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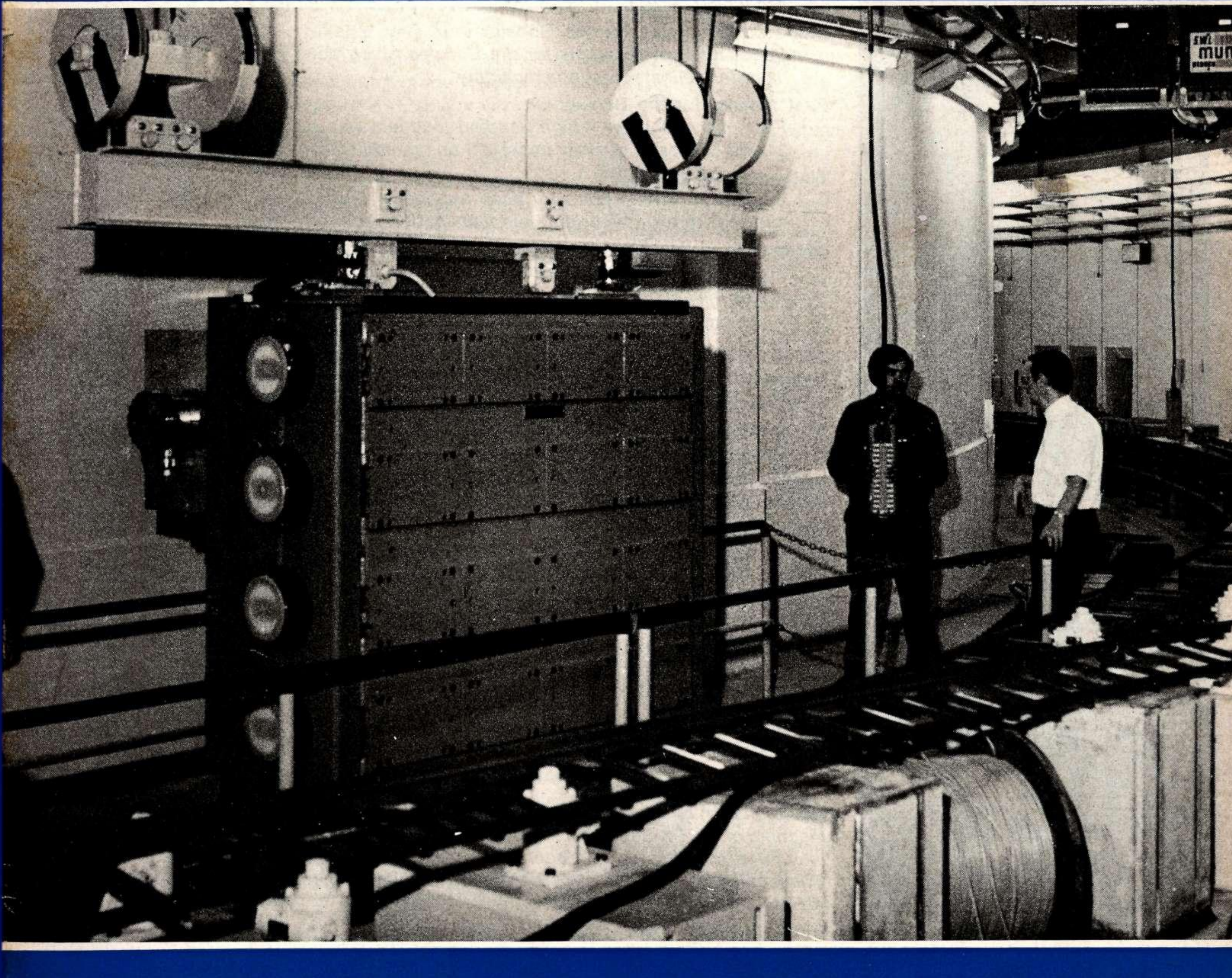
European Organization for Nuclear Research



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. The Organization has its seat at Meyrin near Geneva in Switzerland. There are two adjoining Laboratories known as CERN Laboratory I and CERN Laboratory II.

CERN Laboratory I has existed since 1954. Its experimental programme is based on the use of two proton accelerators — a 600 MeV synchro-cyclotron (SC) and a 28 GeV synchrotron (PS). Large intersecting storage rings (ISR), are fed with protons from the PS for experiments with colliding beams. 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 research material from CERN.

The CERN Laboratory I site covers about 80 hectares almost equally divided on either side of the frontier between France and Switzerland. The staff totals about 3000 people and, in addition, there are about 650 Fellows and Visiting Scientists. Twelve European countries contribute, in proportion to their net national income, to the CERN Laboratory I budget, which totals 353.4 million Swiss francs in 1971.

The CERN Laboratory II was authorized by ten European countries in February 1971 ; it will house a proton synchrotron capable of a peak energy of hundreds of GeV. CERN Laboratory II also spans the Franco-Swiss frontier with 412 hectares in France and 68 hectares in Switzerland. Its budget for 1971 is 29.3 million Swiss francs.

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A photo taken on 24 June during the positioning of the first of the 32 bending magnets of the PS Booster. The special feature of these magnets is that they have four gaps, one for each of the superimposed rings of the machine, which calls for very great precision in the manufacture and assembly. (CERN 260.6.71)

Elementary Particles at Amsterdam

The sixth in this series of meetings which alternate with the International Conferences on High Energy Physics, the last of which was held in Kiev in 1970 (CERN COURIER vol. 10, p. 271). The odd year conference is primarily intended for research workers in Europe, but some non-Europeans were invited to ensure that recent progress made outside Europe would be reported.

If as a private individual you have been to look at Rembrandt's « Night Watch » in the Rijksmuseum of Amsterdam, you will remember the phalanx of grim guards who prevented you from stepping on the carpet in front of it. The physicists attending the Amsterdam International Conference on Elementary Particles were clearly privileged people for when everybody gathered in front of the « Night Watch » at the after dinner reception, offered by the Dutch Minister of Education and Sciences and the Burgomaster and Aldermen of Amsterdam, the friendly guards were hardly to be seen. The evenings' confrontation of science and art made a stimulating combination with the exciting news presented at the Conference sessions during the day.

The Conference which took place at the Rywiel en Automobiel Industrie Congrescentrum from June 30-July 6, was sponsored by the Dutch Ministry of Education and Science and by the University of Amsterdam and took place under the auspices of the European Physical Society and the Dutch Physical Society. Under the very able Chairmanship of Professor Kluyver, it was organized mainly by the Zeeman Laboratory together with the CERN conference secretariat; they were congratulated not merely on organizing the conference so well but also for laying on such excellent weather to accompany it.

The Conference covered strong, electromagnetic and weak interactions, although by some process of natural selection the main emphasis was on hadronic interactions.

Around 440 papers were submitted for presentation and discussion to the 590 participants. In view of this large number of contributions, many of which necessarily covered the same field, the Advisory and Organizing Committees decided to change the traditional procedure. In order to increase the efficiency of the parallel sessions without suppressing them completely, a system of Maxi-and Mini-Rapporteurs was adopted. The rapporteurs of more classical type gave in the plenary sessions a survey of what had happened and where we stand, whereas several (but still few) Mini-Rapporteurs summarized the highly specialized aspects of a given topic in the parallel sessions.

The main interest was directed towards the results coming from the new machines, the 76 GeV proton synchrotron at Serpukhov and the CERN Intersecting Storage Rings; and they did not disappoint. Whilst some of the disturbances which were left by the Kiev Conference have settled down, it is clear that what goes on at very high energies cannot be derived from a simple extrapolation of observations at lower energies. More accurate experiments and supplementary information from the Serpukhov accelerator have essentially destroyed the foundation of one year's speculation on a possible violation of the Pomeranchuk theorem. On the other hand the unexpected elastic scattering data from the ISR indicates that previous predictions are not being fulfilled.

Progress is slow in high energy physics. There are probably very few theories which have crystallized out to the point where one is safe against unexpected surprises. A new puzzle has shown up in the field of weak interactions — the decay of the neutral kaon into two muons — a field where one commonly thinks that our way of dealing with even small observable effects is fairly adequate.

This report on the Conference is necessarily very selective and only the most striking topics have been chosen for discussion which will not do justice to the painstaking detail work which could be found in many of the contributions.

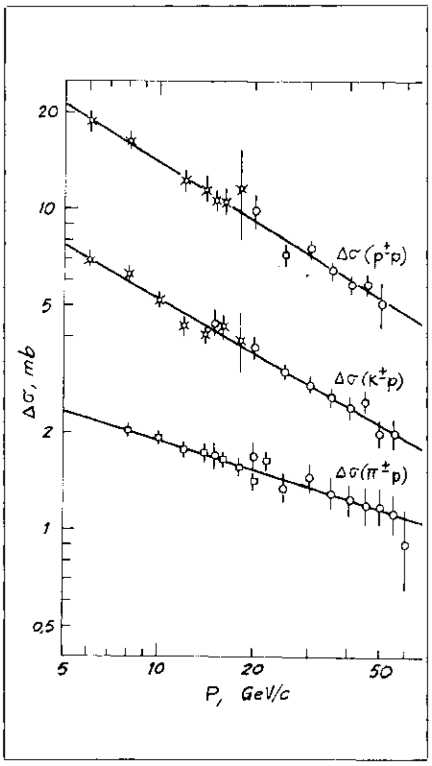
Total cross section measurements from Serpukhov

The total reaction and elastic scattering cross section of elementary particles is the most straightforward cross section measurement which can be imagined, so it is no wonder that each time a new range of energies is available, it is among the first measurements to be done, later to be repeated to obtain the highest possible precision.

The total cross section is a measure of the range of the forces responsible for the interaction of two particles, and in a crude model one expects a cross section of the order of magnitude of the geometrical size of the interacting particles. Due to the high precision of the measurements it should also yield some information on the asymptotic behaviour at very high energies. The energy dependence, therefore, is of great interest. The measurements are also stimulated by the hope that at higher energies a new type of reaction like the production of heavy new particles, e.g. quarks, might show up as a structure in the energy dependence.

The total cross section is directly connected through the 'optical theorem' (which treats the scattering in a way similar to the diffraction of light round an obstruction) with the elastic scattering cross section in the forward direction. Thus the knowledge of the elastic scattering allows an understanding of the total cross section, although the total cross section itself is a complicated composition of the many reaction channels possible at high energies. By making this connection it is possible to compare the data with the available models for the relatively simple elastic scattering process.

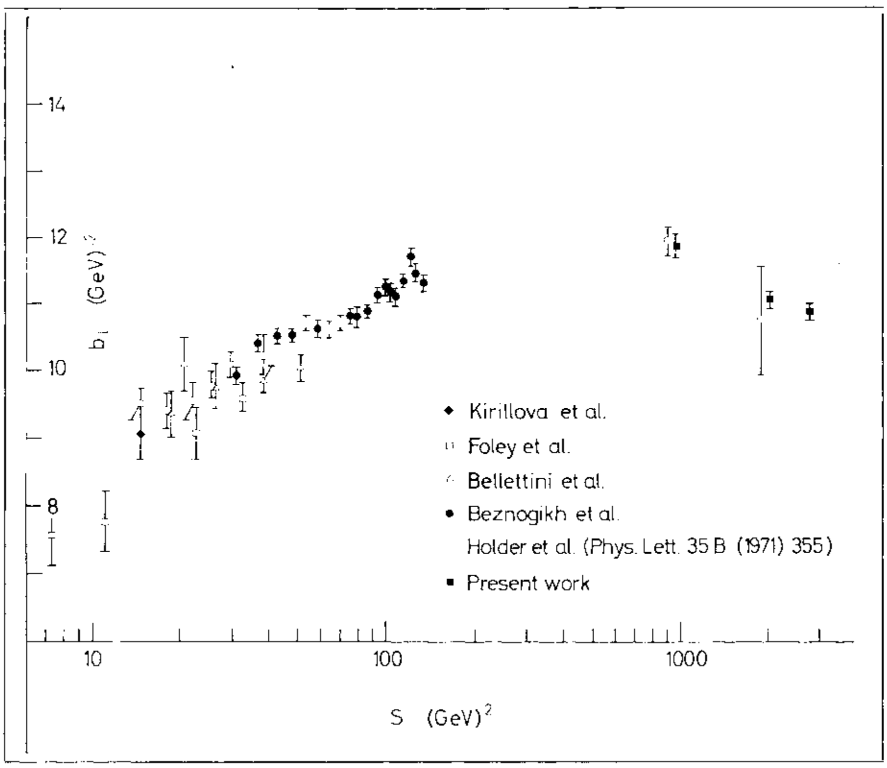
The fact that the total cross sections of most particles seem to stay constant at high energies has the important consequence that the



The difference between the total cross section of a particle and that of its antiparticle each hitting a hydrogen target is plotted against the energy. The open circles are the new data from Serpukhov. The total cross section differences are continuously approaching zero in agreement with the Pomeranchuk theorem.

elastic scattering has to proceed as if by the exchange of a 'pomeron'. If one interprets this process as the exchange of a particle, the particle should have all the characteristics of a vacuum — the particle itself would not be observable. Furthermore there is a definite prediction in the Pomeranchuk theorem which stipulates that the total cross section of particles and antiparticles on a given target is equal in the asymptotic region.

A group from the Institute of High Energy Physics at Serpukhov has now for the first time measured the total cross section of positively charged particles on protons and deuterons at energies up to 60 GeV. Furthermore the earlier measurements of negatively charged particles were very much improved. The main improvement comes from the use of liquid hydrogen and deuterium targets of 1.5 - 3 m length instead of gaseous targets. A standard transmission experiment in 'good geometry' was performed, but a special technique was used in order to extrapolate to zero the solid angle of the beam particles that did not interact in the target. The transmission counters were moved in order to cover a constant momentum transfer interval at different beam momenta. This minimizes systematic scale errors in the wide momentum interval of 15 - 65 GeV/c covered by the experiments.



The slope of the differential elastic scattering cross section is plotted versus the energy in the centre of mass system. The points below S = 150 are mostly from Serpukhov measurements the new ISR points lie above S = 700. The shrinking of the elastic cross section, i.e. the increase in slope, is obvious although the shrinking at the highest energies is less than expected from the Serpukhov data.

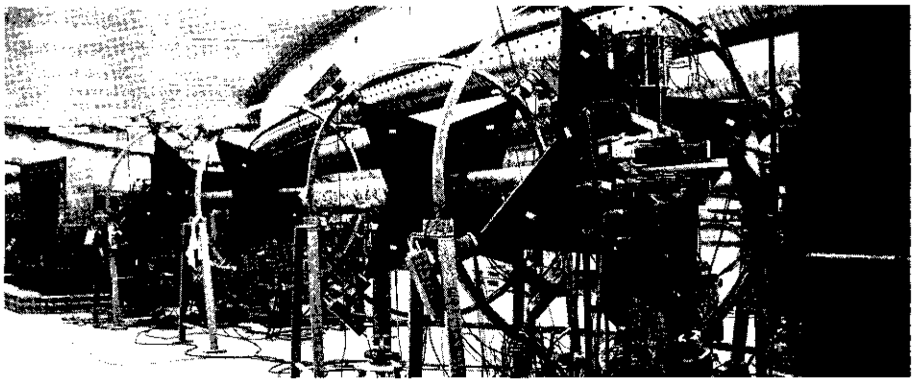
The results show the following striking features:

1) The total cross sections for p±, π± and K± are equal for proton and neutron targets.
2) The pp total cross section is constant above 20 GeV/c within 0.1 %, whereas the p̄p cross section is continuously falling up to the highest energies measured.
3) π⁺p, π⁻p and K⁻p are almost constant.
4) The K⁺p cross section is rising with increasing energy.

