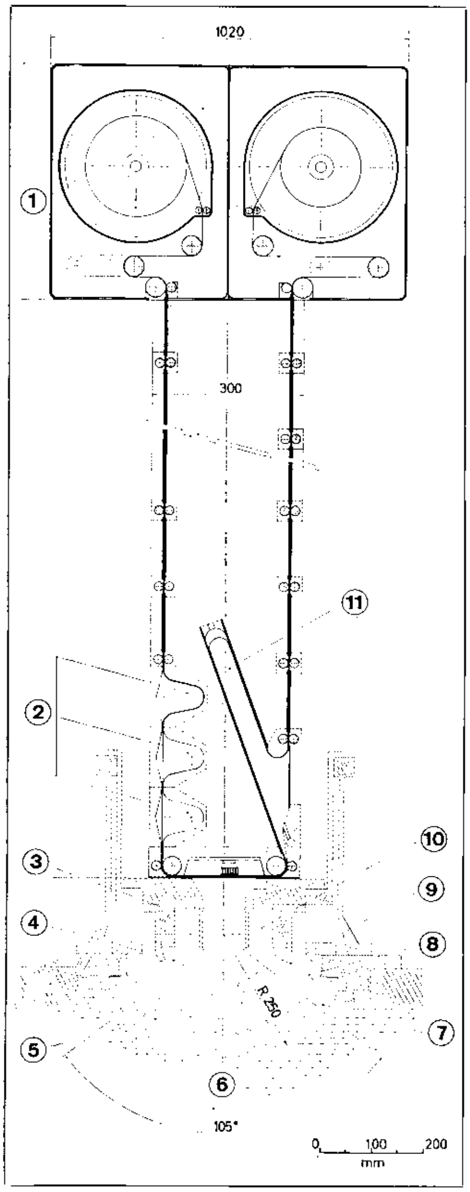

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Figure 3: A possible arrangement of the camera and film-transport system.
1 *70 mm film magazines with the supply reel on the right and take-up reel on the left*
2 *pneumatically-operated film-transport pocket*
3 *wide-angle lens (105°)*
4 *vacuum tank window*
5 *gaseous hydrogen*
6 *liquid hydrogen*
7 *chamber window*
8 *heat-shield window*
9 *clean vacuum*
10 *ring-shaped flash tube*
11 *pneumatically-operated film-supply pocket*

number of events per picture can be seen without confusion of tracks.

Surrounding the chamber proper is the vacuum tank, also a cylindrical structure. They will both be constructed from low carbon stainless steel which has good mechanical properties and low magnetic permeability at liquid hydrogen temperatures, is easy to weld and not subject to structural changes due to the temperature cycles it will have to face. The chambers are designed to withstand internal pressures of 15 kg/cm².

Superconducting magnet

The magnet system is designed to produce a field of 35 kG, accurate to within ±3 % over the useful volume of the chamber. (This compares with 17 kG in the 2 m chamber). The field is produced by two identical, cylindrical coils, composed of double 'pancakes', surrounding the chamber. There will be an air gap of 50 cm at the plane of the beam between the coil cryostats. Spacers, which can be moved or changed in size according to experimental requirements, are positioned in the gap to withstand the high attractive force (about 8500 tons) between the coils.

Using superconducting coils, an iron flux return path is not required. However, the huge stray field cannot be allowed to extend to surrounding equipment or to the structure of the building housing the chamber. It is confined to the immediate chamber region by a screen of low carbon steel surrounding the whole bubble chamber about 3 m from the coils. Access to the area enclosed by the screen will be prohibited during operation of the chamber.

A niobium-titanium or niobium-tin superconducting alloy, electrically stabilized with high purity copper or aluminium, is necessary for the construction of the coils to achieve the field required. The conductor is reinforced with stainless steel for mechanical strength. The dimensions of each coil are: internal diameter 4.7 m, external diameter 5.7 m and height 1.6 m.

Each coil is housed in a separate liquid helium cryostat. The magnet is entirely separated from the chamber and this has considerable advantages in the construction and commissioning programme. A solid-state power supply capable of 5000 A at 10 to 20 V is used to power the magnet.

Expansion system

The purpose of the expansion system is to make the bubble chamber liquid sensitive to charged particles by momentarily reducing the pressure on the chamber so that the liquid is in a superheated state. A novel feature of the proposed design is that the expansion system is located at the bottom of the chamber. This avoids a problem which existing chambers have with the expansion system at the top. Because of the high thermal expansivity and very low viscosity of liquid hydrogen, any warmer liquid tends to rise rapidly through the volume into the region immediately below the piston. The production of spurious bubbles initiated by the movement of the piston is then greatly increased by the presence of the warmer liquid. These bubbles which 'absorb' mechanical energy during the recompression of the chamber, are the main source of unwanted heat.

The problem could be overcome by cooling the piston region more than the rest of the chamber but this would ruin the operating conditions in the useful volume. With the piston at the bottom more intensive cooling in the piston region can be carried out without affecting the useful volume. It involves some design and construction problems but has the further advantages that the top of the chamber is left clear for the optical system and the piston driving mechanism can be conveniently placed in a trench under the chamber where massive concrete foundations can be arranged to absorb the considerable forces created as the piston is plunged in and out.

Figure 4: Location of the chamber on the CERN site:
1 *beams from the 28 GeV synchrotron*
2 *beam from synchrotron by-passing ISR*
3 *beam from ISR*
4 *beam switchyard*
5 *experimental area (West Hall)*
6 *connecting hall for bubble chambers*
7 *hydrogen bubble chamber hall*

Figure 5: A general layout of beams and buildings for the bubble chamber:
1 *bubble chamber hall*
2 *control room*
3 *refrigeration plant*
4 *compressor building*

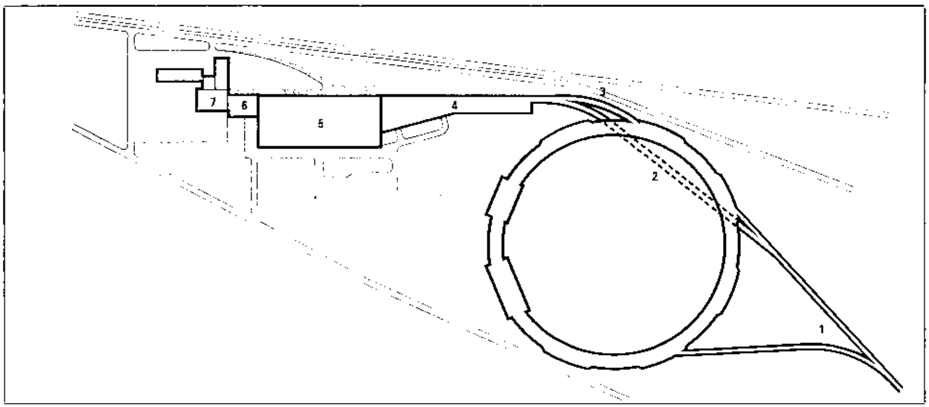
The very cold liquid around the piston is prevented from entering the useful volume by a disc covering almost the entire cross section, which is mounted on springs and not sealed to the walls. Pressure changes are transmitted more evenly to the useful volume by the disc which is driven via the liquid above the piston.

