CERN COURIER

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CERN, the European Organization for Nuclear Research, was established in 1954 to '... provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto'. It acts as a European centre and co-ordinator of research, theoretical and experimental, in the field of sub-nuclear physics. This branch of science is concerned with the fundamental questions of the basic laws governing the structure of matter. 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 1500 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 3100 people and, in addition, there are about 1000 Fellows and Scientific Associates. Twelve European countries contribute, in proportion to their net national income, to the CERN Laboratory I budget, which totals 391.1 million Swiss francs in 1974.

CERN Laboratory II came into being in 1971. It is supported by eleven countries. A 'super proton synchrotron' (SPS), capable of a peak energy of 400 GeV, is being constructed. CERN Laboratory II also spans the Franco-Swiss frontier with 412 hectares in France and 68 hectares in Switzerland. Its budget for 1974 is 227.1 million Swiss francs and the staff totals about 350 plus 10 Scientific Associates.

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The CERN Annual Report for 1973 has been published. Copies are available, on application, from the Public Information Office (CERN, 1211 Geneva 23, Switzerland) stating clearly—name, address, number of copies, language version (English or French).

Cover photograph: Cutting through the molasse rock face towards the end of its seven kilometre journey around the SPS ring—the Robbins tunnelling machine, known affectionately as 'the mole'. The mole completed its boring task on 31 July. (CERN 87.6.74)

Physics at London

This article was prepared by K.W.J. Barnham, I. Halliday and I. Siotis (Imperial College, London)

The XVII International Conference on High Energy Physics was held at the Imperial College of Science and Technology, London, from 1-10 July. It drew together about 800 physicists from 40 countries. Known affectionately as the Rochester Conference, this biennial event is held in rotation in Europe, the USA and the USSR.

CERN COURIER's review of the last Conference held at Chicago in 1972 (Oct. p. 315) detected 'a feeling of excitement and anticipation' and closed with the words 'whether this feeling of excitement is justified and whether something very important does come up, we should know before the next Rochester Conference in two years' time'. Since that time many ideas have been upset and it is clear that the fundamental discoveries made in the past two years have more than vindicated the expectations at Chicago. With many major surprises and advances to discuss, the Conference proved to be one of the most stimulating and exciting for a long time.

It was primarily the opening of the new accelerators and experimental facilities which prompted the sense of expectancy at Chicago and it is from these that the major discoveries have come.

The surprising results from the ISR which revealed that the total proton-proton cross section rises with energy were followed by measurements at FNAL which showed that this increase with energy is also a property of pion and kaon-proton total cross sections. The heavy liquid bubble chamber Gargamelle provided the first evidence for the existence of neutral currents and the results were soon confirmed by two counter experiments at FNAL. Experiments at the Stanford electron-positron storage ring SPEAR provided another major surprise concerning the way in which hadrons are produced in electron-positron collisions.

A conference of outstanding interest—a study in rapt attention.

The SPEAR results solidly confirmed the earlier Cambridge bypass measurements which showed that the cross section for $e^+ e^-$ hadrons stays constant up to the highest energy investigated. These last results are in complete contradiction to the simple quark model (whether coloured or not) predictions. Other ISR surprises such as the unexpectedly large numbers of hadrons at large transverse momenta were confirmed by results from FNAL and were complemented by detailed information on the properties of individual events. Hadrons however are not the only particles produced at large transverse momenta. Experiments from the ISR and FNAL reported results which show that electrons and muons are produced in roughly equal numbers, about ten thousand times less frequently than pions. Again this number is well outside the range of simple quark model predictions. All these unexpected results were complemented by solid progress in the study of weak interactions and the more conventional subjects of hadron physics such as resonance spectroscopy and two-body reactions.

With so much happening so fast it is difficult to give a complete picture of the Conference in a short report. So let us concentrate on trying to answer briefly the main questions physicists who were not in London must now be asking their more fortunate colleagues. The many individuals whose work has contributed to this surge forward in the subject will excuse the fact that reference is made only to their Laboratory, the full list of names being rather overwhelming.

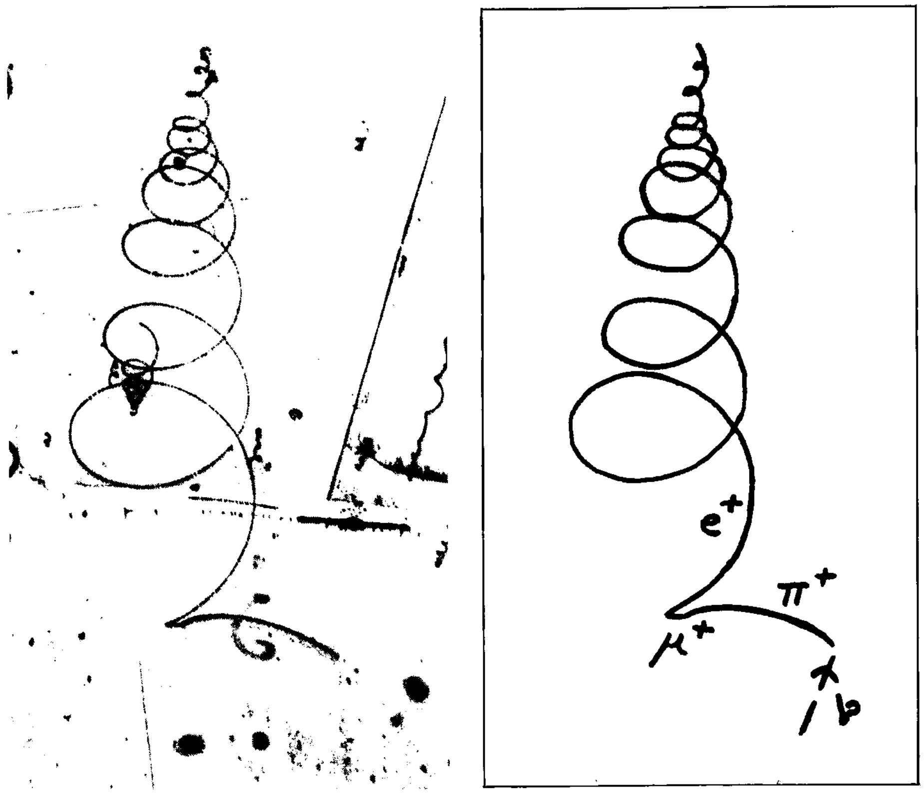
Hadrons from lepton collisions

Let us start with the SPEAR results. The main surprise lies in the fact that the cross section for $e^+ e^- \rightarrow$ hadrons is constant with energy for energies

The Argonne neutrino experiment using the 12 foot bubble chamber, filled with either hydrogen or deuterium, gives very clear information on the existence of neutral currents.

Neutral current evidence from Argonne:

1. *A neutrino interacts with a proton to give a neutron, a positive pion and an outgoing neutrino. Only the positive pion is seen since the other particles produced in the interaction are uncharged.*
2. *A neutrino interacts with a proton to give an outgoing proton and neutrino plus a neutral pion which can be identified via its subsequent decay into two gammas at least one of which is seen materializing as an electron-positron pair.*