Especially the rising K⁺p total cross section has created some confusion, since it does not fit into most of the present models for elastic scattering. Furthermore, since it is fairly constant below 20 GeV, it had given rise to the pre-Amsterdam speculations on a failure of the Pomeranchuk theorem, which were mainly based on the assumption that the K⁺p cross section would stay constant also at higher energies — at a time where only measurements on K⁻p were known. On the whole now, the Pomeranchuk theorem seems to be in pretty good shape again although approaching 'asymptotia' has turned out to be tedious: the π⁺p and π⁻p cross sections seem likely to be equal only around 1000 GeV.

K_L-K_S Regeneration

Another, more direct and very elegant way of measuring a difference in the total cross section for particles and antiparticles is to investigate the regeneration of short-lived kaons (K^o_S) in a beam of long-lived neutral kaons (K^o_L) hitting a target. This particular effect is due to the fact that both K^o_L and K^o_S are composite particles, and if the common constituents K^o and $\bar{K}^o$ have a different reaction probability, e.g. if the antiparticle $\bar{K}^o$ is absorbed stronger than the K^o, the original composition of a



The stars around the ISR beam pipes are scintillation trigger counters used for a total cross section measurement loy the CERN-Rome collaboration.

K_L may be changed by a scattering process into the one corresponding to a K_S. The K_S then can easily be detected by its high decay rate into two charged pions.

Such an experiment on K^o_S regeneration in hydrogen was performed by a Dubna-Serpukhov-Budapest collaboration at Serpukhov. The results are consistent with the Pomeranchuk theorem and fit well into the $K\pm p$ total cross section data. Furthermore the phase of the forward scattering amplitude $f(K^op)$ - $f(\bar{K}^op)$ turns out to be roughly constant at $-118°$ $\pm$ 30° in the momentum interval 14 - 38 GeV/c, close to the expected value - 135° in dominant ω exchange Regge models. This new result resolves the difficulties encountered in the theory when preliminary data of this experiment were reported at the Kiev Conference.

Early ISR results on proton-proton scattering

During the short time that has passed since the Intersecting Storage Rings went into operation, several test stage experiments have observed proton-proton collisions at energies some twenty times higher than before at ordinary accelerators. Some experiments have already produced valuable results which were extensively discussed. The enormous enthusiasm of scientists to be the first in getting results is shown up by a remarkable performance in data handling : the data taken by one of the experimental teams on Tuesday night were analyzed and illustrated in a beautiful slide on Friday morning at the Conference !

Elastic proton-proton scattering at small angles was investigated by two groups independently. The CERN-Rome collaboration aiming at the smallest angles possible placed four sets of 10 small scintillation counters, 10×5 mm² each, 5 m downstream of the interaction region at a few centimetres distance from each beam. Coincidences between both hodoscope sets were recorded and elastically scattered protons showed up in the proper combinations of the 10×10 counter matrices. The dependence of the counting rate on angle was measured in the interval ½ - 1° and the slope of the elastic scattering cross section determined. The slopes given at two different proton beam energies are :

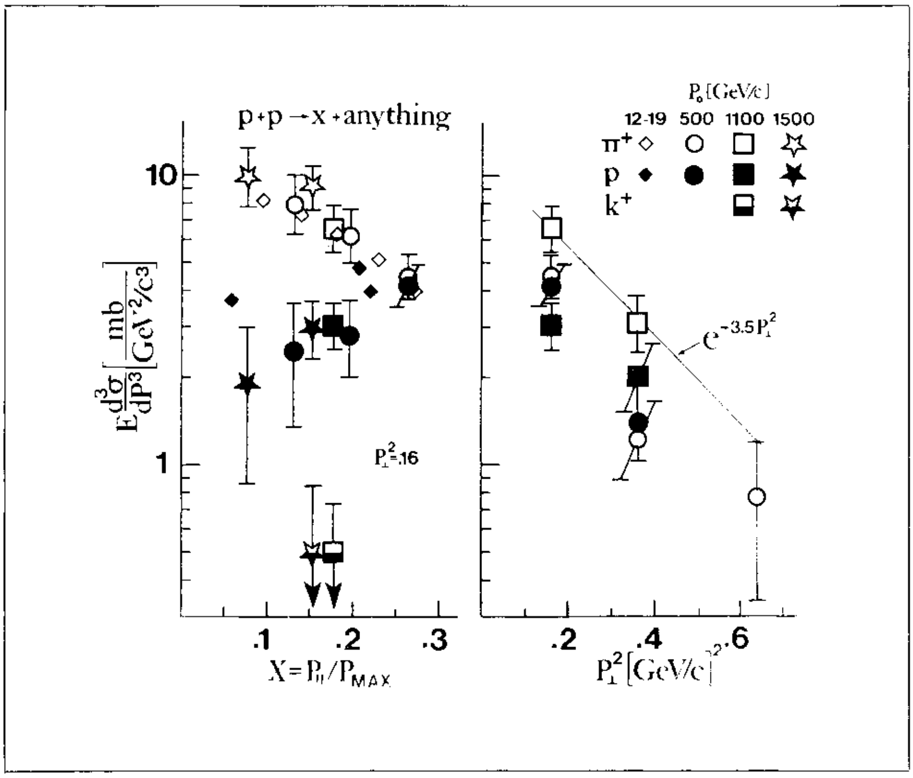
12.6 ± 0.4 $(GeV/c)^{-2}$ at 22.7 + 22.7 GeV, and

12.8 ± 0.4 $(GeV/c)^{-2}$ at 26.8 + 26.8 GeV.

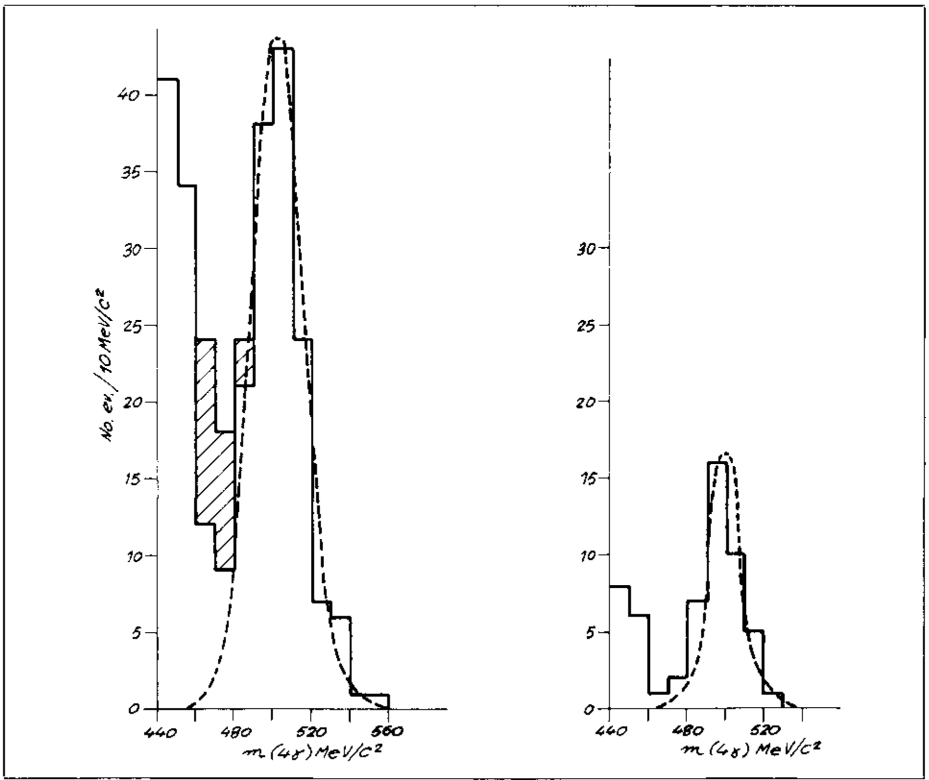
The Aachen-CERN-Harvard-Genova-Torino collaboration has detected elastically scattered protons with the help of four sets of spark chambers, two for each of the two protons. The direction and the interaction point of both particles could be completely reconstructed. The elastic nature of the events is demonstrated by a collinearity requirement. The minimum scattering angle observable was about the same as the largest angle in the other experiment, the angular range being 1 - 2°. The measured slopes at three different beam energies are

12.0 ± 0.2 GeV/c^{-2} at 15.4 + 15.4 GeV
11.1 ± 0.15 GeV/c^{-2} at 22.5 + 22.5 GeV
11.0 ± 0.15 GeV/c^{-2} at 26.6 + 26.6 GeV

The results quoted for the two experiments are different, but given the different angular intervals they are not necessarily in disagreement. In any case it means that the observed shrinking of the slope is less than what one might expect from a simple linear extrapolation of the Serpukhov data at lower energy. In other words, it indicates that the decrease in the effective size of the protons is levelling out as one goes to higher energies.



Inclusive production cross sections from proton-proton collisions at the ISR. The invariant cross section as a function of the longitudinal and the transversal momentum of the secondary particle is shown together with some 'low' energy points. This way of presentation anticipates a certain law of scaling ; points measured at different energies nearly coincide.



The mass distribution of events with four photons in the η_{00} experiment. Left are events with three photons converted in the spark chamber region ; right, events with all photons converted. The full line is the free decay data and the dotted line the regenerator data scaled down. There is a clear peak at the K^0 mass.

Inclusive Experiments

It has become fashionable — purposely — not to observe too many of the details in high energy particle interactions. Thus instead of studying one particular simple reaction channel first and then proceeding to more and more complex processes, a different approach is attempted. Most of the particles — there are typically ten to twenty produced by single ISR proton-proton collisions — are allowed to escape unobserved, and only the angular or momentum distributions of one of the particles are measured. This procedure is due to an idea of R. P. Feynman, C. N. Yang and others who derived certain laws which these distributions should obey.

A team of physicists from Argonne, Bologna and Michigan has performed an experiment at the ISR to study these 'inclusive' reactions of the type $p + p + \rightarrow \pi^+ +$ anything and $p + p \rightarrow p +$ anything. A magnet spectrometer of 45 m length served to detect positively charged particles emerging from the interaction region. Pions and protons were identified with the help of two threshold gas Cherenkov counters. The measured particle production rates were expressed in the form of a special invariant cross section and compared to data measured at much lower energies. And indeed, these cross sections seem to obey the scaling law suggested by Feynman.

CP Violation again

The decay of the neutral kaon is still the only system which definitely exhibits CP violation. In order to understand the source of this CP violation, a series of experiments has been performed throughout the years since its discovery in 1964. In the decay of a kaon into a positively and a negatively charged pion the amount of CP violation is well measured. It is commonly expressed by η_{+-}, i.e. the ratio of the decay amplitude of a long-lived kaon $K^0_L \rightarrow \pi^+ \pi^-$, violating CP conservation, relative to the CP conserving $K^0_S \rightarrow \pi^+ \pi^-$ decay amplitude of a short-lived kaon (CERN COURIER vol. 8, p. 242). This ratio is close to 2×10^{-3}. Unfortunately the well-known absolute value of this ratio is nothing but a measure for the amount of CP violation. Only an accurate knowledge of the phase of this complex quantity and a comparison with the corresponding ratio η_{00} for the $K^0 \rightarrow \pi^0 \pi^0$ decay mode allows further insight into the mechanism of CP violation. To get η_{00} represents a challenging experimental problem : detection of the decay of an uncharged particle into four photons, the final decay products from the intermediate $\pi^0 \rightarrow \gamma\gamma$ decay. The large disagreement of presently known values shows how difficult such a measurement is !

A new precision measurement by the Aachen - CERN - Torino collaboration at CERN should have clarified the situation. The apparatus used consisted of a set of spark chambers, interlaced with thin lead plates for the conversion of photons into electron pairs. The energy of each of the four photons was measured in an array of 61 high resolution lead glass shower counters. The system allowed the reconstruction of the K^0 rest mass with much higher precision than ever before, so that the separation of the rare $K^0_L \rightarrow \pi^0 \pi^0$ decays from background allowed a clean subtraction. The result is

$$|\eta_{00}/\eta_{+-}| = 1.00 \pm 0.06$$

The equality of η_{00} and η_{+-} is predicted by the theory of a superweak interaction which is now very much favoured by the new result. A consequence of this theory is, that the observed CP violation is solely due to a mixing of CP = +1 and CP = —1 states in the neutral kaon system. The interaction is not strong enough to generate CP violating transitions from a pure CP state, and, therefore, no further observation of CP violation can be expected from this source.

Not quite ! There is a new experimental limit from Berkeley telling that less than 1.8×10^{-9} of all K^0_L decay into two muons. This is considerably less than a predicted 'unitary' lower limit, 6×10^{-9}, derived assuming a two photon intermediate state, where the two photons are converted into two muons. Since the real two photon decay of the kaon is known well enough and since the rest is pure quantum electrodynamics, the disagreement between measured and predicted limits is severe. The explanation could again be some effect of CP violation, but nobody seemed to be very happy with that. Will the next conference tell the answer ?

46th Session of CERN Council

It was in a very different atmosphere from that prevailing at the beginning of the last session that Council met on this occasion. The doubts and uncertainties were much in evidence last December, only to be swept away at the adjourned session of February 19 when the decision was taken to construct the new Laboratory. For the first time then on June 24, Council assembled with two Directors general on the platform and this novel situation was one of the main preoccupations of the delegates ; how best to ensure the continued unity of the Organization and collaboration within the Laboratories as well as with the physics community outside.

First, however, came the reports of the Directors general supplemented by an account of the successful commissioning of the Intersecting Storage Rings by Kjell Johnsen.

Professor Jentschke spoke first of the memorable events that had marked the first six months of 1971 — the decision on the new Laboratory, the commissioning of the ISR and the beginning of experiments months ahead of schedule, the bringing into operation of the heavy liquid bubble chamber, Gargamelle, which was inaugurated on May 7.

Turning to the details, he reminded the delegates that of the photographs taken in Gargamelle one in 25 was of a neutrino event — a rate 50 times better than had been possible before. Already 140 physicists from 16 laboratories are looking forward to using the chamber from which it is hoped to learn a great deal about the point structure of the proton and the neutrino.

Another important research facility which has come into operation is a beam line for negative hyperons of 13-20 GeV/c. Considering how rare these particular particles were not so many years ago, the production of a beam of 120 Σ with a relatively low background for a burst of 2.10^{11} protons on the target is a notable achievement (page 191).

