CERN COURIER

No. 2 Vol. 11 February 1971

European Organization for Nuclear Research

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 being commissioned. Scientists from many European Universities, as well as from CERN itself, take part in the experiments and it is estimated that some 1200 physicists draw their research material from CERN.

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 3000 people and, in addition, there are over 650 Fellows and Visiting Scientists.

Twelve European countries participate in the work of CERN, contributing almost 350 million Swiss francs in 1971 in proportion to their net national income.

A project to construct a 300 GeV proton synchrotron on land adjoining the existing Laboratory, so as to provide first class research facilities in this field in Europe through to the end of the century, is awaiting authorization by the Member States.

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Cover photograph: ISR control room, 27 January, 13.40 h. The historic moment when Kjell Johnsen announced that the experimental teams watching two of the intersection regions had observed proton-proton interactions in colliding beams for the first time. (CERN/PI 248.1.71)

Comment

The last few weeks at CERN have been lived in a state of unaccustomed euphoria. At the end of January came the first operation of the Intersecting Storage Rings. Three weeks later came the go-ahead for construction of the 300 GeV accelerator. Both events had many years of hard work and keen anticipation behind them and arriving so close together, they have set up a resonance. Our more stable readers will have to excuse us letting our hair down and projecting some of the excitement we have experienced.

In the early afternoon of 27 January the ISR construction team knew that they had in the bag the success of the ISR as a machine where colliding proton beam physics can be done. Months ahead of schedule, they have stacked and stored high intensity beams with very low decay rates. They have seen the last major hurdle (the possibility of serious beam loss resulting from the effect of one beam on the other) pass beneath them. They then knew that in a few month's time they will be able to provide the high energy physicists with colliding beams of a quality entirely adequate for the first series of experiments.

Never before in accelerator history has commissioning of a machine gone so smoothly, despite the fact that the ISR is the most complex machine ever built and, in the sense of doing something entirely new whose successful operation could not be guaranteed, is among the most adventurous ever built.

To be with the jubilant physicists that day when they were clocking up particles coming from interactions in the colliding beams was a rare experience. Not every day does excitement break through the surface so openly. They were the first people ever to see particle interactions, produced in a controlled fashion, involving an interaction energy of about 30 GeV (equivalent to observing interactions at a 500 GeV conventional accelerator). A few weeks later, with beams of 22.5 GeV in each ring, interactions at an energy equivalent to over 1000 GeV were detected. Only in rare, unpredictable, observations of cosmic rays has this sort of phenomenon been seen before. Now we can produce them in the laboratory.

Hats have been raised all round to a great achievement involving mastery of accelerator physics, superb engineering, meticulous planning and organization, top quality work from manufacturers throughout Europe, and another shining example of European collaboration.

On 19 February, European collaboration was again manifest when the large majority of the Member States expressed their continued faith in CERN in approving construction of the 300 GeV accelerator. To reach this decision has been an uphill struggle for a complex mesh of reasons but now it is through and the work can really begin.

With the 300 GeV as well as the ISR European high energy physics is now guaranteed world-class instruments for its research through to the end of the century. CERN, in the process, has taken on no small weight of responsibility. First, of course, there is the responsibility to the Member States to provide the research facilities within the conditions laid down. Then there is the responsibility to European physicists.

The high energy physicists throughout Europe have for many years given top priority to the 300 GeV project in many cases with the realization that this would severely limit the development of their national resources. This faith in CERN must be justified in ensuring that, with the incredible range of research facilities concentrated in this one place, we draw out the maximum in top quality physics.

First colliding beams

On 27 January colliding beams were achieved at the Intersecting Storage Rings for the first time. We take up the story two days earlier when Ring 2 was brought into action. (To avoid repeating too many detailed explanations of the processes involved, we refer readers back to vol. 10 page 344 where the first operation of Ring 1 is described.)

By 25 January, Ring 2 had reached about the same state as Ring 1 when it was tested in October of last year. It had not been completely baked out, so the vacuum pressure was an average of about 8×10^{-10} torr, and the clearing electrodes, to sweep up the electrons coming from ionization of the residual gas, were not in action. Nevertheless everything that was necessary for operation was ready.

The history of Ring 1 repeated itself almost exactly. The first beam (2 bunches of protons from the PS) was injected at 19.47 h and went round and stayed going round, 3.5 mA circulating. At 20.20, 15 mA were injected and the r.f. accelerating cavities were brought on. The protons were trapped with high efficiency. Q values and the closed orbit were measured and proved to be in excellent agreement with prediction. Also as with Ring 1, the rise in pressure at the r.f. cavities was observed when they were operating with circulating beam. At 21.20 h stacking was tried and the circulating current built up to 370 mA. The peak current of 720 mA was stacked at 22.32 h. As opposed to the low decay rate of the low intensity beams, the high intensity beams decayed rapidly. This again repeated Ring 1 experience where the rapid decay was cured by better vacuum and the clearing electrodes (as described in the January issue page 11).

This then was the state of the machine when, on 27 January, it was decided to go for colliding beams with both rings in action — Ring 1 bouncing with health having stored currents as high as 3 A with good lifetimes, Ring 2 at least standing on its own feet and only needing a little easily administered medicine to be as healthy as its partner.

The run began at 10.00 h with the proton synchrotron making available 4 of its 20 bunches per pulse to the ISR at a momentum of 15.3 GeV/c. The excitement started shortly after mid-day. A very clean stack built the current in Ring 1 to 930 mA. After a few minutes, this dropped abruptly to 586.6 mA and everyone swears they didn't touch a button. Then the miracle started. That current didn't change for more than an hour. At 14.30 h, well over two hours later, the monitors were reading 586.5 mA proving at least that they hadn't got stuck.

So good were the conditions in the ring that hardly a measurable proton was lost. The decay rate was 5×10^{-8} per second corresponding to a half-life (the time for the current to fall to half its value) of many months. One wisecrack was that the ISR had now made itself independent of the PS shutdowns. Perhaps only an accelerator specialist can appreciate the atmosphere in the control room at the realization of the perfection that had been achieved.

But meanwhile an even more significant event occurred. At 13.26 h a single shot from the PS was fired into Ring 2 and 14.7 mA were left circulating. The beams were colliding at the eight intersection regions around the machine. The one remaining worry was that the presence of the big beam in Ring 1 would cause serious loss on the small beam in Ring 2. No such noticeable beam-beam interaction was observed. This was the moment that the ISR team knew that they were home and dry. They had proved, via Ring 1, that they could build big beams and hold them; now the last remaining fear that they would not be able to deliver a usable machine for physics was swept aside. For them, watching the monitor of the current in Ring 2 recording negligeable decay was the moment of glory.

Crowding close on top of this came the news from the groups of physicists who had their eye on the intersection regions. At first tentatively, and then with confidence, they fed through to the control room the information that they were recording particles coming from collisions in the intersecting beams. At about 13.40 h, Kjell Johnsen moved to the microphone in the control room to announce the first ever observation of proton-proton interactions in colliding beams. Doing the sums, with protons of 15.3 GeV/c in each ring, tells us that what was being seen was equivalent to what a conventional accelerator of 500 GeV could produce. Such phenomena had never been produced in a controlled fashion on earth before. The ripple of applause which ran through the control room can be interpretated as a thunderous cheer from people more ebullient than the ISR team.

Before going down to have a look at what was going on at the intersection regions, let us stay in the control room to record, in random order, a few other important observations of the behaviour of the beams which were made during the day.

One series of experiments was to test ability to shape a beam which is needed particularly to provide clean conditions for the experiments with well defined beams passing through one another. This is important first of all so that the experimenters will be able to locate more precisely the source (in the interaction region) of the particles they are observing. Also when there are far less protons going astray, there is less confusion of the detectors with particles coming from interactions not occurring in the col-

Control room scenes.

lision region. (Recording of particles which are not the ones being looked for is called 'background' or accidental counts.)

Beam scrapers, whose name explains their function, were used to trim the beam in the horizontal direction and some improvement in background was observed. Achieving ideal conditions needs further study. More effective was scraping in the vertical direction by moving the beam dump block into the vacuum chamber aperture. On one occasion this reduced the background by an order of magnitude. Essentially the experiments proved that it is possible to shape the beams.

At 18.00 h, 20 bunches from each PS cycle (as opposed to 4 previously) became available and the stacking of an intense beam in each ring was attempted. The first stacks were of about 2 A in Ring I and 86 mA in Ring 2. The particle counting rates at the intersection regions jumped up immediately.

A variety of conditions were achieved and studied during the next six hours. The highest combined currents were 2.2 A in Ring I and about 1.7 A (falling fast) in Ring 2 though the beam quality then was not particularly good for high counting rates. The highest counts were obtained with 2.19 A in Ring I and 0.33 A in Ring 2. Under no beam conditions were any effects which could be ascribed to beam-beam interaction observed.

In both rings an intriguing phenomenon has been found which has been called the 'brick wall' effect. (The name comes from a report on the commissioning of the rings that Kjell Johnsen gave during a meeting of the CERN Board of Directors. Describing the encouraging results obtained up to then in Ring I, he fed in his usual note of caution by saying that we shouldn't be too confident as

1. CERN 137.1.71

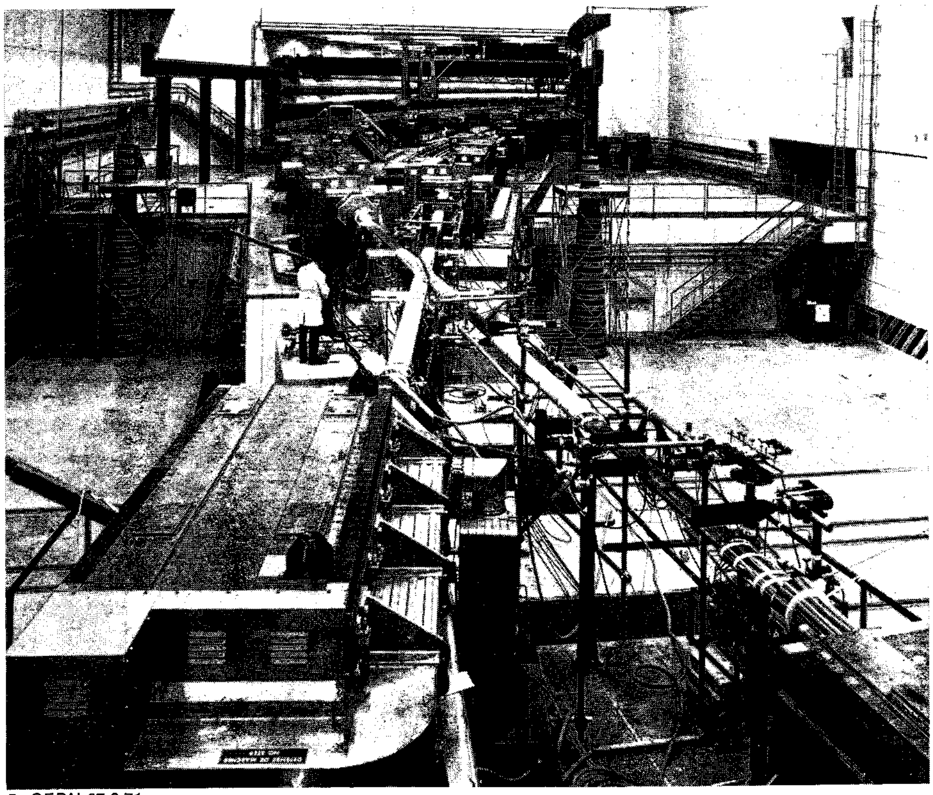
2. CERN 182.1.71

3. CERN 205.1.71

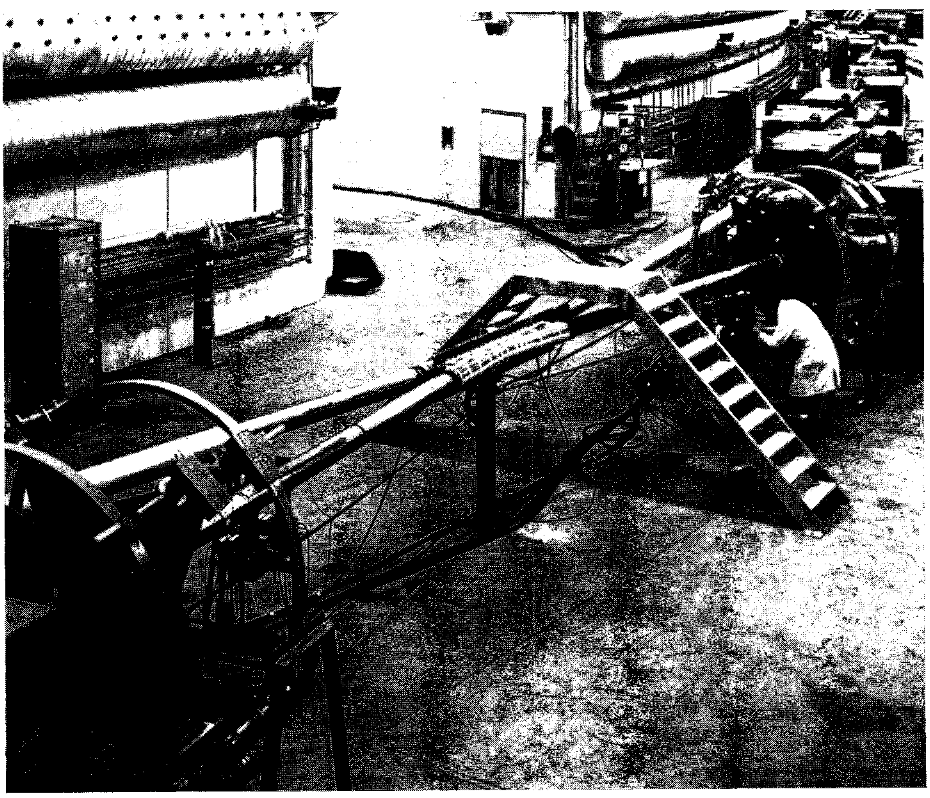
4. CERN 159.1.71

5. Intersection region I-4. Above the beam pipe on the right can be seen counters which detected charged particles emerging from interactions in the colliding beams. An equivalent arrangement of detectors is below the other beam pipe towards the top of the photograph.

