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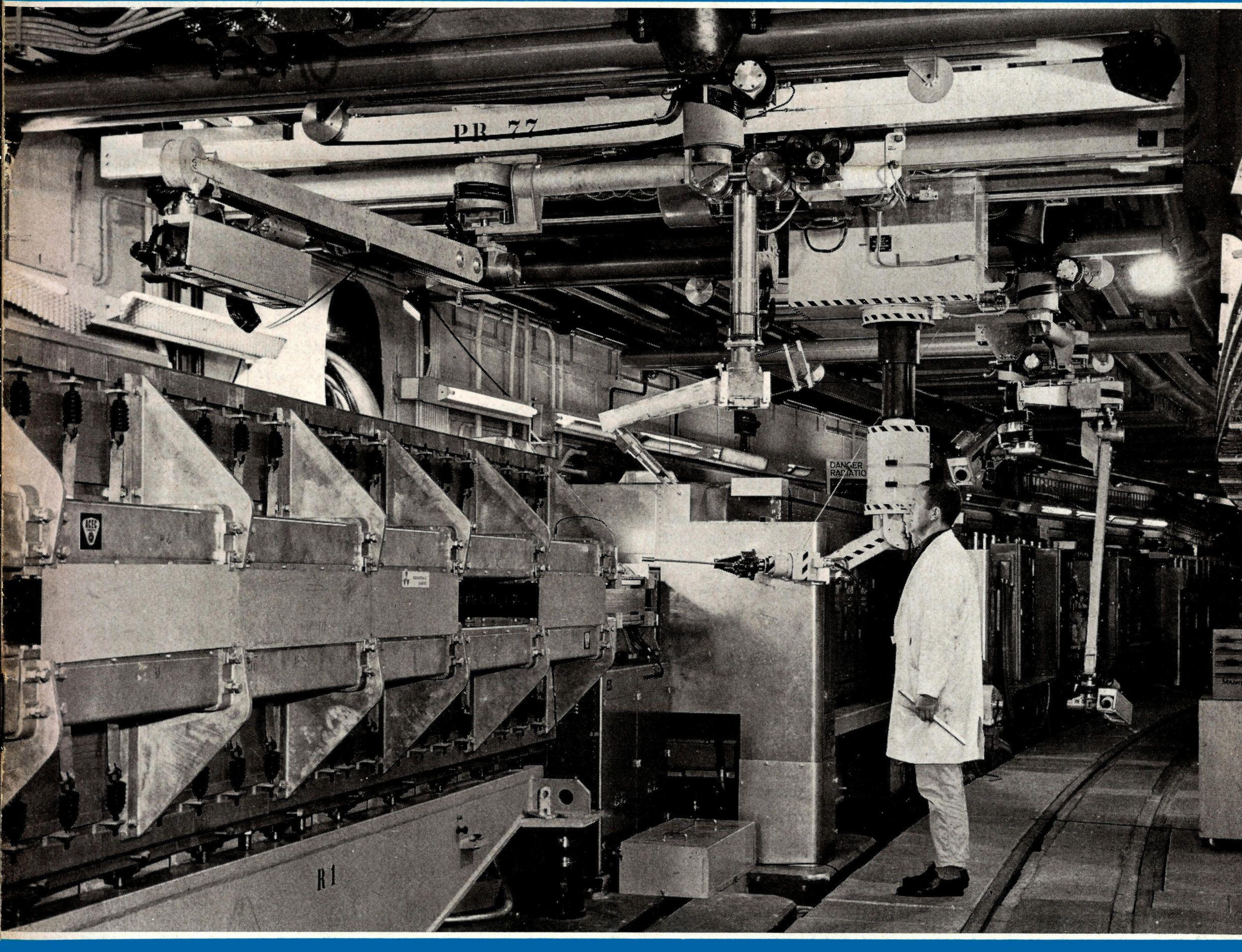

CERN, the European Organization for Nuclear Research, was established in 1954 to '... provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto'. It acts as a European centre and co-ordinator of research, 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 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), for experiments with colliding proton beams, are under construction. Scientists from many European Universities, 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 near Geneva in Switzerland. The site covers approximately 80 hectares equally divided on either side of the frontier between France and Switzerland. The staff totals about 2600 people and, in addition, there are over 400 Fellows and Visiting Scientists.

Thirteen European countries participate in the work of CERN, contributing to the cost of the basic programme, 197,5 million Swiss francs in 1968, in proportion to their net national income. Supplementary programmes cover the construction of the ISR and studies for a proposed 300 GeV proton synchrotron.

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Editor : Brian Southworth
Assistant Editor : Philippe d'Agraives
Advertisements : Micheline Falciola
Photographs : Gérard Bertin

Public Information Office
CERN, 1211 Geneva 23, Switzerland
Tel. (022) 41 98 11 Telex 2 36 98

Printed by: Ed. Cherix et Filanosa S.A.
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Comment

The interest aroused by the article on 'Education of children of CERN staff' in the August issue of CERN COURIER, which was a summary of a detailed report 'Enquête sur la scolarisation des enfants des fonctionnaires du CERN', has been quite exceptional. And the interest has not by any means been limited to CERN staff for whom the subject is obviously a matter of concern.

Some unified approach to education throughout Europe is very desirable as the integration of activities in Europe becomes progressively more widespread. Ideally, this unified approach would preceed such integration. It would be of great benefit to a Europe acting more and more as a single unit, to have accepted some common elements and common standards in education throughout the continent. On the personal level, it would also mean that the people who are called upon to move from country to country, could do so without jeopardizing their children's future.

The practical difficulties are formidable. Despite the enormous changes which have been wrought in education internally, in many countries in recent years, there are aspects of respective systems which are understandably jealously guarded, often being based on generations of experience. It will not be easy to open some of the doors which it is important to open. Even the seemingly straightforward need to achieve recognition of qualifications across frontiers (probably the most important first step) is proving difficult.

At a time when European countries are being asked for further support for experiments in physics, in the shape of a large new Laboratory, it may seem profligate to put forward a case for support for an experiment in European education. However the national pockets that would be dipped into would often be different ones to those furnishing the money for CERN proper, and the support on the education front would certainly not dip deep.

It is incidental that it should be CERN that provides a possible testing ground for an approach to the education problems of the future. While tackling the problems confronting the CERN community, the opportunity exists for an effort on a modest scale, which, by virtue of the structure of the CERN community, will be relevant throughout Europe.

The report prepared at CERN is an analysis of needs ; it does not attempt to spell out a detailed solution. If interest is aroused in the Member States, it will be for the educationalists to move in to tackle the solution. Even presuming that interest is generated, things will not happen tomorrow.

Nevertheless, if the challenge is confronted with anything like the courage and vision which Europe showed when setting up CERN, we may see some 'spin off' due to the existence of CERN, which could contribute to the future of Europe as notably as CERN itself is doing.

Contents

Cover photograph : In the ring tunnel of the proton synchrotron during the shut down which finished at the end of September. Tests are being carried out on a remotely-controlled manipulator (see page 247). The lights and closed-circuit television cameras that the manipulator carries with it, can be seen as the manipulator works on the ring. (CERN/PI 278.9.68)

39th Session of CERN Council

A report on the Council meeting which took place on 2 - 3 October under the chairmanship of Dr. G. Funke.

This special meeting of the Council had essentially two items on its agenda : 1) To review the situation on the proposed 300 GeV Laboratory and to work out the next steps forward for the project ; 2) To agree the budgets for the existing CERN Laboratory for the coming three years.

300 GeV count down

The Director General, Professor B. P. Gregory, opened the discussion with a review of the present situation on the 300 GeV project. Five countries — Austria, Belgium, Federal Republic of Germany, France and Italy — have now declared their intention to participate in a new high energy physics Laboratory, and these countries contribute about 60 % of the present CERN budget.

Following the decision of the U.K. not to support the new Laboratory at the present time, a possible initial programme for the project has been drawn up which reduces the cost by 25 % (slightly more than the contribution of the U.K. to CERN). Thus with 60 % support already assured, and with the expectation that favourable decisions from other countries will soon be forthcoming, it can confidently be said that the project is going ahead.

The 'reduced programme'

After the announcement of the U.K. decision in June, the Council asked CERN to prepare a possible programme to take account of the reduced participation. This involved revising the project so that the foreseen expenditure (a total of 1776 million Swiss francs spread over eight years) would come down to a level which would place no extra burden on the countries who agreed to participate than they faced before the U.K. withdrawal.

At a meeting of the Scientific Policy Committee on 10 July, a series of guidelines were drawn up stressing principally that the reduced programme should retain the ultimate capabilities of the machine both in terms of energy (300 GeV), of intensity (10^{13} protons/second), and of utilization (facilities for extensive exploitation by research teams). The SPC also stated that the time at which physics starts at the machine should not be delayed and that even the restricted project should give value for money as a research facility.

At the same time, with the strong hope that the U.K. government will be able to reverse its decision before very long, the reduced programme has been planned so that it could revert to the full programme without incurring much extra expense when the U.K. joins.

The reduced programme, prepared following these guidelines, is a model of what can be done and not a final proposal. It serves as a basis for decision by demonstrating that it is possible to meet the new situation and to go ahead with the project while still retaining its ultimate aims.

The cost estimates for the construction period of the original project were prepared under three headings —

i) The machine itself (931 MSF)

ii) General Laboratory facilities and services (431.5 MSF)

iii) Preparation for research (413.5 MSF).

On the machine itself only modest savings can be made given the requirement that its ultimate performance will be able to reach that originally planned without much extra expense. However, by starting with a reduced r.f. accelerating system, magnet power supply and injection system, a total saving of 61 MSF can be made. The price paid in machine performance would be a lower intensity (down by a factor of five) and beginning operation at a lower energy (200 GeV). If 20 MSF could be saved elsewhere, operation could begin at 300 GeV. Restoring the full performance will be straight forward with more money available.

Laboratory facilities and services are cut by 160 MSF because of reduced power equipment, less site work and buildings, and the postponement of the main computer installation.

Preparations for the experimental programme carry the heaviest cut, 215 MSF. This takes account of there being 25 % less physicists to accommodate at the machine and accepts that the research will have to take longer getting into top gear - building up to 75 % level over two years after the machine begins operation. Only one ejection system and experimental hall will be built and the experimental equipment will be less ; in particular no large bubble chamber will be built for the start of the research.

These savings bring the total cost of the project to 1335 MSF (at 1967 prices), 75 % of the cost of the project originally planned.

Next steps forward

A series of decisions now have to be taken to bring the project to a reality. One of the major ones is the selection of the site for the new Laboratory. The process of elimination so far had brought the list of possibilities down to nine but this is effectively reduced to five at the moment — the five sites of the countries who are supporting the project : Doberdo (Italy), Drensteinfurt (Federal Republic of Germany), Focant (Belgium), Göpfritz (Austria), Le Luc (France). Obviously, other sites would be added to the list if some other countries joined.

The Council accepted that no further studies on the sites are necessary before taking the final decision. It is hoped that it will be possible to have a first indicative vote at the December Council meeting. Should two or three sites then emerge as the prominent contenders, detailed discussions with the countries concerned could take place prior to the final vote, hopefully in March 1969.

Another decision which needs to be taken at least as fast as the site decision is the appointment of the Director General of the new Laboratory. A project leader is needed to take charge of the final design of the machine which will be carried out before beginning construction on the site. The choice is obviously crucial to the success of the project, and the Council accepted that the best possible man (or two-man team) will be selected, regardless of nationality.

A further essential before the new Laboratory can come formally into being is the ratification of the revised Convention. In December last year, the Council approved amendments to the existing CERN Convention to allow a new Laboratory to be built. Acceptance of the revised Convention in no way implies commitment to support the new Laboratory and the delegates were

CERN/PI 6.10.68

Dr. Hine (standing), the Director General (centre) and the President of the Council in happy mood during the Council Session.

reminded of the need for their government to ratify the amendments to the Convention as soon as possible. The signature of all thirteen countries is needed to enable the project to go ahead, but it is obvious that countries who may not participate will not attempt to hold back the others.

Prior to the December Council session, meetings will take place, involving particularly the five countries who are joining the project, to arrive at a final text of the 'Programme definition', the document within whose framework the new Laboratory will be built and operated.