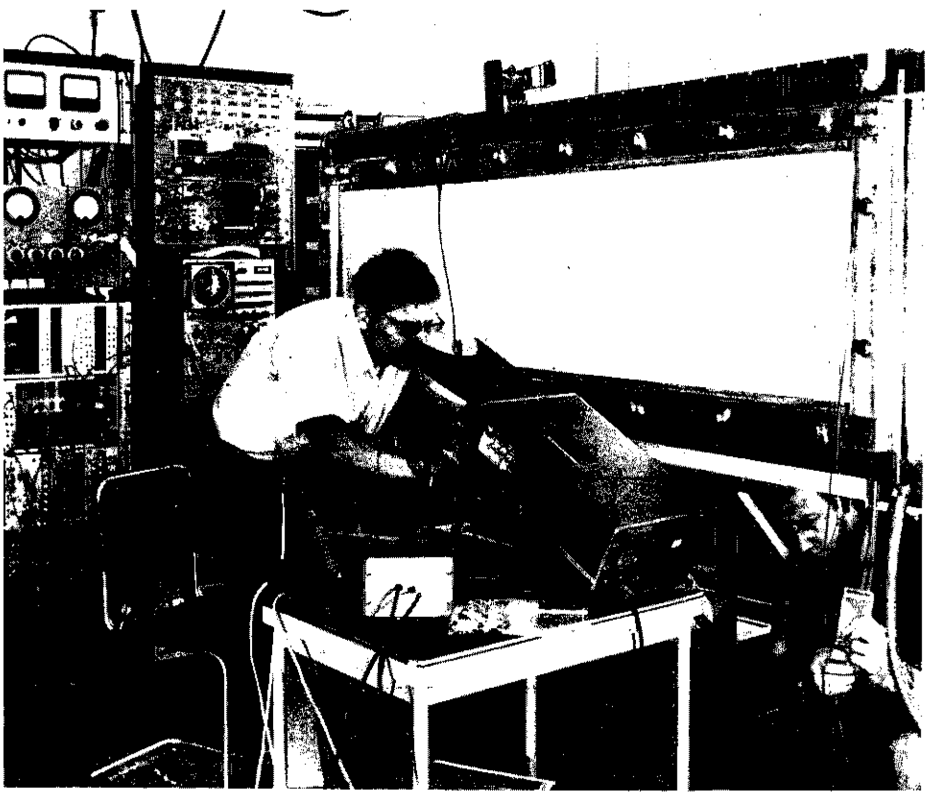
The first of the Booster bending magnets was put into position that very day, and installation of the other 31 will go on until the beginning of November. Each magnet unit is first tested in the assembly hall and fitted with its four vacuum chambers before lowering down into the Booster ring.

The CERN-Heidelberg group has made a big jump forward in the rate at which data can be taken using large multi-wire proportional spark chambers. In the complete array there are some 5500 wires which are operated with a resolving time of $\sim 40\ \mu s$ and can record about 1000 events per PS pulse. In a few hours, more $K_L \rightarrow 2\pi$ events were recorded than had been possible previously in a complete run.

A brief description followed of some of the more notable experiments which had been concluded recently but as these have already been covered in more detail in the report on the Amsterdam Conference they will not be repeated here.

Professor Jentschke spoke also of some of the problems facing a new Director general particularly at this time when CERN was having to adjust to new conditions and restricted budgets which would inevitably entail cuts in the programme. A first task after studying what was going on at CERN was to make a review of the scientific programme, then the technical programme and the future development of the facilities to see where economies can be made. This has been done in a series of seminars in which half the participants came from the European research centres outside CERN.

At the same time a new budget analysis procedure has heen established and a detailed comparison is being



A multiwire proportional chamber, similar to those used by the CERN-Heidelberg group, under test.

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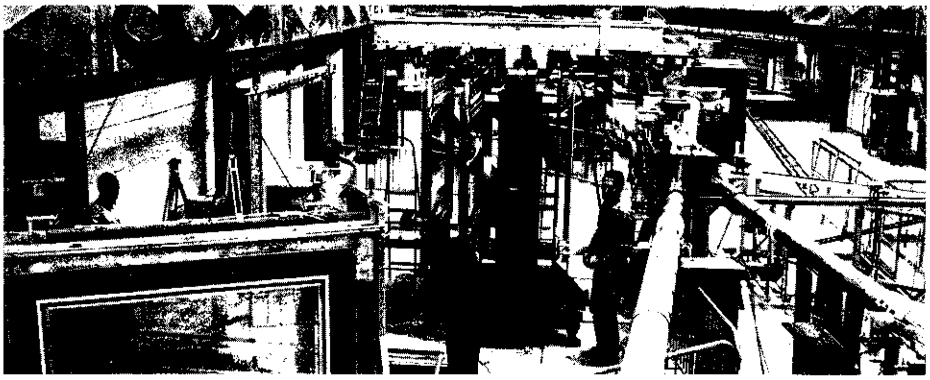

Preparations for the ISR experimental programme begin in earnest as massive detection equipment is moved into position.

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made with the operation of other laboratories. Not it should be said that other laboratories were necessarily more efficient, but with the budget cuts that many had had to face, there was clearly useful information to be gained by studying the practices of other laboratories working under pressure. These pressures in Member States would undoubtedly place an extraload on CERN and it was necessary to take fully into account the new user needs. ECFA had been asked to take steps to coordinate the whole of the European high energy physics programme and to see how this could be optimized to make the best use of all the facilities available. The serious illness of the chairman of ECFA, Dr. T. G. Pickavance, was a great handicap but Prof. G. Salvini has stepped into the breach pro tem.

The ISR

In February already, Council had been informed of the operation of two rings simultaneously on Jan. 27 and the Finance Committee had already taken stock of the financial situation and agreed that March 1 should be considered the end of the construction period and the beginning of operation. This was, however, the first time that Council could be given an overall picture within the framework of the final cost estimate which should be within 1 % of the final accounting figure and has in any case been drawn up, if anything pessimistically.

Professor Johnsen reminded delegates that it was in 1956 at the first international gathering of accelerator physicists that the possibility of producing useful colliding beams was first mooted. Although the alternating gradient principle had still to be finally demonstrated in a large synchrotron, its potentialities were already stimulating a lot of fresh ideas and CERN was beginning to think about the future. It was in fact the MURA group which first began seriously to talk of colliding beams and introduced the idea of stacking. The following year CERN began a study.

In 1959 the PS came into operation and its performance was so encouraging that further studies concentrated on the idea of associated storage rings rather than special accelerators which had been favoured up to that moment. The development was taken up by AR Division and tribute was paid to the contributions of the late Prof. A. Schoch.

The physics community was brought in through ECFA which was created in 1963 and the « thick book » came out in 1964. There then followed a big debate on the wisdom of putting so much effort into such a far-out project, but Council took its courage into its hand and in December 1965 took the decision to go ahead with, as basic targets : completion by July 1971 within an overall budget of 332 MSwFr at 1965 prices.

Site work began in November 1966 and as the months went by much shuffling of the programme was needed because of delays in the completion of certain elements. Nevertheless excellent relations were established with industry and the success of the project is a happy reflection on the way European companies responded to the call for equipment and materials beyond the limits of established technology.

As readers of CERN COURIER will remember the tests on the first ring were advanced to October of last year to get in before the PS shut down in November and December and the results were remarkably encouraging. Ring 2 was operated in January and on Jan. 27 the two rings were operated together for the first time. The initial tests were made with 15 GeV/c beams followed by 22.5 GeV/c in February and 26.5 GeV/c in May.

Over the past few months beams have been available for 20-25 hours/week during which time there has been no major breakdown. With weak beams the machine behaves exactly as expected ; the magnets have comfortably met the specifications of precision and stability, the RF has been excellent and the vacuum has been better than could have been anticipated — the mean pressure is a few $\times 10^{-10}$ torr. There has been some settlement of the ring but the computer has taken care of this.

For currents of up to about 1 A, the lifetime is measured in months, between 1 A and 3 A in weeks and at 4 A the order of a day. The lifetime then is dependent on current and the experimental possibilities are strongly governed by the lifetime.

At 3 A a transverse coherent instability was discovered, the position of which could be changed at will and can be displaced beyond 5 A at least. But, there is still much to be learned about the beam behaviour. A somewhat similar effect also appears at these currents which seems curiously independent of machine conditions and energy and there are pockets of pressure rise which appear to depend on the circulating current rather than on the beam loss. So far a maximum current of 5 1/2 A has been achieved.

There is a small amount of talk between the two beams if the conditions of one are changed drastically but, for the most part, they go their ways blissfully ignoring the other's presence.

The best estimates of the overall cost up to March 1 of this year — agreed to be the completion date for construction, work out at 326 MswFr. (including 12 M for preparations for research) — some 6 M less than the 1965 budget.

The financial aspect as well as the technical success earned warm praise from the delegates and it was sug-

A recent photograph of CERN looking North over the intensively built-up area of Laboratory I to the fields and woods under which the SPS of Laboratory II will be built.

gested that the team had something to teach to the world outside the particle physics community in the way of project management and control. This had been a splendid piece of team work, splendidly led and special mention should be made of the contribution of the members of the parameters committee (see CC Feb., p. 35).

The new Laboratory

The most pressing task Dr. Adams explained after the decision of February 19 was that of staff recruitment, in particular recruitment of the group leaders, as the full-time staff engaged on the 300 GeV programme was still a mere handful. Virtually nobody was instantly available and so far only 10 people had taken up their posts. However, by the end of the year, it was hoped the numbers would have risen to 100-150. Discussions had been held with the SPC and Committee of Council on senior staff and approval was given for the appointment of the following :

- Deputy to the Director general : H. O. Wüster (DESY Laboratory) ;
- Magnet Group Leader : R. Billinge (RHEL and NAL Batavia) ;
- RF : C. Zettler (CERN Lab. I) ;
- Beam Transfer: B. de Raad (CERN Lab. I) ;
- Power Supplies : S. van der Meer (CERN Lab. I) ;
- Controls : M. C. Crowley-Milling (Daresbury Laboratory) ;
- Survey : J. Gervaise (CERN Lab. I);
- Radiation : K. J. Goebel (CERN Lab. I) ;
- Experimental Areas : G. Brianti (CERN Lab. I) ;
- Mechanical Design : H. Horisberger (CERN Lab. I) ;
- Site Installations : R. Lévy-Mandel (Saclay) ;
- Site Administration : A. Klein (F).

The next problem was one of accommodation. Two temporary buildings down near the West Hall are available and a further three are to be erected. The call for tenders for the new laboratory buildings went out early in April and will be adjudicated in September so that construction can begin all being well the following month. They are scheduled for occupation at the end of 1972. The call for tenders for the construction of the work to start early in the new a number of large companies who have considerable experience in boring operations and who have already completed projects of a similar scale and nature. The contracts should be awarded in November for work to start early in the new year.

Arrangements for the acquisition of the necessary land with early access to the most important sector was proceeding smoothly and harmoniously and there was good reason to believe that up to 70 ha would be available by the end of this year and there would be no hold-up in the building programme on that account.

A satisfactory solution to the temporary and permanent electricity supply problem had been worked out with Electricité de France and the general scheme for the water supply with the local Swiss authorities. The arrangements for telephone communication which raise some nice trans-frontier questions were nearly concluded.

Now there was an intensive study of the main design parameters of the SPS in hand in particular the magnet lattice structure.

It was something of a shock to be reminded that parliamentary approval was still to be acquired in some countries before participation in the project could be confirmed but there were no unpleasant surprises. Both Sweden and Norway could confirm their participation and the message's had speedily negotiated both houses

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in Switzerland and was awaiting the completion of the necessary 90 days 'incubation' period.

Inter-Laboratory Collaboration

A great deal of thought has been given to the best means of ensuring the best possible collaboration between the two Laboratories of CERN and with the Universities and research centres outside. The three considerations uppermost in the minds of the administration of CERN and the delegates were :

1. The need to emphasize the unity of CERN as an Organization whilst still recognizing that Laboratory I was responsible for the Basic and ISR Programmes and Laboratory II under a separate Director general and with a separate budget was responsible for the 300 GeV Programme.
2. The need to make the best possible use of existing services to avoid as far as possible duplication or waste.
3. The need to harmonize the physics programmes so that the best use was made of existing facilities and the new facilities best met the developing requirements for research.

Inside CERN a coordinator for experiments relating to the SPS had been nominated (J. V. Allaby) who will be in close touch with Prof. P. Falk-Vairant of Saclay who is chairman of the working group set up by ECFA.

The four existing experimental committees will continue to act as before in the establishment of the scientific programme and for the time being willl be wholly concerned with Lab. I operations but should in due course be able to adapt to the coming into operation of the SPS.

A new Machine Committee drawn from the various European accelerator centres with Prof. F. Amman of Frascati as chairman will maintain the contact between the SPS builders and the physics community on the hardware questions which relate to the operation of the new accelerator. A system of ad hoc study groups tackling specific problems is favoured rather than permanent groups with global responsibilities.

The development of superconducting techniques for synchrotron applications will be carried out in laboratories of the Member States — principally Karlsruhe, RHEL and Saclay and will be coordinated by the committee with code name GESSS.

The structure is moreover not immutable but is designed to be as light and as flexible as possible so that it can take account of experience in this novel situation. The 18 years' background of successful collaboration at CERN should ensure it gets off in this new era on a sound footing.

Before concluding the Council business the President, Prof. Amaldi announced that Dr. G. Funke, Swedish delegate and former Council President had agreed to act as Vice-President until the end of the year to fill the vacancy left by Dr. H. H. Haunschild who has been called to higher duties in Germany. The other Vice-President is Dr. A. Chavanne of Switzerland. Appreciation was also expressed of the work of Prof. Walter Thirring who returns to Austria after two years as Head of the Theoretical Physics Department. Until the end of the year, Leon Van Hove will be acting in his stead.

Varna Summer School

The Black Sea Summer School of Elementary Particles was held at Varna, Bulgaria from 13-27 June. It was organized by the Joint Institute for Nuclear Research, Dubna, USSR, in collaboration with CERN and with representatives from Bulgaria. It was attended by 110 students from 20 countries, including 38 students from the Member States of CERN. The principal lecture courses were : — « Inelastic Particle Interaction Theory » by D. Shirkov (JINR), « Electromagnetic and Weak Interactions » by J. Prentki (CERN), « Multiparticle Production on Nuclei at High Energies » by A. Bialas (Cracow). In addition short lecture courses were given by V. Barashenkov (JINR), O. Kofoed-Hansen (CERN), V. Matveev (JINR), Nguyen Van Hieu (N. Vietnam), while W. Jentschke (CERN), A. Mihul (JINR), A. Baldin (JINR) and V. Iarba (IHEP, Serpukhov) spoke about the research programmes of their laboratories.

Professor Jentschke being bidden farewell at Varna by Mr. M. Loschilov of the Dubna International Department. To the left of Professor Jentschke is Professor A. M. Baldin, in the centre Dr. P. S. Isaev, while Professor Kofoed-Hansen is to the right of Mr. Loschilov.