6. Intersection region I-5. Detection was done here using larger counters arranged in quadrants around the beam pipes (black star-shapes in the photograph). It is estimated that a detection efficiency of around 50 % was achieved. These counters may be left in place for some time to monitor luminosity.



5. CERN 37.2.71



6. CERN 271.1.71

we might run into a brick wall when we reached a current of 2 A. That very night, at a current of just over 2 A, a brick wall was encountered — it was impossible to stack higher currents !) On 27 January, the brick walls stood at about 3 A in Ring I and 1.9 A in Ring 2.

The effect occurs as follows. Feeding in successive pulses from the PS, protons can be stacked steadily up to the brick wall current level and when this is reached the current drops abruptly by about 30 %. Pouring in more protons builds the current again up to the brick wall followed by the same abrupt fall. Just before the end of the run the best clue yet to the nature of the effect was obtained by 'scanning' the beam so as to find out how the stacked protons were distributed in terms of momentum. Scanning both before and after hitting the brick wall showed that it is the lower momentum particles that are lost.

Understanding and solving the brick wall problem will be one of the vital steps in the climb towards still higher stacked beam currents.

Counting the collisions

In two places, one near intersection region I-4 the other near intersection region I-5, teams of physicists, happy as children on Christmas morning, were clocking up interactions in the colliding beams.

At intersection region I-4 a team, which has one or two physicists from practically all the groups which are now preparing experiments to begin at the ISR later this year, had assembled a detection system at very high speed (a day and night between the coming into action of Ring 2 and the run of 27 January). It consisted of three counters positioned above the downstream arm of Ring 1 and three counters positioned below the downstream arm of Ring 2 (photograph 5).

When beams were first established in both rings around 13.30 h the counters recorded, in coincidence (both sets of counters firing at the same time), charged particles which could be distinguished with high probability as coming from colliding protons in the intersection region. Ten events were observed in 640 s whereas only 0.3 accidental counts were expected in the same period.

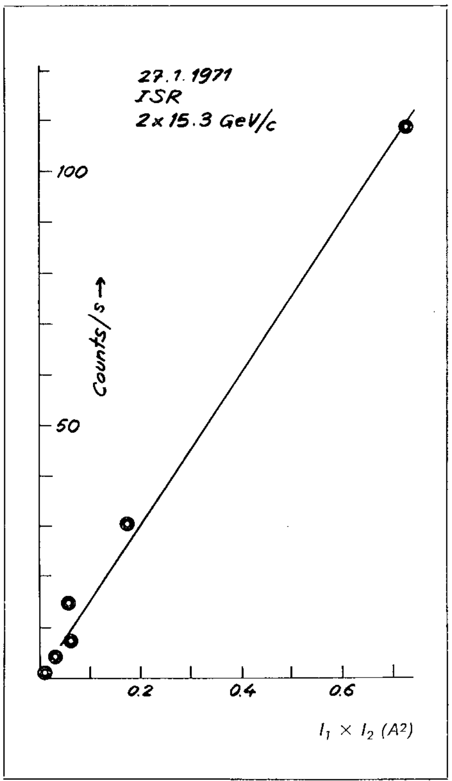
When the high beam currents were established the counting rate increased considerably. With about 2.5 A in Ring 1 and 23 mA in Ring 2, 105 coincidences were recorded in 1400 s while the measured number of accidentals was 11. When the beam in Ring 2 was dumped both counting rates fell to zero over 100 s. The measurement was repeated with 2.2 A and 80 mA and 212 coincidences against 72 accidentals were recorded in 1000 s. The results increased roughly as the product of the two currents as expected.

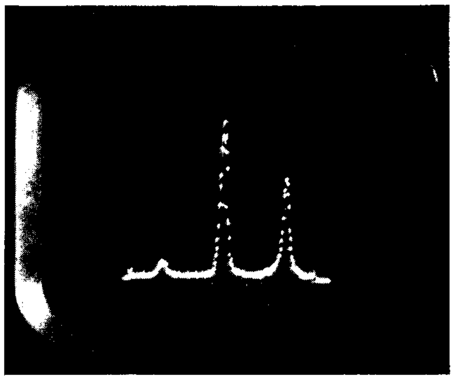
At intersection region I-5 another team had set up discs of scintillation counters with an internal diameter of 170 mm, closely surrounding the circular vacuum chamber, and an outer diameter of 800 mm (see photograph 6). Each disc is divided into quadrants giving separate signals so that coincidences from charged particles flying out from a colliding beam interaction in exactly opposite directions can be more precisely distinguished. The calculated efficiency of this detection system to record collisions is close to 50 %.

When colliding beams were first established, events were clocked up at a rate of one per second, the rate of accidentals was a factor of 20 smaller. For the rest of the day the system ticked away merrily reaching a peak of 110 counts per second under the conditions mentioned above. The graph of counts per second against the product of the beam currents (shown at the top right of this page) which it was possible to draw from the I-5 results, has a slope of 150 counts/s A^2, in rough agreement with expectation.

By a lucky chance, which had not been planned, oscilloscope traces of the counts in the I-5 detectors produced absolutely clinching evidence that we were seeing what we wanted to see. The system recorded as 'coincidences' what the counters were seeing over a (comparatively) long time interval (± 50 ns). Thus any charged particles passing through both sets of counters within this time interval were counted. However the electronics were arranged to sift the events out over the time interval so that the centre peak records true coincidences such as would come from the interaction region where emerging particles take the same length of time to reach each set of counters and fire the counters in exact coincidence. Charged particles produced upstream in each beam pipe, by a proton hitting residual gas molecules or the vacuum chamber wall, could fly through each set of counters during the time for which they would count a coincidence, but since they take about 35 ns to cross from one set to the other, the electronics could distinguish them. The two smaller peaks on either side are the result of this distinction and, as the beam conditions changed, their height varied just as this interpretation would predict.

7. and 8. Results coming from the detection system in intersection region I-5. The graph shows that a healthy counting rate, given the beam conditions, was achieved, increasing linearly as expected with the product of the currents in the two beams. The photograph shows the beautiful scope trace with its three peak structure which confirmed beyond any doubt, as explained in the article, that true proton-proton interactions (the centre peak) were being observed.





The team

Construction and bringing into operation of the ISR has been an example of excellent team-work and all 300 members of the ISR Division share the credit. We pick out here the names of the Parameter Committee which includes the group leaders responsible for the various sections of the machine. It is not our usual practice to indicate nationality but in doing so in this case we illustrate how 'European' this achievement is.

The project was led by Kjell Johnsen, Norway. The Parameter Committee consisted of :
Cees Zilverschoon, The Netherlands (deputy leader for most of the construction period until his appointment as PS Department Director); Wolfgang Schnell, Federal Republic of Germany

(r.f. system and the co-ordination of commissioning) ; George Schaffer, Federal Republic of Germany (control system and computers) ; Lorenzo Resegotti, Italy (magnet system) ; Bastian de Raad, The Netherlands (beam transport and injection) ; Simon van der Meer, The Netherlands (magnet power supplies) ; Eberhard Keil, Federal Republic of Germany (theoretical studies) ; Hans Horisberger, Switzerland (general engineering and coordination of installation); Hugh Hereward, United Kingdom (accelerator problems); Jean Gervaise, France (survey work and machine alignment); Erhard Fischer, Federal Republic of Germany (vacuum system) ; Franco Bonaudi, Italy (general layout and civil engineering, now co-ordinating support to the experimental programme) ; Hildred Blewett, USA (technical administration and budgets).

At this moment of success the team also remembers with gratitude the contributions made by the late Arnold Schoch in the early days of the project.

The end

As the end of the long run approached an inclination to partake of liquid refreshment was observed to be growing in intensity. At midnight the beams were 'dumped' for the last time on a memorable day. The Director General, Professor Jentschke, then expressed his delight at all that had been achieved and his admiration of the work of the ISR team. He had been present in the control room to share the excitement of the moment when first collisions were announced and had watched the ISR team in action for several hours. From his experience as Chairman of the Committee which has been planning the programme of experiments for the ISR, he was aware of the eagerness of Europe's physicists to begin research on this unique machine where they will have available the highest energies in the world. Now it looks as if they are going to be handed a research instrument of a quality and reliability better than they could ever reasonably have anticipated so early.

Noble sentiments having been expressed, Professor Jentschke led the way to a well-merited glass of champagne.

45th Session of CERN Council

The Council Session was resumed on 19 February under the Presidency of Professor E. Amaldi.

At the Council Session in December 1970 the decision on the 300 GeV was left in abeyance to allow some Member States a little more time to reach a decision on participation in the project or to ease the conditions connected with their participation. The 'little more time' proved sufficient for practically all Member States to be able to join the project.

Ten countries declared their willingness to participate. They are listed here with their percentage financial contributions :

Austria	2.01 %
Belgium	3.88 %
Federal Republic of Germany	23.96 %
France	20.48 %
Italy	13.27 %
Netherlands	4.56 %
Norway	1.57 %
Sweden	4.72 %
Switzerland	3.30 %
United Kingdom	22.25 %

Denmark was unable to declare its participation at this stage but hopes to present a decision in the future. Greece was ready to support all relevant decisions but was unable to contribute financially to the project at present. The participation of Norway and Sweden is on condition that their contributions do not exceed what they would have expected to pay if all Member States were in the project. To accommodate this, no commitment will be made which would involve the 300 GeV Laboratory programme, spread over eight years, in costs exceeding 1124 MSF, as compared with 1150 MSF, for the full programme. The budget for 1971 was voted as 29.3 MSF. The percentage contributions may change at the end of this year when, as is customary every three years at CERN, the figures are adjusted on the basis of U.N. statistics of average net national income over the previous three years. However, no Member State participating in the

300 GeV project can be called on to contribute more than 26 %.

France and Switzerland will make available the necessary land for the new Laboratory (412 hectares in France and 68 hectares in Switzerland) — the stipulations regarding the use of different parts of this land have been described before (see vol. 10 page 308). Switzerland will finance the bringing of cooling water to the site. France will finance the bringing of electricity to the site. France has also announced its intention to create a secondary school available to the children of CERN staff at Ferney-Voltaire, where there will be courses in several European languages. It is hoped that primary school facilities will follow.

Doctor J.B. Adams was elected Director General of the 300 GeV Laboratory, now referred to as 'CERN II'. As from now there will thus be two Laboratories, each with its Director General, and separate budgets. When the machine is in action, the programmes will again be brought together under the responsibility of a single Director General.

Recruitement of the leaders of the design and construction groups for the new accelerator will begin immediately and it is hoped that the first construction work (for laboratory and office accommodation and the equipment assembly halls) will begin in the autumn, followed soon after by a start on boring out the machine tunnel.