Assuming that these various items can be resolved by March of next year, the final design could start under the new project leader by the middle of 1969. Then in the second half of 1970, the team could move on to the site to begin construction of Europe's new accelerator.

Professor B. H. Flowers, delegate for the U.K., summed up the discussion on the 300 GeV project. He said that the discussion had shown the spirit of European cooperation in science in action. Even with the reduced programme, a new range in the study of matter and its interactions could be opened up and Europe would retain in the future the position if has held for so many years as second to none in fundamental science. Professor Flowers offered his congratulations and those of the Science Research Council, of which he is Chairman, that the project is going ahead, and said that U.K. Secretary of State for Education and Science, Mr. Edward Short, also wished it to be known that 'he is pleased at the positive decisions that have been taken'.

Budgets 69, 70, 71

The way in which budgets for coming years are agreed at CERN follows what is known as the 'Bannier procedure' (it was worked out in the Finance Committee on the instigation of Mr. J. H. Bannier, delegate for the Netherlands). At the December Council meeting each year, the budget for the following year is voted together with a 'firm estimate' for the year after and 'provisional' figures for the subsequent two years. The firm estimate would normally only be reconsidered if a major change occurred either in the work of CERN or in the financial circumstances of Member States, and the provisional figures could also confidently be used in planning long-term projects. The Bannier procedure has proved invaluable in enabling CERN to organize its projects efficiently.

At the Council meeting of December 1967 however, currency devaluation had produced an abrupt change in financial circumstances and it was not possible at that time to arrive at figures for the coming years. The Bannier procedure could therefore not be applied. In March, the Council asked for a general review of the long-term development of budgets as well as the possibility of short-term savings. A first report on the programme review has been prepared.

Not having a firm estimate for 1969, CERN had not been able to work out a detailed budget for the coming year to present to the Council in December and it was therefore important to agree some figures at this meeting.

The Director General presented the recommendations of the CERN administration for the years 69, 70 and 71. He recalled that at the end of 1965, the Member States had authorized two major developments in the research facilities at CERN — the construction of the intersecting storage rings, and the implementation of an improvement programme at the 28 GeV proton synchrotron. This involves long term commitments stretching through to 1971.

On the intersecting storage rings, everything is going as initially foreseen and the expenditure on this huge project, which is now past its half-way stage, is within the predicted figures. On the improvement programme however, there are many parts (the heavy liquid bubble chamber 'Gargamelle', the large hydrogen chamber, the Omega project, improvements at the synchro-cyclotron,...) and there are some changes and additions which could not be foreseen when the approval of the Council was first sought. Two main items are —

1) The Booster injector, to increase the intensity of the CERN 28 GeV accelerator. This injector has been made more elaborate, and therefore more expensive than predicted, in particular to absorb some possibilities which emerged in 1966 which could contribute greatly to increasing the performance of the intersecting storage rings.
2) The collaboration with the Institute of High Energy Physics, Serpukhov, which was agreed in July 1967. CERN is providing special equipment for use on the Soviet 70 GeV accelerator and is financing CERN teams doing experiments at the machine. This could not be predicted in 1965.

In spite of tightening some areas of expenditure (for example, the staff numbers, which are now 50 less than forecast and will be 150 less than forecast by 1971) the commitments now facing CERN will take all the proposed budget increases over the next few years and will involve holding the physics programme at its present level for four years.

No detailed predictions on budgets for CERN-Meyrin after 1971 were put forward at the Council meeting. Some major considerations for the years from 1972 onwards, when the ISR and the improvements programme are completed, have to be carefully examined. They include the impact

Professor Puppi (left) retiring Chairman of the Scientific Policy Committee in conversation with one of the advisers to the Italian delegation, Dr. S. d'Andrea.

Professor Gentner (left) newly appointed Chairman of the Scientific Policy Committee with Professor Paul delegate of the Federal Republic of Germany.

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of the start of construction of the 300 GeV machine and eventually the start of physics at the machine, the role of the national Laboratories, the long-term future of CERN-Meyrin.

The delegations of the Federal Republic of Germany and the U.K. both called for reductions in the proposed budget figures. Germany based its request on the financial implications of beginning construction of the new Laboratory and on the needs of other areas of science and technology, maintaining that CERN should establish priorities in its work from now on.

The U.K. delegation were concerned in the short-term to make economies whenever possible in view of their financial situation but, more importantly, in the long term were concerned with the image of CERN for governments and for the rest of science. Other fields such as astrophysics, oceanography and molecular biology, whose demands on finance at the moment are comparatively modest, are growing at a tremendous rate and by the early 1970s they will take an increasing proportion of the restricted science budgets. The U.K. urged CERN to take the lead in recognizing this problem, for it is decisions taken and attitudes established now, which will dictate whether CERN is adapted to the situation which will soon prevail.

A compromise solution was put forward by the Director General giving figures in between those proposed by CERN and those proposed by the U.K. This resulted in the following budgets (in units of a million Swiss francs) being agreed unanimously for the next three years —
1969 : 218, 1970 : 229, 1971 : 240
For the ISR project —
1969 : 88.6, 1970 : 79.5, 1971 : 79.5.
Expenditure in 1969 in connection with the 300 GeV project depends greatly on the speed with which decisions are taken and a tentative figure of 8.5 MSF was recorded.

These budgets will be voted at the December meeting. The Director General said that, in preparing the detailed budgets, everything possible will be done to avoid the burden of the reduced budgets falling too heavily on the physics programme, while still fulfilling the various projects under way.

The scale of the contributions of the Member States is due to be revised at the end of this year (an exercise carried out every three years on the basis of U.N. statistics of net national income). The Council decided to reduce the contribution of Greece and of Spain as is allowed for in the Convention in 'special circumstances'.

Appointment

Professor W. Gentner from Heidelberg University was appointed to succeed Professor G. Puppi as Chairman of the Scientific Policy Committee. In bringing the meeting to an end, the President, Dr. G. Funke, expressed the warm appreciation of the Council to Professor Puppi for all the work he has done in the SPC during his term of office.

Formation of the European Physical Society

Photograph below :

The Official Inauguration of the European Physical Society in the Aula Magna of the University of Geneva. On the platform are (left to right) Professor G. Bernardini (President of the Executive Committee of the Society), Dr. D. van Berchem (Rector of the University of Geneva) and Mr. E. Valloton (Head of the Scientific Section of the international department of the Swiss Ministry of Foreign Affairs).

On the afternoon of 26 September, the European Physical Society was officially inaugurated at the Aula Magna of the University of Geneva. This brought to a successful conclusion discussions and preparations which started at Bologna in November 1965.

The idea of the Society was carried forward at a series of meetings at Pisa, CERN, London, Geneva and Prague. On the 25 September a final discussion at CERN, under the Chairmanship of the Director General, Professor B. Gregory, cleared the remaining points on the Constitution of the Society, and on the morning of 26 September more than forty of the leading physicists in Europe and eighteen National Physical Societies were enrolled in the European Physical Society. The National Societies are from :

Austria, Belgium, Czechoslovakia, Finland, France, Federal Republic of Germany, Hungary, Ireland, Israel, Italy, Netherlands, Rumania, Spain, Sweden, Switzerland, U.K., U.S.S.R., Yugoslavia.
(In a number of cases the National Societies signed subject to formal ratification by their own Councils.)

A major scientific Conference — the first to be organized by the EPS — will be held in Florence, 8-12 April 1969, and the first Council of the Society will then be elected. Until the Conference, an Executive Committee will guide the affairs of the EPS. Its members are:
Prof. G. Bernardini, of Pisa, (President); Prof. E. Rudberg, Stockholm (Vice President); Dr. L. Jansen, Geneva (Secretary); Prof. F. Janouch, Prague (Vice Secretary); Dr. L. Cohen, London (Treasurer); Prof. G.J. Béné, Geneva (Vice Treasurer); Prof. J. de Boer, Amsterdam; Prof. H. Curien, Paris; Prof. W. Gentner, Heidelberg; Prof. J. M. Jauch, Geneva; Prof. G. Szigeti, Budapest.

Mme L. Etienne was appointed Executive Secretary.

The seat of the Society is in Geneva and the Secretariat is located at the Institut Battelle, 7 route de Drize, 1227 Carouge.

An article on the EPS based on a talk by the President, Professor Bernardini, appeared in CERN COURIER vol. 8, page 35. To recall the main aims behind its formation — Article 2 of the Constitution states :

'The purpose of the Society is and shall be to contribute to and promote the advancement of physics, in Europe and in neighbouring countries, by all suitable means and in particular :

a) by providing a forum for the discussion of subjects of common interest;
b) by providing means whereby action can be taken on those matters which it appears desirable to handle on the international level.

The Society will concern itself with such things as the co-ordination of Conferences and Summer Schools; the co-ordination of European physics journals and the publication of a Bulletin; the exchange of experience and information relating to physics teaching; the exchange of scientists between physics centres in Europe.

At the official inauguration in the Aula Magna of the University of Geneva, the Rector, Dr. D. van Berchem, recorded his pleasure at the formation of the EPS and at the part the University had played in bringing it into being. Speaking of the selection of Geneva as the seat of the Society, he recalled the role of the city in the development of science and spoke of CERN as being a real manifestation of the spirit and practice of co-operation. Mr. E. Valloton, representing the Swiss authorities, also pointed to CERN as *the* example of scientific co-operation and said that, in order to pursue such co-operation, CERN should be examined very carefully to try to evaluate the crucial elements which have led to its success. He said that the Swiss government has always encouraged international scientific research and welcomes the formation of the EPS.

Professor Bernardini replied as President of the Executive Committee of the Society. His main theme was the 'cultural unity of Europe' and he said, 'The formation of this Society with such a wide membership is a further demonstration of the determination of scientists to work together and make their positive contribution to the strength of European cultural unity'.

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Membership of the EPS is defined in Article 4 of the Convention:

'The following individual, legal persons or bodies may become Ordinary Members of the Society:

a) individuals who have shown by their contribution to European science, by their professional activity or otherwise, to the Council's satisfaction, that they can further the cause and object of the Society;

b) societies, groups or laboratories organized or existing under the laws of the State of their incorporation or of their seat and which, in the Council's opinion, make a significant contribution to European science;

c) individuals who are members of a society or group which has been accepted as an Ordinary Member of EPS and who fulfil the conditions laid down in the foregoing paragraph provided such individual membership in EPS is not precluded by the Constitution or by-laws of their society or group.

Membership fees are fixed in three categories — Individual members (72 Swiss Francs/year); Membership through a National Society which has joined the EPS (the National Society pays a fee varying according to the number of its members); Members of a National Society who wish to enroll also as individual members (18 Swiss Francs/year).

The first issue of the Bulletin of the Society, to be called 'Europhysics News', will be devoted to the formation of the EPS. It will appear on the 15 November.

Enrolling in the European Physical Society —

1. *Professor G. Bernardini (Director of the Scuola Normale Superiore, Pisa)*
2. *Professor L. A. Artsimovich (Academy of Sciences, USSR)*
3. *Dr. L. Cohen (Secretary of the Institute of Physics and the Physical Society, UK)*
4. *Professor B. Gregory (Director General, CERN)*

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CERN/PI 335.9.68 3.

CERN/PI 327.9.68 4.

News from abroad

Superconducting accelerator programme at Stanford

The High Energy Physics Laboratory (HEPL) at Stanford University, USA, has for some years been the scene of an intensive attack on the challenging problem of a superconducting accelerator (SCA). The work, under the leadership of Professors W. M. Fairbank and H. A. Schwettman, has advanced to the stage where a large SCA will be put together during the next few years with every hope of successful operation.

The feasibility of constructing a superconducting linear accelerator was examined at several centres (CERN, Rutherford Laboratory, and Stanford University) in the early 1960s. It became obvious at that time that a severe research programme to achieve major technical advances would be needed to overcome the problems involved and only Stanford decided to confront the work.

In order to explain why the challenge was worth taking up, we should consider the properties of the existing linear accelerator, which have perhaps reached their optimum so far in the 20 GeV electron machine at the Stanford Linear Accelerator Centre. (Note : SLAC is a National Laboratory, distinct from HEPL which is a University Laboratory).