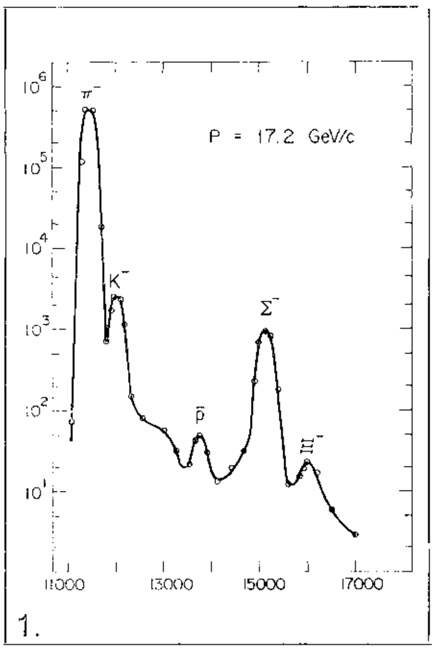
CERN News

1. Mass spectrum of particles at the hyperon channel output. For a given momentum, selected by adjusting the analyzing magnets, the particles' mass is identified by selecting their velocity using the DISC counter. The negative hyperons Σ^- and Ξ^- are clearly visible on the right-hand side of the spectrum.

2. $\Xi^- \rightarrow \Lambda^0 + \pi^-$ decay.
$\hookrightarrow \pi^- + p$
A Ξ^- of 18 GeV/c decays in a streamer chamber located behind the DISC to give a π^- and a Λ^0. The Λ^0 decays into $\pi^- + p$.

Beam of negative hyperons

A CERN-Orsay-Ecole Polytechnique group has begun experiments with the new hyperon beam. The line is very short and incorporates two analyzing magnets and two superconducting lenses (see CERN COURIER vol. 10 page 281) grouped together over a distance of 3.70 m. The hyperons at rest live for only about 10^{-10} seconds and the trick for obtaining a usuable beam is first to produce the hyperons at as high an energy as possible so winning from the time dilation, and, second to make the beam line as short as possible. The beam set up in the East Hall uses the North branch of the proton beam ejected at 24 GeV/c (see CERN COURIER March 1971). The hyperons produced in a target 20 cm long pass through a curved channel with an average section of 4 cm². This channel is located inside two analyzing shim magnets which produce a maximum magnetic field of 3 Tesla. Surrounding the channel is a composite shield consisting of tungsten and uranium next to the beam and lead for the remainder of the volume. By bending the trajectory of stray particles such as μ mesons in the magnetic field their path through the shielding is lengthened. The two superconducting quadrupoles are placed after the first and second magnets respectively.



This configuration gives the maximum intensity of hyperons consistent with good identification and for a momentum measurement accurate to within 10 %.

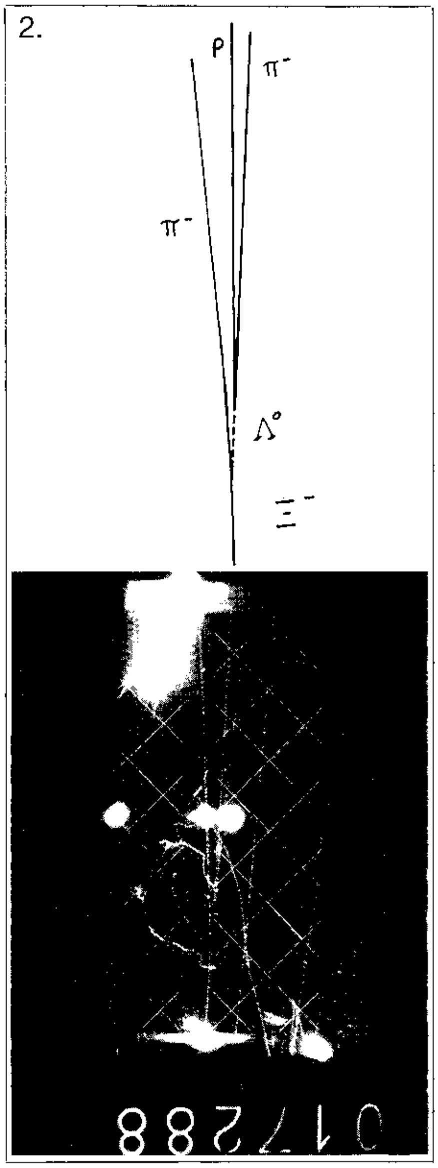
A DISC differential Cherenkov counter is located right at the channel output. By adjusting the pressure of the gas inside (sulphur hexafluoride), the refractive index of the DISC may be controlled, and particles of a given velocity selected. Knowing the momentum and the speed of a particle the mass can be computed and the mass spectrum of the beam (Fig. 1) determined by varying the refractive index in the DISC. To identify Σ^- or Ξ^- hyperons, it is sufficient to set the correct index.

With the DISC adjusted for Ξ^- and used in conjunction with a streamer chamber measurements have been taken over the range 13-20 GeV/c. Fig. 2 shows a Ξ^- decay observed in the streamer chamber when the beam was set at 18 GeV/c.

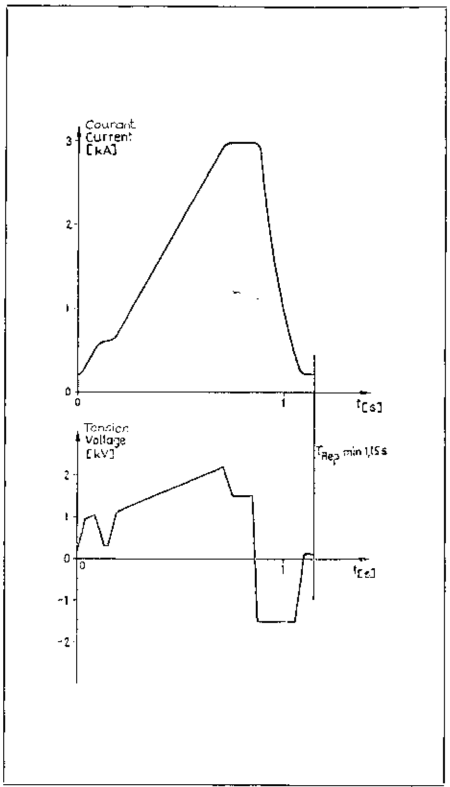
Current experiment

The beam as it is currently being used for the present experiment is producing something of the order of 100 Σ^- identified by the DISC per pulse of 2×10^{11} protons from the PS ; the loss factor due to decay between the target and the DISC is approximately 1000.

Measurements are being made on the total cross-section of Σ^- on hydrogen and deuterium, the results of which will be an important test of the quark model. The present set-up



comprises the following sequence of equipment along the beam line : a DISC framed by two multi-wire proportional chambers, a hydrogen and deuterium target 1 metre long followed by a second DISC framed by two more proportional chambers. With these chambers developed in the Linear Accelerator Laboratory at Orsay, angles can be measured to 0.5 mrad accuracy when the chambers are 60 cm apart.



Current cycle (above) and voltage cycle (below) of the Booster. It can be seen that, unlike the PS where the field rise occurs at a steady voltage, the voltage here is programmed to produce the desirable increase in field.

Next experiment

A second experiment is now being prepared. It will incorporate two large streamer chambers (one of which will be placed in a big magnet) an electron Cherenkov counter and a neutron counter. The aim of this experiment is to study the leptonic decays $\Sigma^- \rightarrow e^- + n + \bar{\nu}$ and $\Xi^- \rightarrow \Lambda^o + e^- + \bar{\nu}$. By studying these rare modes, the parameters of the Cabibbo theory may be measured and the effects of SU3 symmetry breaking investigated. The experiment should produce several thousands Σ^- decays and about 100 Ξ^- decays. These figures are about ten times higher than the total currently accumulated in the world.

A similar hyperon beam has been set up at the Brookhaven National Laboratory and these two beams together will open up a whole new range of hyperon physics. The initial success of these installations has already stimulated plans for the introduction of hyperon beams of very high energy at the National Accelerator Laboratory and in the future at the CERN SPS.

Static power supply for the Booster

'Static' power supplies, that is, those without rotating components (and not involving static electricity), are very popular nowadays when it comes to providing pulsed accelerators with the cyclic supply of high current required by their magnets.

An accelerator like the CERN proton synchrotron accelerates a burst of protons approximately every two seconds. If special precautions were not taken, this would mean that 90 MW of power would be tapped from and then returned to the supply network every two seconds which would cause unacceptably large fluctuations in the local grid system. It has been necessary, therefore, to develop rotating machines which can act as energy accumulators and operate both as motors and as generators; the machine absorbs the surges of power and the supply grid is not affected.

However, these rotating systems are cumbersome and being subjected to continual reversals of torque have a limited life. They require a maintenance team of several men on constant watch. What is more a breakdown may bring the accelerator to a standstill lasting several months. By taking advantage of the improvements in the design and price of current rectifiers and by exploiting the interconnection of supply grids, it is now possible to contemplate the use of static power supplies where current is tapped directly from the major networks.

This solution is being used for supplying the magnets of the 200-500 GeV accelerator at Batavia where there is a large amount of power available from the grid complex serving the industrial area of the Great Lakes. It is planned to do the same at CERN for the SPS.

However, before starting work on the SPS, the Europeans have already had a chance to put this idea into practice ; namely for supplying power to the PS Booster which, in view of its more modest power requirement, was compatible with the size of the local supply grid.

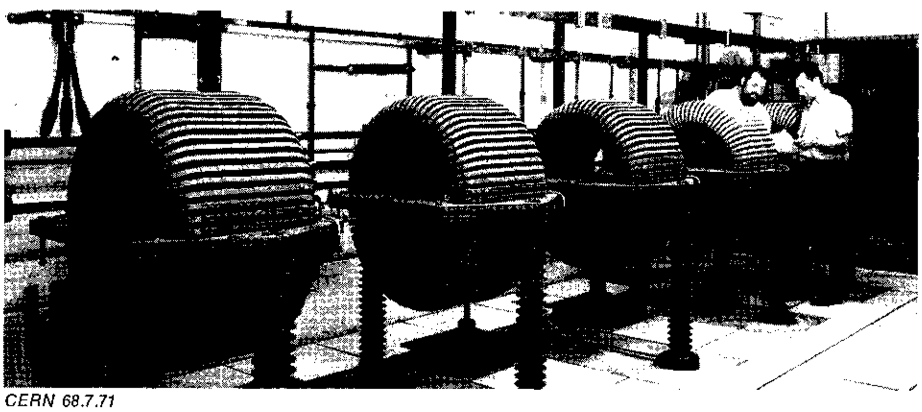
Initial studies in 1968 (see CERN COURIER, vol. 8, page 250) had shown that the scheme was feasible and the decision to go ahead was taken at the end of 1968. The power supply for the Booster is now being installed and tests will begin in Autumn 1971.

Three main requirements have governed the design of this system :

1) reduction of the reactive generating power of voltage fluctuations in the CERN grid to a minimum ; this was done by coupling the thyristors and by triggering them in sequence ;

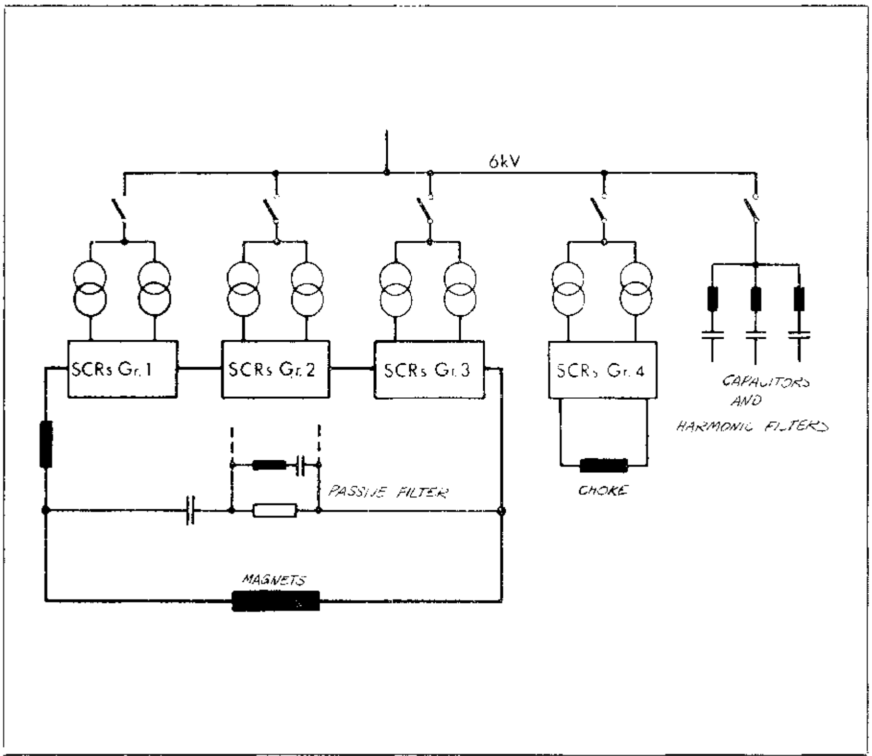
2) development of a constant reactive power throughout the cycle by adding to the reactive power from the sets supplying the magnets an artificial reactive power so that the sum of the two remains constant ;

3) maximum neutralization of this constant reactive power by the addition of capacitor banks (which



One of the most 'aesthetic' parts of the Booster's power supply being installed : these are the circuit coils for the passive filter, with their distinctive toroidal, coreless design.

CERN 68.7.71



General layout of the installation : 3 groups of thyristor rectifiers are used for the power supply itself and the fourth serves to create artificial reactive power which is added to that of the network so that the total of the two remains constant. The capacitor bank on the right serves to reduce the reactive power from 8-9 MVAR to 1 MVAR.

also serve as harmonic filters on the alternating current network).

In this way, the reactive power may be reduced to approximately 1/10 of its value had the magnets been connected directly to the mains (approx. 1 MVAR instead of 8 to 9), and this will limit voltage fluctuations on the CERN grid to approximately 0.3 % — a tolerable level for other users.

The power supply includes the following main components :

— 4 sets of thyristors (3 for supply and 1 for compensation), each of which includes : 1 2.2 MVA twin transformer and a set of 60 medium, 430 A, dodecaphase, air-cooled thyristors with 10 kV insulation against ground ;

— 1 passive filter for direct current (see photo) ;

— 1 bank of compensation and filter capacitors ;

— all the usual equipment for control and protection.

First magnet for the Booster

Since 24 June the Booster buildings have been the scene of increased activity. That date marked the installation of the first of the machine's magnets and the beginning of the process of equipping the tunnel with the hundreds of components which, when fitted together, will form the 4 superimposed rings of the machine.

These single-yoke four-gap magnets are supplied complete with coils, by Alsthom, Belfort, at the rate of 2 per week, and so, all being well, they should all be in position by the beginning of November.

During punching and assembly of the laminations an accuracy of a few hundredths of a millimetre has been achieved for the yokes and approximately 0.2 mm for the alignment of the copper in the gaps.