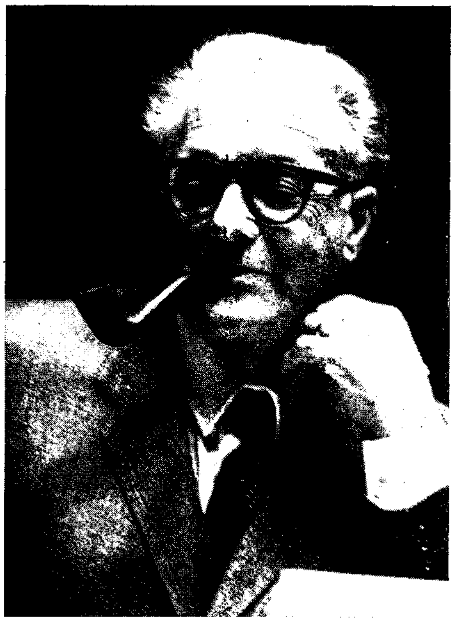
This rather dry summary of the outcome of the February Council session hides, of course, the great excitement at CERN that this important project, which has been debated for the past eight years, is at last under way.

Several speakers recorded, on behalf of the European high energy physics community, their gratitude to the Member States for supporting the project despite a sequence of internal difficulties of financial nature or relating to the complex task of assigning priorities among many competing projects calling for urgent support. The delegates to the CERN Council were thanked especially for their consistent hard work to bring about a favourable decision and for their enthusiasm for CERN from which this stemmed.

Within CERN itself three names were singled out whose contribution towards the decision has been outstanding — Eduardo Amaldi (whom we can reasonably count as 'within CERN itself') who as Chairman of the European Committee for Future Accelerators fathered the 300 GeV project, Bernard Gregory who during his years as Director General devoted a great deal of his time and energy to pushing the project forward, and John Adams whose technical and political astuteness brought the project into the form which finally won such wide acceptance.

One of the letters of participation (from the Netherlands delegation) changing hands at the Council session.

Words of welcome



Professor E. Amaldi
President of the CERN Council :

The decision taken by the CERN Council concerning the construction of the 300 GeV accelerator is of exceptional importance. It represents the conclusion of a long story that began about ten years ago, when a new long range scientific programme began to be considered for the Organization. This programme, which took its final shape in 1963, included the improvement programme of the 28 GeV proton synchrotron, the construction of the Intersecting Storage Rings, and the creation of a new Laboratory around a 300 GeV accelerator.

Today, the improvement programme has reached a very advanced stage and the first beam collisions have been observed in the ISR; but, from the beginning, the principal goal for the future of CERN has been the construction of the 300 GeV machine.

With the decision, the majority of the Member States have expressed their confidence in this Organization, which during the past years has clearly proved its technical efficiency and scientific agressivity. The magnificent way in which the ISR have been brought into action is the last of a long list of successes not only at the scientific and technical level, but also from the organizational and administrative point of view, since the construction of this unique machine has been achieved within the timescale and the budget estimated long ago. This, as well as the many scientific results obtained during the past years, fully justifies the confidence placed in the Organization by the Governments of the Member States.

The contributions of the ten countries, who have expressed their willingness to participate in the construction of the new accelerator, cover 97 % of the expenditure foreseen for the 300 GeV Programme. We are all confident that, in a rather short time, the number of participating Member States will increase further so that the unity of the Organization will be preserved and assured for the next twenty years.

The new accelerator and the facilities foreseen for its scientific utilization will provide the countries of Western Europe with the possibility of maintaining their position in the field of the study of the ultimate constituents of matter for the next ten or twenty years. Therefore, we are grateful to the Governments that have supported the project in spite of the difficulties that most of them have had to overcome and of which we are well aware.

The importance of the decision, however, should be seen not only in its scientific aspects, which are certainly of paramount importance. It has also a wider significance since it expresses the willingness to strengthen the collaboration among European countries : a collaboration which is very tight among the Member States of CERN, but which is also open to scientists from other countries whether they belong to our continent or not. With this decision the Member States have not only shown, in the most concrete form their desire that this old part of the world should keep its present front rank position in one of the most advanced fields of research, but have also endorsed this spirit of wide collaboration by deciding to develop in the most promising way a centre of research where scientists from all parts of the world have a chance of meeting as an obvious part of the very nature of their daily work.

Professor E. Rudberg, President of the European Physical Society :

The decision to go ahead with the 300 GeV machine at CERN is news which will fill European physicists with great joy. There has hardly been, in the past, a co-operative scientific venture comparable to CERN, and certainly none as rewarding, as encouragingly successful. In large measure CERN has enabled Europe to render her proper share of the effort of our time to gain insight into the structure and interactions of nuclear matter and particles.

Great expectation is attached to the new range of high energy which will become accessible to physics research. True, the years of waiting have strained our patience. But they have led, in the end, to a construction which should be more efficient than that originally proposed. Costs are still considerable, and have to be so. It would seem, however, that, rather than detracting from a nation's own resources, a scientific enterprise like CERN has the effect of stimulating the national effort to take a meaningful direction. The decision now taken is in itself a new victory for the spirit of co-operation in Europe; as such it is warmly welcomed by the European Physical Society.

Professor N.N. Bogolubov
Director of the Joint Institute for Nuclear Research (Dubna) :

We send our most sincere congratulations on the occasion of the approval of the 300 GeV programme which will open new wide perspectives in high energy physics in Europe and all through the world. We would like to take this opportunity of expressing the hope that the construction of this accelerator will contribute to the strengthening of international collaboration of physicists.

Professor R.R. Wilson
Director of the USA 200-500 GeV Accelerator Laboratory at Batavia:

I am delighted to hear the good news that the European synchrotron is going ahead. The Batavia project will benefit in many directions from the broader base provided by this new step. We are keenly anticipating the cooperation (and the competition) that Adams and his team will provide — and may they have as much fun as we are having.

Dr. T.G. Pickavance
Chairman of the European Committee for Future Accelerators :

All members of the European Committee for Future Accelerators, who represent the high energy physics community of the European countries which are members of CERN, will be delighted by the decision of the CERN Council to build the 300 GeV accelerator. ECFA urged the construction of such a machine in 1963, and ever since then the project in its various forms has been the first priority of the European high energy physicists culminating in the present 'Project B' which will unite the present and future CERN Laboratories and will be less expensive to member Governments than earlier schemes.

Many sacrifices have been made in national programmes in order to realise this new programme, but European universities and laboratories can now be assured of a place in the forefront of particle physics for decades to come. Comparable expenditure on national projects alone could never have achieved this result, and, with reduced growth rates in science budgets, Europe has had to concentrate a greater proportion of its high energy physics resources on its most important project in this field.

It is most fitting that Professor Amaldi should be the President of the Council at this time, for he was the founder of ECFA and its leader, until he gave up the Chairmanship on his appointment as President in 1970. He has worked tirelessly for the new accelerator from the very beginning. John Adams, who led the team which gave us the 28 GeV proton synchrotron and who originated 'Project B' which has brought in the majority of the CERN member countries, and his new team have our congratulations and our thanks, and will have our enthusiastic support.

CERN News

Two attractive photographs taken recently on the CERN site. Above is the main building looking unusually glamorous in the January snow. Below is an aerial view which shows a growing degree of order around the Intersecting Storage Rings as building construction is progressively finished. The water tower is now the dominant feature of the CERN site.

PS on good form

Attention has been so much centred on the commissioning of the Intersecting Storage Rings in recent months that the 28 GeV proton synchrotron has been rather overlooked. It is taken for granted by now that the PS will do what is asked of it, but its reliable performance in feeding protons to the ISR merits mentioning.

The PS got off to a very good start after its end-of-year shutdown. From the very first run it has been accelerating an average of 1.53×10^{12} protons per pulse (with a peak intensity of 1.88×10^{12} p p p). There was a problem when some split rings in the main magnet power supply began to heat up in the middle of a run to as high a temperature as 250 °C instead of the normal 90 °C. This over-heating was kept under control by additional cooling as a temporary measure (blowing in cold air), and the rings were changed before the next run. Since then there has been no further trouble.

This year's operating programme has even greater flexibility to exploit the protons to the full. For the commissioning tests at the ISR most runs will require only four bunches ejected from straight section 16 ; in this way the experimental programme at the PS can continue with little disturbance. Use of the fast kicker 13 has made it possible, over a short period, to run 4 fast ejections — from straight sections 16, 58 (twice) and 74 — in the same machine cycle, and still have long pulses on targets 1 and 8. This month slow ejection from straight section 62 has started again, supplying a new set of secondary beams.

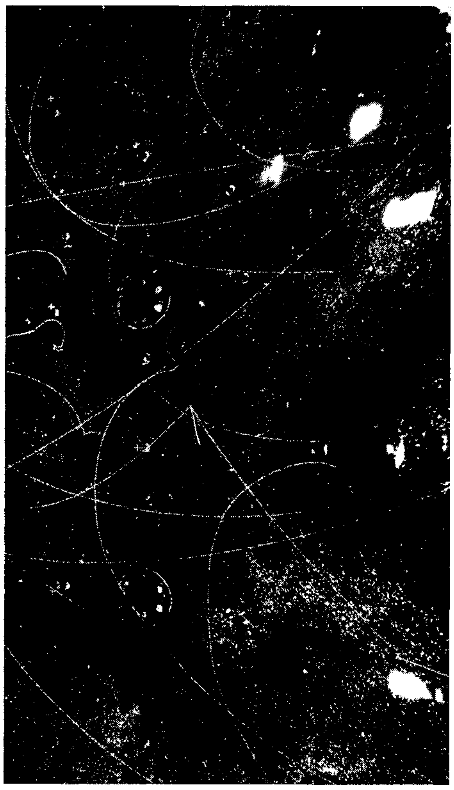
CERN 129.1.71

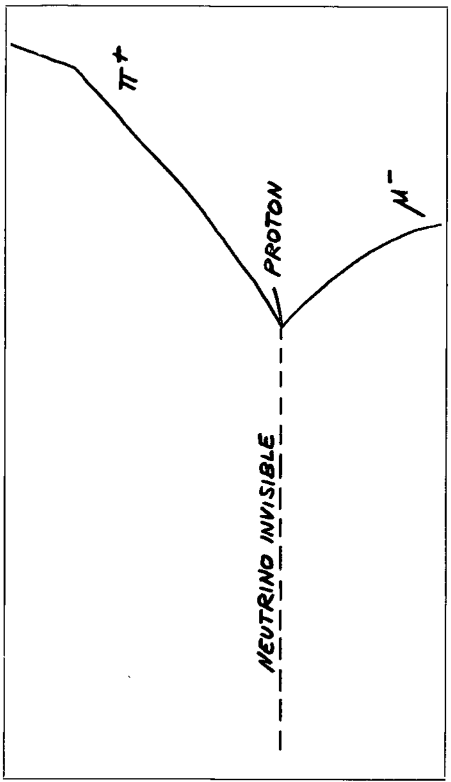
CERN 58.2.71

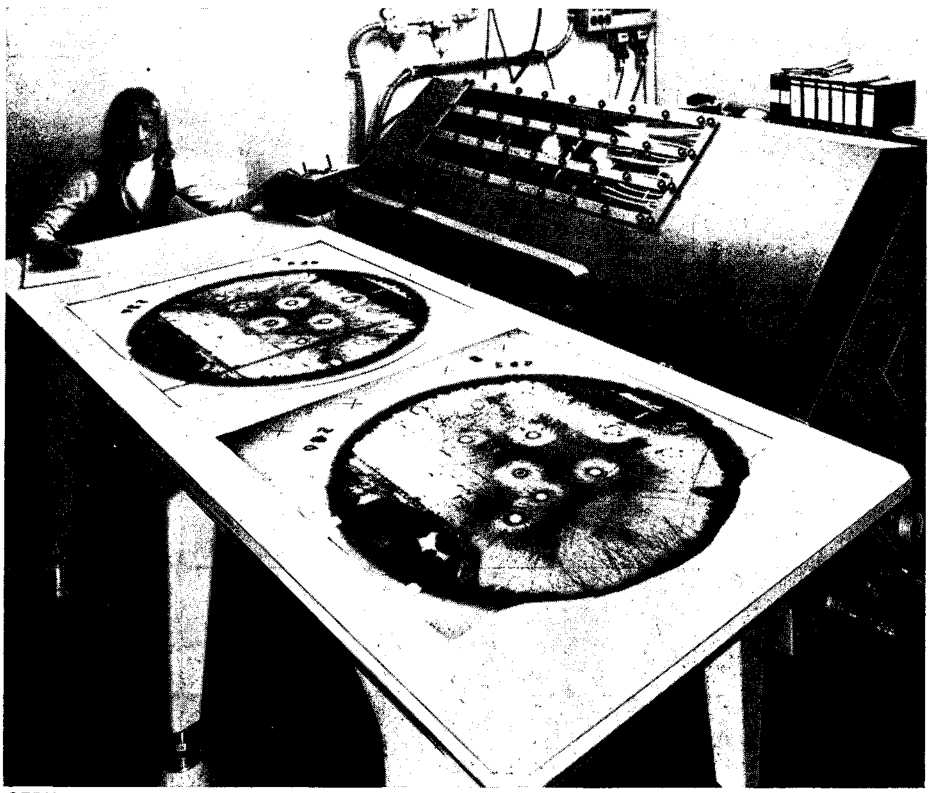
Photograph of a candidate neutrino event taken in the heavy liquid bubble chamber, Gargamelle, on 28 January. The interpretation of the event is indicated on the right. The incoming neutrino has interacted with a proton to give a muon, a pion and a proton.