The 20 GeV accelerator is built up of 100 000 microwave cavities stretching over a length of 3000 m. Radio-frequency power is pumped into these cavities to establish the electric fields which accelerate the electrons. The bulk of the power is absorbed in compensating for the r.f. losses in the copper walls of the cavities. Several thousand megawatts of r.f. power are required from an expensive klyston and modulator system.

Because of the demand for power, the duty cycle of the accelerator has to be kept down to 1 in 1000 (in other words, the accelerator is switched on for only a thousandth of the time). For many experiments this is a serious drawback. A related problem, which also affects the experiments, is that it is difficult to hold the accelerating fields (and thus the final beam energy)

L. Suelzle (kneeling) and E. Jones (from CERN) inspecting the injector for the superconducting electron linac being constructed in the High Energy Physics Laboratory at Stanford University. (Photo Stanford University).

steady when pulsing the machine, coupled with temperature rises in the cavity walls where the power is lost which can change physical dimensions and thus the accelerator's characteristics.

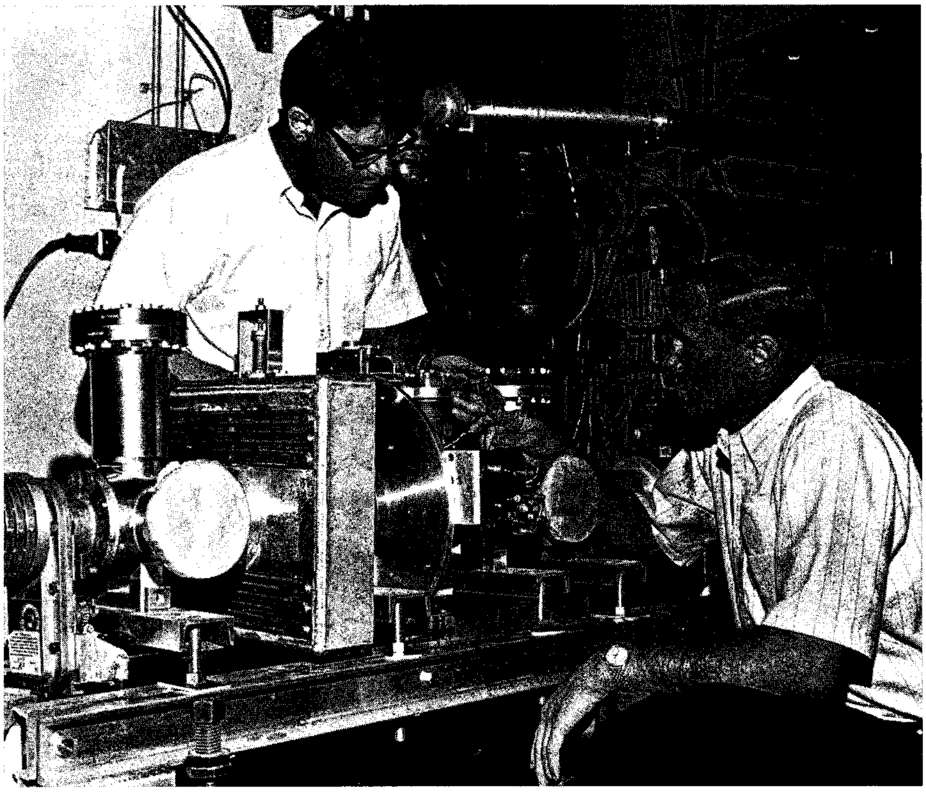
The superconducting accelerator could get round these limitations. If it were possible to build the cavities from a superconductor, and to sit the accelerator efficiently in a very low temperature environment where superconductivity becomes effective:

— There would be a great reduction in the power lost in the cavity walls giving a dramatic saving in r.f. power

— The accelerator could then be operated continuously instead of having a very low duty cycle (the continuously maintained field would also lead to more stable output energy)

— Since the r.f. power system would no longer be under strain, more power could be used to increase the accelerating voltage to the breakdown point, thus reducing the physical length of the accelerator (perhaps a factor of two or three down on conventional linacs of the same energy)

— And, a surprise bonus, if superfluid helium were used as the refrigerating medium it would be possible to maintain extremely stable temperature conditions which would contribute to exceptionally stable output energy.



To achieve these fascinating possibilities, HEPL mounted a long-range research programme to develop :

1. A new superconducting technology to produce high power superconducting microwave cavities where the power loss is a factor of million lower than in conventional cavities.

2. A new superfluid helium technology to handle power dissipation at low temperatures while maintaining near isothermal conditions over distances of hundreds of metres.

Development of cavities

The reason for the requirement of a factor of a million compared with the conventional cavities is twofold. First, if the power dissipation in the walls can be reduced by a factor of a thousand then, for the same power input, the same accelerating voltage can be maintained continuously. Second, on extra factor of a thousand is needed to compensate for the inefficiencies of a refrigerator working at temperatures near absolute zero. In theory, superconducting cavities, made for example of lead or niobium, would produce such an improvement.

A more usual way of expressing what is required is to say that one needs to achieve microwave cavities with Qs exceeding 10^{10}, compared with the conventional Qs of 10^4. Q stands for 'quality factor' and represents the power utilization of the cavity ; the higher the Q the less is the power needed to establish a required voltage.

If the power were fed into the cavity at zero frequency, the resistance of the superconductor would be zero below the transition temperature (when the metal becomes superconducting). However at high frequency, such as is involved in the principle of operation of a linear accelerator, the resistance vanishes only at absolute zero (and then only if some sources of residual resistance are eliminated). Prior to the Stanford work, the maximum values of Q which could be achieved in a superconducting cavity were around 10^7 (independent of temperature) and HEPL had therefore the task of improving on this performance by a factor of a thousand.

One source of residual resistance is that magnetic flux is trapped in the walls of the cavity when they become superconducting. When the cavities are cooled down in the earth's magnetic field, flux is trapped in the walls producing normal conducting regions. In a series of experiments carried out at HEPL, it was found that Q could be pushed progressively higher as the ambient field during cool-down was made lower. This increase continued down to a field level of 0.03 gauss.

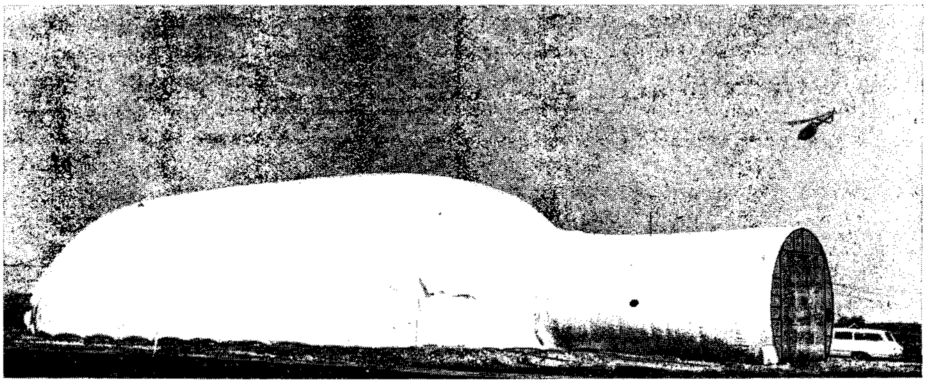
Another source of residual resistance is that large thermal gradients can appear as the metal goes superconducting giving large thermoelectric currents, again resulting in trapped flux. Keeping these thermal gradients as low as possible resulted in further increases in Q.

By now HEPL has shown that, with these precautions, it is possible to take the value of Q above 10^{10}. (Similar values have since been obtained at Brookhaven and Karls-

Some photographs from the National Accelerator Laboratory where the USA 200 GeV accelerator is being constructed :

1. All the Laboratory staff have now moved on to 'The Campus' and this flag-raising ceremony took place on 24 September.
2. As reported in the last issue of CERN COURIER, the Laboratory has experimented with inflatable buildings. The one shown is for the 'Modeling and Measurements Group'.
3. An aerial view of the village of Weston which temporarily houses the Laboratory staff.


1.


2.


3.

ruhe using lead cavities.) The first requirement for a superconducting accelerator has thus been achieved.

Pure niobium looks the best material for the construction of the cavities because of its excellent high voltage properties. With niobium it should be possible to achieve very high accelerating fields leading to a compact accelerator (energy gradients of the order 20 MeV/m). Several techniques for manufacturing cavities of pure niobium, which at first sight could be an extremely expensive business, are being investigated. Electrodeposition on a copper mandrel looks particularly interesting both economically and as a method of accurate construction.

Helium refrigeration

Superfluid helium has remarkably good heat-transfer properties and is an excellent heat reservoir, having high specific heat. It can therefore rapidly spread any heat generated in the cavities throughout a large thermal reservoir and thus play an essential part in the operation of a superconducting accelerator by providing a stable thermal environment.

The Stanford team had, however, to apply itself to the problem of realizing these properties in a practical system. A superfluid refrigerator had never been built, nor had a large-scale cryogenic system such as would be needed for a superconducting accelerator.

The firm Arthur D. Little Inc. modified an existing refrigerator for superfluid operation. This was a 30 W system and tests with it led to the design of a 300 W unit now being installed at HEPL. The use of this refrigerator should demonstrate the feasibility of operating a large and complex system from a central refrigerator. Work is already under way on the design of a 1000-2000 W refrigerator.

The near future

The 300 W refrigerator is designed to cool a superconducting accelerator 150 m long. (A 1.5 m prototype has been in operation since December 1966.) Within the next few years all the individual pieces of work which have been done on various aspects of SCA technology will be brought together in the design, construction and operation of a superconducting electron linac 150 m long. If all goes well it could eventually lead to a superconducting conversion of the SLAC accelerator.

During this exciting stage of the work at Stanford, two CERN people will be working with the team — E. Jones (who did research with the storage ring model, CESAR, at CERN) and P. Bramham (a linac r.f. specialist from the ISR Division).

End of ING

The Intense Neutron Generator (ING) project has been rejected by the Canadian government. It was announced on 20 September that, in accordance with the government decision, the AECL (Atomic Energy of Canada Limited) will phase out its ING studies and experiments by the end of the current fiscal year.

The ING project was centred on the Chalk River Laboratory. It involved the construction of a 1 GeV proton linear accelerator providing a continuous beam of 65 mA to be used principally for the production of an intense flux of neutrons. (See for example CERN COURIER vol. 7 page 200, for a fuller description).

The Canadian government decided that in the light of the other demands on the national treasury, the high cost of ING could not be met at this time. It would have been by far the largest, and most expensive, single scientific project ever funded by the federal government (capital cost $ 166 million at 1966 prices over a construction time of seven years). Canadian scientists are left with TRIUMF (see CERN COURIER vol. 8, page 136), a cyclotron project on the west coast.

Vienna Conference

A report of the conference at Vienna and of some of the developments in sub-nuclear physics discussed there.

The 14th International Conference on High Energy Physics was held at Vienna, from 28 August to 5 September. It was the latest in the major series of biennial conferences covering sub-nuclear physics, often called the 'Rochester conferences' (the first ones were held at Rochester in the 1950s). The sponsors were the Austrian Federal Government, the International Union for Pure and Applied Physics (IUPAP), and CERN.

About a thousand physicists from thirty-nine countries attended, including almost a hundred from CERN, and the organization of the conference was remarkable in coping successfully with such a large number of people.

The setting of the Imperial Palace, the Hofburg, at Vienna was perhaps the most magnificent ever to receive a conference in this series. Using the large conference hall of the Hofburg, it was possible to accommodate all the participants together (though the loudspeaker and projection system were not adequate for such a large throng). In addition, the Austrian hosts were overwhelmingly generous in their hospitality. The entertainment programme included a night at the famous Vienna Opera and a reception at the elegant Town Hall. And to complete their impression of Vienna, the participants could appreciate as they made their way around the city that all the beautiful problems in life are not confined to physics.

But these pleasant memories were inevitably coloured by the nearness to the Conference, both in time and space, of the occupation of Czechoslovakia, which was deeply felt by the assembled scientists.