The measurements, which have been done at CERN using a semi-automatic system in conjunction with a computer and a print-out (see CERN COURIER vol. 11, page 95), have shown that all the magnets delivered by the end of June were well within the specifications. The next job at CERN is to add the triple shimming (correction of systematic, statistical and vertical gradient effects), in order to ensure a field in the useful aperture homogeneous to $\pm 2 \times 10^{-4}$.

The delivery of the first focussing elements, supplied by BBC Mannheim, has also begun ; the complete set should be at CERN also by the beginning of November. Precision measurements carried out on these magnets also show that the specifications have been fully observed. They are made in an air-conditioned area and are followed by a highly accurate optical and magnetic alignment of the four gaps.

Finally, the first of the 21 correcting pole lenses ordered from Lintott has just arrived at CERN and it will shortly be its turn to be counted.

Wall-papering the BEBC

The last of the big vessels for the 3.7 m liquid hydrogen chamber BEBC, the body itself, was delivered in June and is now being prepared for its final transplant. One of the jobs that still had to be done was the lining of the interior with a reflective covering of Scotchlite. The Scotchlite is designed to reflect the light coming from the annular flash back into the camera lens with a very low angle of divergence (see figure) irrespective of the incident angle. The chamber then when viewed through the central part hole looks uniformly white and any bubbles appear as dark discs (the so-called bright field illumination). Tracks are dark lines on white and the developed film shows white lines on a black background. The advantages of

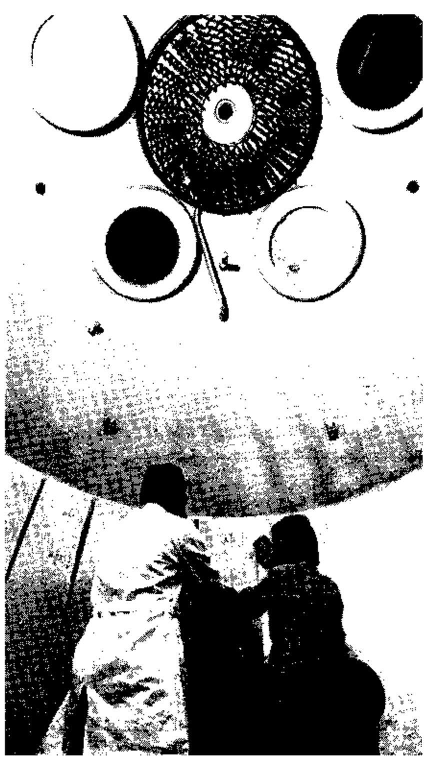
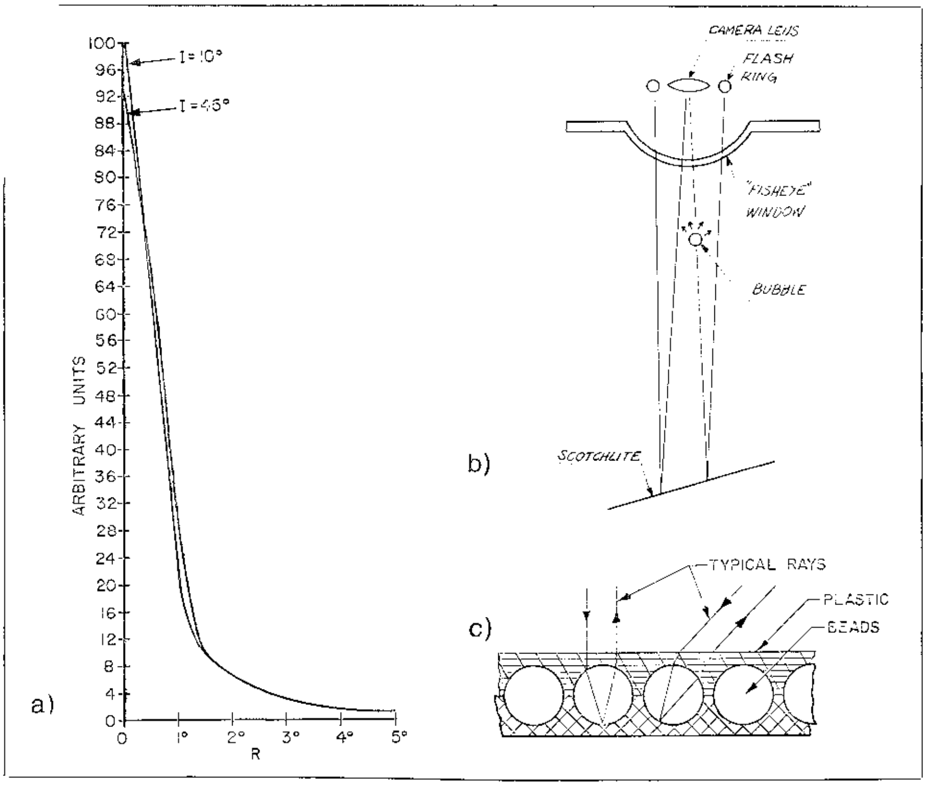


Photo taken during the fitting of the Scotchlite reflective covering to the interior of the BEBC chamber body, which is the same size as a small studio.

CERN 292.6.71



a) Curve showing the intensity of the reflected light as a function of the reflecting cone's aperture for two characteristic angles of incidence (10° and 45°).

b) Schematic diagram of the diffusion by a bubble, of light originating from a flash around the objective and reflected by the Scotchlite.

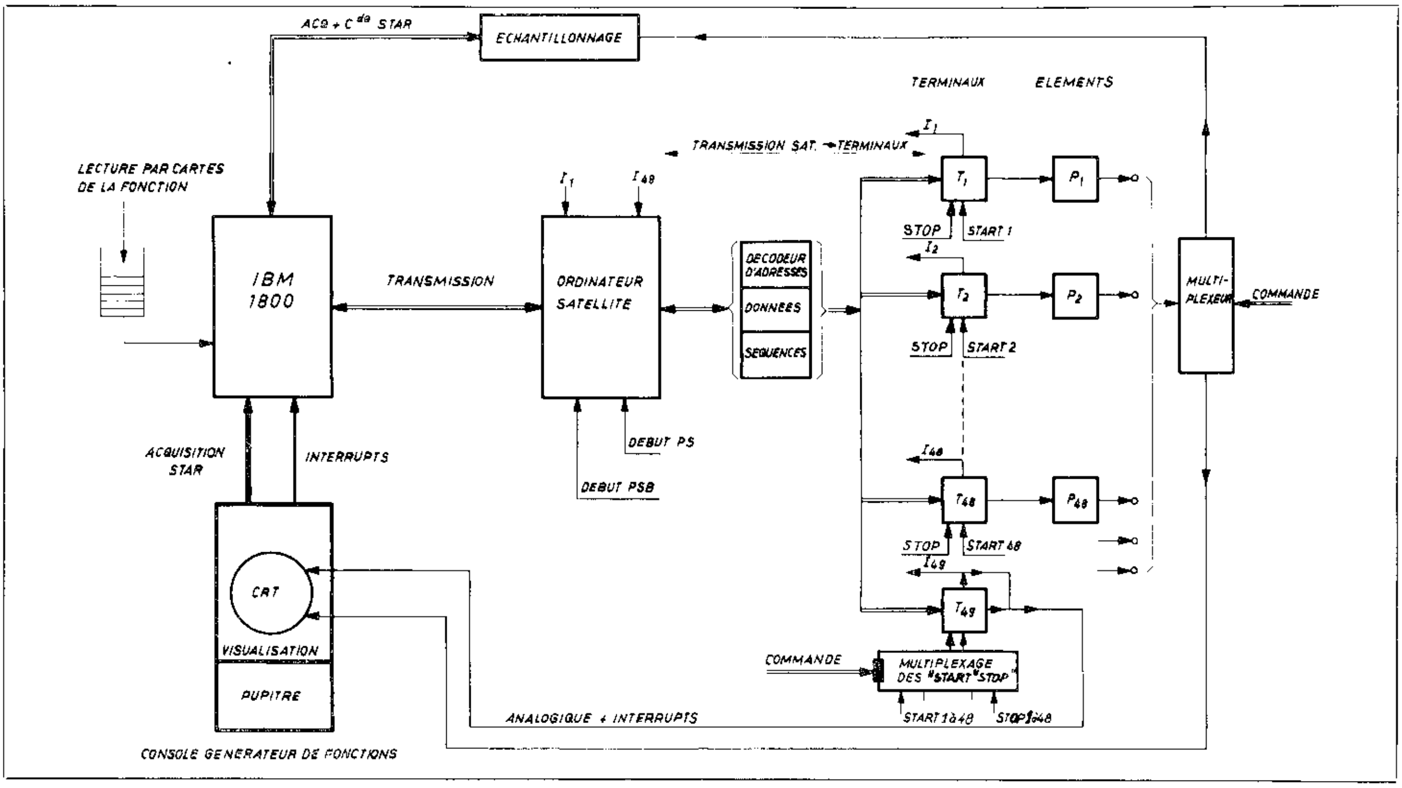
c) Very enlarged section of the Scotchlite covering. The millions of beads immersed in a plastic covering reflect the light in a direction nearly parallel to the path of the incident rays.

this technique, which was first applied at Berkeley in 1963, is that very large volumes can be photographed through small apertures.

The Scotchlite is a special reflective covering supplied by the firm 3M. It comes as a thin, flexible sheet in rolls 12 inches wide and because of its peculiar reflective properties has the rather unnerving habit of appearing to be always in hiding. It consists of a layer of glass-like beads mounted on an aluminized plastic sheet. The beads which are of very high refractive index and of a composition which remains a trade secret are about 25 µm diameter. Some 1000 Millions/m² are required. They are protected from external agents by a thin strip of colourless Mylar (R).

The Scotchlite comes protected on both sides by impregnated paper. It is self-adhesive and is simply pressed into place after the protective paper has been removed. However, it adheres so firmly and so quickly that it is often impossible to remove a badly positioned sheet without spoiling it. First however, the stainless steel surface of the chamber had to be prepared in order to get perfect sticking even in liquid H_2 at 25° K. (1) The first process was one of degreasing with an acid which contains surface-active agents and non-inflammable solvents followed by rinsing in tap water ; (2) pickling in a mixture of nitric and hydrofluoric acid sprayed on to the surface, followed by rinsing with water ; (3) passivation with dilute HNO_3 and rinsing with tap water and finally with distilled or demineralized water.

When this has been done, the application of the Scotchlite could begin — a task entrusted to a skilled 'decorator' who had his fair share of the awkward corners know to all amateur paper hangers.



Below left:

Basic layout of the function generator.
A total of 48 functions are stored in the satellite computer which retransmits them, on request, to the terminals ; the latter in turn convert them into analog voltage signals.
When a function is presented to the IBM 1800 in the form of a Fortran punched card, it is broken down into vectors, the co-ordinates of which are recorded in binary code.
The IBM 1800 takes about 30 seconds to compute a function.

The IBM 1800 memory core can store in advance 100 functions in binary form ; in one second these can be made to replace those stored in the satellite computer.
By means of the control desk connected to the IBM 1800 and to the oscilloscope, 'empirical' modifications can be made manually to the functions already stored in the memory.

Computerized function generator for the PS and Booster

For several years, now, tests related to the automatic control of accelerators have been under way at the PS, involving the use of an IBM 1800 computer located in the control room. Last year a trial run was made on the automatic control of the PS compensating windings. In view of the encouraging results, it was decided to design a function generator common to the PS and Booster, to provide automatic operation of the greater part of the latter's control system. Because of the pulsed characteristics of synchrotrons, a large number of their parameters must comply with varying time functions in the accelerator's cycle. These functions relate, for example, to the power supplies, the RF system etc., for which they serve as the reference values.

In view of the increasing speed at which digital computers can operate, they are now able to take over the task of producing these functions ; furthermore, advantage can be taken of programming flexibility to adjust them as required.

For the operation of the PS and Booster, a computer-operated function generator has been designed which is able to control 48 different functions simultaneously. The functions, in the form of Fortran punched cards, are presented to the IBM 1800 computer, which breaks them down into a series of vectors and calculates their co-ordinates in a linear form.

Each vector is characterized by its initial amplitude, slope and duration, in such a way that over the time-interval the function is represented by the vector within the limits of a tolerance specified by the operator. The characteristics of a vector are coded in the form of two binary words consisting of 116 bits.

The data are then stored in the core of a satellite computer (Varian 620), which retransmits them, when instructed, to terminals where they are converted into analog voltage signals.

At the beginning of the acceleration cycle the first two words representing the first vector of each function are sent to each 'terminal'. This component, of which there is one per function, reconstructs the vector: the original amplitude, followed by an analog slope for a time equal to the duration of the vector. When this time has expired, the terminal sends an 'interrupt' signal to the computer requesting the issue of the following vector. This procedure continues up to the last vector representing the function in the cycle.

The 48 stored functions normally correspond to operations relating to the cycle. For example, in the case of the Booster, there are two functions for controlling the dipoles, eight for the quadrupoles, twelve for the RF voltage etc...

As we have seen, the main computer is used for producing the vectors from a function which has been defined analytically in the form of punched cards ; an existing function can, however, also be modified according to instructions given by the operator from a special console, linked with an oscilloscope that displays the input function which the operator wishes to modify, together with the reply function of the physics system to be controlled. By this means the operator can effect a total or partial modification of the function between two acceleration cycles.

This function generator will be introduced gradually on the PS and into the Booster test programme.

Death of Professor Bernas

Professor René Bernas, Director of the Nuclear and Mass Spectrometry Centre of CNRS at Orsay, who has led a number of experiments at CERN on the identification and isolation of short-lived radio-isotopes died in Paris on July 7 at the age of 51. With his team he was preparing an experiment on sodium 35 to begin at the PS at the end of this year.

He was among the group which initiated the ISOLDE project at CERN and since 1965, he has developed a new technique for the detection of radio-isotopes which has formed the basis of a number of experiments at CERN on lithium, sodium, rubidium and caesium.

A modest person but a scientist of rigorous method and an excellent group leader, he will be sadly missed by his friends at CERN and elsewhere.

In memory of Professor Powell

On Saturday June 19th, 1971 a gathering of old friends took place on the Alpe Giumello, above Lake Como, to install a specially made bench in memory of Cecil Powell who died there nearly two years ago.

The bench was designed by Bruno Munari and was constructed in the laboratory of Professor Occhialini in Milan. It is situated in a wonderful position overlooking the Valsassina and Lake Como and was donated by a group of scientists to mark their affection for their colleague and friend.