Initial results from Gargamelle seem to show that the neutrino event rate is about one in twenty photographs, which represents an increase in relation to previous experiments of a factor of fifty.

Scanning and measuring of the first Gargamelle photographs using a new table specially designed to take film from the new generation of large bubble chambers.







CERN 78.2.71

Measuring first Gargamelle photos

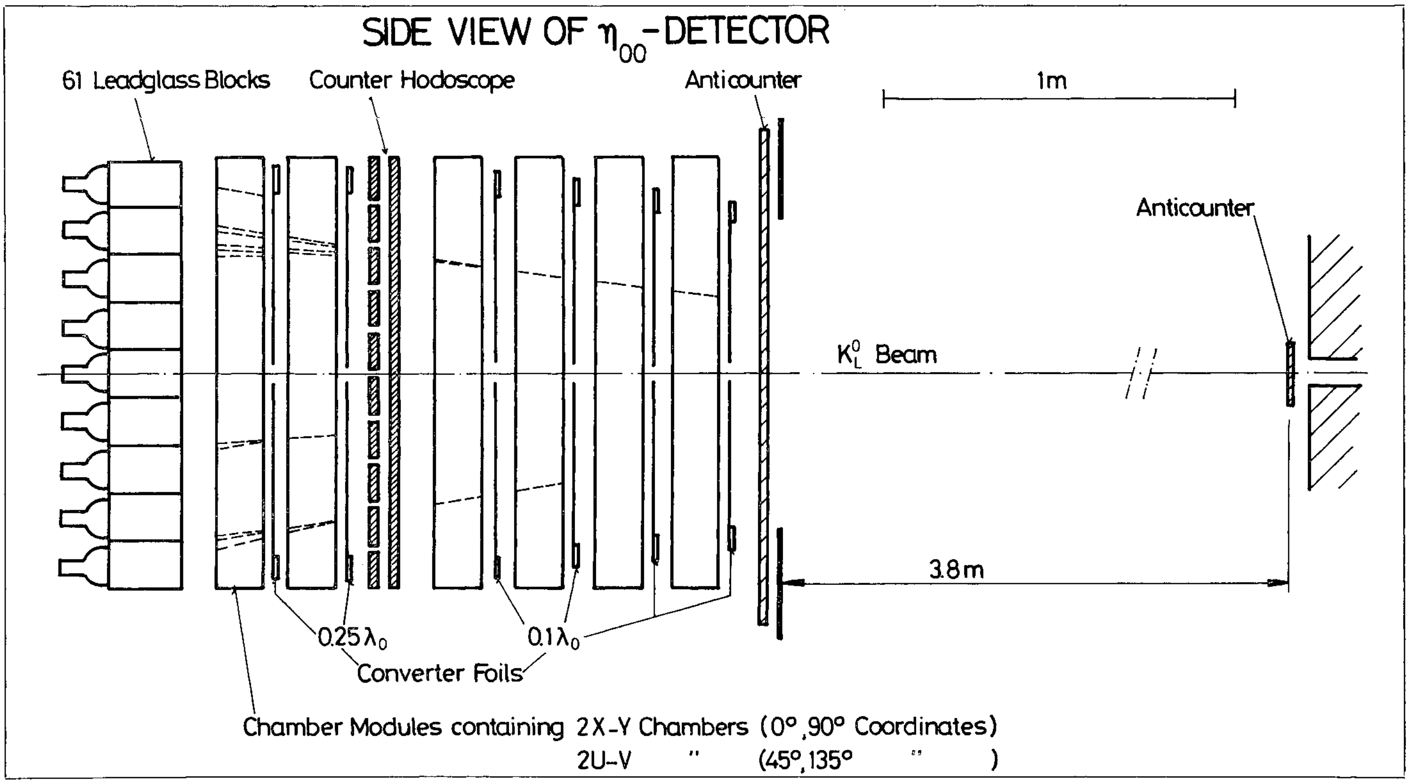
At the beginning of 1969, four European high energy physics Laboratories joined together in ordering, from SAAB, fourteen scanning and measuring tables for analysis of the photographs taken in the Gargamelle heavy liquid bubble chamber. A prototype had been built at CERN (see vol. 9, page 36). The first of four tables ordered by CERN was delivered at the beginning of December 1970 while the other three are due to follow in time to be used for the neutrino experiments due to start at the beginning of May.

Testing and first measurements are now in progress (as shown in the photograph) using the first neutrino test film taken in Gargamelle. The actual particle tracks, which are of good quality, were produced by muons which filtered through weak points in the shielding (see last issue page 13). There will be no muon leakage when then shielding is in its final form for the neutrino experiment. The small white spots seen in the projections on the table are due to the flashes, while the black ones are reflections and parasitic boiling, which will be eventually reduced.

The other centres which are acquiring tables are University College London (3), the Technical University of Aachen (3) and the Free University of Brussels (4). They also expect the tables to be delivered before the beginning of May.

Measuring eta zero zero

Since May 1970, a CERN - Aachen - Turin collaboration (P. Darriulat, J. Deutsch, M.I. Ferrero, C. Grosso, M. Holder, J. Pilcher, C. Rubbia, M. Sciré,



A. Straude, E. Radermacher, K. Tittel) has been working on an experiment in the East Hall aimed at accurately measuring parameters in neutral kaon decay. The measurement we will discuss here is that of eta zero zero — the ratio between the probability of the long-lived kaon decaying into two neutral pions and the probability of the short-lived kaon decaying into two neutral pions.

The interest in this measurement was described in some detail in vol. 8 page 242. Essentially it is concerned with trying to understand what happens in those decays of the long-lived kaon (into two charged pions or two neutral pions) which violate charge-parity (CP). One possible interpretation is that the long-lived kaon is converted into a short-lived kaon (perhaps under the influence of a 'superweak' force) violating CP. It is the short-lived kaon which then decays into two pions.

If this is indeed the sequence of events then the parameter eta zero zero should be equal to the parameter eta plus minus (the ratio between the probability of the long-lived kaon decaying into two charged pions and the probability of short-lived kaon decaying into two charged pions). This is because all the decays observed would in fact be decays of the short-lived but some of the short-lived would have been produced from conversion of long-lived kaons.

The measurement of eta zero zero is no easy matter. Neutral pions are more difficult to get hold of than their charged counterparts and, particularly, it is difficult to be sure of recording only the decays into two neutral pions rather than recording just two of the neutral pions from the three pion decays which occur about a thousand times more frequently. There was great confusion when the first measurements were made and a variety of conflicting values for eta zero zero were quoted. By now the results seem to be settling down close to the value of eta plus minus. The present experiment aims to push the measurement of eta zero zero to high accuracy.

Measurements are made under two different experimental conditions. In one, the decay of the long-lived kaon into two neutral pions is observed directly, while in the other the same decay mode is observed for the short-lived obtained by 'regeneration' (in a copper block). The two sets of measurements are standardized in relation to one other by recording the decays of the long-lived into three neutral pions (identified by the simultaneous presence of six gammas in the detector) which occur.

All charged particles are filtered from a beam of secondary particles produced in a target by the slow ejected proton beam from the PS. Only neutral particles remain, gammas are eliminated by conversion to electrons on passing through lead plates.

The kaon decays are detected at third hand. The decay into neutral pions is followed by neutral pion decay into gammas which, in lead plate, convert into observable electron-positron showers. From this is deduced the direction and energy of the gammas and, working back, it is possible to calculate the mass and the original direction of the original kaon. The electron-positron showers are observed in spark chambers.

Energy measurements are obtained from total-absorption, lead-glass Cherenkov counters, specially developed by the group (see cover of CERN COURIER, July 1969), with an accuracy of ± 5 %. The Cherenkov light is transformed by a photomultiplier into an electrical signal proportional to the energy of the gamma.

An event is recorded when the following three conditions are satisfied :

1) no charged particles enter the detector ;

2) at least two gammas have converted in the lead plates (detected by means of a hodoscope placed among the wire chambers) ;

3) at least three gammas have converted and are detected at the same time in the Cherenkov counter system.

The event of interest is identified at a rate of about one every four hours under normal PS operating conditions, Schematic layout of the detection system where the eta zero zero parameter in the decay of the long-lived neutral kaon is being measured to high accuracy.

The distinvar in action during measurements on the foundations for the 3.7 m European hydrogen bubble chamber.

Below: Assembly of the shield for the chamber. When it is completed it will have a diameter of 12 m and a height of 10 m surrounding the chamber assembly which itself will be about 4.6 m diameter and 2 m high.

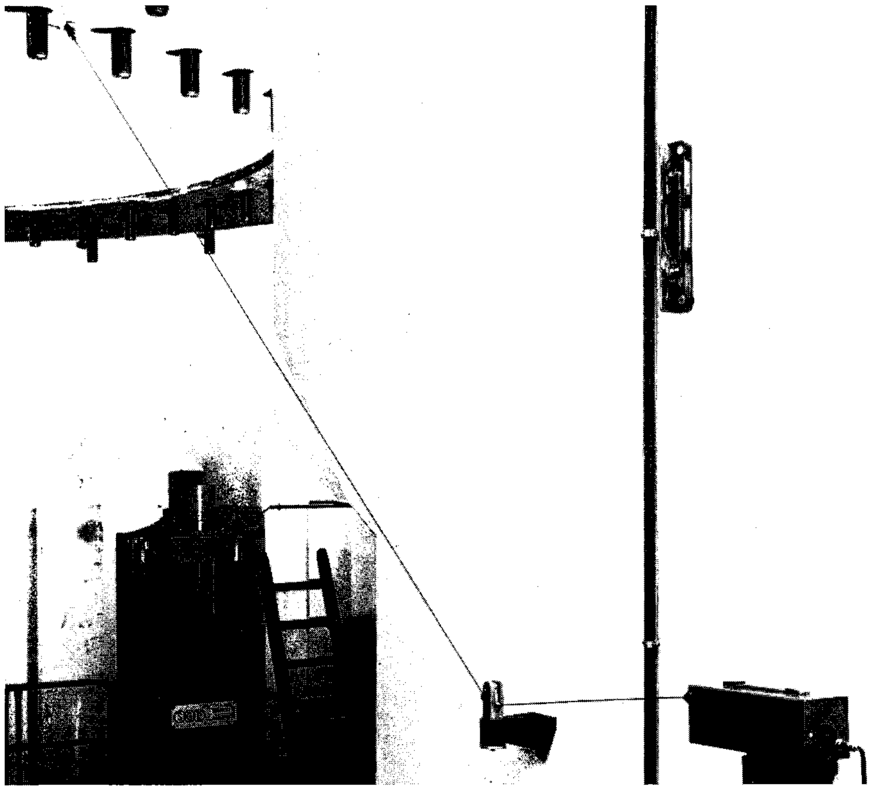
so that, during a scheduled eight weeks of data-taking, a total number of between 100 and 150 events is expected.

BEBC foundations nicely settled

In CERN COURIER vol. 10 page 40 we described the special care taken in laying the foundations for the European hydrogen bubble chamber. The fact that construction of the foundations is now complete does not mean that this special care has been relaxed. Measurements were recently made to learn the extent of deformations undergone by the projecting concrete raft which will support some eight hundred tons (a load consisting of part of the shielding, the vacuum tank, the body of the chamber, the cryostats, the magnet coil dewars and the main support structure).

As was expected, the deformations are only slight and at first sight would seem almost impossible to measure. However the CERN survey team are accustomed to working to extremes of accuracy and find no difficulty in dealing with 'split hairs'. Measurements were made at three points on the support using a Distinvar. This automatic measuring device was designed at CERN (see vol. 7, page 250) and comprises an electronic balance connected to an invar wire. It is capable of accuracies of better than one part in a million.