Since the disc and the piston move in an inhomogeneous magnetic field, they will be constructed from non-conducting material to avoid eddy currents which cause heating. Epoxy resin with fibre glass reinforcement will probably be chosen using a honeycomb structure for lightness. A piston stroke of 10 cm produces the required relative change in volume of about 1 %. The piston and its related components form an oscillating system (using the elastic properties of the liquid hydrogen and of gas springs). The system will operate at its resonant frequency which will correspond to an expansion cycle of about 40 ms. The chamber can be expanded about twice per second.

Optics

The domed head of the chamber has four spherical windows ('fish-eyes') as viewing ports for cameras and a fifth window with a periscope which can be used for an additional camera, a television camera or for direct viewing of the chamber. With this arrangement of cameras it is possible to use different configurations of plates in the hydrogen volume for those experiments where detection of neutrals and gammas is crucial. These plates reduce the path-lengths before the uncharged particles 'materialize' into charged

5 services building
6 connecting hall
7 25 GeV experimental hall
8 storage areas
9 beam switchyard
10 proton beam
11 neutrino beam
12 iron filter for neutrino beam
13 beam-line with radiofrequency separators
14 beam-line with electrostatic separators
15 earth shielding mound



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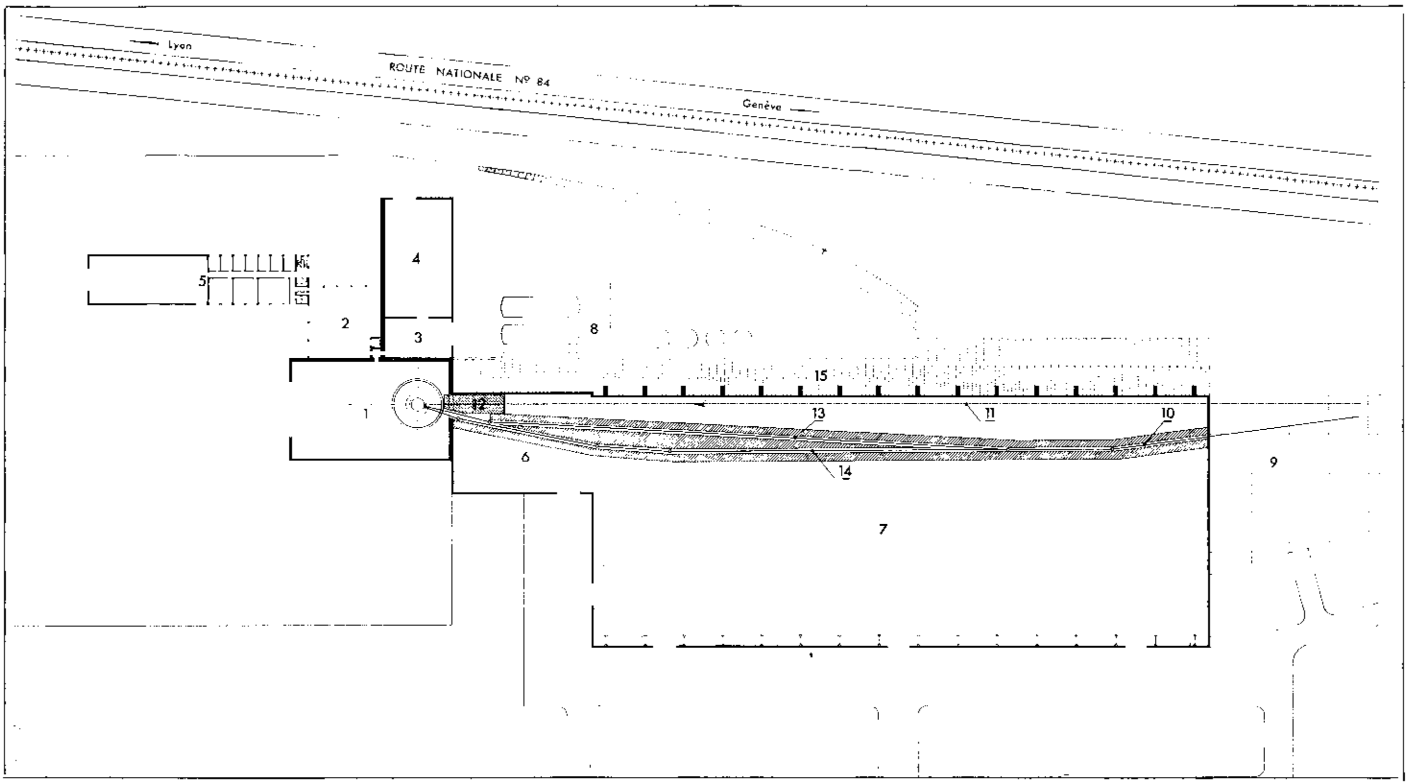

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particles which can be detected in the chamber. A further experimental possibility which has occurred since the design study was completed is the use of a separately enclosed hydrogen target volume, perhaps 1 metre in diameter, while the rest of the chamber is filled with a hydrogen-neon mixture. (See CERN COURIER, vol. 7, page 112.)

Bright-field illumination is used with Scotchlite 'wall-papered' to the sides of the chamber and the top surface of the disc in the expansion system. The light sources are ring shaped flash tubes placed around the lenses; laser light may be used if it proves possible to construct reliable and powerful lasers to produce light in the wavelength region suitable for the Scotchlite.

Wide-angle lenses (105°) are used accepting a depth of 1 m of useless hydrogen between the camera positions and the volume where the interactions occur. With this compromise arrangement, the wide angle lenses will not result in unfamiliar looking photographs which would be difficult to scan. Calculations on the distortion of tracks caused by thermal turbulence in the depth of hydrogen through which the tracks are photographed do not give cause for great concern but careful layout of the cooling system and careful temperature control will be necessary.

Figure 3 shows a possible design of one of the cameras; more detailed studies will be carried out before deciding on a final arrangement. The camera objective looks through a set of three fish-eye windows. The film size is 70 mm, which is readily available, and the film is loaded outside the magnet screen. Several metres of transport system are then needed to take the film through the camera and since parts of the system are in the high magnetic field, metallic components and electromagnetically operating devices have to be avoided. A driving system using compressed air may therefore be used.