To turn to the physics — the conference was one of consolidation rather than revelation. There were no dramatic announcements of results such as fired the conferences in the early 1960s (and this may well remain the case for some years, perhaps until a new energy range opens up). Nevertheless, many more pieces were added to the jigsaw puzzle, mainly slotting into their expected places. Results on the weak interaction and the electromagnetic interaction which were thin on the ground a few years ago, are now flowing in in profusion. For the weak interaction, the flurry of activity is mainly a consequence of trying to understand the violation of charge-parity (CP) symmetry in the decay of the long-lived neutral kaon. For the electromagnetic interaction, the existence of full experimental programmes particularly at the DESY electron synchrotron and at the linear accelerator at Stanford has added many more results. Some experiments have been refined to a point where accuracies unbelievable even two years ago, are being achieved. On the theoretical side a lot of new ideas were added to the melting pot, not many of them thoroughly developed. They will, however, be the source of interesting work using new approaches.

Almost a thousand papers were received for discussion during the parallel sessions and the 'Discussion Leaders' had the difficult job of filtering these down to a number which could reasonably be accommodated. They were broken down into seven groups — Current and field algebras, quarks, and related topics; Electromagnetic interactions; Resonances; Dynamics of strong interactions; Weak interactions and CP violation; Intermediate and high energy collisions; Fundamental and theoretical questions.

What follows now is a necessarily very selective review of the information presented at the conference — picking out a few experiments and a few important topics from theory.

Weak interaction

Eta zero zero confrontation

As mentioned above, an intensive attack has been launched on the weak interaction in an effort to understand the mechanism of CP violation in the decay of the long lived neutral kaon, K°_L. One important need is to determine the value of eta zero zero.

To explain what this means we need to go quickly through some facts on the CP violation. (For more detail see CERN COURIER vol. 6, page 171; vol. 7, page 31; vol. 8, page 11.) In 1964 came the first observation of the decay of the K°_L into two charged pions. If charge parity symmetry were conserved this decay would not be possible, but by now it is well experimentally established and the rate at which it occurs (a few decays in a thousand) has been accurately measured. The rate at which the short-lived kaon, K°_S, decays into two charged pions (which does not violate CP) is also known. It is then possible to give a value for the 'relative decay amplitude' called 'eta plus minus', which compares the amplitudes (the square roots of the rates) of the decay of the K°_L into two charged pions and of the K°_S into two charged pions

$$\eta_{+-} = \frac{A\ (K^\circ_L \rightarrow \pi^+ \pi^-)}{A\ (K^\circ_L \rightarrow \pi^+ \pi^-)}$$

The value of eta plus minus is now well established as about 2×10^{-3}.

In 1966, the decay of the K°_L into two neutral pions, which also violates CP, was observed in two experiments — a spark chamber experiment done at CERN by a Rutherford, Harwell, Aachen, CERN group and a spark chamber experiment done at Princeton. It is a much more difficult decay to get hold of since it involves detecting the electron showers, which are produced by the gamma rays, which are produced by the neutral pions, which are produced by the long-lived kaons. Great care has to be taken to distinguish the two pion decay from the profusely occurring three pion decay. Nevertheless, both experiments measured the rate of the decay and were therefore able to put forward a value for eta zero zero

$$\eta_{00} = \frac{A\ (K^\circ_L \rightarrow \pi^\circ \pi^\circ)}{A\ (K^\circ_S \rightarrow \pi^\circ \pi^\circ)}$$

Why is the value of eta zero zero important ? The answer lies in trying to analyse just what is happening when we observe the long-lived kaon decaying into two pions in violation of CP symmetry. Are we seeing directly the rare occurrence of a K°_L decaying into two pions or are we seeing the decays of a K°_S into which a K°_L has converted ? (Although the K°_S is 'allowed' to decay into two pions this doesn't get around the CP violation because we still have to confront it in converting K°_L into K°_S). If the second alternative is correct — that a 'super-weak' force is acting on K°_L which on rare occasions converts a K°_L into a K°_S — then the ratio of the observed K°_L decay into two neutral pions compared with two charged pions, should equal the ratio of the K°_S decay into two neutral pions compared with two charged pions (just because

The huge hall used for the Conference sessions in the Imperial Palace at Vienna.

we are saying that we are not seeing the decay of K°_L at all, but always of K°_S into which K°_L is occasionally converted). Then η_{00} should equal η_{+-} having a value of about 2×10^{-3}. If this is not the case we eliminate the superweak theory of CP violation.

Both 1966 experiments gave η_{00} equal to about 4×10^{-3} and the two results were very close together. Three further measurements entered the discussion at Vienna

1. A Hawaii/Berkeley team in an experiment at Berkeley comes close to 4×10^{-3}, in line with the 1966 results.
2. A CERN heavy liquid bubble chamber experiment involving CERN, Ecole Polytechnique and Orsay gives a value close to 2×10^{-3}. This experiment involved perhaps the most searching analysis of any bubble chamber experiment yet, because, when it became obvious that the result did not tie up with the two 1966 results, the scientists stood on their heads to look for possible errors.
3. Preliminary news from an experiment led by V. Fitch at Princeton which has observed no two neutral pion decays so far. This was a significant contribution to the discussion simply because if η_{00} in nearer 4×10^{-3} some events should have appeared (the event rate goes up as the square of η_{00}).

Also, further analysis of the first Princeton result has brought it down to nearer 2×10^{-3}.

Obviously, in the light of this confrontation, each experiment has been put under a microscope but without discovering any flaws. Further experiments will be done and the possibility of using the new large heavy liquid bubble chamber, Gargamelle, which would be a very efficient detector of neutral pions, is under consideration at CERN.

Neutrino results

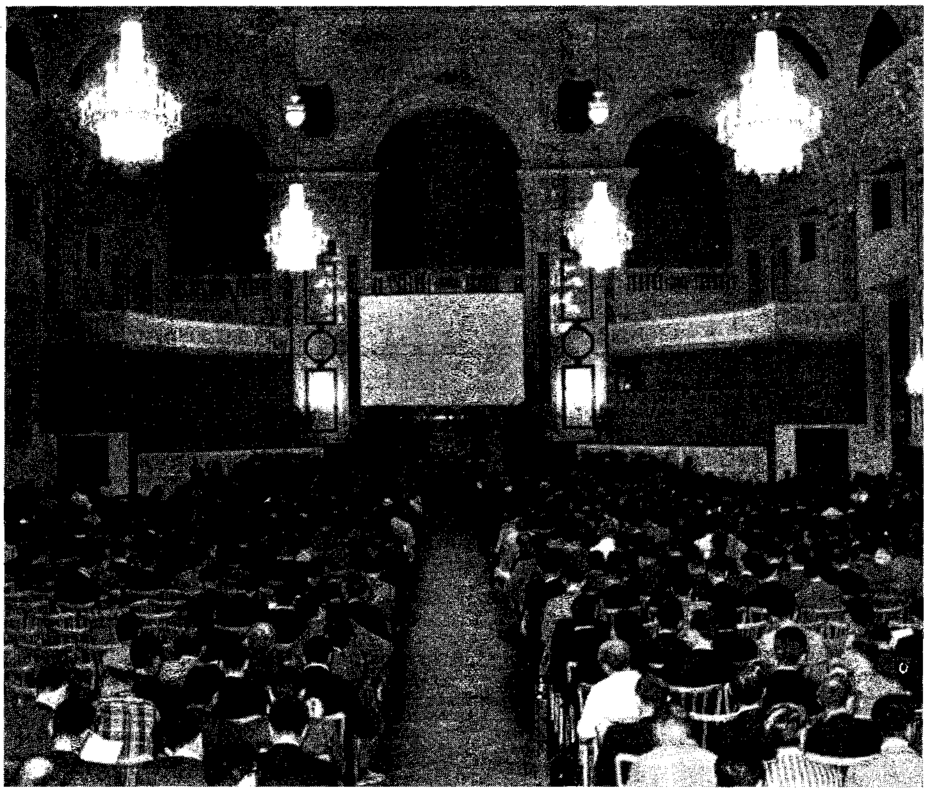
The preliminary results of the latest series of neutrino experiments at CERN (see CERN COURIER vol. 6, page 211) were reported at the conference. For the first time, information based on neutrino interactions on free protons could be announced. It proved easy to pick out the free proton events from those involving a proton bound in a nucleus.

Prior to this experiment there was no experimental figure for the cross-section of the neutrino interaction with a nucleon to produce a pion. The previous experiments, in order to see an acceptable number of interactions per day, were compelled to use freon in the bubble chamber and any interaction with a nucleon producing a pion was very difficult to analyse because the pion is affected by the other nucleons in the heavy nucleus. Now that the neutrino flux in the CERN beam-line has been greatly increased, an acceptable event rate can be achieved using the less dense propane in the chamber, and propane has hydrogen atoms with 'free' protons at their nucleus. Thus pion production can occur without interference from other nucleons. The results show that, as expected, the dominant contribution to the inelastic cross-section comes from the formation of the nucleon resonance N* (1236).

$$\nu_\mu + N \rightarrow N^* + \pi + \mu$$

The spark chamber experiment done in association with the bubble chamber experiment also confirmed an expectation. One of their measurements was to check the muon conservation law, namely that the muon neutrinos (ν_μ) always transform to negative muons and the muon antineutrinos ($\overline{\nu}_\mu$) to positive muons. With spark chambers before and after the bubble chamber they used the magnetic field of the chamber to determine the charge on the muon. With the CERN beam of neutrinos only negative muons should have been seen. The result was $\mu^+/\mu^- = 0.3\,\%$ which is consistent with the background $\overline{\nu}/\nu = 0.2\,\%$.

A side effect of the research on cosmic and solar neutrinos with detectors located deep underground has been the measurement of the angular distribution of very high energy muons. A report from the Utah University team down the Park City lead mine found that the measured muon flux did not vary with angle in the expected way (see CERN COURIER vol. 8, page 12) suggesting that the source of these muons was not exclusively the decay of pions and kaons.



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A photograph taken during the reception in the Vienna Town Hall. This was just one of the events laid on by the City of Vienna which received the Conference with quite exceptional generosity.

This result has since been contested (for example by a Durham University group) and at the Conference, M.G.K. Menon reported similar measurements carried out in the Kolar gold mines in India at different depths. His team found the muon flux to vary with angle as expected.

Theory

The theoretical attack on the weak interaction has moved into a new phase in that people are now busy trying to calculate higher order corrections. So far the theory describes the interaction very well to lowest order, but it runs into trouble if it is extended to higher orders. The present efforts are directed towards modifying the theory to correct this and some possible models have been proposed.

On the delicate problem of CP violation, the theoretical position is wide open and theorists are largely maintaining a discreet silence for the time being until the experimental position is clarified.

Electromagnetic interaction

C violation

One of the major topics of the conference held two years ago at Berkeley was the possible violation of charge symmetry in the electromagnetic decay of the eta meson into three pions (see CERN COURIER vol. 6, page 171). The first experiment (bubble chamber experiment at Brookhaven) based on the observation of one and a half thousand events rocked the boat by claiming a clear indication of C violation (giving an asymmetry of 0.072 ± 0.028). A spark chamber experiment at CERN, reported at Berkeley, had observed more events (ten and a half thousand) and showed no C violation (asymmetry 0.003 ± 0.010).

Still more events, 40 000, have been observed in an experiment at Brookhaven by a Columbia University, BNL team and an observed asymmetry of 0.015 ± 0.005 was reported at the conference. Standing by itself this may have been regarded as a strong indication of C violation but, with the other experiments behind it, a verdict of 'violation not proven' is generally recorded.

It appears that American eta mesons have a tendency to break the law while Western European eta mesons are well-behaved (they have, of course, a much longer cultural tradition behind them). Apart from spinning a coin in mid-Atlantic (which would be unscientific, though cheaper), perhaps the clinching result will be the behaviour of Eastern European eta mesons at Serpukov.

g-2

The muon storage ring group from CERN reported their measurements of the 'g minus 2' of the positive and negative muon. The experiment was one of the most refined ever to be undertaken, aiming to measure 'g-2' to an accuracy more than ten times better than ever before. The value of 'g-2', which is related to the anomalous magnetic moment of the muon, is important because —

i) It is a way of testing just how far the very successful theory of quantum electrodynamics continues to apply when investigated at smaller and smaller distances; one of the gratifying surprises of physics is that this theory which was developed to explain phenomena on the scale of 10^{-8} cm has continued to hold good down to 10^{-14} cm.

ii) It could provide a clue to the reason for the existence of the muon ; the electron and the muon differ essentially only in their mass and why Nature has need of two different 'identical' particles has been an intriguing question for many years.