Deformations of 16, 24 and 40 μm (measured to an accuracy of ± 5 μm) were detected with a loading of 155 tons during the tests, and these results agree closely with the theoretical calculations. The deformation should be even less when the lower ring of the shielding is made integral with the concrete raft.



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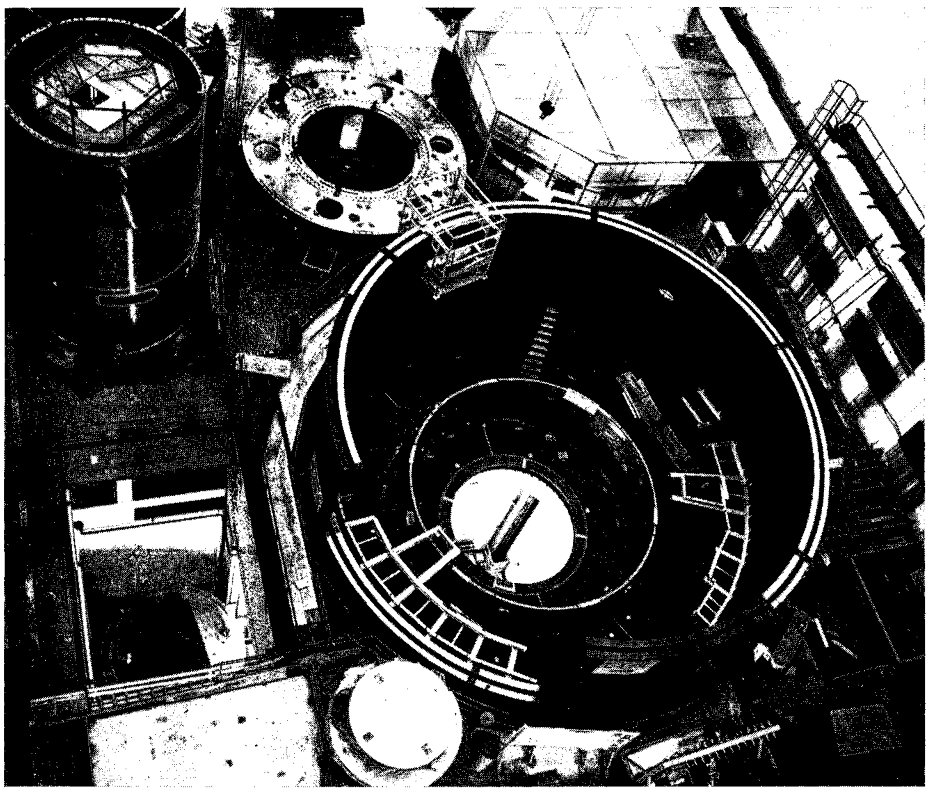

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Around the Laboratories

JAPAN
10 GeV synchrotron

These brief notes present the major features of the 10 GeV proton synchrotron to be constructed at a new research centre at Tsukuba, about 60 km north east of Tokyo, under the leadership of S. Suwa.

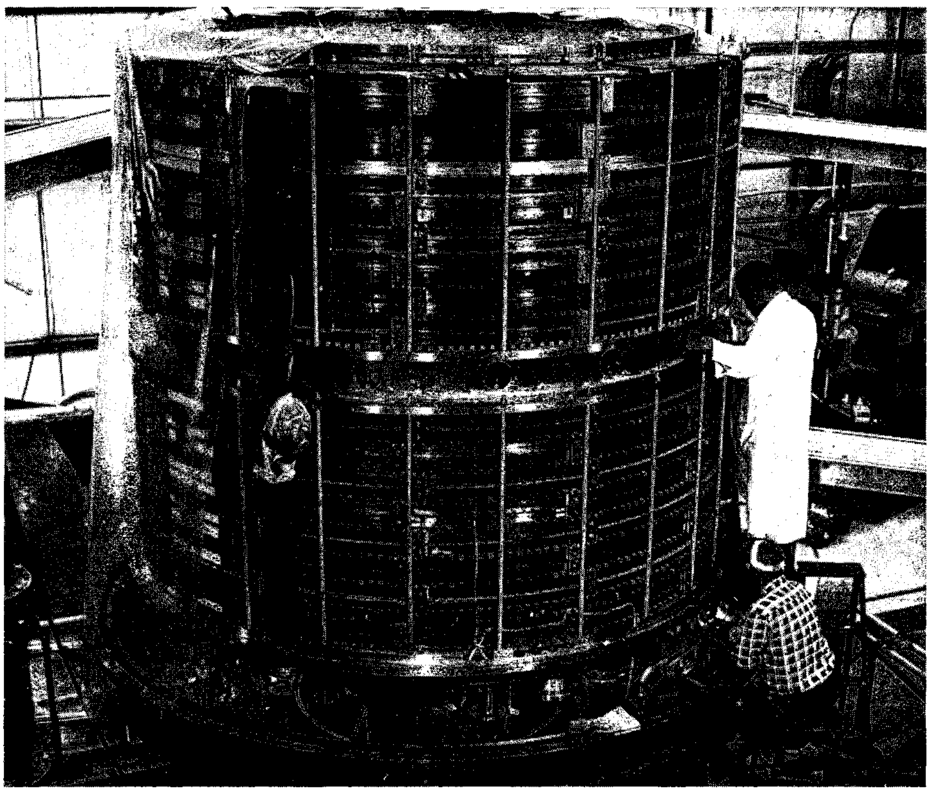
A Laboratory to house a 40 GeV proton synchrotron had been under discussion in Japan for many years. Its design, worked out at the Institute for Nuclear Study at the University of Tokyo, was presented at the Cambridge Accelerator Conference in 1967 (see vol. 7 page 201). In August 1969 the Scientific Affairs Council of the Ministry of Education recommended that a project about a quarter of the scale of the initial proposition should be supported (at a total cost of about 8000 million yen). In 1970 the Ministry of Education assigned money for new detailed studies which have concentrated on a 10 GeV machine.

Several designs, comparing slow-cycling to rapid-cycling machines, combined-function to separated-function lattices, etc., were investigated and their corresponding costs drawn up. In conclusion detailed parameters were worked out for a 10 GeV slow-cycling, combined-function synchrotron fed by a 500 MeV fast-cycling booster. The booster will itself be fed by a 20 MeV linear injector giving a current of 100 mA.

The booster diameter will be 10.4 m with magnetic field rising from 0.2 T at injection to 1.2 T at 500 MeV. The r.f. frequency will swing from 1.9 to 7 MHz, the peak energy gain per turn being 6.1 keV. The maximum repetition rate will be 20 Hz and, in normal operation, it is intended that eight pulses from the booster will be fed into the main synchrotron ring on each cycle.

In the main ring, 83 m in diameter, the magnetic field will rise to a peak of 1.7 T corresponding to 10 GeV. There will be 20 normal cells (FOFODODO), giving 80 magnets in all, with four long straight sections of the Collins type. The magnet lengths are about 1.6 m with apertures 120 $\times$ 64 mm^2. The r.f. frequency will swing from 7 to 9.2 MHz, the peak energy gain per turn being 28 keV.

The space charge limit is calculated as 2.1×10^{13} protons per pulse and it is hoped to accelerate between 1 and 2×10^{13} per pulse. The pulse repetition rate without flat top would be two cycles per second.



Finishing touches to the superconducting magnet for the 7 foot bubble chamber at Brookhaven. The magnet has been powered to 2.8 T.

(Photo Brookhaven)

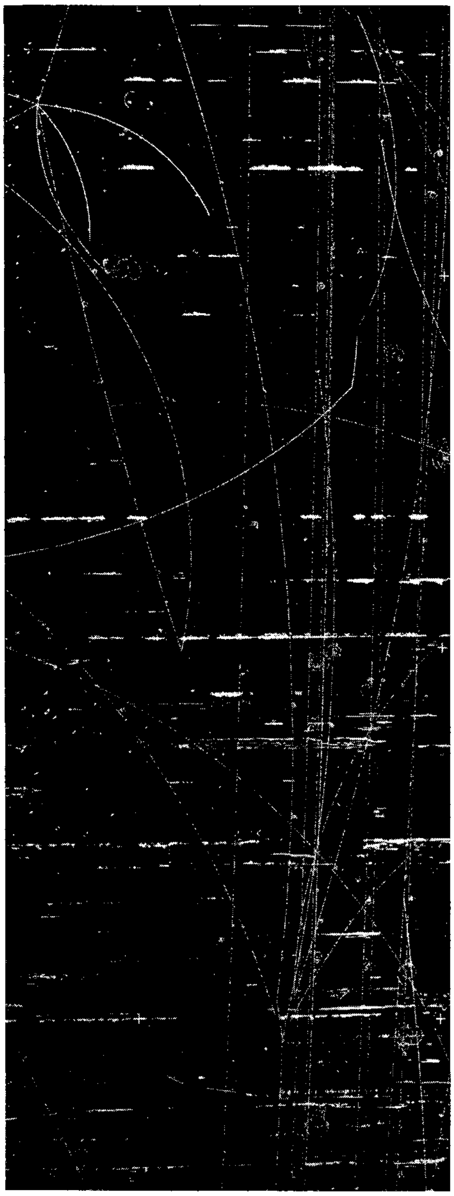
BROOKHAVEN
Superconducting magnet fully powered

It was announced at the beginning of February that the large superconducting magnet for the 7 foot hydrogen bubble chamber (described in vol. 9 page 12) at the Brookhaven National Laboratory has been powered to give a peak field very close to the design figure of 3 T. It is the largest air-cored superconducting magnet in operation having dimensions of 2.44 m internal diameter, 2.80 m external diameter and a total height of about 2.4 m.

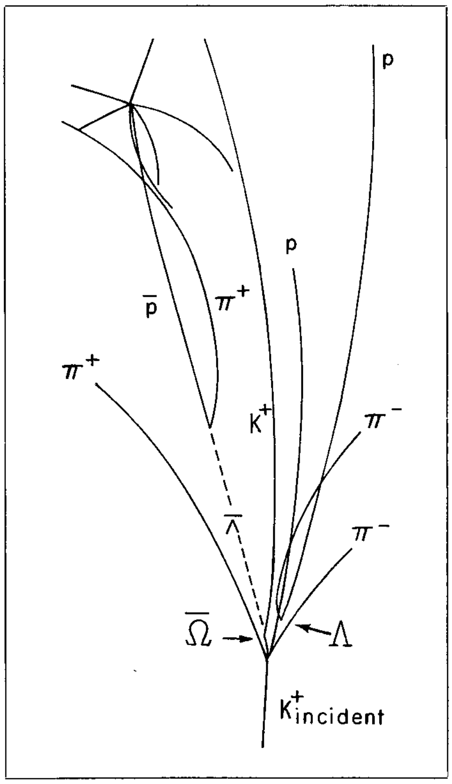
The coils consist of 16 double pancakes in two coil halves — 32 layers of 45 turns per layer. The pancakes are built up of four strips — the superconductor (six niobium-titanium filaments embedded in a copper ribbon 50 mm wide and 2 mm thick), mylar insulation, stainless steel strengthener, and helium cooling channel.

Commissioning of the magnet has met its fair share of difficulties but these are now resolved with successful operation at design levels. The coils were powered with 5460 A giving a peak field of 2.82 T.

The total cost of the magnet and its refrigeration system was $ 500 000 which is comparable to the capital cost of an equivalent iron-cored conventional magnet. However from now on considerable savings will accumulate since the superconducting magnet requires only a few kW of power in operation (costing between $ 1 and $ 1.5 per hour) compared with many MW which would be required for a conventional magnet (costing over $ 100 hour). A programme of neutrino physics is planned for the bubble chamber.



The photograph, taken in the 82 inch bubble chamber (filled with deuterium) at the Stanford Linear Accelerator Centre, from which a team of Berkeley physicists have identified the anti omega minus for the first time. The sequence of interactions is indicated below.



BERKELEY
Anti Omega identified

A team from the Lawrence Radiation Laboratory, Berkeley, announced at a meeting of the American Physical Society in New York on 1 February the identification of an anti omega minus (omega plus) from a bubble chamber photograph.