Installation

It is planned to install the proposed bubble chamber in a building beyond the new experimental hall (West Hall) for 25 GeV experiments which is being built in association with the intersecting storage ring project (see figure 4). A possible layout of beams for the hydrogen bubble chamber is given in figure 5; neutrino beams and separated particle beams are shown.

Construction programme

Design work and experimental studies will continue until spring 1968; a 1 m diameter model will be built to test optical systems and study thermal problems connected with the expansion system. About the beginning of 1968 invitations to tender for most of the major components will be issued and it is hoped to place contracts in the following summer.

General assembly of the chamber is scheduled for the beginning of 1971 and commissioning for the end of the same year.

The total cost of the project is calculated as 84 million Swiss francs (at 1966 prices), spread over the years 1966 to 1971. This will be provided equally by the three partners who will each have one representative on the steering committee to supervise the project.

Physics School in Sicily

from information supplied by Professor A. Zichichi

The fifth Course of the International School of Physics 'Ettore Majorana' took place from 1 to 14 July at Erice (Trapani) Sicily.

127 participants came from 62 laboratories in the following countries : Austria, Belgium, Brazil, Canada, China, Czechoslovakia, Denmark, Finland, France, Germany, Greece, Hungary, India, Israel, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Rumania, Spain, Sudan, Sweden, Switzerland, United Kingdom, United States, Yugoslavia.

Seven series of lectures (a total of 34 hours) and 15 seminars were given. 30 discussion sessions were held.

A brief sketch of the contents of the lectures follows.

Weak and electromagnetic currents

Professor Cabibbo of CERN described some recent work on the computation of radiative corrections to beta decay, done in collaboration with L. Maiani and G. Preparata.

According to the theory of leptonic weak interactions developed by Cabibbo at CERN in 1963, the coupling constant in Fermi beta decay is G cos Θ, G being the universal Fermi constant as measured in muon decay, and cos Θ a correction factor which differs from unity by about 2 %. This correction is of the same order of magnitude as radiative corrections, which must therefore be computed with great accuracy in order to obtain a meaningful test of the theory.

The discussion was centered on the ultra-violet divergences which can appear in radiative corrections, making their computation impossible. The requirement that such divergences do not appear, considerably limits the range of possible models of hadrons, excluding the simple versions of the quark model with fractional charges. However, this requirement is easily met in models with only integrally charged particles. Professor Cabibbo discussed in detail one such model, which reproduces most of the desirable results of the quark model.

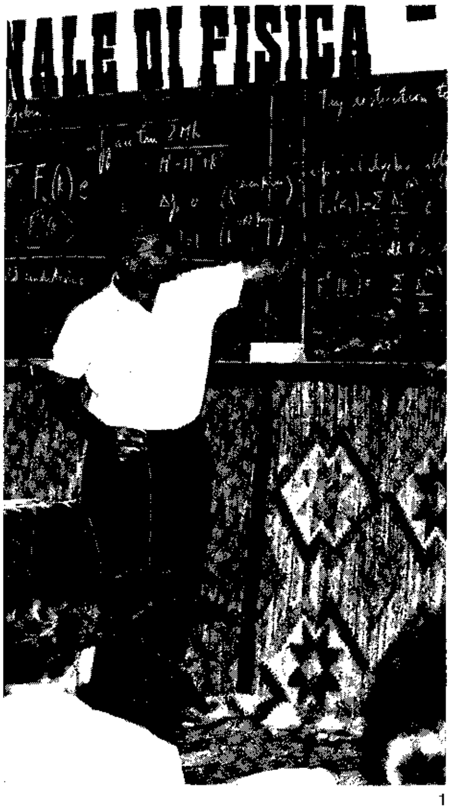
Theory of soft pions

Professor Coleman, from Harvard University, USA, reviewed the development in recent years of new techniques (based on the notion of partially conserved axial vector current and on the algebra of currents) for the theoretical analysis of low energy pion physics.

Among the various applications discussed were the Goldberger-Treiman relation, Adler's rule for calculating the emission of one soft pion, the Weinberg-Tomezawa formula for S-wave scattering lengths, (which, for the case of pion-nucleon scattering, is equivalent to the famous Adler-Weissberger relation), the new predictions of small pion-pion S-wave scattering lengths, and the Callan-Treiman relations for K_{l3} and K_{l4} decays.

Relativistic quark model of baryons and mesons

The course given by Professor Gell-Mann, from California Institute of Technology,



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Photographs taken at the school

1. *Professor Gell-Mann*
2. *Lectures in session (left to right — Zumino, Coleman, Zichichi, Cabibbo, Glashow, Gell-Mann)*
3. *Professor Jentschke*
4. *Students at one of the lectures*

(Foto Piacentino)

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Pasadena, USA, was a direct continuation of his lectures of last year on the relativistic quark model.

Starting from the chiral SU(3) × SU(3) commutation relations of current densities, as suggested by the ordinary quark model, he investigated the possibility of constructing simple representations of this infinite dimensional algebra satisfying the requirements of special relativity. The relativity restrictions, which take the form of momentum conditions on matrix elements, must be imposed from outside, because the commutation relations, taken between states of infinite momentum, are not expressed in covariant form. Since no non-trivial solution of this set of equations has yet been found, attention was focused on the possibility of constructing solutions in the form of a series expansion.

An explicit representation has been produced for completely degenerate masses. These corrections have been evaluated up to second order in the difference of mass operator, thus obtaining an approximate representation suitable to accommodate states constructed out of quarks only one of which is not carrying isospin zero, such as K-like or Ξ-like states.

Chiral symmetry and strong interactions

Much recent work depends on the exact validity of SU(2) × SU(2) in a fictitious world in which the pion is massless. In his lectures, Professor Glashow, from Harvard University, Cambridge, Massachusetts, USA, considered an extension of this point of view to the larger group SU(3) × SU(3) due to Weinberg, Schetyer and himself. The fictitious world in which this symmetry is exact involves a massless octet of pseudoscalar mesons and a massless scalar kaon. With the intrinsic breaking of this symmetry group taken into account, the mass of the unobserved scalar kaon is predicted to be about 600 MeV with a lifetime of about 10^{-16} seconds. Also the vector and axial vector mesons are studied along these lines and one can successfully account for their observed masses. Furthermore, from the vector meson masses, information about weak interaction form factors can be extracted. Finally, these techniques can be applied to the calculation of the absolute decay rate of the neutral kaon. With conventional techniques this calculation yields infinite and meaningless results. However, the method developed in the lecture gives a finite answer providing that the weak interactions are mediated by a vector boson. From the observed decay rate of the kaon, the mass of this boson is predicted to be about 8 GeV.

Meson resonances

Professor Hughes, from the University of Glasgow, UK, presented a review of the current situation regarding the meson resonances. His lectures started with a short account of the various experimental techniques, and a brief study of the most relevant spurious effects which can simulate a resonance, such as rescattering and the Deck effect. Then, the data on masses and quantum numbers of the bosons were examined in detail in order to determine what is certain, what remains to be confirmed, and what should probably be forgotten.