(For a full description of the experiment and its aims, see CERN COURIER vol. 6, page 152.)

The theory predicts a value for g-2 of 116560 x 10^{-8}. The experiment gave (116575 ± 71) x 10^{-8} for the positive muon and (116625 ± 24) x 10^{-8} for the negative muon. These results are twenty times more precise than the previous figures. During the course of the experiment they were consistently higher than the theoretical prediction but not enough to shake the belief in quantum electrodynamics which still stands down to distances below 10^{-14} cm.

The possibility of pushing the accuracy still further is now being investigated at CERN.

Theory

Some of the results from Stanford are posing big problems for theorists. They concern particularly electroproduction at high momentum transfer. When resonance production goes down, an inexplicable background remains which is large and constant.

Photo production of the neutral pion and the photoproduction of charged pions by polarized gammas pose new difficulties for the Regge pole analysts. For elastic electron scattering, explanations of the form factors at large momentum transfer in terms of a composite structure of the nucleon were presented but the position is still not clear.

Strong interaction

Here, more than anywhere, the weight of accumulating information is growing at a great rate. In bubble chamber experiments

Part of the audience during one of the Conference sessions. The hall of the Imperial Palace was able to accommodate more scientists than had ever been brought together at any previous high-energy physics Conference.

(Photos : Foto Schikola, Vienna)


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the statistics are climbing at the rate of about four every two years and the present statistical accuracies are forcing more attention to be paid to systematic errors such as are involved in the optical properties of the chambers.

At the last conference two years ago in Berkeley, two-body collisions were mainly known in terms of elastic scattering near the forward direction. Now data exists over the whole angular region for pion-proton, proton-proton and anti-proton interactions. All these have different structures and it will need a lot of work to interpret them theoretically. In terms of quasi-elastic scattering (such as pion plus proton giving a proton and a boson resonance), many results have come from bubble chamber and missing mass spectrometer experiments.

The situation with regard to resonances was summarized by H. Harari (Weizmann Institute) in a thoroughly well-prepared and well-presented talk. He showed that, particularly for the baryon resonances, the observed particles fit very well into the places assigned to them by SU6 theory or the quark model. For the boson resonances, things are not so clear cut.

Mixing angle

Results involving the electromagnetic interaction, which have an important bearing on unitary symmetry theory, were reported by several groups including the Bologna/CERN team. Three measurements were reported for the 'ω - Ø mixing angle' giving values which fit that needed to explain the omega (ω) and phi (Ø) vector mesons in terms of SU3.

When shuffling the observed particles into the groups corresponding to the SU3 scheme, an anomaly arose for the group of vector mesons. In the expected group of eight, seven mesons were found to fit nicely but none fitted into the slot for a particle of mass about 960 MeV (called ω_8).

Instead two maverick particles were found — the omega meson of mass 760 MeV and the phi meson with a mass of 1020 MeV. J. J. Sakurai suggested that the two observed particles are in fact mixtures of the ω_8 and an SU3 singlet particle ω_1 (both of these particles having the same quantum numbers). This can be expressed by the 'ω - Ø mixing angle'.

The way used to determine this angle by the Bologna/CERN team was to measure the electromagnetic decays of the omega and the phi into electron-positron pairs. The omega and the phi are linked with the photon, which materializes into the electron-positron pair, by their ω_8 component. Thus to examine the electromagnetic decays is effectively to switch off the ω_1, making it possible to determine how the ω_8 and ω_1 mix to give the observed omega and phi mesons.

However, the electromagnetic decays of the mesons are very rare and difficult to observe. The team measured the decays using a complex array of detectors mainly built at Bologna. Although only a handful of events for each particle state were seen it was possible to give a value for the mixing angle $(23^{+7}_{-5})^\circ$ which confirms that the SU3 explanation of the omega and phi in terms of the mixing of two particles is correct.

Similar values came from elegant and difficult experiments done by the Orsay colliding beam group, who used electron-positron collisions in the Orsay storage ring to produce the mesons, and from the MIT/DESY group who used photoproduction of the mesons at the DESY electron synchrotron.

Theory

The strong interaction is fertile ground for theorists also. The complexity of the experimental observations has resulted in many different theoretical approaches.

To understand the behaviour of cross-sections at high energies and the exchange of quantum numbers, the Regge pole model remains the most successful. The known particles fit well with the concept of Regge trajectories but complications have occurred involving the introduction of 'conspiracies' (special connections) between trajectories in order to explain, for example, experimental results in which pion exchange is prominent. These complications may result in 'Regge cuts' assuming a much more important role in the theory than they have done up to now.

One of the most satisfying developments since the Berkeley conference has been the recognition of 'duality' between the Regge pole picture and the resonance production picture of particle interactions. Previously, theorists were in the aesthetically displeasing position of having an interpretation which was good at high energies but bad at low energies (Regge pole picture) and another interpretation which was bad at high energies but good at low energies (resonance picture). An analysis which seems to resolve the conflict by showing that, in fact, each picture contains the other was first proposed by Dolen, Horn and Schmid and it has since been extensively used to determine Regge parameters for low and intermediate energy interactions. Much work is under way on this theme; in particular, a model proposed last summer at CERN by G. Veneziabo is being explored further.

For the first time, a major effort has emerged to understand interactions where many particles are produced (as opposed to essentially two-body processes which may produce two resonances which decay to give more particles). The most promising interpretations are based on multi-

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Regge pole exchange which many groups used for interpreting their data following the pioneering work of Chan Hong-Mo and collaborators at CERN. This model is proving very successful and led G. Chew, F. Low, and M. Goldberger, to some interesting theoretical developments which were sketched at the conference.

On symmetries, SU3 theory still stands in good array. The development of the Regge pole model has put forward the possibility of some particles which would not fit the classification of particles based on the postulate of quarks, but M. Gell-Mann and G. Zweig have already prepared for the possibility of these particles being detected experimentally by working out a modified quark model.

New results have emerged from the work using algebra of fields, in particular in connection with processes involving hard (actual) pions; the early current algebra work obtained its results assuming soft (zero mass) pions. A beautiful result of more mathematical nature was presented by D. Atkinson in S-matrix theory. He has explicitly shown the compatibility of crossing-symmetry, unitarity and the Mandelstam representation for a scattering amplitude.

And with that flurry of specialists terms this brief review of some of the topics of the Vienna conference is concluded.

The conference indicated many interesting theoretical paths to follow, many experimental results which are still needed, and results which need further precision. No doubt much of this will be cleared by the time of the next conference in the series which will be held in the Soviet Union in 1970.

Start up of the PS

The proton synchrotron began operation again on 9 September after a long shut down. Up to 23 September, the machine was operated only at night and at low energy (800 MeV) because the civil engineering work at various points around the ring, particularly the reinforcement of the shielding and the piercing of the connecting tunnels for the Booster and the ISR, was still in progress.

It was possible during this running-in period to eliminate the faults inevitably present after the many modifications and additions which had been carried out during the shut down. These two weeks were also used to carry out a series of tests to improve the overall injection efficiency; these tests will be continued in the normal course of development of the machine.

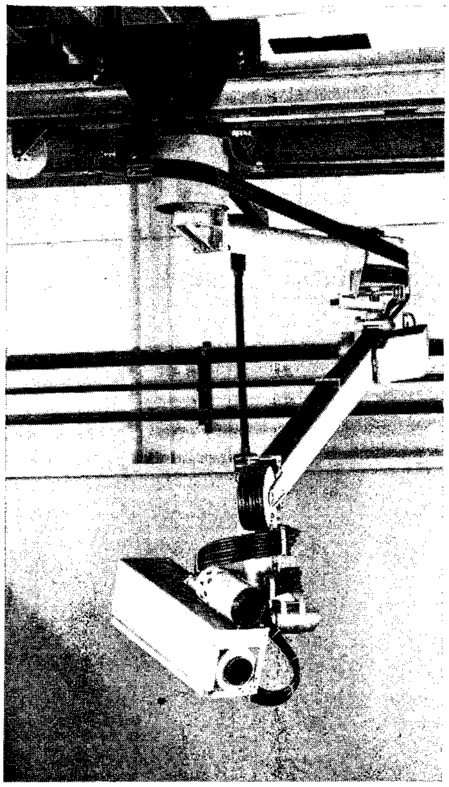
On 25 September, when all the civil engineering work had been finished on schedule (despite the bad weather), the PS came back into normal operation. Operation began with a step-by-step increase in energy to find the optimum settings of the currents feeding the pole face windings. The main problem here was to obtain a sufficiently uniform magnetic field at high field levels over an adequate width inside the vacuum chamber to enable the beam to be directed onto targets. The width of uniform field at high field levels could not be predicted accurately in advance. Uniform field at peak energy of over 4.5 cm was achieved which is ample. The variation in the currents for the pole face windings are now programmed.

Once this had been cleared, the next step was to establish the maximum energy for regular operation. It was found to be 27.2 GeV with a repetition rate of one pulse every 3.2 s (with the previous magnet power supply, the theoretical repetition rate at this energy was one pulse every 6 s) and it may prove possible to lower this figure to 2.8 s. (These performance figures are close to those on the AGS at Brookhaven). The new power supply is working well, but there are still a few adjustments to be made to the static converters.

The new concrete shielding roof which was built over the top of the existing PS tunnel over the target zone from which beams are taken to the North and South experimental halls (see CERN COURIER vol. 8, page 178). This precaution has been taken to prepare for the radiation levels which will be generated as the intensity of the proton synchrotron is increased.

CERN/PI 141.9.68

One of the new remotely-controlled arms carrying a television camera which observes the manipulator in action. It is less bulky, stronger and has a further degree of freedom of movement compared with its predecessor.



CERN/PI 104.8.68

On 5 October an intensity of 10^{12} protons per pulse was obtained.

At the time of writing, experiments have started only in the South Hall, fed by two internal targets, one in straight-section 1 receiving 80 % of the beam, and the other in straight-section 8 receiving the other 20 %. All the other experiments in the PS programme should begin progressively through to the months of January or February, 1969.

Tests on the 'straight flush' system (see CERN COURIER vol. 8, page 175) began on 10 October and the system has already performed many of its tricks. The ejection channel from straight-section 58 can be supplied with up to three bunches of protons per pulse and adjustments ready for feeding beams to the 2 m bubble chamber can begin. Experiments are under way also on the full-aperture kicker (see CERN COURIER vol. 8, page 26) and on the slow-ejection system for the East Hall.

From the start up, a considerable improvement has been achieved in the vacuum monitoring system. Information on the pressure in each of the straight-sections of the ring can be read from dials or printed out by the IBM 1800 computer in the control room. The latter also gives the averages of the measurements and indicates those sections where the vacuum is poor.

Modified manipulator of the PS

A 'General Mills' remotely controlled manipulator has been installed in the PS ring since mid-1967 (see CERN COURIER vol. 7, page 85). Although such devices are by now quite common, they have not so far been used in places with no direct visual access such as an accelerator tunnel. The aim of the tests at the PS is to study all the problems involved in the operation of a manipulator seen only by television cameras.

In May 1968, a second, smaller telemanipulator of quite a different design, which was made at CERN, was added. The whole apparatus proved most useful when the PS was shut down in June 1968; especially for dismantling the septum magnets from straight-sections 58 and 62, which had some very 'hot' components.

The new small manipulator was particularly useful. It has a long, thin arm which is suitable for delicate work because, in contrast with the arm of the large manipulator, it does not block the field of view of the cameras or cast shadows. Nevertheless it is a prototype and has some faults ; for example, its counterbalancing system is cumbersome. This is to be improved.

It has also been necessary to modify the observation system : the three cameras (two for detailed views and one for an overall view) have had to be replaced because they produced very low level signals which could easily be disturbed by the surrounding motors. The lighting system has also been improved — the lights on the cameras have been replaced by halogen lamps which are about ten times more compact, and those fixed on the bridge have been replaced by more powerful ones. The counterbalanced arms supporting the cameras have been replaced by stronger ones which are now fixed to a carriage and no longer directly to the bridge, which gives them longer range in the lateral direction.