Over half a million photographs were taken in the 82 inch bubble chamber at the Stanford Linear Accelerator Centre. Electrons were accelerated to 19 GeV and aimed at an aluminium target to yield a beam of 12 GeV positive kaons. This beam was fired into the chamber, which was filled with deuterium, and the anti omega was produced in the interaction

$$K^+ + d \to \Omega^+ \Lambda \Lambda p \pi^+ \pi^-$$

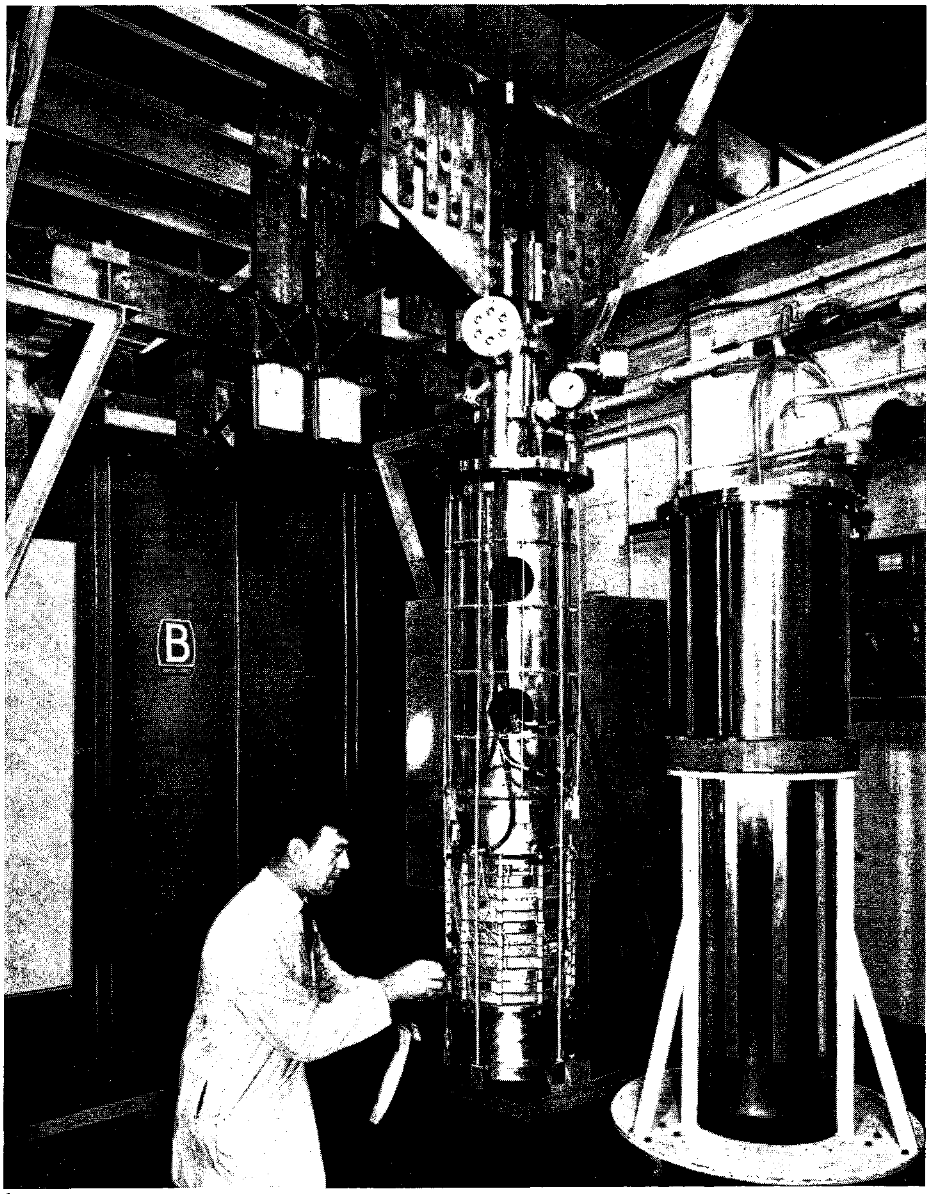
The anti omega travelled about 25 mm in the chamber before decaying into an anti lambda and a positive kaon. The anti lambda left no track, since it carried no charge, but after travelling some 275 mm it could be identified when it decayed into an antiproton and a positive pion. The antiproton went on to annihilate with a proton producing the fireworks in the top left-hand corner of the picture.

There are other anti omega 'candidates' among the half million pictures, which are being measured on Frankenstein machines at Berkeley, but none as clear as the photograph shown where a full sequence of events is recorded making the analysis much surer. The anti omega mass is calculated as 1673 MeV.

Identification of the omega minus at Brookhaven in 1964 was one of the triumphs of particle physics. Its existence and properties had been clearly predicted by the SU3 theory of M. Gell-Mann and Y. Ne'eman, as it was the missing particle from a ten member group of particles whose properties slotted nicely into the pattern given by the theory. By now 29 omegas have been seen at Laboratories throughout the world. There was little doubt that its anti-particle, omega plus, should exist ; the Berkeley team (A. Firestone, G. Goldhaber, D. Lissauer, B. M. Sheldon and G. H. Trilling) have now clinched the matter.

Another experiment which also has to do with the SU3 system for classifying particles was reported at the same meeting on 5 February. It was carried out by a combined LRL-Livermore team (A. F. Clark, D. E. Smith, W. M. Powell, H. F. Finn and N. E. Hansen) and concerned a search for quarks — the type of particle which is postulated as the underlying reason for the SU3 classification.

In 1969 (see vol. 9 page 307) a Sydney team claimed to have found five quark 'candidates' in Wilson cloud chamber photographs of high energy cosmic ray showers recording about 60 000 tracks. The identification is based on the fact that a quark, carrying only a fraction of the normal unit electric charge, would leave a less



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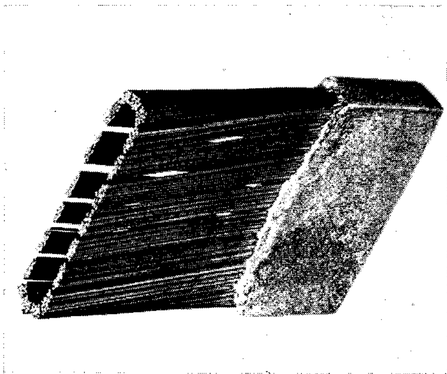


2.

1. The RACOON II superconducting coil at the Rutherford Laboratory built to test the conductor for the magnet of the proposed high field bubble chamber. It is shown connected to its 15 000 A power supply when it was powered to give a peak field of 6.6 T.

The coil will also be operated within the bore of a 5 T conventional magnet to subject the superconducting strip to the full 8.4 T which it would see in the bubble chamber. It will then be necessary to support the superconducting magnet directly from the coil of the conventional magnet. Forces generated between the two magnets due to any radial or axial misalignment between the respective magnetic centres must be restrained to prevent any movement of the superconducting coil. The remotely operated wedges, which can be seen in the photograph, transmit radial misalignment forces via the specially constructed cryostat (standing alongside) to the conventional magnet. Axial misalignment forces are transmitted via the large diameter stainless steel tube which supports the superconducting coil from the cryostat top plate.

2. The conductor of the RACOON II coil consisting of 361 niobium-titanium filaments of about 0.3 mm diameter in a copper matrix of cross-section 25 mm by 6 mm. The group of filaments is twisted with a pitch of 0.5 m to eliminate magnetization currents. The conductor was developed and manufactured by Imperial Metal Industries (Kynoch) Ltd.

dense trail of droplets in its wake since it would produce less ionization.

The Sydney results were disputed (see, for example, vol. 10 page 16) but they stirred up sufficient interest for several attempts to be made to check their claim. The Berkeley team recorded over 100 000 particle tracks in high definition cloud chamber photographs. The chambers were triggered on high energy cosmic ray showers by means of three scintillation counters per chamber. They found no evidence of fractionally charged particles.

Given the size of the chambers used in the experiment (450 mm in diameter, 100 mm illuminated depth) and the detection probability during the scanning process (artificial quark-like tracks were fed into some of the photographs to check ability to pick them out) it is estimated that, on the basis of the Sydney results, ten to twenty tracks should have been observed.

RUTHERFORD RACOON II tests

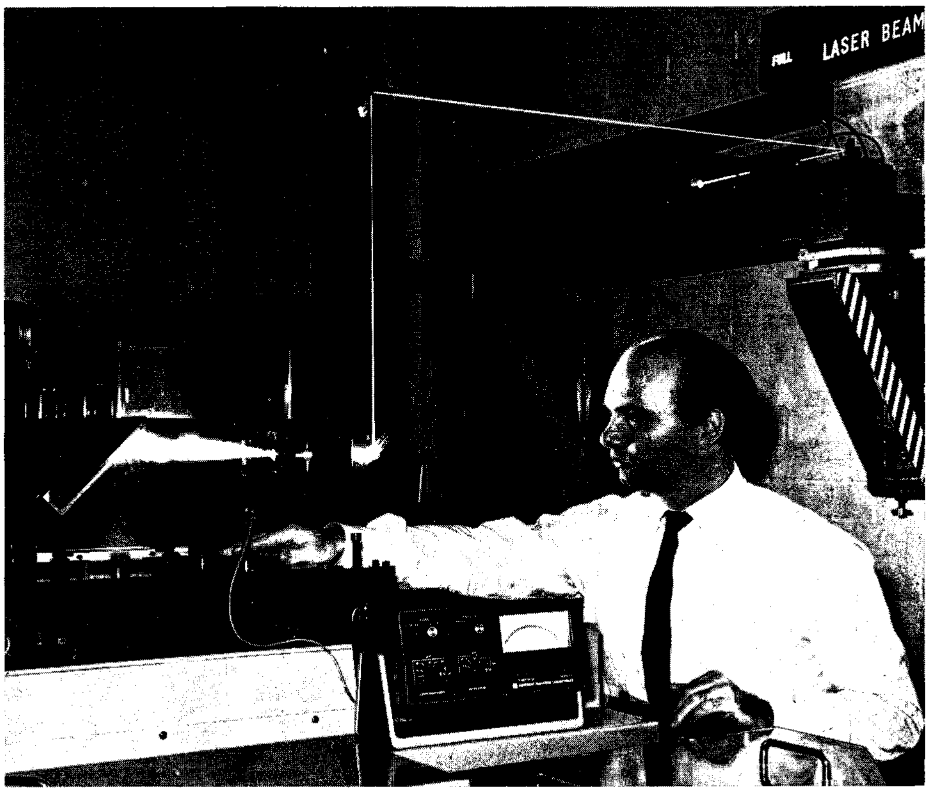
For several years preparatory studies have been under way at the Rutherford Laboratory in connection with a high field bubble chamber project. (The project was described in vol. 8 page 109.) The proposed chamber incorporates several advanced technological features not least of which is a superconducting magnet to produce a 7 T field at the centre of the hydrogen volume 1.5 m diameter, 1.8 m high. A crucial advantage of the chamber would come from this high field which would make possible high precision momentum measurements of the particle tracks.

A superconducting magnet, known as RACOON II, has been built using the conductor developed for the chamber magnet and the first stage of tests was successfully completed in January. Operating fully immersed in liquid helium, RACOON II was energized with currents up to 14 800 A and reached a peak magnetic field of 6.6 T. This is believed to be the highest current at which a superconducting coil has yet operated. The peak current density achieved in the conductor (almost 100 A/mm^2) can be compared with the 5 to 10 A/mm^2 at which copper conductors of typical water cooled magnets run.

RACOON II uses about 100 m of stabilized superconducting strip wound into six double pancake coils each of 25 turns. The conductor consists of 361 niobium-titanium filaments each 0.3 mm in diameter. The filaments are embedded in a copper matrix of cross-section 25 mm by 6 mm and twisted about the longitudinal axis of the conductor with a pitch of 0.5 m. In the magnet for the high field bubble chamber the conductor would operate at 7 500 A.

HPD 2 in operation at the Rutherford Laboratory using an argon laser to produce a small, intense spot of light to scan bubble chamber film.

(Photos Rutherford)



The stable performance observed at currents of almost 15 000 A in the recent tests confirms that the conductor will have an entirely adequate margin of stability when operating at its design current. Twisted filament conductor is used to ensure that magnetization current loops set up within the conductor when it is being energized will decay fairly rapidly. Measurements of the decay of such currents in RACOON II yielded a time constant of 40 minutes. Similar time constants are predicted for the bubble chamber magnet.

The second stage of the RACOON II test programme is aimed at proving that the selected superconducting strip will also carry its design current of 7 500 A in a magnetic field of 8.4 T, this being the peak field which would be experienced in the bubble chamber coils. For this test, RACOON II in its own cryostat will be mounted within the bore of a 5 T water cooled magnet at the Royal Radar Establishment, Malvern. When both coils are energized simultaneously it is expected that peak fields in excess of 8.4 T will be generated.