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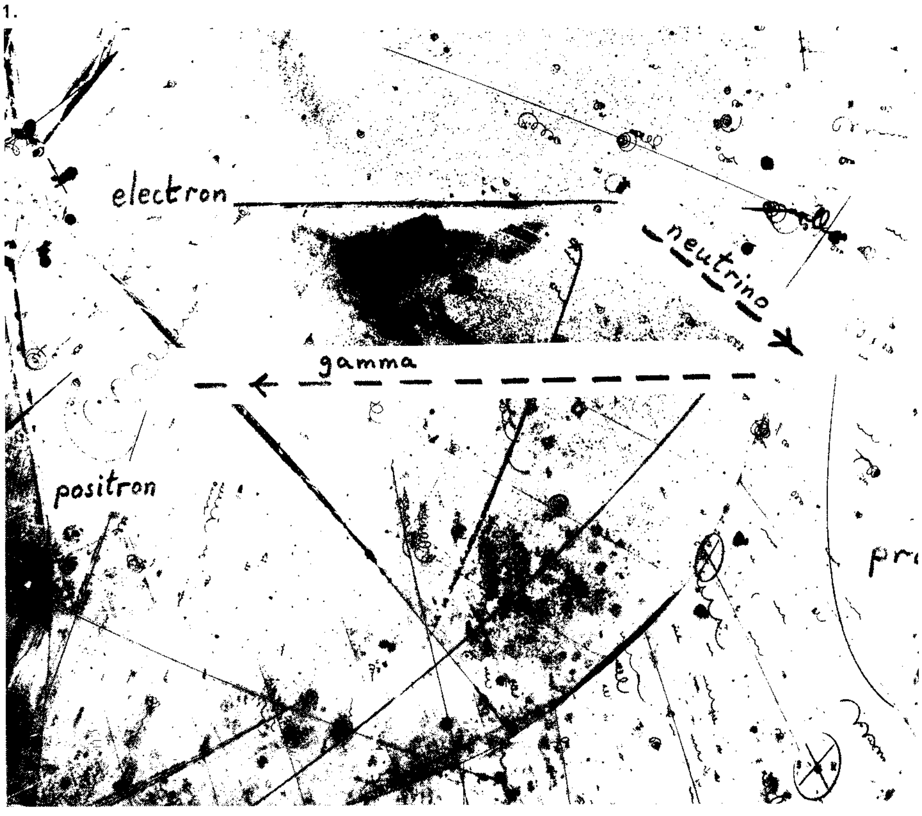


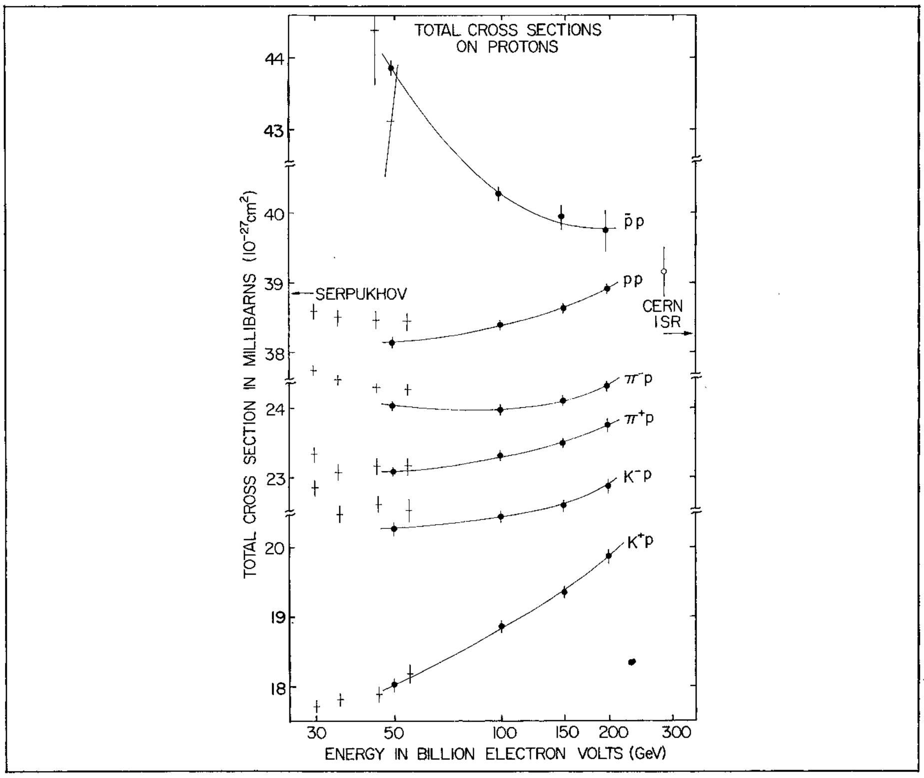
2.

above 3 GeV. The expected mechanism for this process is one in which the electron-positron pair annihilate into a virtual timelike photon which then materialises into hadrons. Care is taken in the experiments to exclude contributions from the competing process in which the hadrons are produced by photon-photon interactions in a double Bremsstrahlung diagram. The one photon annihilation process can also lead to a final state consisting of two oppositely charged muons whose cross section is predicted by QED to fall as the inverse of the center of mass energy squared. Parton models which have been so successful in describing the SLAC results on deep inelastic lepton scattering can then predict the ratio $e^+ e^- \rightarrow$ hadrons / $e^+ e^- \rightarrow \mu^+ \mu^-$ to be a constant equal to the sum of the squares of the parton charges. With quark partons this constant is 2/3, coloured quarks would give 2 and an SU3 octet of quarks would give 4. Experimentally this ratio turns out not to be a constant and, more surprisingly, at the highest energies available it reaches a value of 6!

A second big surprise from the SPEAR results is that single hadron energy distributions only show the type of scaling expected from deep inelastic electron scattering for large secondary hadron energies. At lower secondary hadron energies the distributions show a behaviour which is very similar to that of hadrons produced in very high energy proton-proton collisions. A third SPEAR result appears to have provoked intense theoretical activity. It was observed that as the energy of the e^+ and e^- beams is increased the fraction of that energy going into the observed charged particles decreases. Hence a large proportion of the energy must be going into neutral particles.

All these results proved to be a disaster for the hitherto successful

New total cross section data from the Fermi Lab. (black dots) show a general rise with increasing energy for various incident particles on protons. Additional proton-proton cross section measurements made at the CERN ISR lie off the figure to the right (see next figure).



quark-parton model. However this is clearly not a disaster for physics. Experimentalists would be very upset if a new facility exploring unknown areas of nature *didn't* produce unexpected results.

Neutral currents

Let us now turn to neutral currents whose birth was consecrated at this Conference. The necessity of neutral currents or heavy leptons (or both) emerged as a result of the attempts to renormalise the theory of weak interactions so as to cure its diverging high energy behaviour. The first evidence of neutral current interactions was the observation at CERN of events of the type ν_μ + nucleon $\rightarrow$ ν_μ + hadrons in the large heavy liquid bubble chamber Gargamelle. It was the absence of a charged muon in the final state which provided the evidence for the existence of neutral currents. A thorough discussion of the experimental evidence from Gargamelle was presented at this Conference and at the same time results were confirmed by two experiments at FNAL. The results can be presented in terms of the ratio of neutral to charged current events which turns out to be about 20 % for neutrino and 40 % for antineutrino induced reactions. The next stage will obviously be the detailed experimental study of their properties.

New confirmation of the existence of neutral currents in weak interactions came from Argonne. An Argonne/Concordia College/Purdue University team used the twelve foot bubble chamber filled with hydrogen or deuterium to look for two types of interaction

$$\nu + p \rightarrow \nu + n + \pi^+$$
$$\nu + p \rightarrow \nu + p + \pi^0$$

In the first type only the positive pion is seen emerging from the interaction; in the second type the proton and at least one electron-positron pair from the neutral pion decay is seen emerging.

In 700 000 pictures they have twelve clear examples of neutral current interactions. The use of the hydrogen chamber has the advantage over the CERN and FNAL information in being able to identify all the produce of some interactions. The team is now working on interactions

$$\nu + n \rightarrow \nu + p + \pi^-$$

in which everything about the interaction can be measured — the neutrino energy, the momentum transfer, the proton/pion masses and so on.