The experimental results were compared with the SU(3) assignments suggested by the non-relativistic quark model, which introduces some order to an otherwise apparently chaotic situation.

The administration of radiative corrections

Professor Touschek from Laboratori Nazionali di Frascati, Italy, described a new method, devised by himself and collaborators, for the treatment, in a rather simple way, of the infra-red radiative corrections to a large class of processes.

This method for the 'administration' of radiative corrections is based on a semi-classical treatment; the Block-Nordsiek theorem is used to predict the probability distribution for the emitted photons, and each particular experiment is characterized by a function describing the energy and momentum of the experimental apparatus. This method makes the task of comparing results obtained by different experimental set-ups easy and supplies the experimenter with a tool for applying the radiative corrections himself.

The method of the algebra of fields and that of phenomenological Lagrangians

The algebra of currents due to Gell-Mann proposes equal time commutation relations between the various components of the vector and axial vector currents which enter the weak and electromagnetic interactions. These commutation relations have been used to derive sum rules which can be compared with experiment. The commutators between two time components are rather well established, while those between one time and one space, or between two space components are not at all well established, and are model-dependent.

Professor Zumino, from New York University, showed how, if one makes the assumption that the currents are proportional to a set of Yang-Mills vector an axial vector fields, one obtains precise expressions for these commutators, which are the simplest choice compatible with relativistic invariance. This approach, the 'algebra of fields', was introduced by Lee, Weinberg and Zumino. Among the applications, one derives a relation between the mass of the axial vector particle (A_1) and that of the vector particle (ϱ), $m_{A_1}^2 = 2\, m_{\varrho}^2$. Prof. Zumino discussed also the phenomenological-Lagrangian approach to the ideas of SU(2) $\times$ SU(2) and partially conserved axial vector current. This is an alternative to the traditional approach, discussed in Professor Coleman's lectures. In this method, due to Weinberg, Schwinger, Wess and Zumino, one assigns the pion and the nucleon to a non-linear realization of the group and constructs Lagrangians having simple behaviour under the group. Applications include the study of the A_1 and ϱ decays.

Fifteen seminars followed these lectures and gave Professors B. Gregory, CERN, W. Jentschke, DESY, RFA, and G. H. Stafford, Rutherford High Energy Laboratory, UK, the opportunity of reporting various experiments carried out in their respective laboratories.

The 'Provincia di Catania' where Ettore Majorna was born, has established an annual prize called Premio Internazionale di Fisica 'Ettore Majorana' to honour his memory.

This prize was awarded on this first occasion to Professor Murray Gell-Mann of the California Institute of Technology with the following citation:

"The research activity of Professor Murray Gell-Mann has been characterized by an extraordinary contribution of original and fundamental ideas which have remarkably extented our understanding of the fundamental properties of matter. Among the many fundamental contributions in the field of strong and weak interactions, the following original ideas deserve special mention: 1) the law of strangeness conservation; 2) the theoretical prediction of the existence of the K^0_2 meson; 3) the eight-fold way theory of approximate symmetry; 4) the algebra of currents; 5) the notion of quarks.

All of these ideas concern the symmetry properties of elementary particles, a subject which Ettore Majorana investigated with such brilliancy and enthusiasm."

The prize was given to Professor Murray Gell-Mann by the Mayor of Erice at the Closing Ceremony of the School.

CERN News

Troubles

Two accidents have affected the experimental programme at the proton synchrotron. The first involved the main power supply to the synchrotron magnet ring; the second occurred on the heavy liquid bubble chamber being used in the neutrino experiments.

The fault which shut down the power supply from 28 June until 9 July had its origin in an incident which happened on 23 May, when the oil pumps feeding the bearings of the main converter set were accidentally switched off. The fault was detected very quickly by the protection devices and the main converter set switched off automatically from the net-work. During its slow-down the flow of oil to bearings was cut off for about a minute.

An examination of the bearings was carried out on 5 June and, though signs of damage were detectable, particularly on bearing number 1, it seemed possible to avoid disrupting the machine operation programme at that stage for repairs. On 28 June, however, the temperature of bearing number 1 rose above an acceptable level and the power supply had to be stopped for attention to the bearings. The machine was started up again on 10 July.

The incident on the heavy liquid bubble chamber resulted in damage to the large window through which the cameras view the particle events. The chamber was being pumped down in preparation for a helium test for leaks on the diaphragm which transmits the pressure to the bubble chamber liquid. This involved pumping each side of the diaphragm to low vacuum.

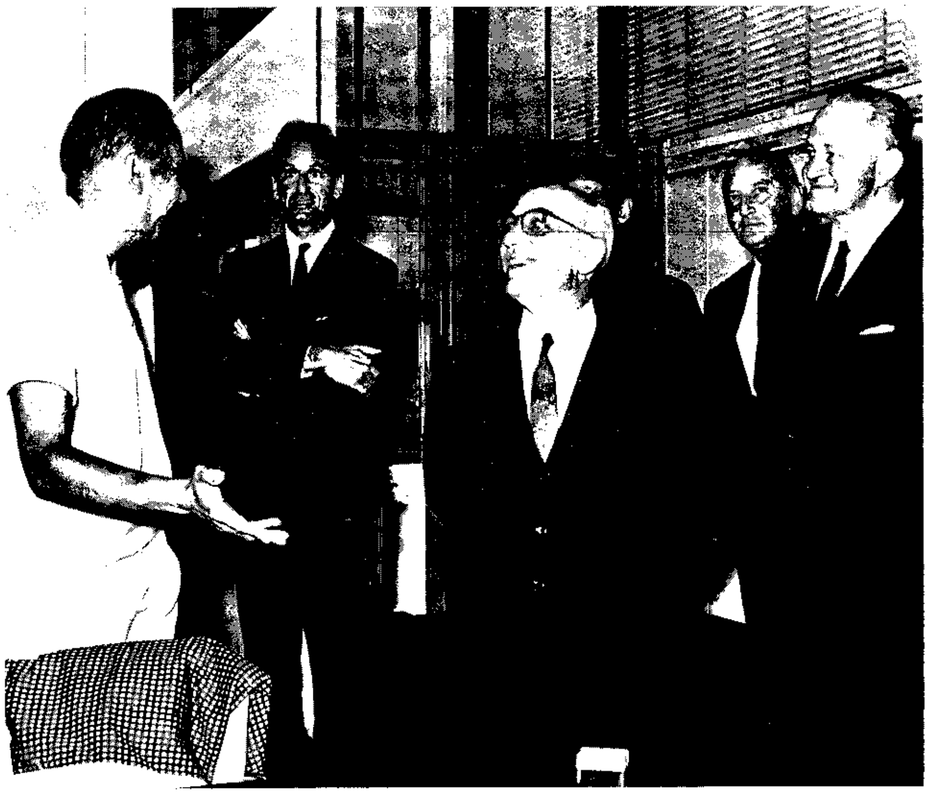
Somehow, air entered behind the diaphragm and forced it into the chamber volume towards the large window with a pressure of around 7 tons. Supports which fasten a metal plate to the chamber-body came off (they are constructed to take about 4 tons weight, which is more than enough in normal operation) and the plate was thrown forward causing three very small pock marks in the glass window.