The HPD 2 automatic measuring machine at the Laboratory is preparing to measure film from its first experiment. At the end of last year the machine digitized its first frame.

The feature of particular interest in this HPD 2 is the use of a laser beam to provide the spot of light which scans the bubble chamber film for tracks. A powerful (200 mW) continuous wave argon laser provides a measuring spot of only 300 μm half height which has three hundred times the intensity used in the Laboratory's HPD 1. The laser system was developed in collaboration with W. T. Welford of Imperial College London and is the first application in an HPD type machine. Other Laboratories, including CERN, have participated in discussions about the laser application and will be watching progress with interest in view of possible use on their own machines.

Other major improvements compared with the HPD 1 version are the use of an on-line computer (DDP 516), construction of the machine's electronics using the latest integrated circuits, and operation with a disk revolution frequency of 100 Hz (half this figure is more usual). A proposal is being studied to push the disk to 150 Hz in about a year's time.

BATAVIA
Booster beams

Another 'milestone' en route to the completion of the 200-500 GeV accelerator at the National Accelerator Laboratory was passed at the beginning of February when beams were accelerated for the first time in the Booster.

The Booster is designed to take the 200 MeV beam from the Linac and to accelerate it to an energy of 8 GeV, at a repetition rate of 15 pulses per seconds, for injection into the Main Ring. The last of the magnets moved into the Booster ring on 14 December and installation was virtually complete a week later (3 months ahead of the revised schedule). The ring was then pumped down to an average pressure below 10^{-6} torr and the magnets were powered to the 8 GeV level. Some problems were encountered with standing waves, particularly at 300 Hz, in the magnet field around the ring but these have been cleared by rapidly building harmonic filters for each of the four magnet power supplies using spare capacitors and model magnets.

On 23, 24 January the beam was injected and taken full circle. After tuning there was little loss following injection. The deviations from the expected orbit were of the order of 20 mm even without applying corrections. A pulsed kicker to push the beam from its injection orbit was then installed and on 29 January the first multiple turn tests were carried out. Again after a few hours of tuning, good quality beams were achieved and the betatron oscillation frequencies were shown to be close to the design values.

On 6 February, r.f. cavities were brought on and protons were accelerated to an energy of 1 GeV. (Half the r.f. cavities are needed for acceleration to this energy.) It looks as if the Booster will be in excellent shape to feed beams to the Main Ring in a few months' time.

Construction of the Booster has been brought to completion by Roy Billinge with Helen Edwards as Associate Section Leader. The Booster Section are feeling very pleased with themselves.

Photographed looking over a model of the site at Batavia on 25 January are the Director of the National Accelerator Laboratory, R.R. Wilson (left) and B.P. Gregory. During his visit to the USA, Professor Gregory, Director General of CERN until the end of last year, spoke at the meeting of the American Physical Society at New York on the 'Intersecting Storage Rings Programme'.

(Photo NAL)

Amsterdam Conference

The Amsterdam International Conference on Elementary Particles will be held in Amsterdam, The Netherlands, from 30 June to 6 July.

The Conference will cover strong, weak and electromagnetic interactions with the main emphasis on hadronic interactions. A change in Conference format will be tried for the first time in having the parallel sessions each devoted to a highly specialized topic and having the Rapporteurs reporting exclusively on recent progress and current problems without attempting to survey the entire field. Rapporteurs will also not be restricted to covering only contributions submitted to the Conference but will be able to draw on any source for their material.

The Conference is primarily intended for physicists in Europe active in the field of high energy physics. Participation is by invitation only.

Erice School

An International School of Subnuclear Physics will be held at the 'Ettore Majorana' Centre for Scientific Culture at Erice, Sicily, from 8-26 July. The subject will be 'Properties of the Fundamental Interactions'.

The emphasis of the programme is on the progress, theoretical and experimental, in the past year. There will be a series of theoretical and of review lectures together with fourteen seminars on specialized topics. Further special lectures will be given by G.F. Chew, J.B. Adams, R.R. Wilson and V.F. Weisskopf.

People wishing to attend the course should write to the Secretary of the School, Miss M. Zaini, CERN, 1211 Geneva 23, Switzerland. The closing date for applications is 31 March.

EPS Conference

Below is the programme for the first specialized Conference organized by the High Energy and Particle Physics Division of the European Physical Society. The Conference (see vol. 10, page 392) is to be held at Bologna on 14-16 April under the title 'Meson Resonances and Related Electromagnetic Phenomena'.

	a) 9.00 - 10.30		b) 11.00 - 12.30		c) 15.00 - 16.30		d) 17.00 - 18.30
14	π-π and $K\pi$		δ, S^*, K_1K_1 threshold - All non-strange mesons of mass around 1000 MeV.		ω-ρ interference		A_1, B and Q-region - The spin 1^+ states.
15	Meson splitting: A_2, f^0, K^*, etc.	BREAK	Intermediate mass mesons - E, F_1, R, S mesons and the L-region, etc.	LUNCH	Non-strange mesons above $\bar{p}p$ threshold - Includes T, U, V, W, etc. mesons, and studies of $\bar{p}p$ and $\bar{p}n$ interactions, cross-sections, polarization, and final states.	BREAK	Electromagnetic interactions of mesons - Decay modes of π^0, η, ρ, ω, X^0, and ϕ - Primakoff production.
16	Hadron production by colliding e^+e^- beams.		Production of vector mesons using hadronic targets.		Theoretical predictions on meson classification and their decay properties. The problem of exotics and their relations to duality. The narrow widths problem of high-mass resonances.		"Outstanding problems"

Electron Ring Accelerators Three years later

On 4, 5 February an informal meeting was held at the Max Planck Institute for Plasma Physics, Garching near Munich, to discuss recent progress in the effort to master the acceleration technique known as collective ion acceleration.

This type of accelerator research burst into prominence in 1967 with the announcement at the Cambridge Conference (see vol. 7 page 201) of the successful work at Dubna on a method of achieving collective ion acceleration by forming rings of electrons and adding positive ions. To recap briefly (a much fuller explanation can be found in vol. 8 page 28) on the method and its potential advantages :

Electrons of a few MeV energy are fired into a 'compressor' where a magnetic field forms them into a ring of typically 250 mm radius. The field is then rapidly increased and the ring, containing say 10^{13} electrons, shrinks to some tens of mm radius (the electron energy increasing in the process). Positively charged particles can be fed into the ring (attracted by the high negative potential) by, for example, allowing gas into the compressor which is then ionized to give say 10^{11} positive ions in the ring. If magnetic or electric fields are then applied to the compressed ring so that it moves in a particular direction, the electrons can carry the positive ions with them provided the pull of the fields is not so strong as to drag the oppositely charged particles apart.

The attraction of the technique lies in the fact that accelerating electrons is a comparatively easy task. If the electron ring is accelerated to a certain energy, the energy of the positive ions they carry with them can be tens of times greater because of the higher mass of the ions. Potentially then, the electron ring accelerator (ERA) is an economical way of accelerating protons or heavier positive ions to high energies.

To sum up the research of the past three years however 'it is easier said than done'. On the one hand, the method has been shown to work — results of experiments at Dubna in 1969 and 1970 confirm the principles sketched above. On the other hand, the problems of ring formation and stability seem a long way from being completely mastered and practical ERAs are not for tomorrow. In particular it is significant that the exciting possibility of a cheap very high energy proton accelerator of this type is no longer at the forefront of discussions — heavy ion acceleration to comparatively modest energies is more prominent in discussing the prospects with ERAs in the comparatively near future.

The Garching meeting, attended by 35 scientists from Europe interested in this field, was one of a series which have been held about once a year since the 300 GeV Steering Committee decided to keep a close watch on developments in this potential method of achieving high proton energies. Though the Steering Committee is now disbanded, the meetings have continued as a useful annual pool of information on how the research is progressing. In particular they have served as a forum for the European groups (from Garching and Karlsruhe) who are actively studying the technique. Though the two largest groups are at Dubna and Berkeley, we will start with the news from Europe reported at the meeting.

The group from Garching has so far been the more successful. In the autumn of 1969 they compressed rings to about 50 mm radius containing between 10^{10} and 10^{11} electrons using a Febatron field emission type electron injector and a compressor with three coils to produce the magnetic fields. The compressor differs from the others in having a very fast compression time (around 10 μs compared with about 250 μs) with the aim of passing very quickly through the magnetic field conditions which correspond to resonances which can 'blow up' the electron rings.

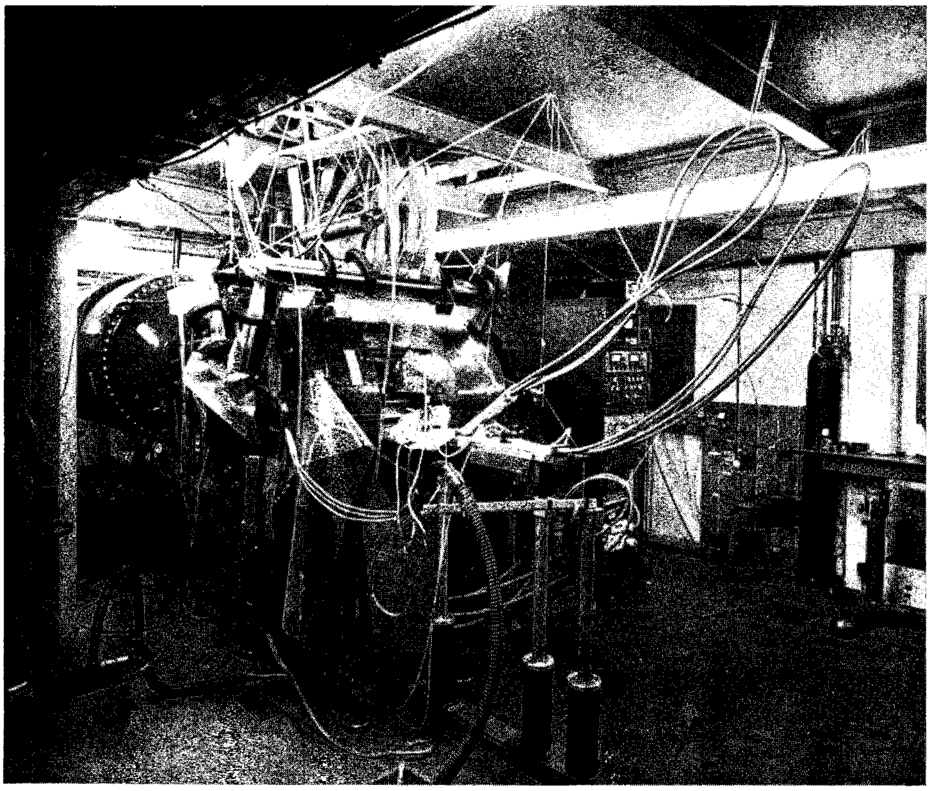
Since this achievement, progress has been slower. It will be necessary, for a useful ERA, to have a higher number (10^{13} or more) of electrons in the compressed rings but it has not yet been possible to increase the intensity beyond the 10^{10} to 10^{11} region compressed to a radius of 30 mm. Though it is not completely clear whether the loss of injected current is due to poor injection or to loss in the first few turns due to crossing resonances (it is difficult to study the beam over the first turns since any probe introduced in this region so disturbs the fields as to render the results meaningless), it is believed that the quality of the injected beam (energy drift, energy spread and high emittance) is the cause of the troubles.

Efforts are therefore being concentrated on improving the electron injector. One attack is to improve the field emission injector. A more interesting approach is to develop a laser initiated electron source. Some very encouraging results have been obtained from the first tests on this idea.

A laser beam pulse (17 ns half width) was concentrated on a disk of tantalum with a spot size between 1 and 10^{-2} mm². This created a tiny bubble of plasma (electron and tantalum ion cloud) at the illuminated spot. Applying volts between the tantalum and an anode pulled electrons from the surface of the bubble. The maximum current achieved was 800 A with 200 kV applied. The electron pulse was timed not by the laser but by the voltage pulse (providing it was close enough to the start of the laser pulse for the plasma bubble to be still there). The voltage pulse was provided from

The enclosed compressor at the Max Planck Institute for Plasma Physics, Garching near Munich, where the formation of electron rings is being studied. The Febatron injector is the horizontal cylinder on the left. An open view of the compressor with one bank of three coils visible can be seen in vol. 9 page 391.