The next major problem to be tackled is that of the limitation in the area where the manipulator can work, dictated by the length of the control cables (40 m) between the bridge and the input/output point on the wall of the ring. Work has started on a system which will allow cables to be disconnected from a distance and be reconnected on a connection box 40 m further away.

LSD at CERN

In autumn 1966, the Track Chamber Division at CERN, in collaboration with Collège de France and Ecole Polytechnique, undertook to build two automatic measuring machines for bubble chamber photographs of the type known as the digital Spiral Reader. (In French 'lecteur à spirale digitalisée - LSD'; honi soit qui mal y pense !) One is intended for use at CERN and the other at the Collège de France.

It is only necessary to point to the number of photographs taken in the three CERN bubble chambers in the last year — over 7 000 000 — to bring out the need for measuring systems which are as automatic as possible.

There are three stages prior to the analysis proper of the particle events recorded on a photograph :

1) Scanning : the selection of the events with which the experiment is concerned (perhaps events with two or four prongs, or neutral particle decays...). An event will involve only a fraction of the many tracks produced on a photograph during the exposure time and only a fraction of the total number of photographs taken during an experiment will record the interesting events. It is a relatively simple operation for the trained human eye to pick these out but it is still too complex an operation for machines to do efficiently. (There are attempts being made to develop automatic scanning but they are still at the experimental stage.) One is limited therefore, to producing equipment which reduces human intervention to the bare minimum.
2) Measurement : the accurate recording of the coordinates of a certain number of points on each trajectory of the events selected. This process can be either semi or fully automatic.
3) Processing : This begins with the reconstruction in space of the trajectories using information from the three views taken. This is done by computers in every case and serves first to eliminate incorrect measurements.

Almost all the present methods of film measurement involve a man/machine col-

The principle of the Spiral Reader : A radial slit (E) projected optically onto a bubble chamber photograph moves in a spiral centred on the vertex (D) of an event on the photograph. The slit measures in polar coordinates the positions of those particle tracks which make an angle of less than 20° to the radius — all the tracks drawn in full on the diagram. The sections of track drawn dashed are not measured. This eliminates a high proportion of the tracks not forming part of the event but can miss also part of tracks (C) which are part of the event.

SR I in operation at Berkeley. In September 1964, this became the first Spiral Reader to be used in production measurements. It measured its millionth picture at the end of last year. (Photo LRL)

Diagram of the CERN Spiral Reader (LSD) showing :

(1) projection table

(2) film transport

(3) the system producing the spiral movement of the slit (the periscope protrudes from the centre of the cone)

(4) television camera

(5) mirror positioned inside the cone (not shown directly on the diagram, but its position can be realized from the trace of reflected light).

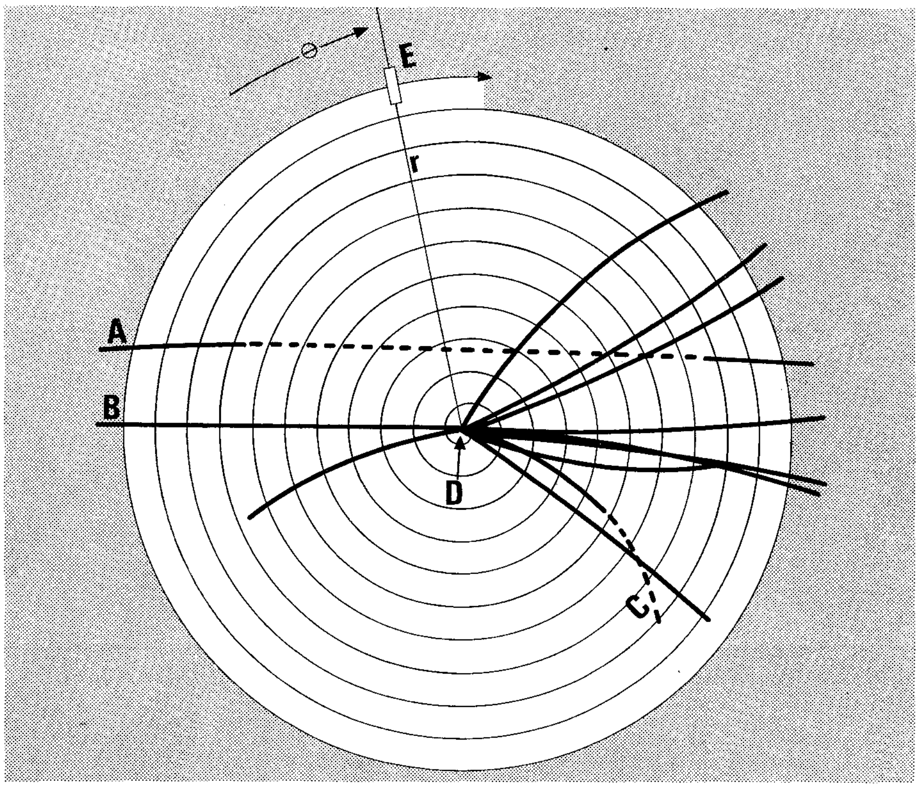


Figure 1

laboration. Various types of machine with varying degrees of automation are in use. They include the IEP's (Instrument for the Evaluation of Photographs — see CERN COURIER vol. 6, page 7 and vol. 7, page 185) and the HPDs (see CERN COURIER vol. 6, page 7).

A further method, the Spiral Reader, has come to fruition quite recently. It is based on a principle which originated at Berkeley where two measuring machines of this type have been brought into operation (see below). CERN's Spiral Reader or LSD follows the same basic principle though it is different in many design features. Human intervention is reduced to indicating to the machine the vertex of an event (at D on Figure 1).

The LSD takes advantage of the fact that the events always have a 'star' formation which makes it feasible to survey their topography in polar coordinates. The principle of the device is as follows : A radial slit moves in a spiral around a point of reference. The spiral is centred on the vertex of an event and, by means of an optical system, the slit moves over the bubble chamber photograph. Each time it encounters the track of a particle, a photomultiplier tube produces a pulse which records its location in polar coordinates.

The advantage of using a slit is that it does not record every track but only the 'radial' ones. The intensity of the light passing through the slit varies depending upon how parallel the slit is to the track and by recording only the pluses of a certain amplitude, (the standard used being that corresponding to tracks making an angle of less than about 20° to the radius) almost all the tracks not forming part of the event will be eliminated.

The use of a slit, however, is a disadvantage for those tracks which are heavily curved, having an angle of more than 20° to the radius at the end of their trajectory. In such a case, only a part of the length of the track is measured (the part close to the vertex). This is usually adequate because the heavily curved tracks will be low energy particles.

Practical details

The main components of the LSD are a film transport system, an optical system, a pro-

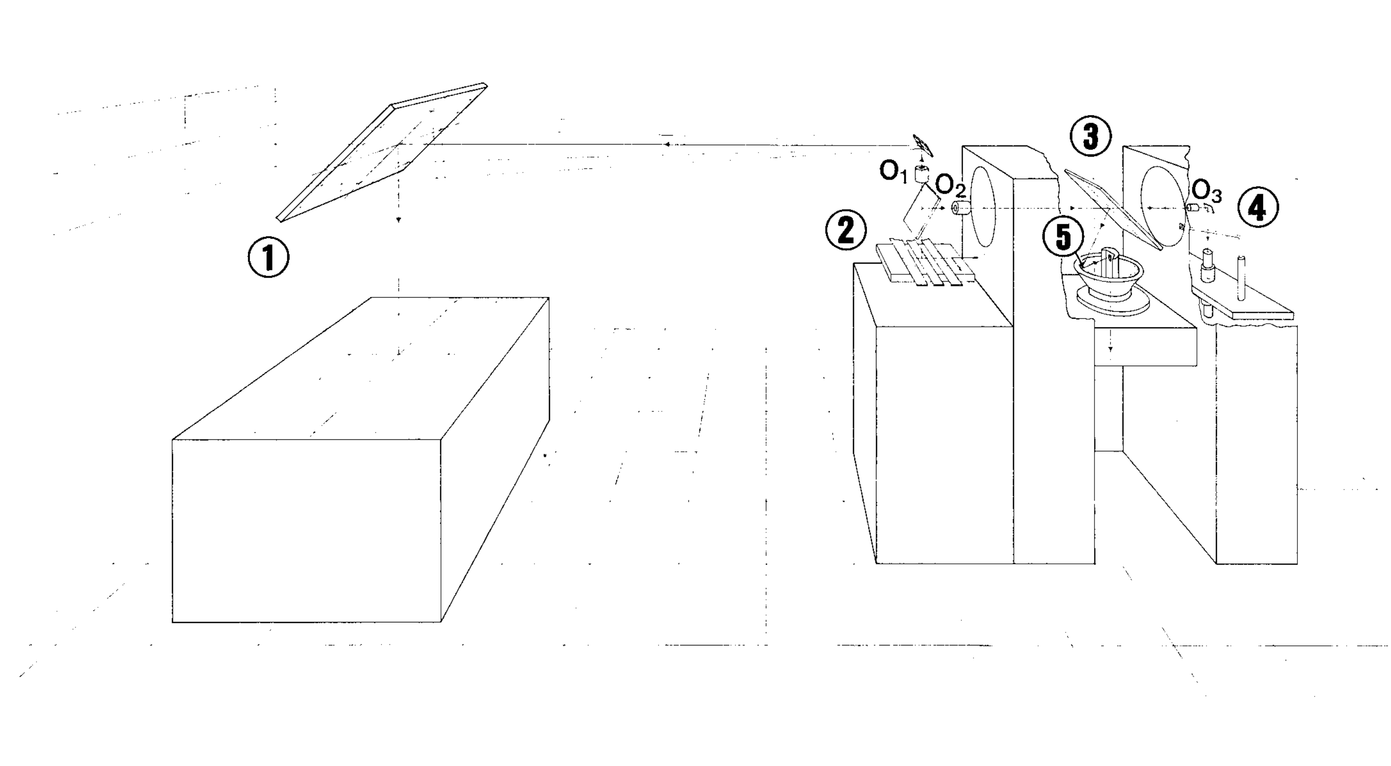


Figure 2

jection table, closed-circuit television giving high magnification, a spiral scanning system, a system for measuring the fiducial marks, a computer and its peripheral equipment. (See Figure 2.)

Film system and table

Three films (50 mm film up to now, although it is possible to modify the system to take 35 mm film) are wound on the same spool and are exposed in parallel on a mobile, servo-controlled table. The position of the table can be measured to within 2 μ by a Heidenhain linear coder.

Optical system

The light used for the projection is provided by a xenon lamp and reaches the film after reflection from a cold mirror which prevents the film from being heated. The image is then passed through a set of Schneider Repro-Claron lenses (O_1, O_2 and O_3) and mirrors to the projection table, the spiral scanning system and television camera.

Projection table

This provides a 10 x magnification, and allows the operator to have a general view of the photograph. A small control desk is attached to it.

Television camera

The camera (manufactured by Grundig) projects a greatly magnified image (200 x) of the event, so that the operator can super-impose the centre of the spiral very accurately on the vertex.

Spiral scan

This is the distinctive feature of the machine. The spiral movement of the slit is produced by an optical-mechanical system. A periscope moves vertically along the axis of a cone, along the inside wall of which is a small mirror (at 5 on the diagram) inclined at an angle of 45° to the horizontal. The periscope-mirror assembly revolves at a speed of 900 rpm, with the mirror permanently oriented towards the periscope aperture, which is formed by a fine vertical slit (50 μ x 1000 μ). The light reflected by the mirror enters the periscope through the slit and reaches a photomultiplier via a glass-fibre guide made by Sovis.

The uniform rise of the periscope provides the spiral scanning action, maximum travel being 150 mm corresponding to an 80 cm radius circle in the 2 m bubble chamber. The movement of the periscope and the angle of rotation are tracked by the Heidenhain coders. The order of accuracy is 2 μ in radius and (360/129 600)° in angle.

Measurement of the fiducials

The fiducial marks on each photograph can be measured automatically in one single operation by means of V-slits connected to four pairs of photomultipliers. The equipment is adjusted for a given type of bubble chamber and must be readjusted if a different chamber is used.