It had been intended eventually to change this window, which was not optically polished, for an optically polished one, which was ready at the glassworks. It

Herr Hans van Heppe (left), Secretary of State to the Federal Ministry for Scientific Research, Federal Republic of Germany, and the Director General, Professor Gregory (centre) sign, on 21 July, the France/Germany/CERN agreement for the construction of a large hydrogen bubble chamber (see page 143). Professor Perrin, French delegate to the CERN Council is on the right.

Signor Fanfani (centre of photograph), Italian Minister for Foreign Affairs, shares a joke with Professor Peyrou (extreme left) during a visit to CERN on 2 August.

CERN/PI 67.7.67



CERN/PI 2.8.67

was decided to bring this change forward to avoid any risk of the damaged window breaking under operating conditions due to high stresses introduced by the marks in the glass. The damaged window has gone to be polished and the marks will be removed in the process.

Installation of the new window put back the scheduled dates for the neutrino experiments. However, excellent collaboration came from the Schott glassworks, who produced the windows, and from Zeiss, who etched the reference marks on the new glass, to keep the delay to a minimum. Another neutrino run was able to take place mid-August and the run was very successful.

Family Day

23 September has been set aside as Family Day at CERN during which the families and friends of employees can visit the site, inspect the installations and in particular the offices and work places of their hosts.

Further details of the arrangements will be circulated to CERN staff nearer the time but it can already be said there will be a programme of films on CERN in the Auditorium, there will be exhibits in the experimental halls and in the laboratories and there will, at the same time, be diversions organized for the children to allow the parents to relax a little on their own.

By the end of the day, friends and relations, particularly those more recently arrived at Meyrin, should have a somewhat clearer picture of what goes on at CERN and why it is that the bread-winner should need to spend so much time there, often at such curious hours.

Slow ejection efficiency up

Tests with a new thin septum lens incorporated in the slow ejection system of the proton synchrotron have achieved ejection efficiencies up to 80 %. This is considerably higher than the average of around 50 % which has been achieved before and is a most important result for the second part of the machine improvement programme which is concerned with increasing the intensity of the accelerated beam.

Slow ejection is used predominently for counter and spark chamber experiments, which require particles spraying into their experimental equipment for times up to two hundred milliseconds. The fast ejection process of bending the accelerated beam abruptly out of the magnet ring (see CERN COURIER, vol. 7, page 124) is not appropriate since it provides a beam for only a few microseconds. What is needed is a system to peel off protons little by little, leaving the rest of the beam circulating still under control in the ring.

The method, used for the first time at CERN in 1963, is known as 'resonant ejection'. Under normal operating conditions, the magnet fields in the magnet

1. *An aerial photograph of the CERN site taken on 15 August. In the foreground, the ISR site ; in the background, the city of Geneva.*
2. *A lengthened exhaust chimney swings into position near the neutrino beam line. The chimney carries any leaking propane from the heavy liquid bubble chamber out into the atmosphere. It has been extended to cope with any major release of propane without other additional, and expensive, safeguards.*
3. *Professor Arnold Schoch*

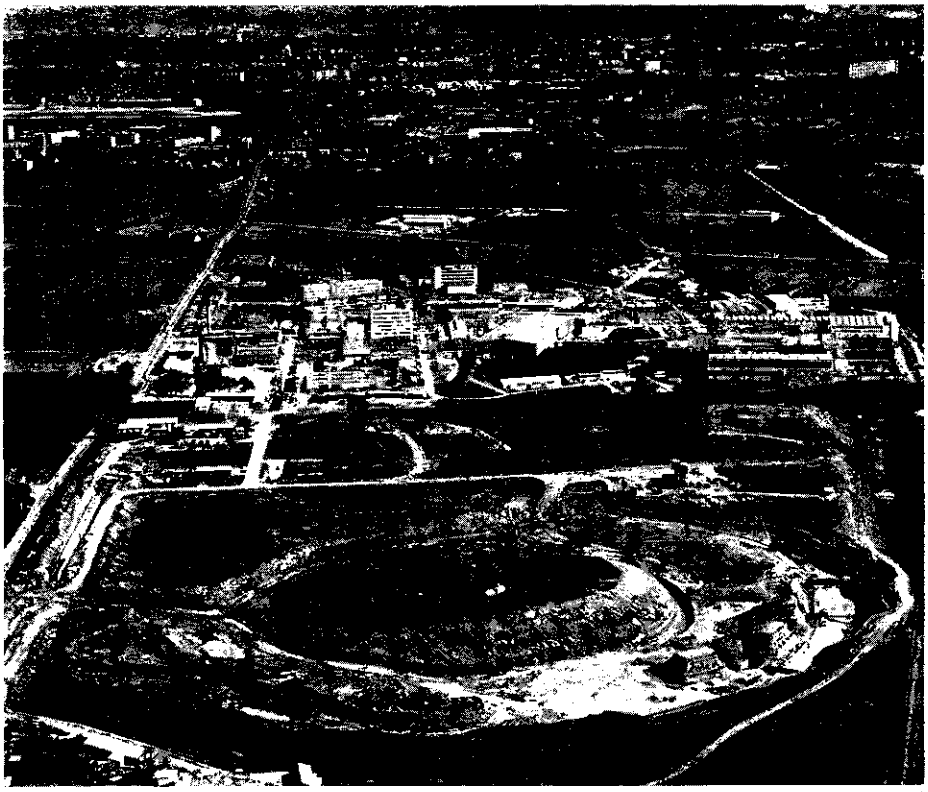
are so arranged that the inevitable disturbances that the protons feel, do not build up and throw the protons out of the beam, since the protons never come back to exactly the same place after one turn. In other words, the machine is designed to avoid resonances. To produce slow ejection, however, resonance is deliberately introduced by switching on quadrupole and sextupole magnets to change the magnet field conditions. Then the protons do come back to practically the same position on successive turns and the effect of the push that they receive on each turn grows bigger until some of the protons change the amplitude of their oscillation by up to 2 cm per turn at a particular point in the machine. (See CERN COURIER, vol. 5, page 151).

It is at this point that a septum magnet is placed to bend these protons out. The 'mouth' of the septum magnet has a thin metal plate (the septum) to shied the still orbiting protons from its field until they arrive to be ejected. Even though the septum is only 0.3 cm thick some 20 % of the protons will, in theory, inevitably hit the septum. The septum on this high field magnet can not be made thinner because it needs to be cooled.