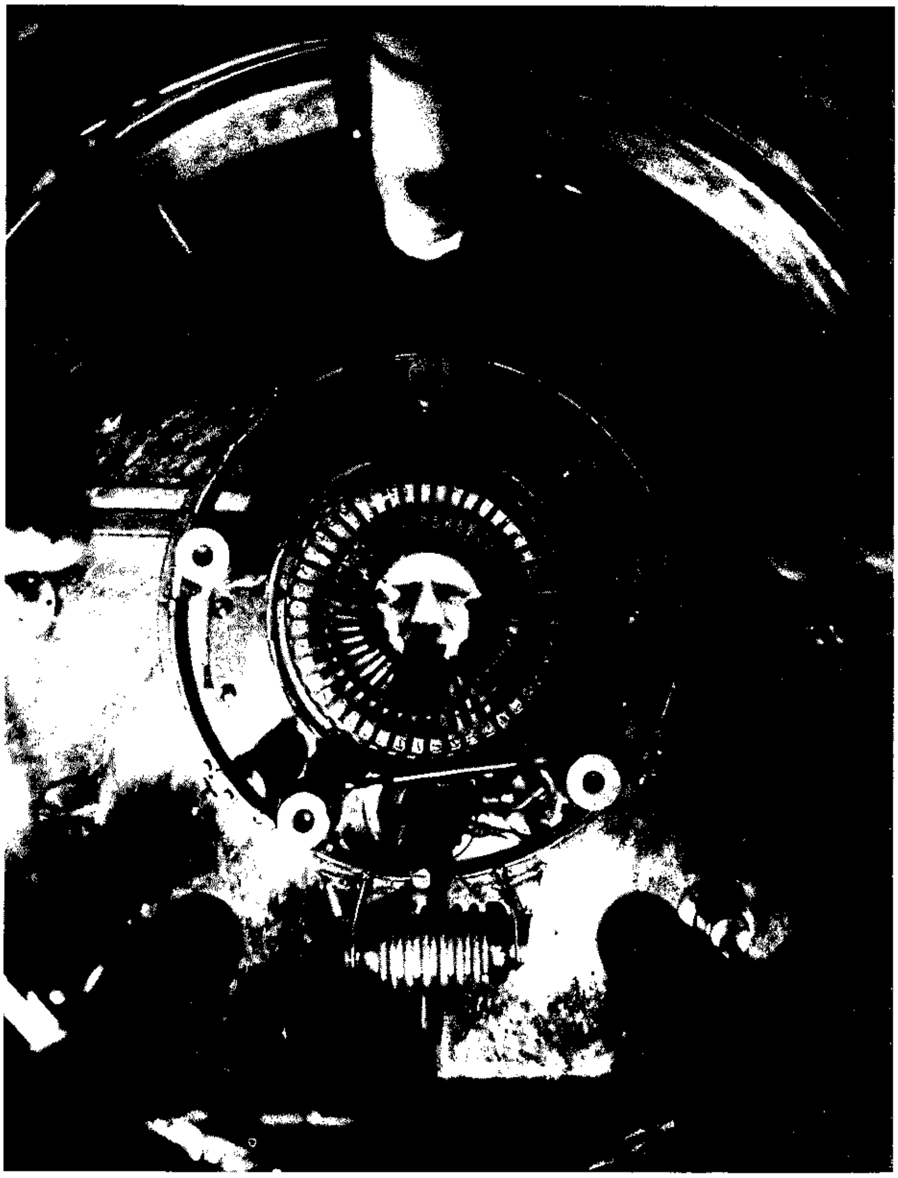
The representatives of the Commune of Casargo were also there accompanied by a group of young girls in their local costumes who presented to Mrs. Powell a beautifull floral tribute composed of gentians and edelweiss gathered in the surrounding moutains.

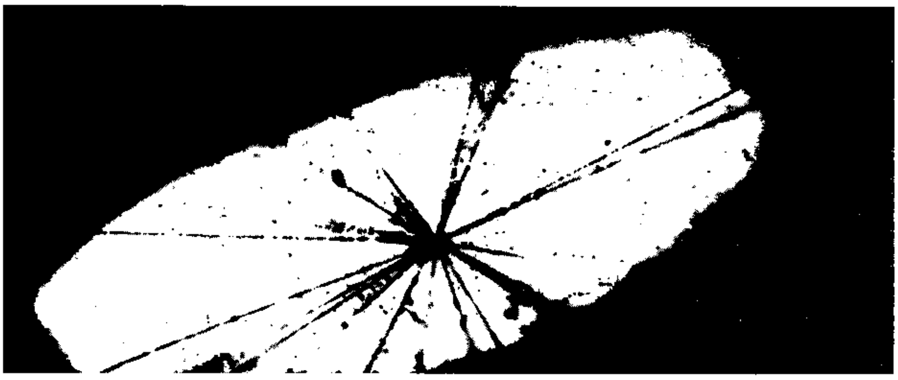
Around the Laboratories

Looking into the compressor of the Dubna Electron Ring Accelerator. It was this latest version of the compressor which was used for the formation of electron rings holding alpha particles when the alphas were accelerated to an energy of about 7 MeV per nucleon.

A blown-up photograph of the profile of the deuteron beam of momentum 9.4 GeV/c accelerated in the Dubna synchrophasotron recorded on X-ray film at the point where a nuclear emulsion is irradiated. Superimposed is a picture of an interaction of a deuteron with a nucleus of the emulsion.

(Photos Dubna)





DUBNA Accelerator developments

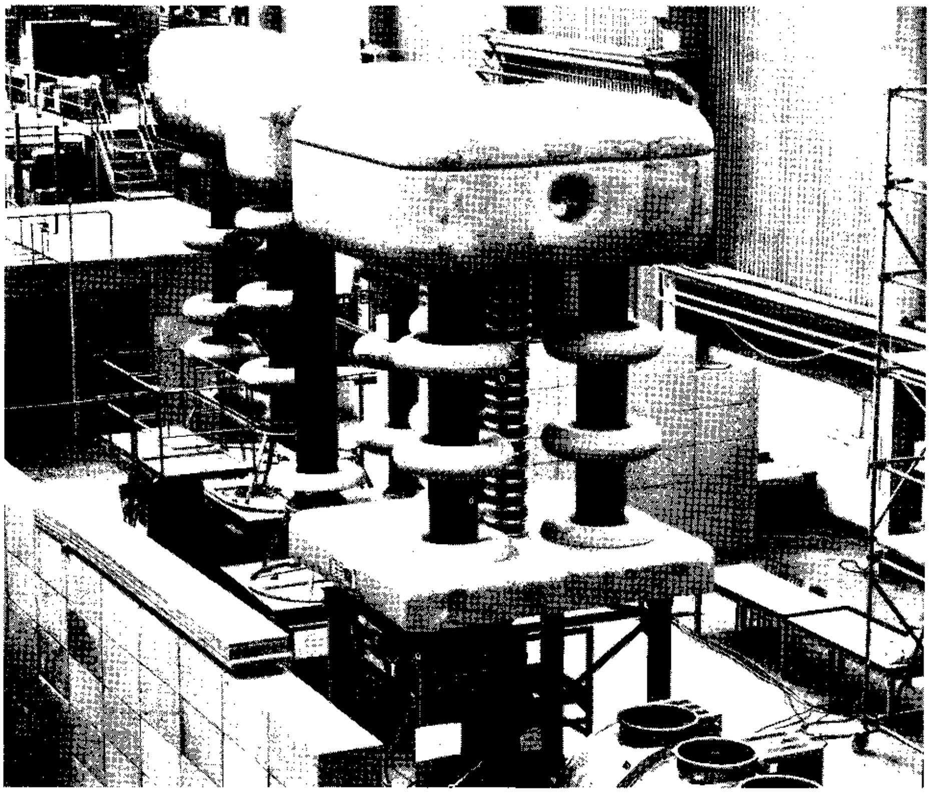
Some more details on the acceleration of deuterons by the 10 GeV proton synchrophasotron (reported in vol. 10, page 386). The maximum momentum of the accelerated particles is 11 GeV/c and fast ejection has been performed. Only slight modifications were needed to the existing systems of the synchrophasotron in order to set up the necessary conditions for the acceleration of deuterons.

Acceleration was carried out at the second multiple of the normal frequency in the synchrophasotron injector, with the velocity of the deuterons entering and leaving the linac a factor of two lower in comparison with protons. Acceleration in the main ring was performed in two phases: first of all, at the second multiple of the normal r.f. frequency, and then, when the limit of the accelerating system had been reached, at normal acceleration frequencies in a virtually 'flat-top' magnetic field.

The operating conditions of the pre-injector's ion source were virtually the same for deuterons as for hydrogen. When a deuteron beam was first accelerated in the linac, the voltage at the pre-injector was reduced by a factor of two and the gap between the drift tubes narrowed. In the first two gaps, the particles did not receive an energy increment and in the third and fourth gaps they were bunched before entering the fifth gap where acceleration proper began. When this had been correctly implemented it allowed a higher voltage at the pre-injector and the current of accelerated deuterons was increased by a factor of six. Using a debuncher at the output end of the linac, the capture of deuterons was increased

Proton injector for 1 mA and 0.8 MeV and prototype cryostat.

(Photo Karlsruhe)



by a factor of two. The proportion of particles lost at this stage was approximately the same as for proton acceleration.

With the two-phase proton acceleration, the maximum (90-95 %) particle recapture when switching from one to the other was achieved by selecting optimum values for the shape of the magnetic field in the 'flat-top' mode, for the slope and amplitude of the r.f. accelerating voltage, and also for the radial position of the bunch before changing to the second phase. By compensating phase disturbance, losses during the change were reduced by a factor of two. In general the particle loss in the change from the first to the second acceleration phase did not exceed 40 %.

The normal proton fast ejection system was used to eject the deuterons from the accelerator. Several stacks of nuclear emulsions placed in a strong pulsed magnetic field have been irradiated in the ejected deuteron beam.

Acceleration of alphas in Electron Ring Accelerator

We have already reported (vol. 11, page 50) that V.P. Sarantsev's group working on electron ring accelerators achieved acceleration of alpha particles to about 7 GeV per nucleon towards the end of last year. The preliminary work had showed that the vacuum in the compressor needed improving. The necessary modifications were carried out and in October 1970 a vacuum of 3 to 5×10^{-8} torr was reached. During November and December the compressor was used several times for the acceleration of alphas.

The 100 A, 1.5 MeV electron beam from the induction linac was injected into the compressor's weak-focusing field on a radius of 40 cm. During adiabatic compression the ring's radius was reduced to 6 cm. Ions were drawn into the ring from a helium medium in which compression took place and the ring's final cross-section measured approximately 2 mm diameter.

In order to eject the ring from the compressor, the magnetic field was distorted. Booster coils were shunted at a specific moment to produce a magnetic field with a gradient along the axis which set up the necessary accelerating force.

After the electron component had been separated out, the beam of alpha-particles was recorded and its parameters determined by a technique for measuring the radioactivity induced in a target via the reaction

$$_{29}Cu^{63} + {}_{2}He^{4} \rightarrow {}_{31}Ga^{66} + {}_{0}n^{1}$$

The energy of the alpha particles was determined by means of a composite target consisting of five copper and five aluminium foils. An examination of the gamma spectra from each foil revealed that the maximum intensity occurred on the fourth foil corresponding to penetration of alpha-particles of energy 29 ± 6 MeV. Competitive reactions, producing the isotopes Ga^{65} and Ga^{68}, could be distinguished from the main reaction by the substantial differences in half-life. The contribution from the reaction (γn) was negligible. The intensity of the resulting alpha beam was estimated in terms of the value of the peaks in the gamma spectrum and was 3 to 5×10^{9} particles for the various runs.

These experiments have confirmed that it is intrinsically possible to build an accelerator based on the collective ion method.

KARLSRUHE Superconductivity in r.f. structures

Work is in progress at Karlsruhe on superconducting r.f. structures and some very encouraging results using a new method of treating niobium surfaces, have been obtained. The work is directed towards applying superconducting technology in a small proton linear accelerator and in an r.f. separator.

1) The small linac is a pilot study for a much bigger superconducting facility. It is designed to have an energy of 60 MeV with a continuous current of 1 mA using three stage acceleration — a conventional 0.8 MeV Cockcroft-Walton, a helix-loaded superconducting resonant structure taking the energy to 15 MeV (allowing more intense beams at low energies to be accelerated than in a drift-tube structure), and a drift-tube section taking the energy to 60 MeV.

2) The superconducting r.f. separator would provide not only higher deflecting fields but also longer duty cycles than conventional r.f. separators. If

the studies go well, such a separator may be built for use at the CERN proton synchrotron, possibly becoming available in 1973.

However before moving to the production stage of either project there is a central problem to be solved — the production of niobium surfaces, on the required scale, which will provide very low r.f. resistance up to high field levels.

The pioneering work at Stanford (HEPL) has shown that in sealed-off X-band test cavities, very low surface resistances (10^{-8} to $10^{-9}\,\Omega$) can be obtained up to magnetic fields of 900 G (1080 G was obtained once). These test cavities were treated in an ultra high vacuum (UHV) furnace at about 2300° K and 10^{-9} torr. But lower frequency cavities and full size accelerator cavities treated in the same way have so far always showed field limitations at considerably lower levels — of the order of 200 to 400 G (see the information on Illinois, for example, in the May issue page 136).

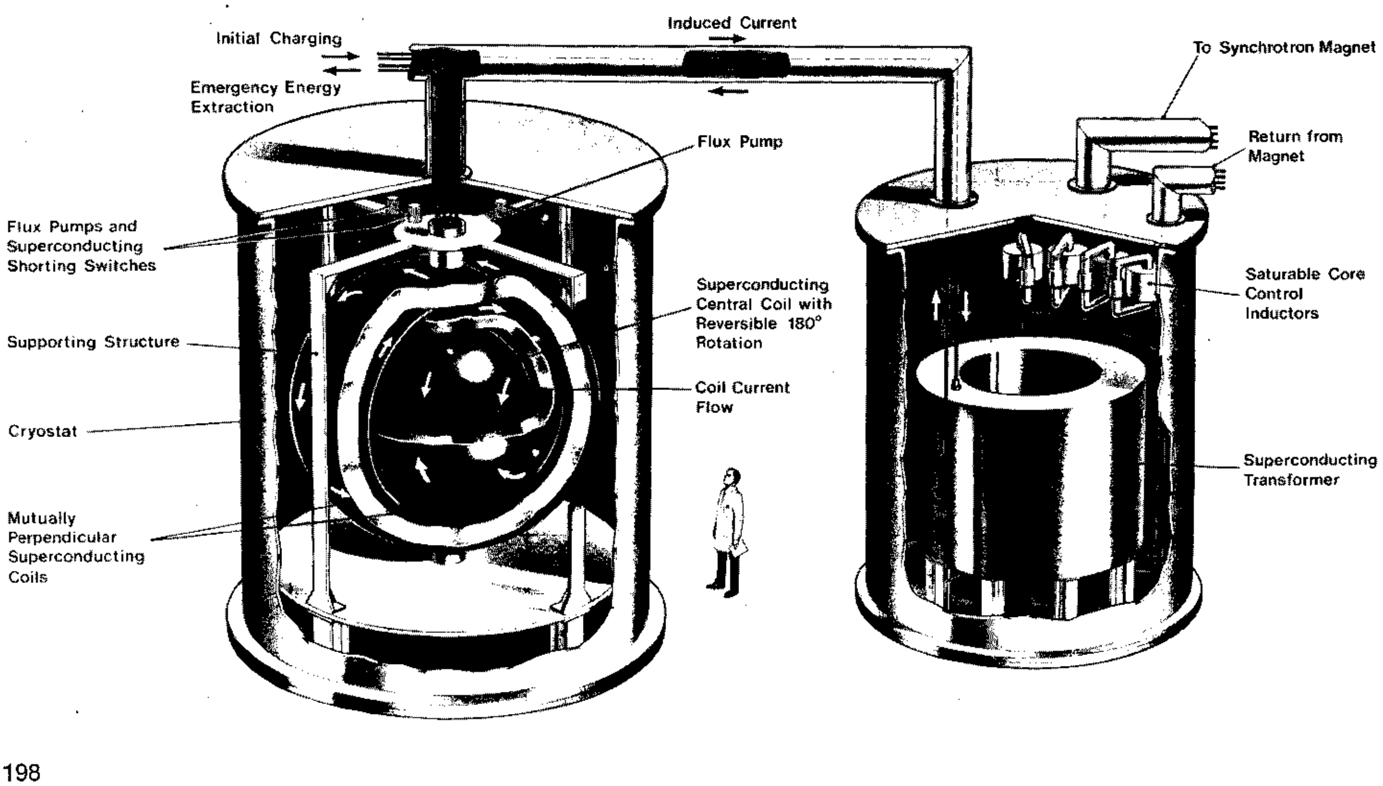
Because the installation of an UHV furnace at Karlsruhe has been delayed, other methods of producing good niobium surfaces have been tried in collaboration with the Siemens research laboratories at Erlangen. First the surfaces were electropolished and hydrogen outgassed in a normal vacuum furnace and results following this treatment were encouraging.