Computer

A PDP 9 together with its peripheral equipment (two tape units, teletype, oscilloscope and fast card-reader) is an integral part of the operation of the LSD. It has a memory of 8192 words of 18 bits. Its functions are — to control the film transport, the movement of the projection table and the periscope, the automatic measurement of the fiducial marks; to pass instructions to the machine from the operator and to inform the operator of any problems on the machine; to record the measurements and store them on magnetic tape.

Programme

Construction of the LSD is progressing to schedule and is now at an advanced stage. Tests are under way to determine the precision which the machine can achieve. About twenty events have been measured and analysed on the CDC 6600. A filtering programme (POOH) adapted to CERN standards has correctly reconstituted events 'in space' using the data from the LSD. Start-up of the machine for 'production measurements' is planned for 1 April, 1969.

Execution on an industrial scale

A group of Danish, Norwegian, Swedish, Austrian, British and Israeli physicists was set up in 1967 under the name of the 'Spiral Reader Purchasers Group' to find out if there was a company capable of manufacturing the LSD on an industrial scale, using the design developed at CERN. The Swedish firm of SAAB was finally selected and has already received three orders (Copenhagen/Stockholm ; Saclay ; Vienna).

The use of the spiral reader technique for measuring bubble chamber film originated at the Lawrence Radiation Laboratory, Berkeley, and was pushed to a successful conclusion under the leadership of Professor L. Alvarez. The first idea came from B. McCormick leading to the construction of a device involving a circular scan of radial slits about a vertex. This was modified to a spiral scan of a single slit in 1960. The circuitry was converted to digital and the scanning motion was generated by a periscope, a rotating cone and the slit. In 1964, a PDP-4 computer was integrated into the design and in September of that year 'Spiral Reader I' began production measurements. It has been in operation ever since with high reliability and heavy utilization — its millionth event was measured on 23 December 1967.

Construction of Spiral Reader II at Berkeley began in February 1966 and it came into service in June 1967. It can measure up to 120 bubble chamber events per hour. The two Spiral Readers measured over one million events in 1967. Many improvements have been incorporated in the second version and of special interest is the investigation of a laser system to speed up the measurement of short or obscured tracks, which have so far required special attention from the operator.

The Berkeley Spiral Reader team, under F. Solmitz, are also involved in the production of a further Spiral Reader, in collaboration with the Stanford Linear Accelerator Centre, to be used at Stanford.

Direct from the mains

It was mentioned in the article describing the Booster in CERN COURIER vol. 8, page 8, that it may be feasible to power the magnets of the four synchrotron rings directly from the mains. This would do away with the rotating power supply (motor-alternator set) which is usually used to smooth out the surges of power required by the pulsed operation of a synchrotron. Rotating plant, subjected to the stringent demands of accelerator operation, has proved to be the most fragile part of the machine, and the possibility of dispensing with it is of great interest (see CERN COURIER vol. 8, page 108).

The maximum power required for the Booster magnets is nearly eighteen times lower than that of the PS itself in normal operation and represents a pulsed load which, it has been calculated, could be borne by the mains supply coming into the CERN Laboratory. Obviously, however, experimental tests were needed before the possibility could be pursued further.

Advantage was therefore taken of the PS shutdown to carry out such tests, with the cooperation of the Geneva electricity authorities, on 15 and 16 August. Since the Booster magnets are not yet available, the PS ring was used, pulsing the magnets at a lower voltage (3 kV) than normal. This simulated (though not exactly) the pulse conditions which will prevail for the Booster.

Tests took place at the time of peak electricity load during the day and of minimum load during the night. Repetition rates of 3, 4, 6 and 9.9 s were used.

The influence of the pulses was measured at different points in CERN and on the Geneva grid. The measurements were concerned with frequency variations, voltage fluctuations and variations in the power supplied by the generators. The results were analysed on the ATLAS computer in the UK using the BOMM computer programme for time series analysis.

The results of the tests were —

a) Frequency variations

The maximum value of the frequency variation induced by the pulses did not exceed 0.01 % corresponding to a peak-to-peak variation of 0.005 Hz under normal conditions. This value is of the same order as the usual 'noise' on the mains supply within the frequency range of the pulses.

b) Voltage fluctuations

The voltage fluctuations measured on the CERN site during the tests were higher than could be tolerated by some other CERN users. If the Booster magnets are supplied from the mains it will be necessary to include a compensation system to hold the voltage steady.

c) Effect on the generators

It proved difficult to detect any effect on the generators supplying the grid. The measurements made at the Verbois and Chancy hydro-electric generating stations showed no variation — the influence of the pulses was too small to give any deflection on the recorders.

Thus the experimental results have largely confirmed the theoretical predictions and were even better in some respects. They have proved that it is feasible to connect the Booster magnets to the mains. It could provide important experience for the possible connection of the 300 GeV magnet to the mains.

Cross-channel link

Another important test of the ability of electricity networks to take large pulsed loads was carried out on 20 - 21 June. The power authorities of France (Electricité de France) and the United Kingdom (Central Electricity Generating Board) passed a series of pulses of 80 - 160 MW over the interconnecting cross-channel submarine cable (d.c. link).

CERN, Daresbury and Rutherford collaborated with the CEGB and EPF in the frequency measurement programme and the analysis of the pulse-induced frequency disturbance was done at the Atlas Computer Laboratory using the BOMM programmes. The efforts of the two large national power authorities in mounting this experiment on their systems and furthering our interest in this subject are greatly appreciated.

The tests were conducted under conditions of peak and of minimum load on the networks, passing a series of square pulses at three different frequencies. The maximum observed frequency change induced by the pulse exchange was 0.05 % measured in the UK and 0.03 % measured at CERN. Figures of this order are likely to be completely acceptable to national power authorities, yet they resulted from conditions more severe than would be required for the 300 GeV magnet power supply.

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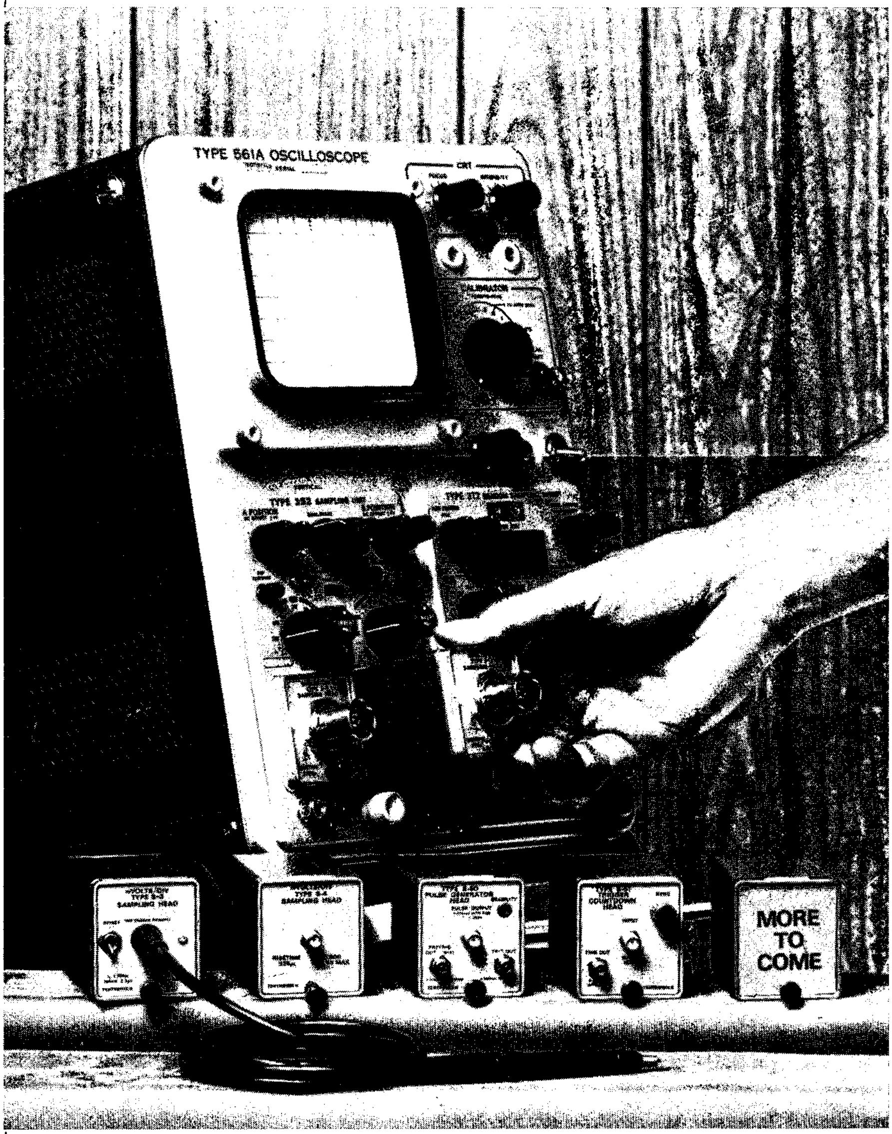
New 25-ps Sampling Oscilloscope

Four new Sampling Heads provide new measurement capabilities in Tektronix Type 561A, 564, 567 and 568 Oscilloscopes. Used with the Type 3T2 Random Sampling Sweep and the Type 3S2 Dual-Trace Sampling Plug-In Unit, the six Sampling Heads offer a step ahead in the measurement performance, designed to meet customers changing measurement needs.

Previously announced Sampling Heads include the Type S-2, featuring a 50-ps risetime and the Type S-1, featuring a 350-ps risetime and an unexcelled transient response.



25-ps Sampling Head

The new Type S-4 Sampling Head features a 25-ps risetime• and DC-to-14 GHz bandwidth. This 50-Ω Sampling Head gives increased detail and resolution making fast pulse measurements.

Sampling Probe Head

The new Type S-3 Sampling Probe Head has 350-ps risetime and an input impedance of 100 KΩ paralleled by 2.3 pF. The type S-3 is designed to measure high impedance signal sources and is easy to use when probing into miniature circuits.

25-ps Pulse Generator

The new Type S-50 Pulse Generator Head has a 25-ps risetime and features high resolution, 35-ps TDR measurement when used with the Type S-4 Sampling Head. Powered by the 3S2 Plug-In or Type 285 Power Supply.

18 GHz Triggering

The new Type S-51, 1-to-18 GHz trigger countdown unit provides stable oscilloscope triggering to 18 GHz and displays to 14 GHz and above with the Type S-4 Sampling Head. Powered by the 3S2 Plug-In or Type 285 Power Supply.