The innovation, which has successfully undergone its preliminary tests, is to introduce a magnet lens with a very thin septum (nominally only 0.2 mm thick) in advance of the main septum magnet. Its job is principally to steer the beam into the mouth of the main magnet so that it will not hit its septum. The bending it has to introduce is comparatively modest and can be done with much lower fields, the cooling problem is therefore less acute and hence it is possible to use the very thin septum.

The tests have been done with an interim arrangement which cannot yet be used to provide beams for experiments. The septum lens is installed in straight section 79, some 38 mm from the centre of the vacuum vessel aperture and, in this position it causes some loss (up to 10 %) of the injected beam. Its logical position in straight section 63, where it would not interfere with the injected beam, is at present occupied by a beam transport element. The septum lens will probably be installed in straight section 63 during the 1968 shutdown.

These successfull tests on the slow ejection system have most important implications for the 'booster project'. This project is concerned with increasing the energy at which protons are injected into the synchrotron ring. It will result in much higher beam intensities and if ejection efficiencies of only 50 % were the norm, the loss of the other 50 % of a very intense beam inside the ring would introduce very serious problems of radioactivity. With the higher ejection efficiencies that the recent tests give promise of, the booster project can be approached with much greater confidence.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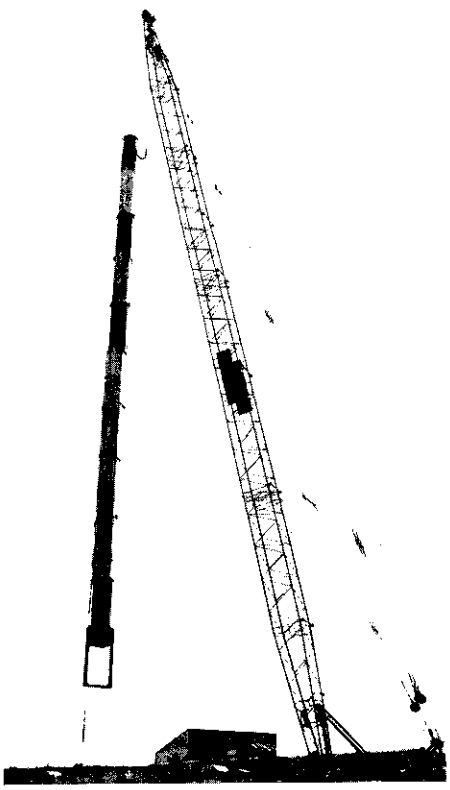
Death of Professor Schoch

It was with deep sorrow that we learned of the death, at Karlsruhe on 23 July, of Professor Arnold Schoch. Professor Schoch, who was at one time Head of the Accelerator Research Division, left CERN in November of last year to return to academic life. He was appointed Professor at Karlsruhe University in the Federal Republic of Germany.

By his contribution to the study of future accelerators, Professor Schoch has left his mark in the field of high-energy physics. A tribute to his work appeared in CERN COURIER, vol. 6 page 239.

All those who knew him, and especially those who worked with him during his stay at CERN, will retain a warm memory of Professor Schoch.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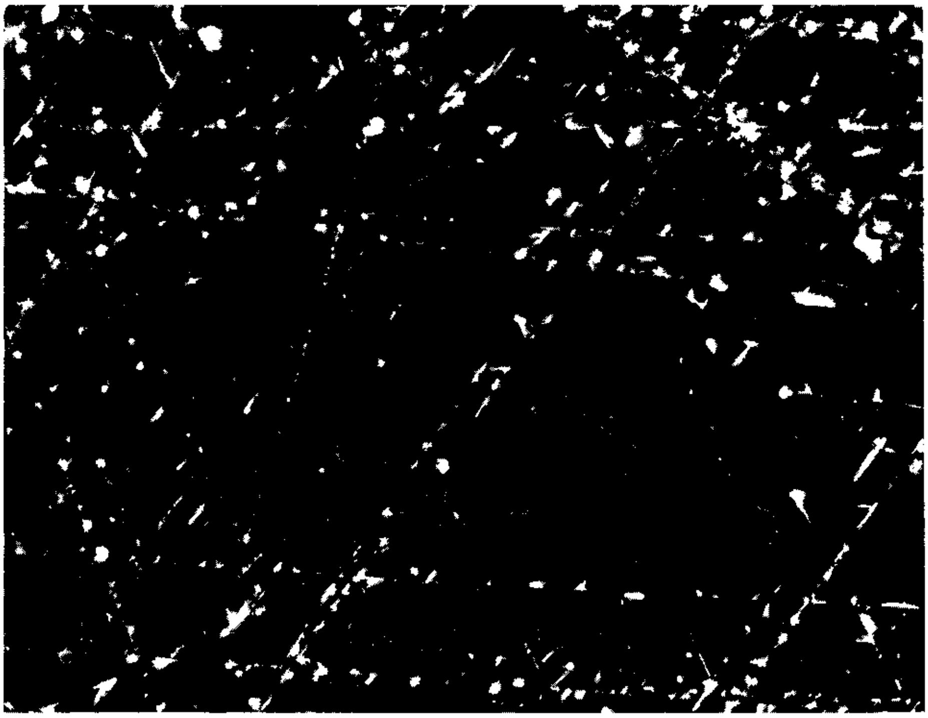
News from Abroad



A negative of mica sheet showing both crystal dislocations and charged particle tracks. For example, considering the two lines going almost diagonally accross the centre of the photograph — one is in line with a crystal plane, the other is due to the passage of a charged particle (the particle tracks tend to be close to the lines of the dislocations because in these orientations the "neucleating centres" will join up to form a line).

Neutrinos on record

A few years ago, Dr. F. M. Russell, a scientist now working at the Rutherford Laboratory, UK, was pursuing one of his hobbies, mineralogy, while on holiday in North Carolina. He was examining specimens of mica when he noticed that some of the dark markings in the mica sheet did not line up with the markings that one would expect to see at dislocations in the structure of the mica. Being a physicist, he stopped to ask himself why and after months of independent research has concluded that the markings record neutrino events which occurred during the formation of the mica going back thousands of millions of years.

Mica is characterized by a particularly regular crystal structure. This structure gives six well defined orientations within the crystal where dislocations can occur. The dark lines most commonly found correspond to these dislocations to which iron atoms have migrated during the formation period (around 10 000 years) of the mica. Close observation reveals however that there are some markings which do not line up with any of the six crystal planes. The indication is that their origin does not lie in the structure of the mica itself, unless some unknown solid-state phenomenon was operating during the formation period. Their characteristics indicate that they are due to the passage of charged particles.