In a second step the niobium was anodized and results at least equal to those achieved with UHV furnace treatment could be obtained. A helix-loaded resonator at as low a frequency as 90 MHz was operated several times over extended periods with a surface resistance of $7 \times 10^{-8}\,\Omega$ at a magnetic peak field of 500 G in steady state and up to 700 G over short periods. This would correspond to an accelerating field of 1.2 MV/m on the axis, which is in excess of the design value of 1 MV/m for the low energy part of the small proton linear accelerator.

In order to make possible a direct comparison with results obtained in S-band (2 to 4 GHz) and X-band (9 GHz) cavities, measurements were also carried out with a TM-resonator at 2.6 GHz. It was electropolished, hydrogen outgassed (at a temperature of about 1200° Ki and pressure of about 10^{-4} torr) and subsequently anodized. The maximum magnetic peak field in different experiments was 325 G, the lowest surface resistance in this mode $5.10^{-8}\,\Omega$. These results are directly comparable with those of cavities outgassed in a UHV furnace.

So far in a six-cell r.f. separator structure at 2.9 GHz, which was chemically polished and heat treated at 1800° K and 10^{-5} torr, a surface resistance of $3.10^{-7}\,\Omega$ at a peak field of 220 G has been obtained. This

Superconducting Power Supply



An artists' drawing of how a superconducting power supply for a synchrotron, such as is being studied at Rutherford, might look. The scale of this particular supply is such as would be appropriate for a 100 MJ energy storage and transfer system.

would correspond to an equivalent deflecting field of 1.4 MV/m and a total loss of 20 W in a 3 m practical separator structure.

RUTHERFORD Superconducting power supply

In the studies on superconducting synchrotrons, it is appreciated as a major difficulty that the amount of energy which will have to flow between the superconducting magnets and the energy store is very high. For a 1000 GeV machine it is likely to be several hundreds of megajoules, a good order of magnitude higher than the quantities we are accustomed to handling in present conventional synchrotrons. The difficulty rests, however, not so much in the quantity as in the rate of transfer where peak powers, given say a 5 s rise time for the magnetic field, could reach several hundred megawatts. Extension of conventional power supply techniques (either motor-generators or static compensator systems) could probably meet the requirements using the brute force approach. A considerably more subtle approach is being tried at the Rutherford Laboratory.

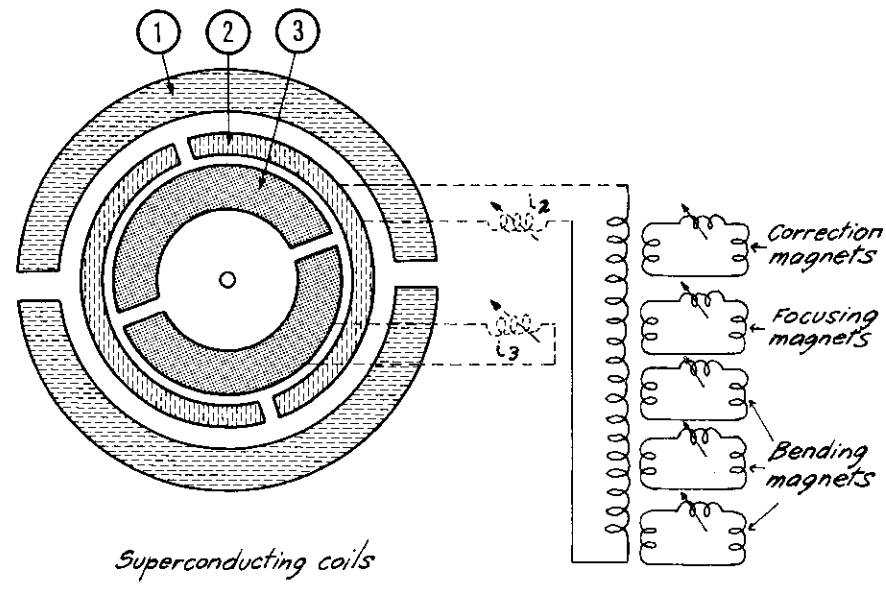
The idea came from P.F. Smith and has been developed into a practical scheme together with J.D. Lewin. It carries superconductivity all the way in using a superconducting energy store, transfer system and transformer in the feeding of the magnets.

An artist's drawing of how a 100 MJ superconducting power supply could look is shown in the photograph. The energy store and transfer system is on the left and consists of three superconducting coils wound approximately spherically.

What happens electrically can perhaps be best understood by consulting the simplified circuit diagram. The diagram illustrates the situation when the outer coil is fixed and is wound so that current flows perpendicular to that in the two inner coils. It provides a fixed field in which the inner coils can move. The two inner coils are mechanically fastened together with their magnetic axes at 90° from one another. The coil of smallest radius acts as the energy store ; the central coil acts as the energy transfer coil from which current flows out towards the superconducting synchrotron magnets. The inner coils can be turned through 180°, stopped at any point and the motion is reversible.

When we consider the movement of the inner coils through an angle Θ, we can show that, if we have established the appropriate magnetic symmetry, the mutual inductance between the fixed coil and the energy store coil will vary as sin Θ while that between the fixed coil and the energy transfer coil varies as cos Θ. The currents in the two inner coils then also vary as cosine and sine. Swinging the inner spheres through 90° will take a current from zero to its peak value (or vice-versa) thus transfering all the energy. Stopping the motion and reversing the motion will ensure flat-tops (and injection platforms) and decay of the current in the energy transfer coil, which will provide the sort of synchrotron magnet powering cycle to which we are accustomed.

When a superconducting transformer is attached to the energy transfer coil it acts as a biasing device — the movement of the inner coil can be increased to 180° and the energy needed in the outer coil can be halved while still ensuring that the same amount of energy is fed towards the superconducting synchrotron magnets. Other advantages in using a



One possible arrangement of the three superconducting spheres so as to achieve the desired current cycles in the synchrotron. The outer sphere (1) is the 'field coil' within which move the energy store (3) and the energy transfer coil (2) coupled in such a way that the currents i_2 and i_3 vary as the cosine and sine transfering energy from the store to the synchrotron. The superconducting transformer is indicated on the right.

transformer are that different currents and voltages can be selected for the synchrotron as opposed to the power supply, and that separate windings can tap off different currents for the bending magnets, focusing magnets and correction magnets.

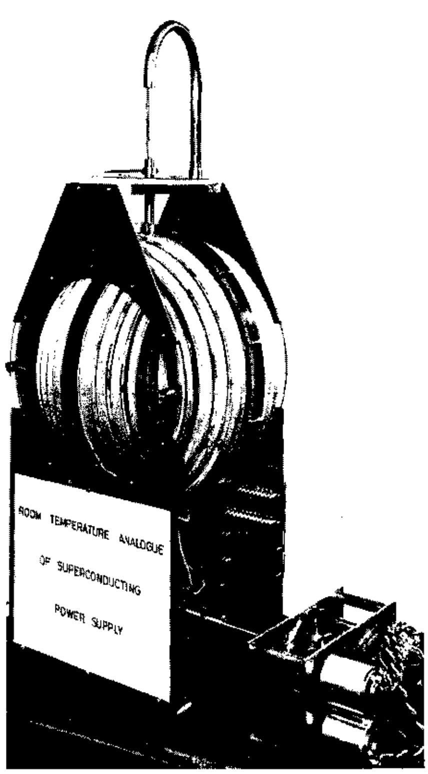
The arrangement of the coils which is currently preferred is an inside out version of the one described above — the field coil being on the inside and the energy store on the outside. Only the central coil, for the energy transfer, need then move. The result is the same as in the arrangement described above which is simpler to understand.

With a completely superconducting system there will be no energy loss while all the energy transfers are going on. In practice perhaps a loss of the order of 0.01 % would be encountered probably necessitating only intermittent topping up of the total energy. The size of a single system for 1000 MJ is estimated as about 7 m diameter for the outer coil. It may however be preferable to have several smaller units of say 100 MJ with a 3 m diameter outer coil or many much smaller units switched in succession to several transformers (though there may be tricky switching problems).

So far, so good ... on paper ... but the novelty of this idea obviously requires thorough theoretical and practical examination before it can be faced on a large scale for incorporation in an actual machine. There have already been theoretical studies of stresses in the system, of dynamic behaviour (where the use of control inductors to correct for magnetic asymmetries has been analysed), of coil topology, of losses and their replenishment.

The emphasis has now moved to practical tests beginning with a room temperature analogue model. This is based on the same principle as the Edgar integrator (used in the measurement of magnetic fields) where the circuit holds constant the flux through a search coil and the secondary winding of a mutual inductance (simulating the constant flux condition in the superconducting power supply). By winding each coil of the analogue model of multistrand cable with some strands monitoring the flux through the coil, the circuits can be arranged to simulate the superconducting energy transfer system.

This room temperature model has been in operation for several months and demonstrates how current cycles such as are used in superconducting magnets can be obtained. The next step is to repeat the exercise with a small superconducting model which is scheduled to be in action early next year.



The small room temperature analogue model with which many of the features of a superconducting power supply can be demonstrated. This model, simulating power supply behaviour and yielding synchrotron-like current cycles, has been in action for several months.

(Photos Rutherford)

CAMBRIDGE
Quality beams in Bypass

Work towards electron-positron colliding beam physics at the Cambridge Electron Accelerator is concentrating on studies of the electron and positron beams injected into the synchrotron ring so as to improve their intensities and qualities to the necessary levels.

An electron current of up to the design peak value (100 mA) has been achieved and it has been shown that beams (of lower intensity) are properly located and are close to anticipated height as they pass through the interaction region.

The CEA Bypass scheme was described in vol. 6 page 218. It involves the addition of a loop to the electron synchrotron within which intense electron and positron beams, accelerated and stored orbiting in opposite directions in the synchrotron, are focused to an especially small cross-section and collided. The design aims are about 100 mA peak current at energies between 1 and 3.5 GeV colliding in the interaction region with a luminosity of 10^{31} cm^{-2} s^{-1}.

Improvements of beam intensity came from a study of instabilities associated with coherent synchrotron oscillations. Previously, coherent betatron oscillations had been mastered using newly installed sextupole magnets and were no longer limiting beam current. In tackling the synchrotron oscillations it was suspected that the intense beams were inducing voltages in the r.f. cavities high enough to provoke beam loss. The first dodge therefore was to adjust the cavity tuners so that the 'natural' frequency of the cavities moved comfortably away from the frequency of the r.f. (475.725 MH^2 compared with the applied 475.790 MH^2). This immediately made it possible to accumulate a sausage of electrons of 100 mA peak current (10 mA average). Operation in this way was simple and reliable.

Further manœuvres to the same end (aiming to reduce the induced voltage by reducing the shunt impedance seen by the beam by powering only one or two of the sixteen cavities and disconnecting the others) are now under study.

With beams orbiting through the Bypass, their geometry at the interaction point was investigated by rapidly moving a thin (1 to 5 μm diameter) horizontal fibre made of silica and carbon through the beam region and observing the resulting bremsstrahlung as particles hit the fibre. The system was in fact more sensitive by about an order of magnitude than by observing synchrotron radiation

When the controls were set to avoid these resonances and with a single beam in orbit (intensity less than 5 mA average) the FWHH height of the beam was less than 0.06 mm which is close to the expected value. The precise value could not be found because of the appreciable diameter of the fibre and because the passage of the fibre through the beam (taking about 0.1 ms, corresponding to 140 revolutions of the beam) introduced some scattering itself.

With both beams orbiting, the fibre was used to confirm that the beams were properly located vertically and that they responded to the beam controls.

BATAVIA
Longest June on record

With only the merest adjustment of the Calendar, to show that nothing is impossible if you really try, a first beam was circulated in the main ring of the NAL accelerator before July officially dawned (in Illinois). It was 6.40 a.m. on 'June 31' that with a 7 GeV injection from the booster which is behaving well, the first turn was observed. Although losses were high they could be explained by a kink in the vacuum vessel and a poor vacuum. Eight turns were obtained the next day. Water has been a troublesome interloper in the main ring magnets and they will be successively withdrawn and vacuum impregnated with epoxy. The cooking operation used to dry out the tunnel has improved the magnet insulation but not the cabling it seems.