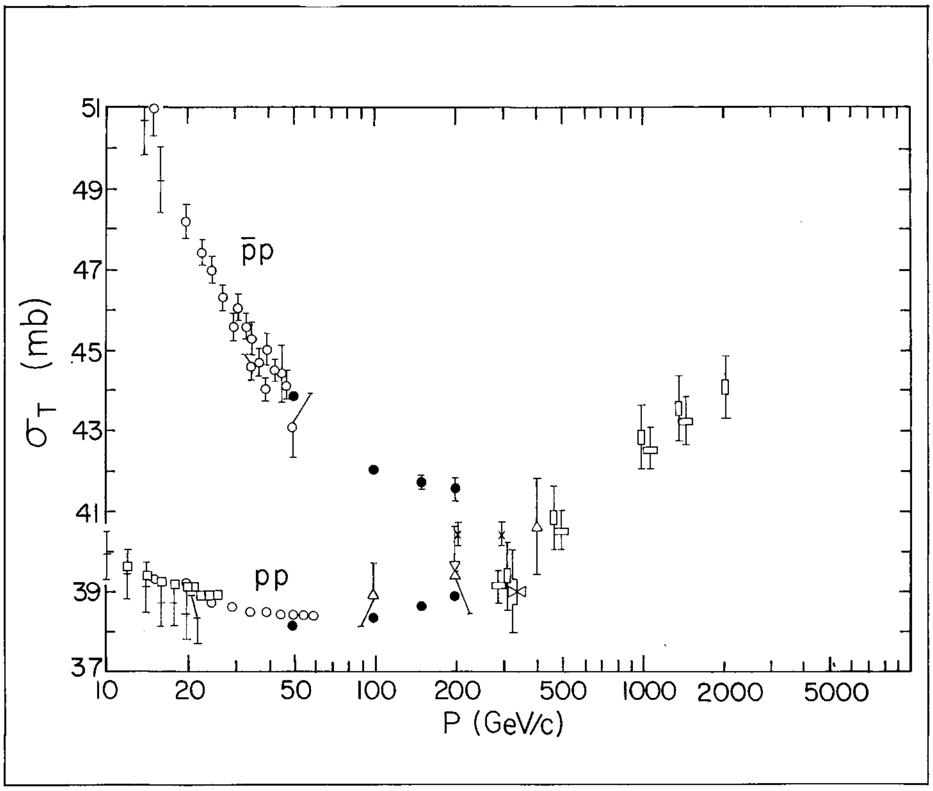
Need for charm

The successful prediction of neutral currents has strengthened theorists' confidence in renormalisable models and they are now predicting the existence of a new quantum number, charm. It is the experimental absence of strangeness — changing neutral currents in conjunction with the need to renormalise certain diverging weak interaction processes involving quarks which leads to the necessity of charm. During the next two years we shall certainly witness an intense experimental activity in the search for charmed particles.

Hadron interaction cross sections

Turning to hadronic interactions many results were presented which would have been thought exciting in any ordinary year. Total cross section measurements for $\pi^\pm$, $K^\pm$, p and $\bar{p}$ on proton and deuterium targets were presented by groups from FNAL. All except the $p\bar{p}$ cross section show a rise over the FNAL energy range and the pp results interpolate smoothly between the Serpukhov and ISR points. The $p\bar{p}$ cross sections flatten out with increasing energy and thus avoid crossing the rising pp points. The very basic theorem according to which particle and antiparticle cross sections should approach each other as the energy is increased is beautifully satisfied by the new results. In fact the difference between the two is very well described by a $1/\sqrt{s}$ behaviour as predicted by Regge models. On the other hand it seems unlikely that data at presently accessible energies will be able to distinguish between models predicting different functional dependences for the rise in the cross section. As was stressed by the rapporteur all available data can be fitted by a ln s or $(\ln s)^2$ rise or even a power law in s. Experimental attempts to pin down the mechanism responsible for the rise led to apparently contradictory results. Groups from the ISR and FNAL studying the pionisation and diffractive components of proton-proton interactions separately claimed that the contribution to the total cross section of their respective kinematic regions could account for

Total pp and $p\bar{p}$ results from the low energy data through Serpukhov, the new Fermi Lab. results (the black points) and the CERN ISR results.



the rise. We thus seem to witness the parts adding up to more than the whole unless of course the two observations are the result of the same mechanism.

High transverse momentum particles

Staying with the ISR the first results from Split Field Magnet experiments were presented and included measurements of elastic pp scattering at high momentum transfer. The variation with energy of the position of the dip in the cross section first reported at the Chicago Conference tends to support a simple picture of geometrical scaling i.e. the proton behaves like a 'grey disk' whose radius increases with energy.

Some very important results on high energy two-body reactions were presented by groups working at Serpukhov and FNAL. They reported measurements of $\pi^- p \rightarrow \pi^\circ$ n and $\pi^- p \rightarrow \eta n$ at momenta up to 100 GeV/c which, when combined with recent precise measurements at the CERN PS, lead to beautifully straight ρ and A_2 Regge trajectories.

The report on the observation of unexpectedly large numbers of particles at high transverse momentum was one of the highlights of the Chicago Conference two years ago. As has often been stressed high transverse momentum events may be the manifestation of pointlike constituents in the proton. It is therefore extremely important to study in detail the properties of subevents, in particular the quantum numbers of the emerging particles, the effective mass distributions and the correlations among them.

Results from the ISR and FNAL show very high production ratios of kaons, protons and antiprotons to pions. Thus for example at $p_\perp \sim 6$ GeV/c and $E_{Lab} \simeq 400$ GeV they find $K^+/\pi^+ \simeq 0.7$. Another important result from the ISR concerns the multiplicity of particles associated with one of large $p_\perp$. In the hemisphere opposite to the large $p_\perp$ particle the multiplicity grows by a factor of 4 between $p_\perp \sim 0.7$ and 3.7 GeV/c. This is independent of the incident energy. In the hemisphere towards the large $p_\perp$ particle the multiplicity is strongly energy dependent and at the lower energies decreases with increasing $p_\perp$. At the highest energies it becomes independent of $p_\perp$. An intriguing result of the same experiment was that triggering on one π° with large $p_\perp$ enormously increases the chances of finding nearby another π° with a similar $p_\perp$. The effective mass spectrum of the two pions does not show any obvious resonant structure.

The study of large transverse momentum phenomena is still at a very early stage and, as the rapporteur on the subject pointed out, we cannot yet draw any real conclusions but many questions have been raised which need further detailed experimental study.

Pointers to the future

Extrapolating forward from the discoveries of the past two years it is not too optimistic to predict that the next two will be at least as exciting. We may well have seen at this Conference the first hints of some of the forthcoming sensations. At least three results first reported at this Conference were received with the sort of reaction which suggests that they are good candidates for tomorrow's major story, though at present all three are, to varying degrees, subject to confirmation.

Firstly, the results mentioned earlier from a number of FNAL and ISR experiments observing single lepton production at large transverse momenta. Is this observation, and the difficulties of parton models to explain it, related to the SPEAR results on $e^+ e^- \rightarrow$ hadrons or are we seeing very substantial production of ∅ mesons which then decay to lepton pairs? This is undoubtedly the firmest of the three results to be discussed and in the next two years several experimental searches for lepton pair production at high transverse momentum will be made.

The second very interesting result was the observation at FNAL of two neutrino induced reactions with not only a μ^- in the final state but also a μ^+. Both events occurred at the highest neutrino energies and we may be observing the onset of a new process.

Thirdly, another experiment at FNAL studying deep inelastic muon scattering from a nuclear target shows some weak indication of a deviation with the scaling which would have been expected from lower energy deep inelastic lepton scattering. The breakdown of scaling at high energies would indicate that some new process was taking place involving the existence of a fundamental length. However this is a very difficult experiment to perform needing a thorough understanding of the systematic errors.

Three hints then from the Conference which could lead to an even more interesting Rochester Conference in two years' time. How widespread was the sense of expectancy that the next two years will witness very important discoveries? Well, one rapporteur went on record as being prepared to bet any physicist a crate of wine that by the next Conference charmed particles with masses below 12 GeV will have been found.

So we can make one firm prediction for the next Rochester Conference. There will either be excitement among physicists at a discovery of great importance or a number of professionally despondent but inebriated physicists.