Mica is formed at depths of several kilometers, being brought to the surface often millions of years later during major movements of the earth's crust. Only neutrinos could penetrate to these depths and the markings would record the conversion of neutrinos to muon pairs, the charged muons affecting the mica.

One interesting possibility is that examination of mica deposits, which can be accurately dated back to over two thousand million years, could give evidence of any long-term changes in neutrino flux over this period of time.

Stanford

In an experiment using the electron linear accelerator 'Mark III' at Stanford, California, a group of scientists have succeeded in applying a new technique of electron scattering to the study of the shape of certain deformed, or nonsperical, atomic nuclei. The results were reported in Physical Review Letters, 17 April 1967, 'Scattering of fast Electrons by Oriented Ho^{165} Nuclei', R. S. Safrata, J. S. McCarthy, W. A. Little, M. R. Yearian, and R. Hofstadter.

A well-defined diffraction pattern was obtained for atomic nuclei in crystalline samples of an isotope of the rare-earth element holium of mass number 165 subjected to an electron beam of energy 200 MeV. The diffraction pattern was produced by measuring with standard techniques the intensity of the scattered beam at different scattering angles. Different types of atomic nuclei show less abundant scattering at particular scattering angles, and from the distribution of these scattering 'dips', the shape of the particular nuclei under examination can be determined.

Spherical nuclei are known to give well-defined diffraction patterns, but deformed nuclei usually give a blurred pattern, with no particular dips from which the shape and charge distribution can be determined.

The Stanford group found, however, that when their test sample (a single crystal of holmium 165) was subjected to an external magnetic field, a well-defined pattern with significant dips became apparent.

The experiment was conducted at low temperature, with the sample located in a magnetic field produced by a pair of superconducting Helmholtz coils.

In considering their results, the Stanford team concluded that the diffraction patterns produced by the aligned holium nuclei were not in agreement with any of the current theories. They feel that this may be due to certain particular characteristics of highly deformed atomic nuclei such as holium and that the approximations and theorical difficulties involved in estimating these factors are primarily responsible for the disagreement between the various theorical models and the experimental results.

The group concludes that experiments involving electron scattering from oriented nuclei are far more sensitive to small changes in the factors describing the nuclear charge-density distribution than is the case with measurements on randomly oriented nuclei.

Book Review

Niels Bohr

His life and work as seen by his friends and colleagues, edited by S. Rozental. Translated from the Danish edition published in 1964. (Amsterdam, North-Holland Publishing Company, 1967, 58 s.)

I first heard the name 'Niels Bohr' at University when a brilliant lecturer, whose facial resemblance to an owl gave added weight to his every word, unfolded the Bohr theory of the hydrogen atom. A small group of us were so overwhelmed by the beauty of the theory and the imaginative leaps away from classical physics which it involved, that we spent the whole night talking atomic physics, followed by futile attempts to stay awake during the lectures next day. An immature response perhaps (especially as we were later to learn that the theory had been superseded), but a small indication of the deep effect that Bohr's work had even on people who then knew little of the extent of his contribution to physics and to human thought generally.

Far more mature assessments are contained in this book of tributes to one of the greatest men of science. The contributions are by contemporaries, who shared in the research during those fascinating years of the emergence of quantum theory, by students, whose evolving minds were nourished in Bohr's Institute, by senior public figures, who appreciated his contributions to public affairs, and by people who knew him in his private life.

All the contributions to the book are written on bended knee, which in itself says much for the stature of the man as a scientist and a human being. But it limits the scope of the book and in a few cases has resulted in rather dull reading. The book is a tribute and not a true biography, so that despite the many aspects of Bohr's life which are treated, a fully rounded character does not emerge. For example, it is difficult to believe that one so 'good' that the only sin of his youth was to put too much sugar on his fruit, could be as obviously loveable as so many of his contemporaries found him.

Bohr's scientific work is treated in several ways, and the different approaches are very illuminating. There are several chapters covering his research in a historical fashion (when, where and how it happened), one chapter devoted specifically to reviewing his research (bringing it all together to explain what it was about in a way accessible to the layman) and, most interesting of all, there are the recollections of his colleagues sprinkled throughout the book.

The way he tackled his first piece of research work on liquid jet vibrations with a view to determining surface tension (which won him a prize from the Royal Danish Academy of Sciences and Letters) already said much about the penetrating approach he was to bring to the mighty problems he confronted later. The more he found out about his jet, the more questions he could see to be answered, and the more refinements he could see to improve his conclusions. His father had almost to force him to write up the experiment and not go on continuously improving the results.

And so it was in later years, increasing knowledge only widened the front from which further questions emerged and he pursued topics relentlessly, never satisfied that he had gone far enough. His more famous work is well known and is covered in the book. Sufficient here just to mention his analysis of the spectral lines of hydrogen and the model of the hydrogen atom which came from it, and more importantly from the same work, his formulation of the correspondence principle (that when theories on the atomic scale are extended to larger scale, they should then tie up with the proven laws of classical physics) ; his work on 'complementarity' and the implications of man being, as Bohr put it, 'an observer of that nature of which he himself is part' ; and finally his theory of atomic fission 'the liquid drop model'.

This list gives little idea of what Bohr's work really meant for physics. He did more than contribute new analyses and new theories, he 'taught physicists to think in a new way'. His interest was much broader than the problem he was directly investigating and many of the contributors to the book emphasize his role as thinker on the philosophical and human implications of the new theories. Heisenberg states that 'Bohr was primarily a philosopher, not a physicist'. Frisch, in a beautifully written article, talks of conversations ranging from religion to genetics, from politics to art, and of cycling home through the streets of Copenhagen 'intoxicated with the heady spirit of Platonic dialogue'.

Photo Herdis and Herm. Jacobsen

Bohr used conversation as one of the principle means of sharpening his ideas He dictated his papers often pacing around one of his pupils who was serving as secretary, using them as a foil to perfect a phrase. Yet he was not a good lecturer. Pais describes him as a 'divinely bad public speaker' and Courant suggests that this may have been because of the difficulty of presenting a 'multi-dimensional fabric of thought in a one-dimensional linear order'.

Pais projects one of the best pictures of Bohr's personality as also does one of Bohr's young collaborators, Jørgen Kalckar. Kalckar in one flash of poetry says more than appears in paragraphs elsewhere : 'I wonder if anyone who has not known Bohr would be able to appreciate the joy of picking and eating ripe blackcurrents in the pouring rain'.