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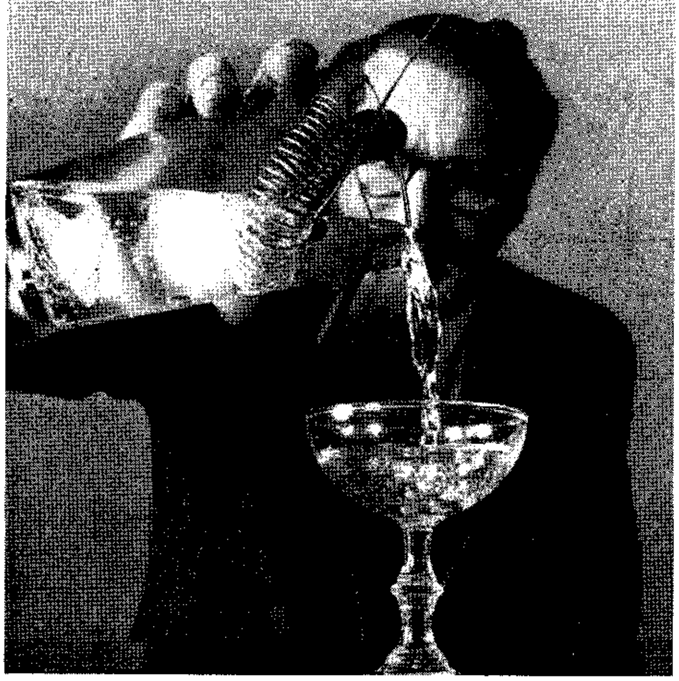

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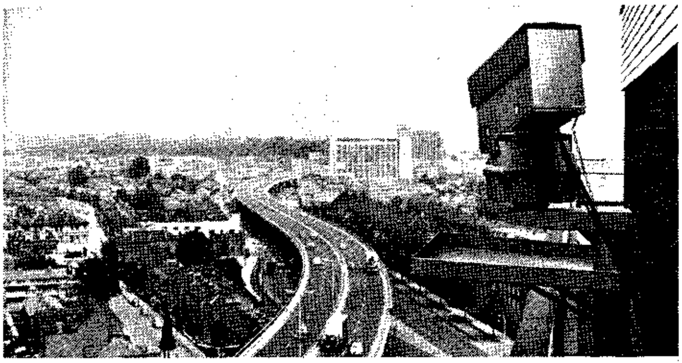

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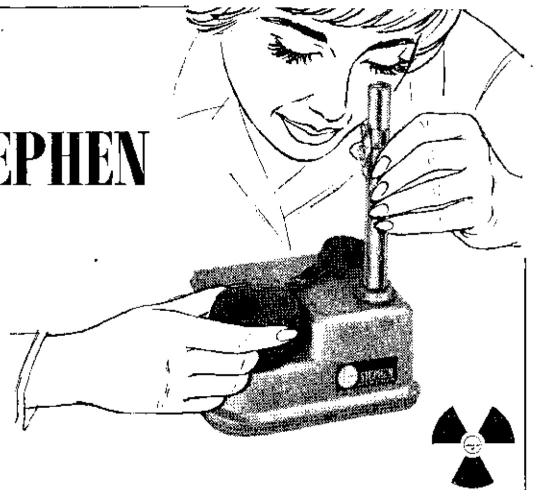

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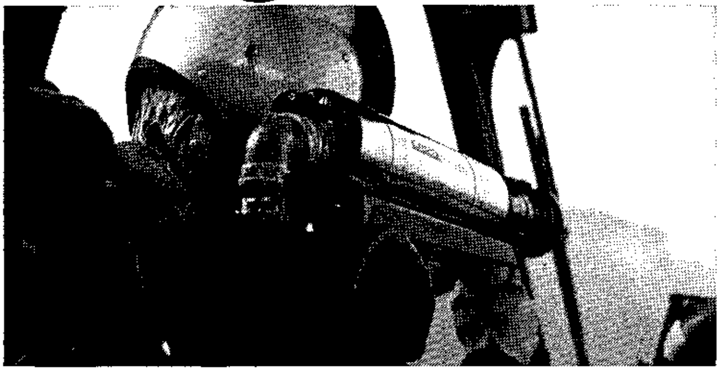

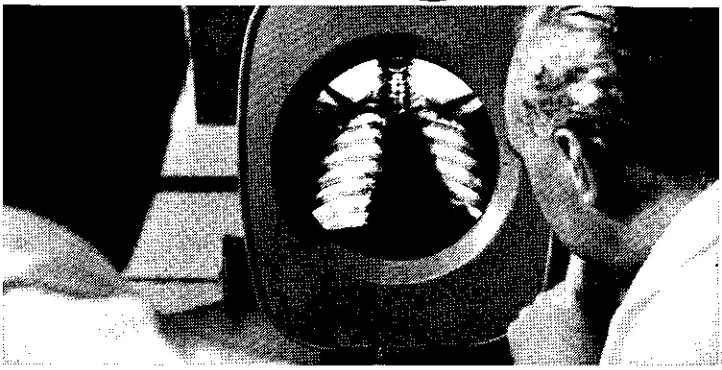

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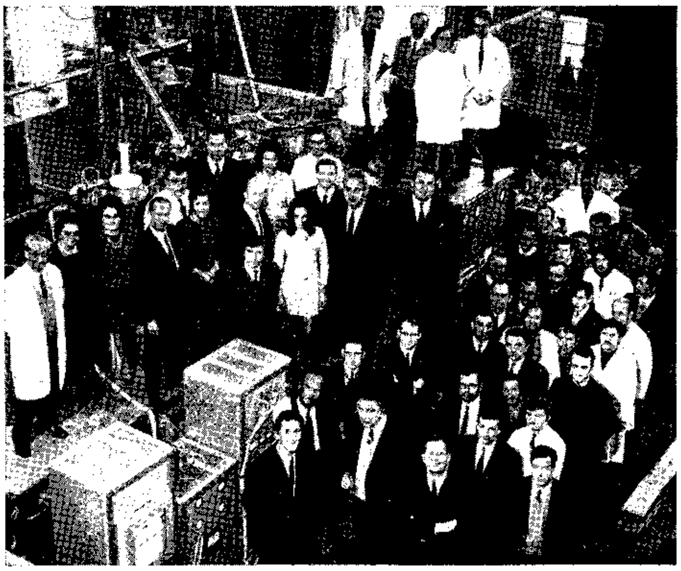

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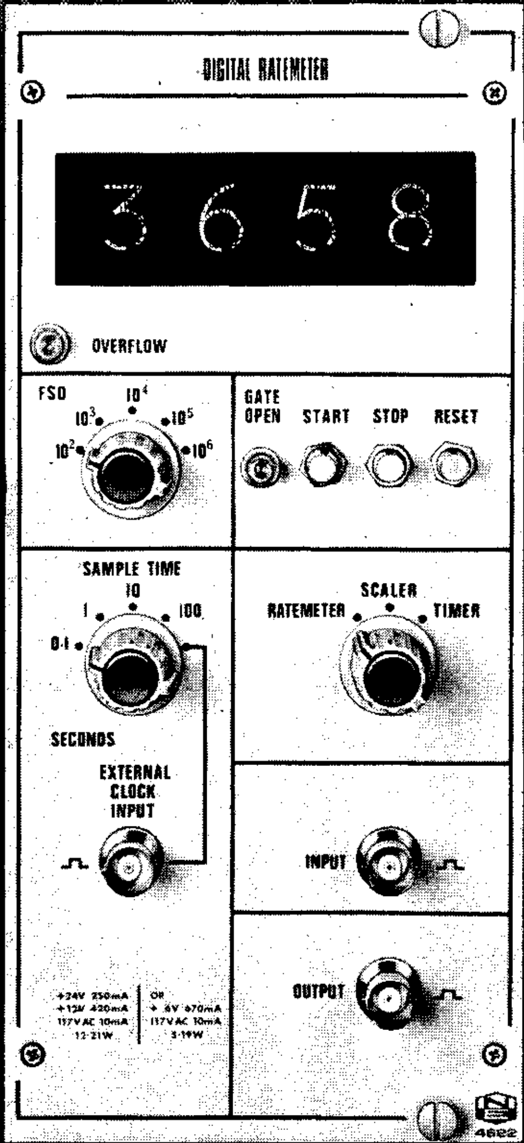

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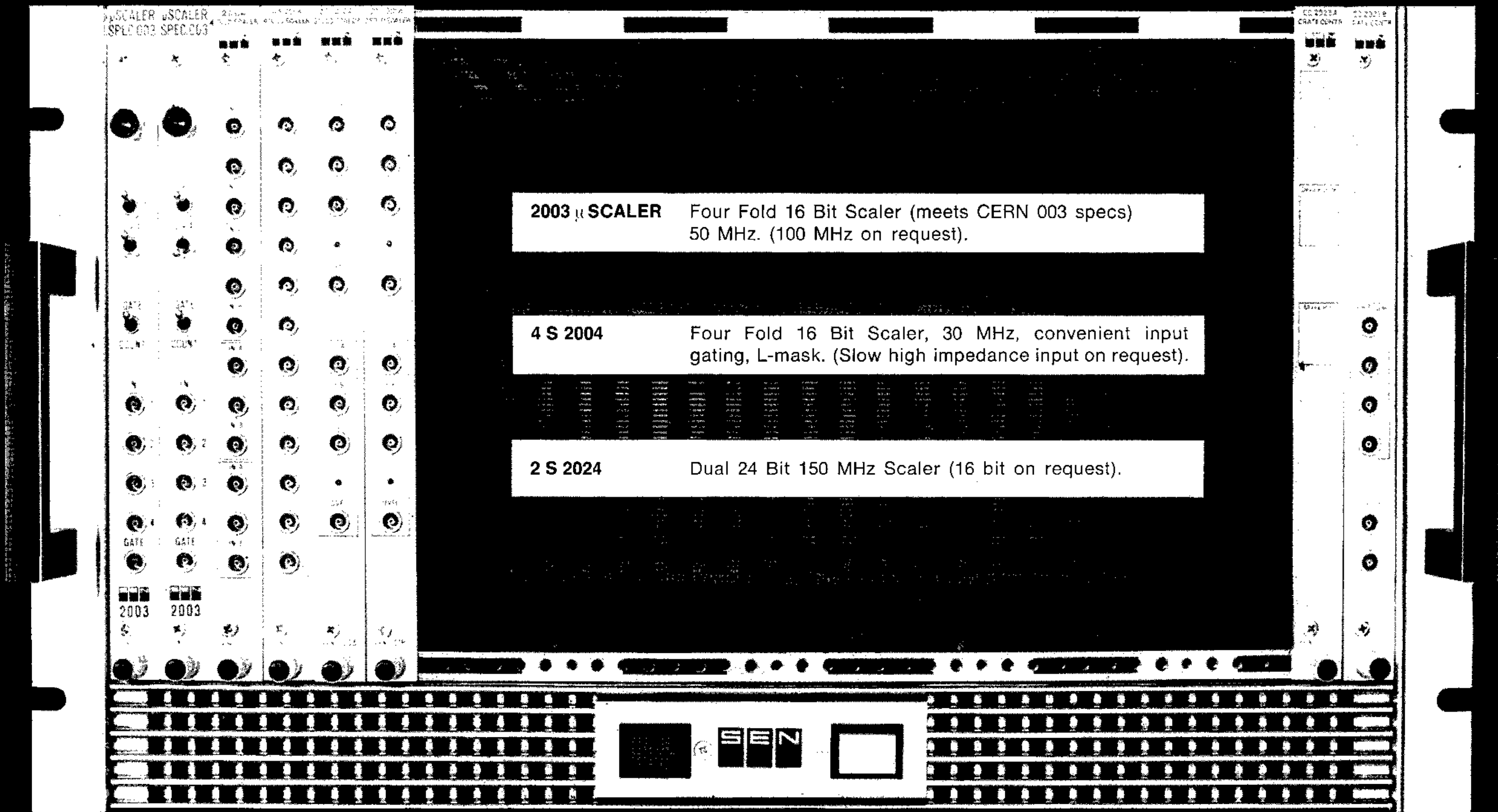

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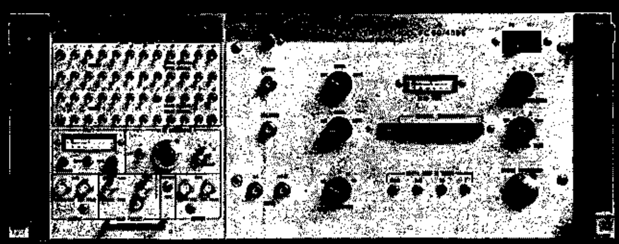

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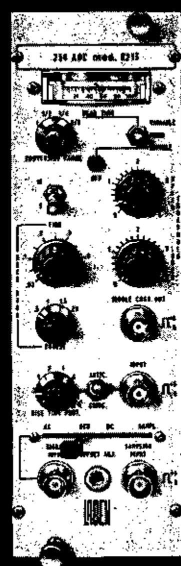

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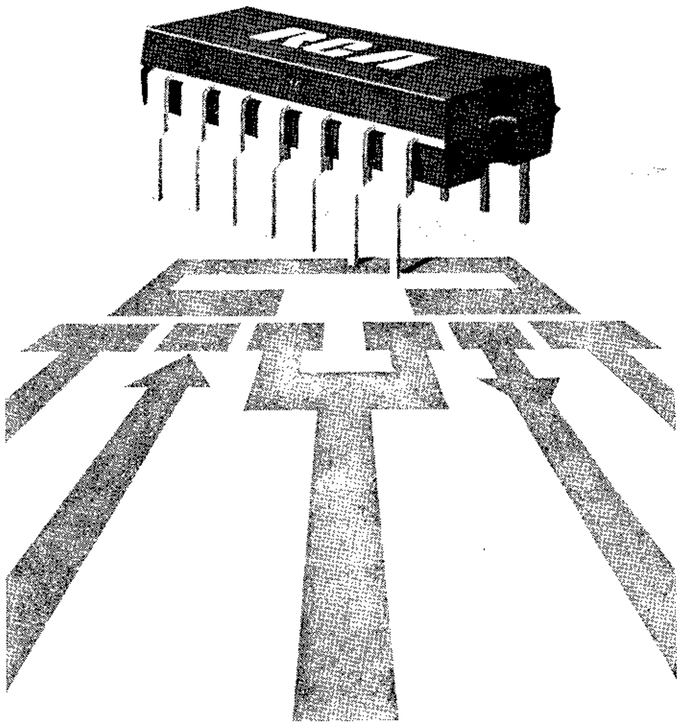

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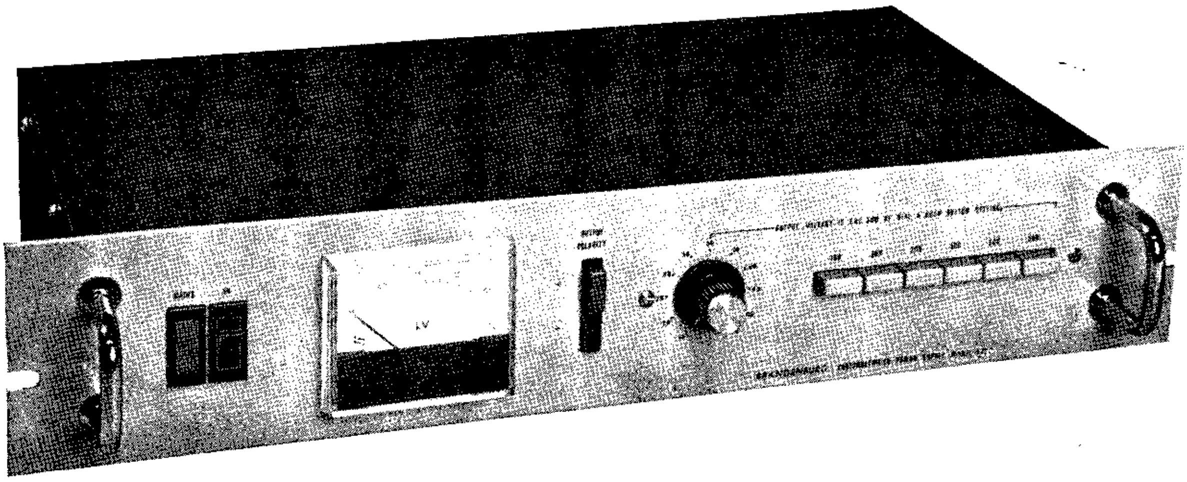

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