52nd Session of CERN Council

The Council met on 26, 27 June under the Presidency of Professor W. Gentner

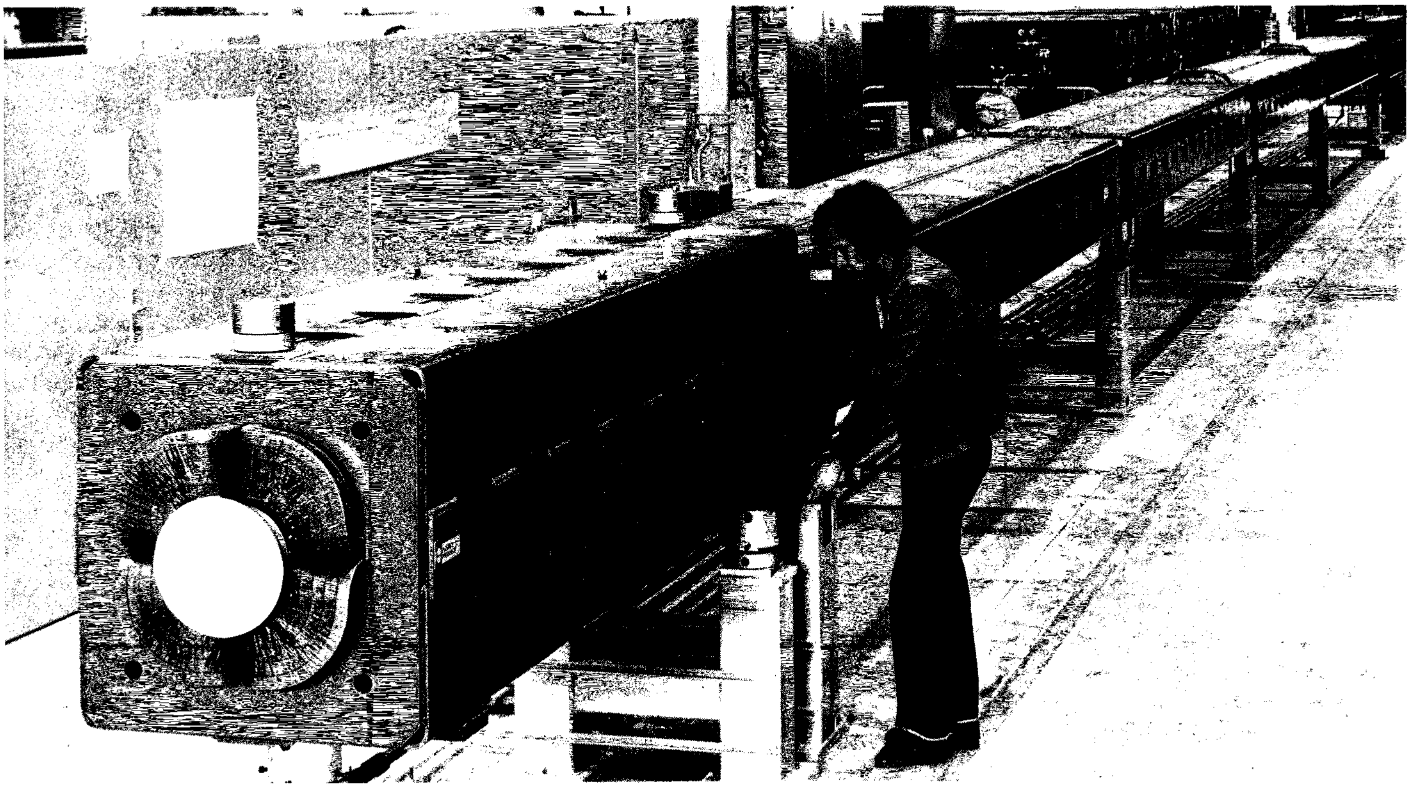
At the June Council Session the Directors General presented reports of progress at the two CERN Laboratories. W. K. Jentschke mentioned some recent physics results from the 28 GeV proton synchrotron and the intersecting storage rings. As covered in the report of the London Conference, there is further evidence for neutral currents from the neutrino experiments with the Gargamelle heavy liquid bubble chamber. Another example of neutrino-electron scattering has been seen and over two hundred events on nucleons are now confirmed. In addition, an experiment with a proton beam into the chamber has checked that the estimate of the background, which could result in other events being confused with neutral current events, is correct.

While the existence of neutral currents is supporting evidence for the attempt to unify the interpretation of weak and electromagnetic interactions, a subversive new type of interaction remains the only way to explain the behaviour of the neutral kaon. The so-called superweak force has been postulated to account for the disrespect of the neutral kaon for the symmetry of charge and parity in Nature. Since the combined symmetry of charge, parity and time is still believed to be good, the violation of charge-parity implies a violation of time symmetry to restore the balance. The superweak theory makes rather precise predictions as to how the symmetry of time will be broken.

The network of survey reference points on the Laboratory II site is being extended to meet the geodetic needs of the accelerator and of its North Experimental Area. The work has been greatly eased by the use of a geodolite, on loan from the Fermi Laboratory, which is a distance measuring instrument using a modulated laser beam. It is capable of accuracies of one part in a million over distances longer than could previously be measured in one stage at CERN.

CERN 420.5.74

To test assembly and alignment procedures for the imminent installation of components in the SPS tunnel, a 30 m stretch of machine comprising four bending magnets flanked by two quadrupoles has been linked up in the Laboratory II large assembly hall.



CERN 269.6.74

A CERN/Orsay team in 1970 showed that time symmetry violation does occur and this has now been confirmed in a more precise experiment by a CERN/Heidelberg team. In essence what it does is to watch the neutral kaons and, after a fixed time, measure how many convert to anti-neutral kaons. Taking anti-neutral kaons it watches, after the same fixed time, how many convert to neutral kaons. If time is symmetric these should be equal but, in fact, the second figure is about 1 % greater than the first. This measurement is in good agreement with the prediction of superweak theory which remains an uncomfortable phenomenon on the sidelines of our present interpretation of Nature.

Another experiment which is just beginning to take data is the new version of the g-2 measurement aiming to push the accuracy of this key figure, which emerges from the roots of quantum electrodynamics, still further. After about a week of tests with the pion beam, injecting into a storage ring where muons are produced in pion decay, a first attempt to observe what the muons are doing was made on 15 June. With only a seven hour run, excellent clean results were obtained which already give g-2 to the accuracy of the 1966-67 results. This promises well for being able to improve the accuracy considerably and thus to penetrate deeper into the nature of the electromagnetic force and of the muon.

L. Van Hove carried the physics story much further at the Council Session when he reviewed the outcome of the last few years of research to mark the end of his three year term as Director of the Theoretical Physics Department. Since we did a rather similar review in our May issue, we will leave this topic but may return to it in a subsequent issue since it illuminated in different ways our present interpretation of particle interactions.

The steady progress in the building of the 400 GeV proton synchrotron the SPS, in Laboratory II was reporte by J.B. Adams. He emphasized particularly the work on the machine tunnel (including the showing of a film, directed by G. Pessis, on tunnel construction). At the time of the Council Session, 'the mole' had bored its way around 90 % of the 7 km circumference of the machine, maintaining an accuracy of better than 5 cm compared to its scheduled position.

Meanwhile the lining of the raw tunnel has begun in the half of the ring no longer used by the mole and its spoil-removing/preliminary-lining entourage. This involves filling in the joints of the preliminary lining, mounting steel sheets for water proofing, casting a second concrete lining, injecting cement between the linings and laying the tunnel floor. Over a sixth of the ring is completed and the installation of services (power lines, etc.) has started. The first magnet is scheduled to be wheeled into the tunnel in October.

Assembly and testing of magnets is under way on a large scale. Over 100 bending magnets have been built, satisfactorily tested and stacked, awaiting their descent into the ring. About fifty quadrupoles have been delivered and some of the various types of correction magnets are beginning to arrive. A trial assembly of a half period (the sequence of magnets which is normally repeated around the ring) of the machine has been satisfactorily carried out in the large Assembly hall.

The high power components of the accelerating system are now being built and the first section of an r.f. tank is expected to be delivered soon. There have been problems with the 125 kW power amplifiers and the ceramic discs in the power transmission lines but they have been cleared and both amplifiers and discs are being produced which meet all the requirements.