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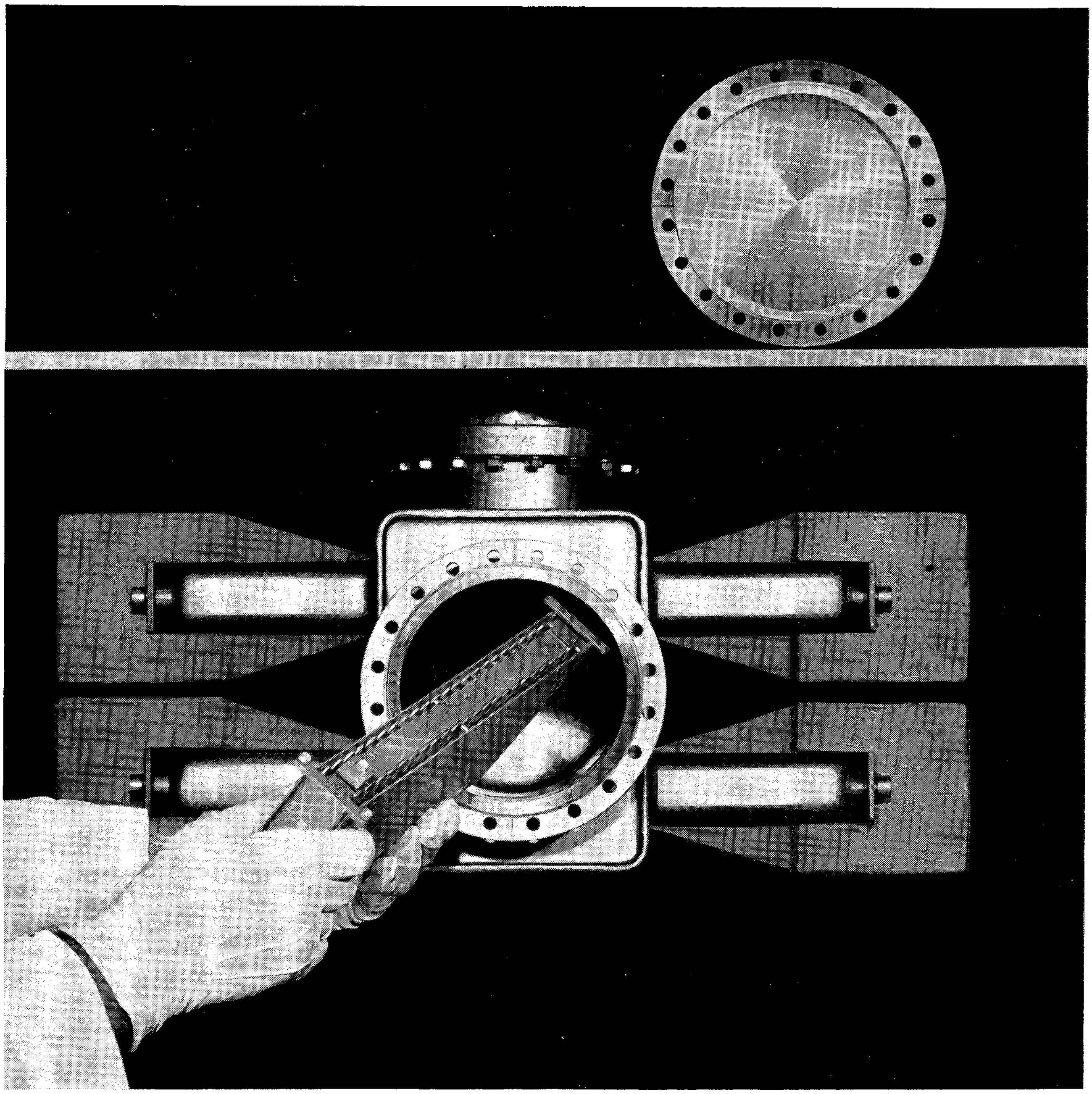
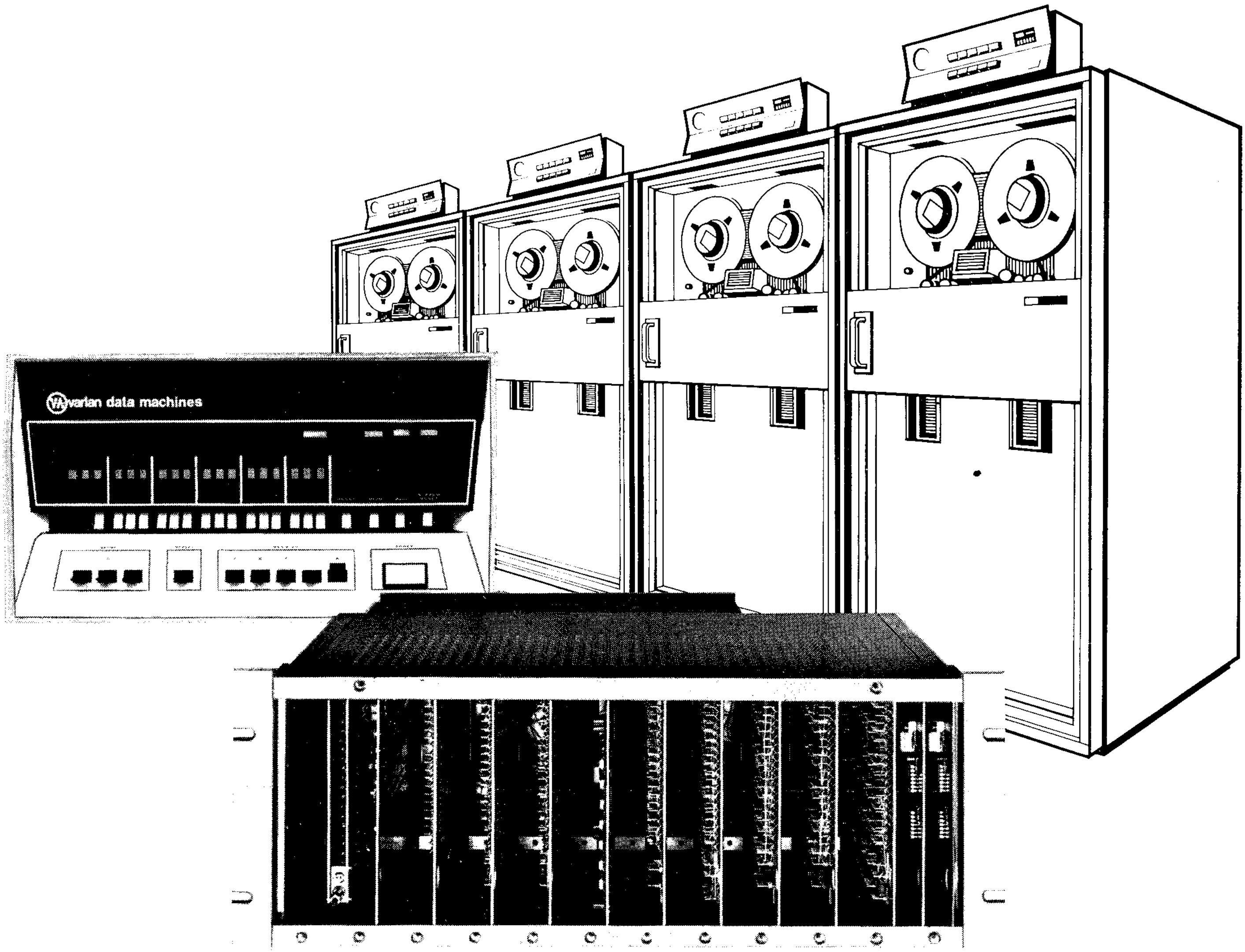


HOW TO MAKE A BIG COMPUTER SYSTEM FROM A TINY $ 10.000 MACHINE?



Simply attach several magnetic tape units to your real time computer using a SEN interface

Displayed above is an interface to the VARIAN DATA MACHINES 620 i computer designed to control up to four (4) IBM 2400 series magnetic tape transports. This interface has an elaborate and convenient data transfer logic. Data flow to or from the memory is under control of two Address Registers (Trap Transfer). To write a record, for example, the initial and final addresses of the memory portion from which the data has to be taken are set into the corresponding registers. Then a write instruction is given and the write process goes along without further program control. The end of each tape operation can be signalized by an interrupt.

Ask SEN to know more about this interface and to see how it will boost the usefulness of your computer and ease the work of your programmers.

SUMMARY OF SPECIFICATIONS

- **7 track IBM Recording**
- **High or Low Density**
- **Interface assembles BCD or binary characters from machine words (either 16 or 18 bit machine words)**
- **8 instruction codes for Read-Write-Tape motion operations**
- **8 instruction codes status sensing**
- **3 instruction codes for the Memory Address Registers**
- **Interrupt available at the end of each tape operation**

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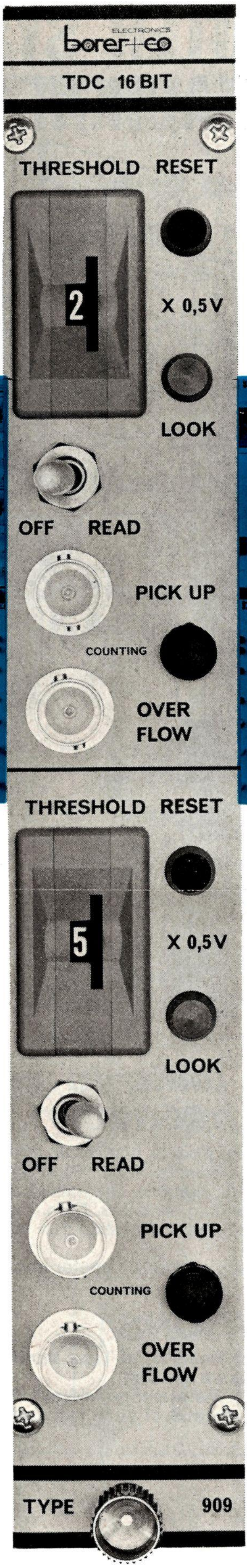

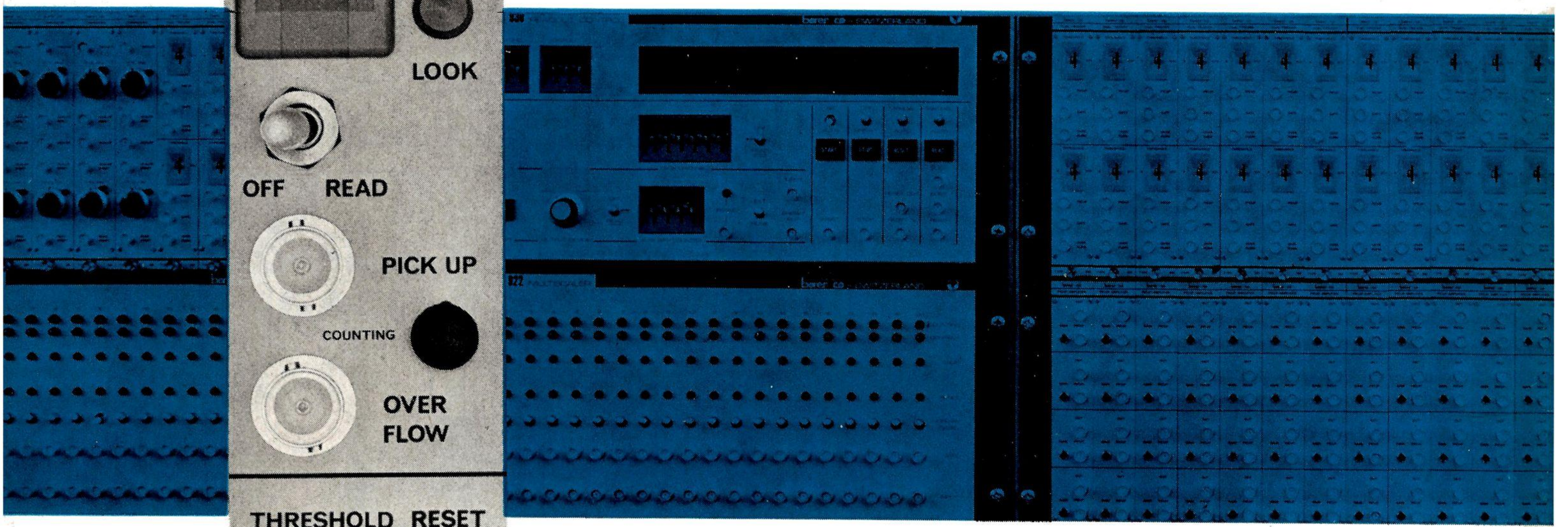

Time to Digital Converter 909

The TDC 909 consists of two independent channels for digitizing the sonic transit time of spark chambers. It consists of a special discriminator input-circuit giving low jitter triggering of the subsequent 16 bit binary scaler, which counts the pulses from a clock-generator with a maximum speed of 20 MHz. The threshold of the input-discriminator is variable from 0,5 to 4,5 Volt in steps of a 0,5 Volt. For multiple-spark-detection with wire-spark-chambers, a special overflow-output is provided, by passing the second and all the following pick-up signals, which can be used to trigger second or further channels. In this way there is no limit to the multiple-spark-detection by switching TDC's in cascade. The double-spark-resolution is 0,5 μs or 2,5 millimeters for wire-spark-chambers. Using the LOOK-button the contents of this 16 bit binary scaler are displayed on the central control unit in decimal form.

The HIDAC Data Acquisition System is designed for collection of all data in experimental high and low energy nuclear physics. Many special units are available for particular applications, such as recording of data from spark chambers, Hodoscope-arrays, time-of-flight measurements, pulse-height information and counting-rates up to 100 MHz. This equipment was conceived from the many special units over the last few years, together with the latest requirements for ON-LINE control. Our programme does not only consist of a single component for the system, but we have a fully integrated range from spark chambers to interface of computers. We do not claim to have developed this system entirely ourselves, but with the help of our many customers it therefore covers most the requirements in the field.

On the left one the modules is introduced.

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