There are many delightful little anecdotes. Some of them concern the way Bohr brought the scientific way of thinking to other areas of life. Casimir tells of how he used to drag Bohr to see Western and gangster films — "After a thoroughly stupid Tom Mix film, his verdict went about as follows : 'I did not like that picture, it was too improbable. That the scoundrel runs off with the beautiful girl is logical, it always happens. That the bridge collapses under their carriage is unlikely but I am willing to accept it. That the heroine remains suspended in mid-air over a precipice is even more unlikely, but again I accept it. I am even willing to accept that at that very moment Tom Mix is coming by on his horse. But that at that very moment there should be a fellow with a motion picture camera to film the whole business, that is more than I am willing to believe'." Bohr also analysed why the goodie always beat the baddie to the draw — a mechanical, reflex action always takes less time than a voluntary decision. His son, Hans, recollects the tea-table problems he posed to his children. One of them was 'Given two glasses containing equal volumes of wine and water : if you take a teaspoonful of wine and put it into the water, and then return a teaspoonful of the mixture to the wine, will there be more wine in the water or water in the wine ?' The answer is not immediately obvious.

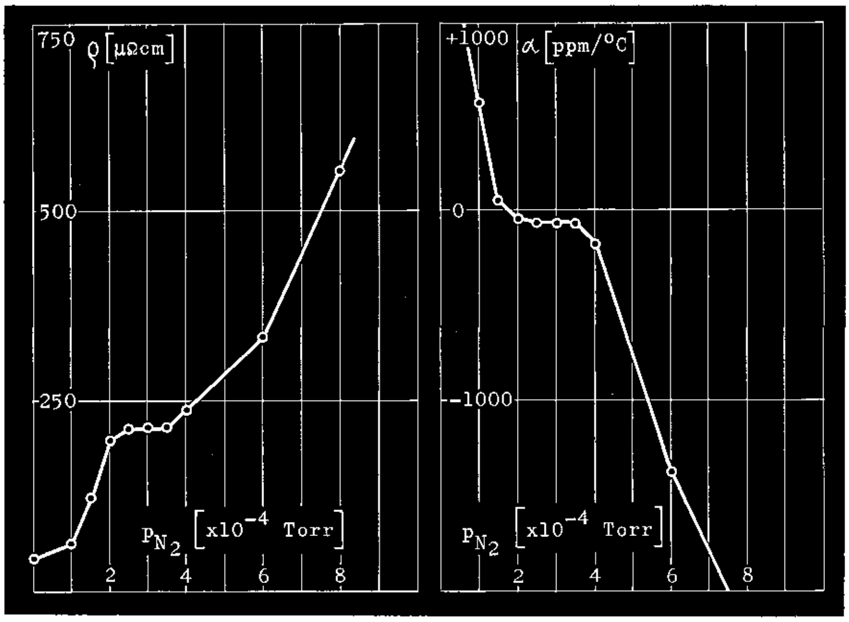
Several writers comment on the long drawn out controversy between Bohr and Einstein, which began at the Solvay conference in 1927. A clash of intellectual dinasaurs. Einstein, such a great revolutionary thinker himself, could never accept all the implications of quantum theory. Bohr was often saddened by his failure to convince Einstein but it is obvious that they both greatly enjoyed flexing their minds against such worthy opposition. That their personal relationship remained excellent is illustrated by a story from Pais — he was sitting in a room with Bohr, who was lost in thought, when Einstein tiptoed in and stole some of Bohr's tobacco (his doctor had forbidden him to buy tobacco but hadn't mentioned stealing it).

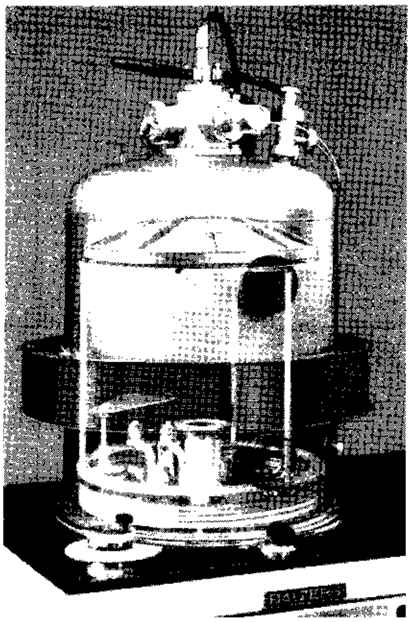
Weisskopf covers his contributions to international scientific collaboration. His Institute for Theoretical Physics in Copenhagen received an endless stream of outstanding scientists of all nationalities Scientific co-operation between the Scandinavian countries through NORDITA owed much to Bohr and so, of course, did CERN. So many people have claim to be a Father of CERN that one begins to feel that the Mother's conduct was not beyond reproach. But rarely can the claim to paternity have been asserted as strongly as Weisskopf's 'It was Niels Bohr's personality, Niels Bohr's weight and Niels Bohr's work that made this place (CERN) possible'. On the national scale, what it meant for the scientific life of the country to have a scientist of the calibre of Bohr stay and work in Danemark, is obvious from the three articles by Pedersen, Kampmann and Pihl.

And so on... This review can only touch on a few of the facets of Bohr's life covered in these contributions. Suffice it to say that anyone who loves physics will draw some inspiration from this book.

B. S.

Tantalum films with a specific resistance as low as 30–40 μΩ · cm





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The double exposure photograph (top right) shows the SPUTRON II in a BA 510. The target is in the centre of the vacuum chamber base, with an evaporation source next to it.
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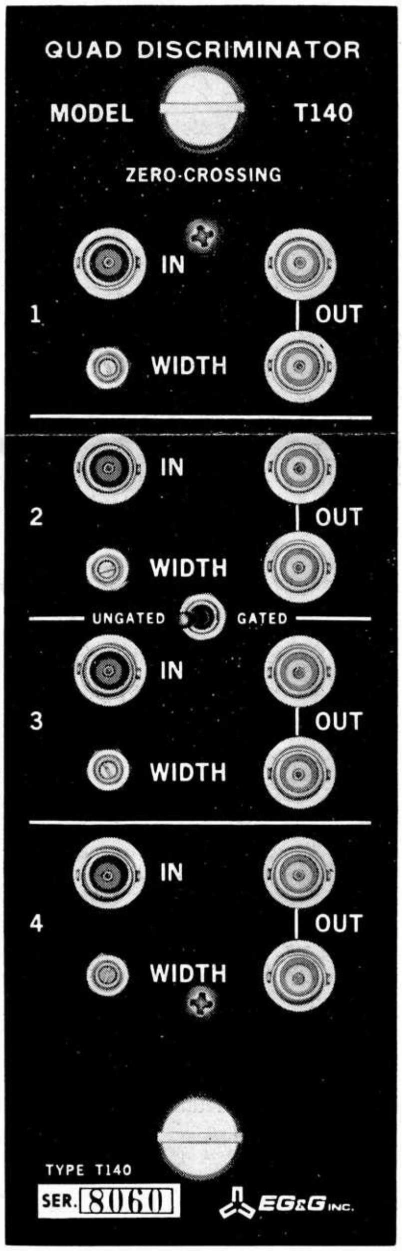

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