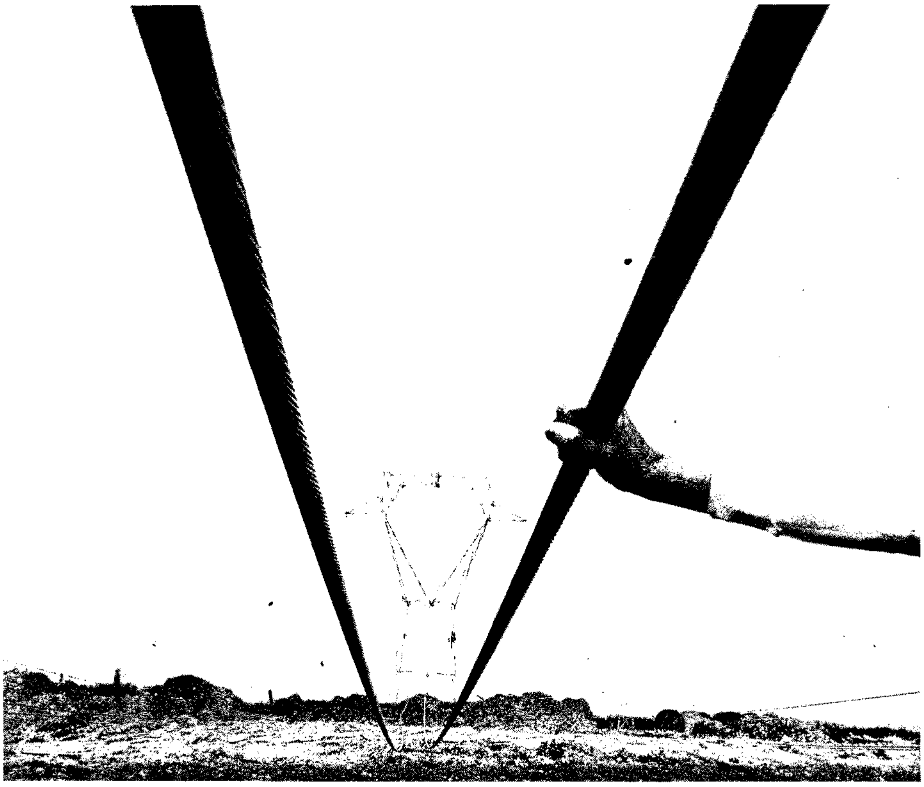
Magnets (quadrupoles and bending magnets) for the injection beam-line from the PS are on site and the septum magnets for the injection system are being manufactured. The design of the kicker magnets is complete and components, such as ferrite blocks, vacuum tanks and ceramic feedthroughs, have been ordered. These magnets will be powered by current pulses as high as 10 kA with very short rise and fall times and pulse durations of some microseconds. Special pulse forming networks with a deuterium thyratron and ignitrons have been developed to provide these pulses and are being subjected to lifetests aiming for their survival over as many as 10^7 pulses.

A full-scale prototype of the electrostatic septum for the ejection system, one of the trickiest of the machine

Major services to the Laboratory II site are nearing completion:

1. *Installation of the 380 kV electrical power lines is well advanced over the 40 km linking the Laboratory to the European grid at Génissiat. The hand is guaranteed to release the cable before the lines are powered.*

2. *Two 5000 m^3 reservoirs are to hold the site water supply brought from Lac Léman. One of them has already been filled and is distributing water, via the pumping station, to part of the site.*



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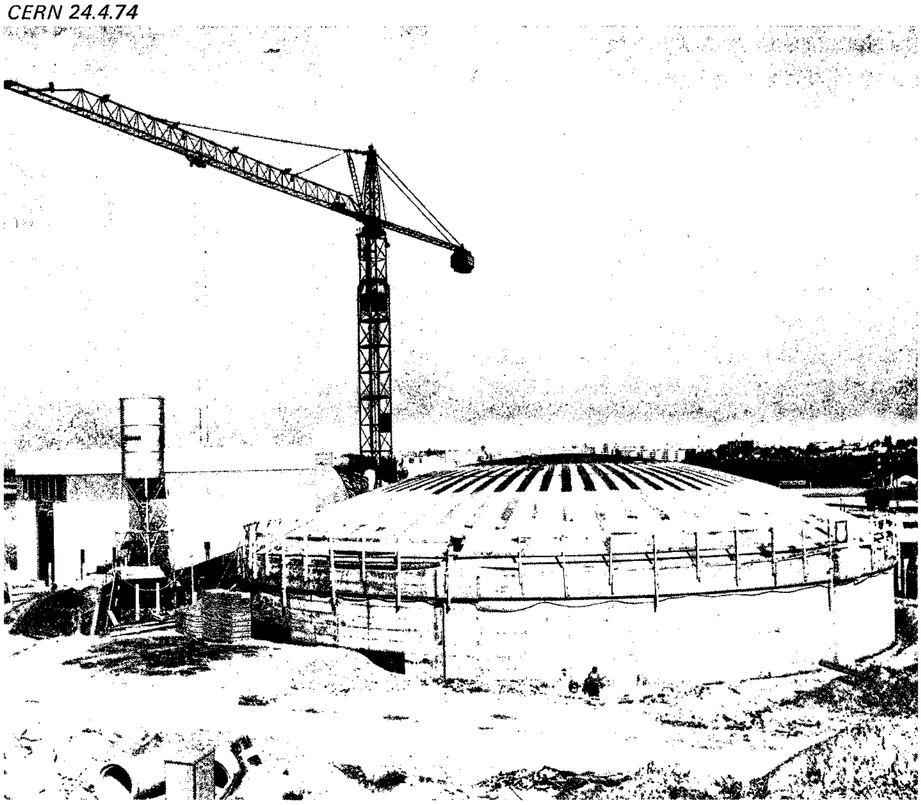

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Personalities in the news:

1. *L. Leprince-Ringuet*
2. *K. Johnsen*
3. *L. Van Hove*

1. *CERN 3497*

2. *CERN 291.2.71*

3. *CERN 2734*

components, has been built. It is 3 m long with the septum made of a plane of stretched 0.15 mm diameter tungsten wires spaced 1.5 mm apart. To eject 400 GeV protons, it is required to hold a field gradient of 100 kV/cm between the wires and the titanium cathode. The prototype achieved 120 kV/cm with a gap of 17.5 mm and a pressure of 10^{-6} torr. However, lower pressures are desirable so as to reduce the number of ions liberated by the beam which can initiate electrical breakdown and at 10^{-9} torr performance of the prototype was reduced by about a factor of two. Studies to optimise operating conditions are continuing.

For the control system, three quarters of the 24 computers are delivered and performing well. The first part of the 'message transfer system' has been installed; prototypes of the CAMAC and multiplexor modules are in action. A total of 1500 km of cable for carrying control signals and light currents have been ordered. Some is already being installed in the Auxiliary Building by access shaft No 2.

The layout of beams in the West Hall and for the North Area has been approved by the Committees which oversee the experimental programmes. Detailed design of the beams is now under way. To the West, of particular interest will be the neutrino facility where both wide-band and narrow-band (energy spread) neutrino beams will be sent to feed an array of detectors including the 3.7 m European bubble chamber, the Gargamelle heavy liquid bubble chamber and electronic detectors. To the North, of particular interest will be the muon beam where very high intensities at peak energies will be available.

Everything remains on schedule for commissioning the accelerator in the second half of 1976.

Collaboration with ESO

The Agreement for scientific and technical collaboration between CERN and the European Southern Observatory has been extended for a further three years. The Agreement covers particularly the help given by CERN in the construction of a 3.6 m optical telescope destined for the Observatory at La Silla in Chile.

Budgets in coming years

At the end of each year the Council considers CERN budgets for the following four years thus making it possible, both in the Member States and in CERN itself, to do long-term planning with a good understanding of the likely financial situation. In addition, for the building of the SPS a total budget and a budget profile over the years of construction have been agreed.

These forecast figures are adjusted to take account of the movements of raw material prices, salaries, etc. in accordance with a 'cost variation index'. A preliminary estimate of the index is usually presented at the June Council Session and this year it is coming out in the uncomfortably high region of 10 %. This reflects the rate of inflation prevailing in Europe and, compounded by currency exchange problems, will not make life easy during the financial discussions later this year.