(Photo MPI)



a Blumlein line and was not very good (10 % slope on the 'flat' top) but, subtracting the energy spread that this produced, it was possible to deduce that the remaining energy spread was less than 800 eV.

In addition to this much lower energy spread, the emittance measurements carried out on the electron beam indicated that values at least an order of magnitude better than the field emission beam is possible (the field geometry around the plasma bubble is more favourable to good quality beams). This type of injector is to be built with a 2 MeV Blumlein line and, if possible, with a higher repetition-rate liquid laser.

For proton filling of the electron rings it had been intended to fire a proton beam produced by a duoplasmatron source into the compressor. Although this has been investigated to the extent of developing a proton injector and producing rings of 10^{10} protons, it is now likely to be dropped in favour of simply feeding hydrogen gas to the compressor.

Other improvements will include building up the condenser bank for powering the compressor magnet coils to cope also with an expansion type acceleration section (where the rings would be accelerated out of the compressor down a section of decreasing magnetic field).

At Karlsruhe fully compressed rings have not yet been achieved. The difficulties may be due to bad vacuum or to electron ring blow up when crossing the n = ½ resonance. Here again the quality of the injected beam from the 2.2 MeV Febatron is suspected. Electrons have been injected into the compressor, bent into rings of 235 mm radius and compressed to about 220 mm radius with a lifetime of a few μs.

Work is being concentrated on improving the Febatron injector and it is hoped that such developments as having a windowless tube might result in beam quality not very much below those of the laser type injector at Garching.

A molecular beam injector capable of feeding the electron rings with a wide variety of ions is being developed but, as with the duoplasmatron proton injector investigated at Garching, the necessity of such subtilties compared with feeding the compressor with the appropriate gas was questioned at the meeting.

Two new European groups have been considering entering the field. One is at Saclay where the Van de Graaf, rendered redundant by the installation of the new Saturne injector, is considered as the electron source. They are now working on the design of a compressor and its magnet coil system. The particular interest (rather than positive ion acceleration) is to produce very cleanly defined short electron pulses for research in physical chemistry.

The other group is a collaboration of Italian Universities at Bari and Lecce. They are constructing a model to test the possibility of obtaining dense electron rings by cycloidal trajectories in a magnetic field of linear (rather than circular) geometry. This a new approach whose possibilities are not yet clear.

There were no members of the Dubna or Berkeley groups at the meeting so the following information is second-hand.

First from Dubna: In the autumn of 1970 their electron ring accelerator was used to accelerate helium ions (alpha particles) to an energy of about 7 MeV per nucleon. This involved an acceleration length, from the plane of the compressor where the rings were formed, of 320 mm. The accelerated alphas were identified by having them hit a copper target where they interacted to give gallium:

$$Cu^{63} + \alpha \rightarrow Ga^{66} + n$$

This interaction has a threshold of 11 MeV. The gallium 66 has a 9.5 hour half-life and there was therefore ample time to carry out an experiment on compression, loading and acceleration and then to carry away the copper target to investigate the gallium formation using the gamma emission of the gallium 66. The estimates of alpha loading of the electron rings seem to be around 10^{10} ions per ring. These results, more than the information on nitrogen ion acceleration reported at the Yerevan Conference (vol. 9 page 260) provide the crucial evidence that ERAs work, and sustain the position of the Dubna team as leaders in the field.

Future plans are to increase the electron intensity to 10^{14} in the compressed ring. An induction type injector (such as has been built at Berkeley) is to be built to yield currents of 2000 A at 3 to 3.5 MeV. A 1 MeV model has given 600 A.

At Berkeley : Recent months have been given to experiments in 'Compressor IV' which is designed to study injection and ring instabilities particularly during the initial stages of compression. The new injector has been operating reliably at 2 MeV (the electron source performance was greatly improved by replacing the needle-shaped field emission cathodes by a tantalum spiral which operated satisfactorily for 360000 pulses). The beam-line to the compressor has a variety of devices for modifying the injected beam characteristics (energy spread, pulse length, etc.) to study their effects.

As with Compressor III, high electron loss in the first turns was found. This has been studied using a new collector probe which can be placed at any angle and radius.

The most significant recent results are that, although at low intensity levels rings can be formed and compressed without trouble, at high intensity levels the rings become unstable within the first few centimetres of compression. The instability appears to be driven by image currents in the side walls and possibly the inflector. The effects of changes in these structures are being investigated.

Compressor V, which is designed for experiments on extraction and acceleration of the rings loaded with ions, is being assembled. All components for extension of the injector to give an energy of 4 MeV are also ready to be installed.

For high energy acceleration of the electron rings it will be necessary to pass them through a system of r.f. accelerating cavities. This has led to intensive investigation of the energy loss at increasing energies when passing through periodic structures. The controversy of 1 ½ years has now settled down to general agreement on the scaling laws of radiation loss with energy. The essential features are that, in a long periodic structure, the rate of energy loss at high energies does not increase with energy, whereas at low energies and with short structures there is an energy dependence. The problem has now ceased to be of major concern and the main work to be done is the calculation of favourable structure geometries to reduce the energy loss as far as possible. It is intended to carry out experiments in the Stanford electron linear accelerator to investigate this phenomenon.

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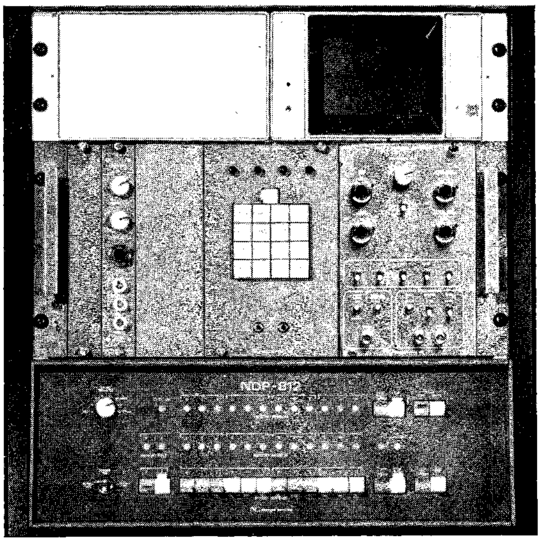

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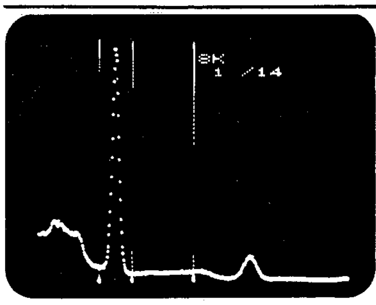
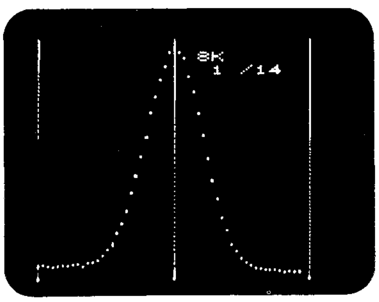
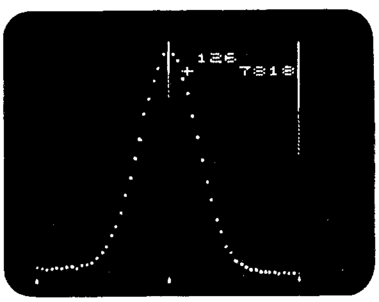


512 channel Na^{22} spectrum with left and right markers bracketing peak and center marker at channel 256



Expanded marker area with display of Z full scale value (8K), current group (1) and total groups (14)



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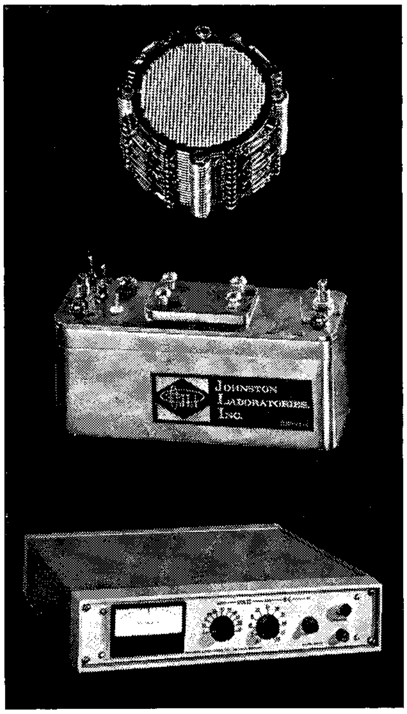

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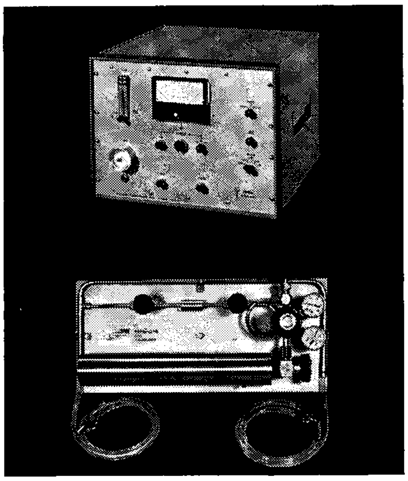

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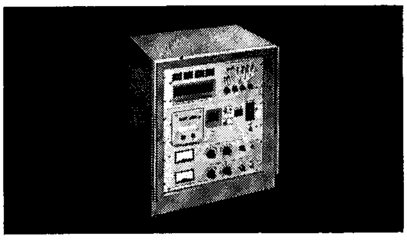

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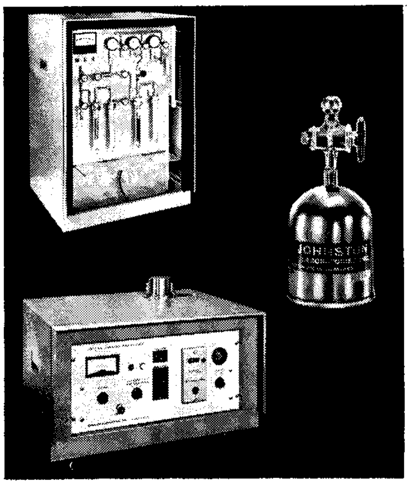

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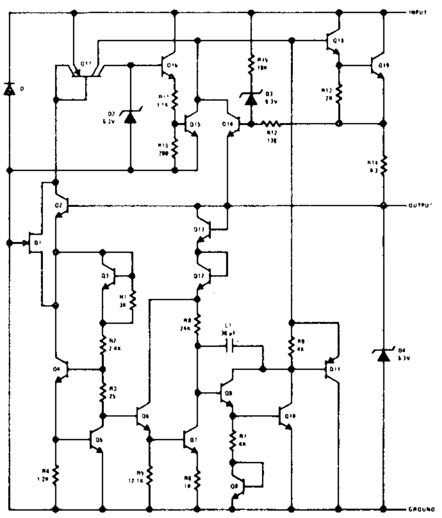

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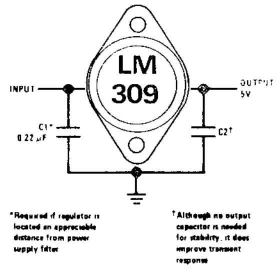

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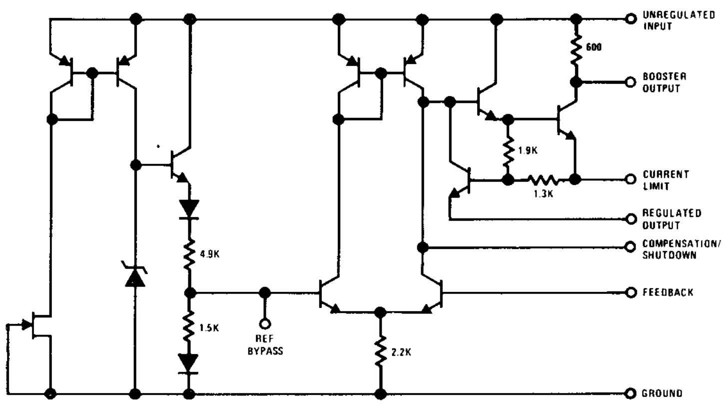

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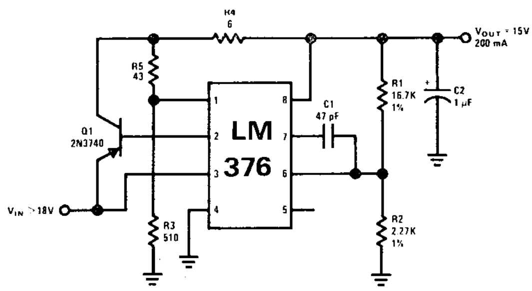

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