Appointments

The Council approved the election c two new members of the Scientific Policy Committee — R.H. Dalitz and A. Lagarrigue. They succeed two members of long standing who have contributed considerably to the development of CERN — L. Leprince-Ringuet, a member of the SPC from its very first meeting twenty years ago, and S.A. Wouthuysen, a member of the SPC for the past ten years.

Within CERN itself, S. Fubini takes over from L. Van Hove, who has completed three years as Director of the Theoretical Physics Department, and W. Schnell takes over as Director of the Intersecting Storage Rings Department from K. Johnsen, who is to devote himself to further studies on storage rings. F. Ferger becomes Head of the ISR Division for three years beginning July 1974.

CERN News

The trapping efficiencies at various r.f. voltages as measured in the Booster for two energy spreads of the beam from the Linac. Note how the efficiency is higher with a small energy spread. Being able to use this higher efficiency contributed to the recent Booster intensity record.

Multi-exposure oscillogrammes of a Booster bunch produced by trapping a beam from the Linac with low energy spread. The lower trace has no r.f. phase modulation; the upper trace has phase modulation of ± 4°.

Booster accelerates 10^{13} protons per pulse

During a machine development run on 18 June, the 800 MeV Booster reached an intensity of 1.02×10^{13} protons per pulse for the first time. This intensity was maintained for several thousand pulses but the accelerated beam quality was not suited for transfer to the main synchrotron ring and more work needs to be done to master beam behaviour. Nevertheless it is an encouraging achievement to have reached design intensity.

Many refinements to machine components over the past months together with a very stable Linac beam contributed to the success and, in addition, two special tricks were called into play. The first trick was to increase the multi-turn injection efficiency into the Booster by injecting into a larger phase space area. This was set up by collapsing the deformation of the injection closed orbit, which is used in multi-turn injection, faster than usual. It gave more accelerated intensity but the resulting horizontal beam emittance at 800 MeV was 25 % too large for the beam to squeeze through the transfer line and into the PS.

The second trick involves the r.f. system. It has been known for a long time that, when the protons from the Linac have a low spread in energy (obtained by using a debuncher), the Booster trapping efficiency is high. However if this low energy spread is combined with high beam intensity, the bunches circulating in the Booster become unstable longitudinally. To avoid this, a larger energy spread is usually provided from the Linac which lowers the trapping efficiency to about 80 % but gives much happier bunches.

Even for lower energy spreads, instabilities take longer to grow to serious proportions than it takes to trap the incoming beam into bunches. L. Magnani discovered in a preceding run that feeding the r.f. phase loop with a signal that shakes the bunches at their natural oscillation frequency usually prevents the instabilities from developing. It is not yet fully known why this trick works, but the net result is that it makes it possible to take lower energy spreads, trapping as much as 95 % of the protons accumulated by multi-turn injection into the four superposed Booster rings, and to accelerate high intensities to 800 MeV.

It is not yet clear when 10^{13} protons per pulse can be reached in the PS for normal operation. However, the Linac people are attempting to provide an improved beam for future Booster development runs. The Booster people are involved in further experiments to investigate the remaining instabilities and to cure them. The PS people, amongst other things, are finalizing the injection procedure of the Booster beam and expect to experiment further this year with the improved gamma transition jump (see vol. 14, page 10) and with extra correction lenses, all of which need to work well to provide 10^{13} protons per pulse of the required quality from the PS.

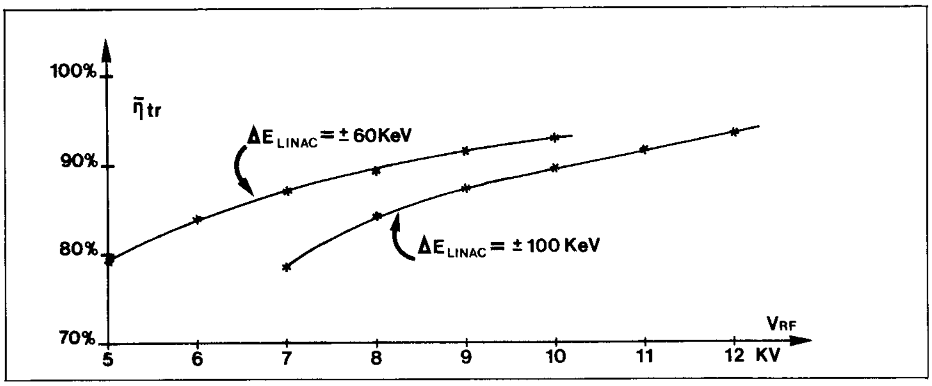
SPS: Completion of the 7 km tunnel

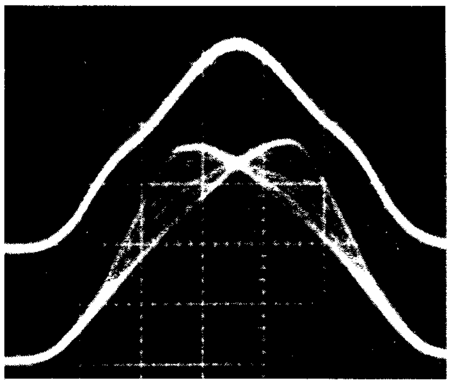
On 31 July the Robbins machine completed the job of boring the SPS tunnel — a ring 6900 metres in circumference and 4.8 metres in diameter (see, inter alia, vol. 12, page 124 and vol. 13, page 70). The contract for the underground works was placed with the group ACCEL comprising Losinger, Prader and Cuenod of Switzerland; Soc. Grands Travaux de Marseille and Forgal of France.

It was on 12 March 1973 that the 'mole' with its attendant train was ready 50 metres underground, to start boring through the layer of molasse it was not to leave before completing its journey.

Apart from rest days there were four breaks in the work of the machine totalling eleven weeks out of the sixteen and a half months' operations.

1) In July 1973 there was a halt of two weeks, caused by the unexpected encounter of pockets of methane in the second sextant, just beyond shaft PA2. These pockets





At precisely 10.32 a.m. on 31 July, the Robbins boring machine (the 'mole') reached the end of its 7 km circular journey, marking the completion of the piercing of the tunnel and of a major stage in the construction programme for the 400 GeV accelerator on CERN Laboratory II site. The photograph shows a group of VIPs and journalists present in the tunnel at the final breakthrough. On the right, the beam transfer tunnel from the PS joins the main ring.

CERN 236.7.74

showed up as fissures or crazing, often quite large, which when exposed gave rise to dangerous concentrations of gas in the tunnel. The safety services took quick action, and after the section had been adequately ventilated a permanent detector system was installed. Detectors were placed at three points: at the head of the machine, near the device which placed the pre-cast concrete vault sections and again at the end of the train. In addition, mobile detectors kept a check on the methane concentration in the tunnel during week-ends. This double detection system was kept going up to the end of the boring operation. Other safety measures were also taken: the capacity of the ventilation system, for example, was increased and a system installed for trapping escaping gas.

Mention should also be made of another type of incident which, although not halting the boring operation, occasionally slowed it up to a rate of less than 10 metres per day. Regions of fractured molasse which were encountered intermittently made it necessary to install supporting rings between the head of the 'mole' and the device for placing the vault sections.

2) In August 1973 there was a planned pause of four weeks, at shaft PA2 to pierce the entrance to the North ejection line and concrete the wall between the two tunnels.

3) Two weeks over Christmas and the New Year.

4) Finally, three weeks at shaft PP4 were needed for fitting out the new marshalling yard as service operations were moved over from the PGC and for the installation of the three sets of demountable shuttering with which the interior vault is formed progressively over the three sextants already bored.

The Robbins boring machine has finished its job on the SPS with commendable efficiency, boring at an average rate of about 21 metres per day — faster than had been originally foreseen. By the end of July, all the civil engineering work had been completed between shafts PA3 and PP4, service installations are already going in and the first magnets are due to go down in October.

NUE Experiment, Aachen-Padua collaboration

A new experiment aimed at investigating neutral leptonic currents was put under way at the beginning of July. This experiment, which gets its name from a combination of NU (neutrino) and E (electron), continues the series of studies with the Gargamelle heavy liquid bubble chamber, but makes use of an array of spark chambers.

The experiment is being done by an Aachen/Padua collaboration and is mainly directed at investigating neutrino scattering of the type

$$\nu_\mu + e^- \rightarrow \nu_\mu + e^-$$

and measurement of the cross section of this reaction. The results will extend the research made with Gargamelle, which led to important developments in our understanding of weak interactions (see vol. 13, page 291). The experiment, which was approved last October, has been set up at great speed with the help of the CERN technical services.

A light-tight and dust-proof building was erected behind Gargamelle along the line of the neutrino beam. Temperature in the building is kept constant in order to avoid air movement and distortion of the spark chambers.

The equipment consists of 150 aluminium thick-walled optical spark chambers. Together they form a 7 m

View of the equipment for the NUE experiment which has started on the study of leptonic neutral currents. The body of the detector in the centre of the photograph is 7 m long and consists of 150 spark chambers. The two mirrors, each of over 15 m², reflect the track images to a camera, which has already taken over 36 000 pictures.

Example of a neutrino event photographed with the equipment of the NUE experiment. The long track of the muon can be easily seen.

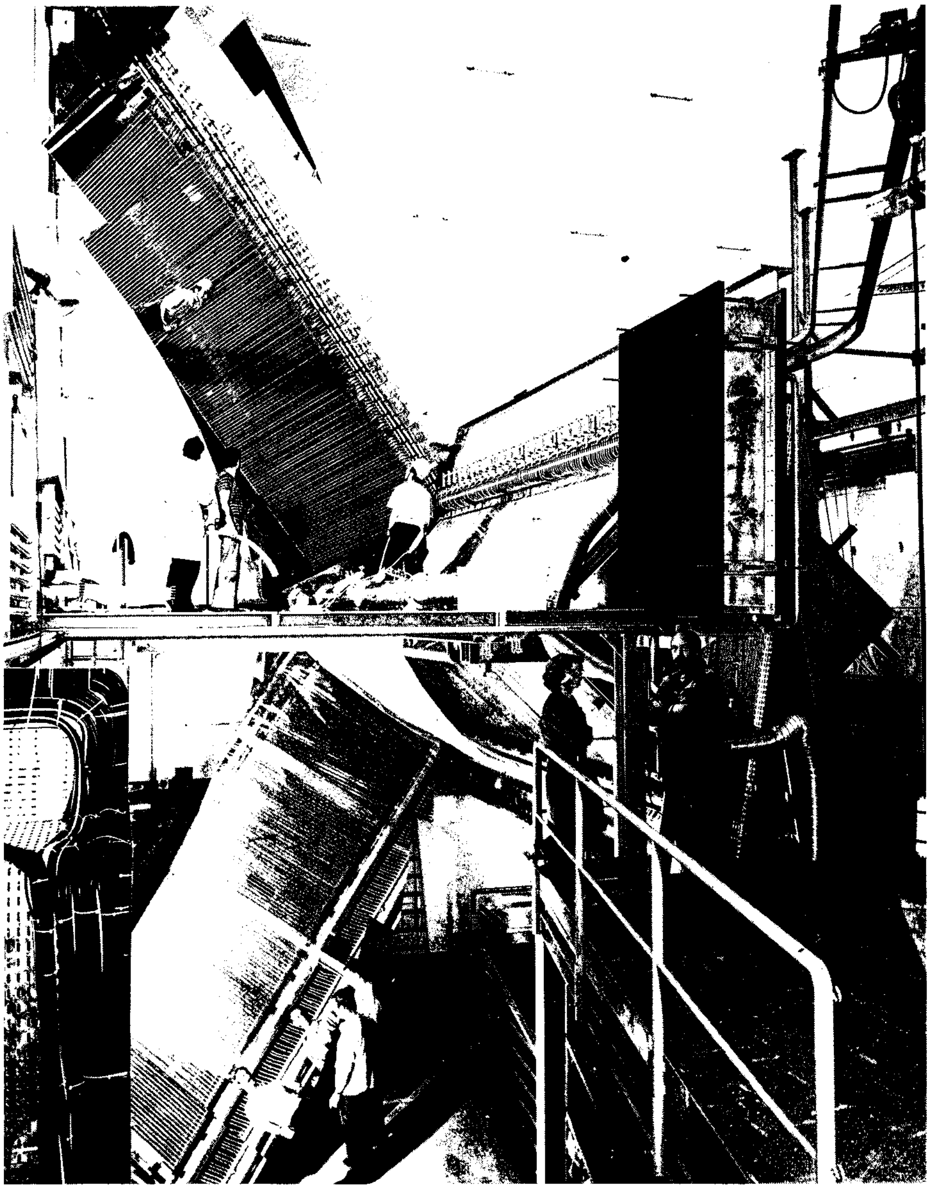
long detector with a useful weight of 20 tons — twice that of the Gargamelle detection unit with heavy freon filling. Each chamber is in the form of a 4 cm thick module weighing 230 kg and with an area of 2 × 2 m². One module consists of three plates, with a potential difference of 8 kV applied between the middle plate and the outer plates. The inert gas used is a mixture of helium and neon (Neogal) circulating in a closed system incorporating purification plant.

The flash from the sparks is reflected into the camera by two mirrors. Each mirror, some 15 m² in area, consists of an assembly of eight aluminium honeycomb supports covered with a thin layer of aluminium-coated mylar. The two images obtained are projected on to the same film exposure by two lenses mounted side by side.

Triggering of the chambers is not selective according to the type of event wanted, as is usually the case with spark chambers, but takes place automatically after the neutrino beam passes through, at each pulse of the CERN proton synchrotron. The idea behind this is to 'see everything' as the particular events investigated are so rare (1/10000 neutrino events), no risk must be taken of missing them.

Apart from its substantial useful weight which enables a high number of neutrino events to be obtained, the equipment has the advantage of giving very clear images in the sense that the detector is 'bare' and nothing in the vicinity can create secondary events.

This experiment, in which 36 000 photographs were taken at the beginning of July, will provide altogether a million photographs. Amongst these it should be possible to find about a dozen neutral leptonic current events — a significant addition to the two such candidates so far recorded in Gargamelle (see vol. 14, page 167, and vol. 13, page 212).



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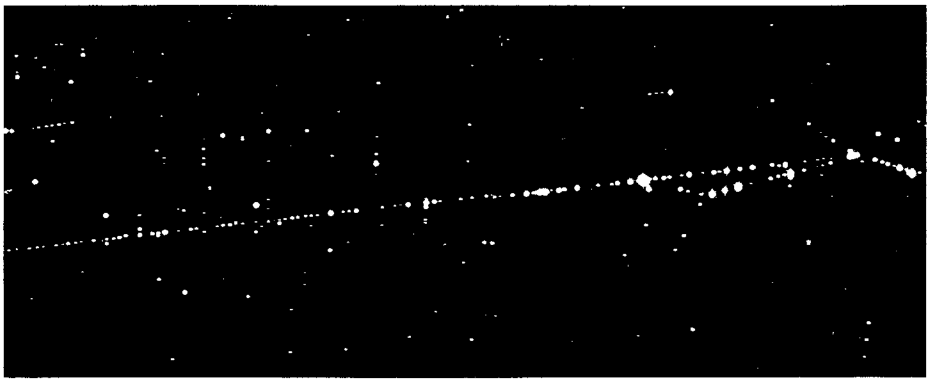

Under the title of 'Sweden at CERN' an exhibition of Swedish equipment from eight companies, in association with a series of lectures, took place from 10 to 14 June. The photograph was taken during a reception on 12 June and features, left to right, J. Nilsson (Director of the Swedish Council for Atomic Research), G. Engblom (Director of the Swedish Export Council), J.B. Adams (Director General of CERN Laboratory II), S. Nilsson (Swedish Ambassador at Berne), and W.K. Jentschke (Director General of CERN Laboratory I).

Photograph of a magnet constructed at CERN for SIN, the Swiss Institute for Nuclear Research at Villigen. It is one of two compensation magnets being built for separated, pure pion beams of momentum up to 550 MeV/c. The magnet is 300 mm long with an aperture of 313 mm. The bending force is 0.067 T.m at 250 A, corresponding to a deflection of the order of 36.5 milliradians at 550 MeV/c.

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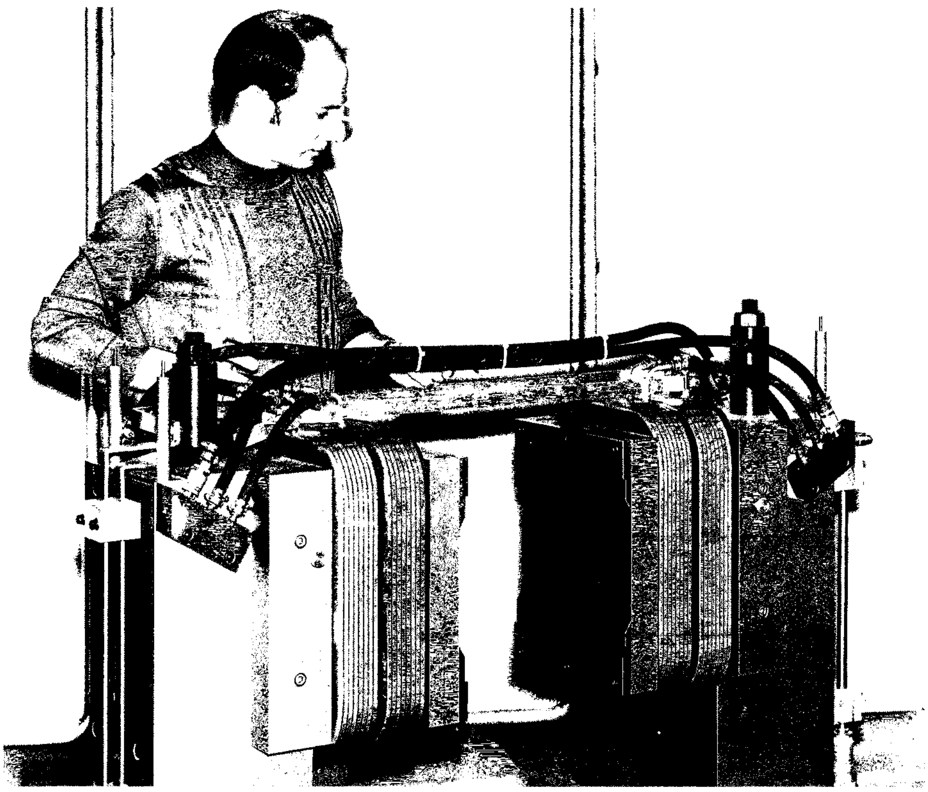

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Record luminosity in ISR

In recent developments on the ISR during which studies have been made of the interdependence of the pressure in the system and the maximum current that can be stacked, a luminosity of 1.04×10^{31} cm^{-2} s^{-1} has been achieved. Luminosity is the parameter which when multiplied by the proton-proton cross section gives the rate of interaction and is as a result the determining number as to the rate at which the physics research can go on. This new high figure was obtained with a current of 22 A in each of the two rings and with an effective beam height of 4.75 mm. The luminosity is proportional to the product of the beam currents and inversely proportional to the effective height.

Since the ISR have been put into operation the intensity of the beams which are usable for physics has been steadily increased and physics runs have been made with luminosities of 5×10^{30} cm^{-2} s^{-1}. It has been appreciated for some time that the determining factor in the maximum current which could be stacked is the quality of the vacuum. As this has been steadily improved with mean pressures now about 10^{-11} torr and sensitive zones one by one sorted out, the question of instabilities is becoming of comparable importance. Finding appropriate working lines with the proper compensation for the space charge Q shift has always been a preoccupation but the ultimate limit to beam intensity was set by the runaway rise in pressure that occurred at certain spots as the current built up. Now it is a bit of both.

Rather as an off-shoot to the drive for higher luminosities is the drive for higher currents as such, but it is worth noting that currents of 27.4 A have been stocked in ring 2 and of 26.7 A in ring 1. The beams were not of a quality

Site of the new Linac. On the left, a retainment wall, necessary because of the slope of the site.
On the right, the building of the present Linac which will have to stand up to the requirements of CERN's major installations for another good three years. Early in 1978, the new machine is scheduled to take over.

as regards life-time and background suitable for physics experiments but the famous brick wall of the past (used to describe the barrier to higher intensities) has turned out to be more of a movable partition in steady retreat.

Still the old Linac

Although the days of the old Linac are numbered now that a new 'proton factory' is being built (vol. 13, p. 332) it continues to supply a beam whose characteristics have greatly changed since the Linac was commissioned in 1959 and must do so until 1977.

Five years ago the aim was set to increase the length and intensity of the output pulses to give 100 mA for 100 μs in a beam whose dimensions in the horizontal, vertical and longitudinal phase-planes were closely defined.

Remembering that the original design target was 10 mA for 10 μs it will be understood that providing a beam of high quality with the required reliability is not easy, particularly as the Booster is far more exacting in its demands than the PS. It is necessary to maintain with precision a desired quality not only from pulse to pulse but also throughout the increased pulse length, all the more so when studies are being made of the behaviour of the following machine, ie., the Booster. In addition it was requested to switch quickly — even from one pulse to the next — from feeding the Booster to feeding the PS direct which again helped to expose the limitations of the old machine.

This is why a programme of short term improvements was put in hand at the same time as a long term solution was prepared, namely to build a new Linac. The decision was taken to relax a number of specifications, e.g., to reduce the intensity requirement to 50 mA, and to reconstruct a number of components.

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To improve the reliability, the r.f. system has been considerably modified: the risk of flash-over has been eliminated by replacing the flexible coaxial cables with rigid lines and fitting the r.f. amplifiers with improved output coupling loops and lines of adjustable length. The master oscillator and the first stages of amplification have also been replaced whilst a set of circulators will be put in shortly which should reduce coupling between cavities. Stability has been improved by stabilising the modulator high voltage supply and trigger and by replacing the coupling loops between the cavities.

In the pre-accelerator a new system for stabilising the high tension has also been added. To help start-up and adjustments during operation the control room instrumentation has been improved, particularly for the measurement of the phase of the accelerating cavities. Further work is under way on the computer acquisition of an additional set of important parameters.

These various modifications have made it possible to furnish 5×10^{12} ppp to recent neutrino experiments and to run a good number of experiments on the Booster. To understand better the limits to its capabilities a beam not only more intense but more dense is required. For this a buncher (which compresses the bunches in longitudinal phase space) has been rebuilt and put in between the pre-accelerator and the Linac. With it in use 85 mA have been achieved recently and the Booster has been able to accelerate over 10^{13} ppp to 800 MeV.

If one wanted to push further the performance of the old Linac there are many more things that would require serious face-lifts: replacement of the tanks and the entire vacuum system, further rebuilding, of the r.f. and the control systems, building of the low energy beam transport. Since

The Academy of Sciences, Paris has just awarded its Grand Prix in the mathematical and physical sciences to André Martin, of the Theoretical Studies Division at CERN, for his research on strong interactions between particles at the upper limit of very high energies. It will be remembered that, less than a year ago, Martin received an honorary doctorate from the University of Lausanne for his work (see vol. 13, page 372).

(Photo '24 Heures')

Interval during an augmented session of the CERN-Serpukhov collaboration Scientific Committee. Left to right in the front rows: Messrs. A. Serov (State Committee), I.G. Morosov (Vice-Minister for Atomic Energy), V.S. Kaftanov (ITEP) and V. Dzhelepov (Dubna).

the construction of a new Linac has been undertaken, investments in the old machine will be restricted to maintenance as soon as the programme spelled out above is finished.

CERN-Serpukhov collaboration: from 70 to 400 GeV

During the past six years, physicists from CERN and its Member States, and from the Soviet Union, forming joint teams, performed electronic and bubble chamber experiments at the Serpukhov accelerator (see vol. 12, p. 172). The Agreement signed in 1967 between the State Committee for Atomic Energy, Moscow, and CERN, cleared the way for research with the highest energy protons available in Europe: those accelerated to 70 GeV by the Serpukhov accelerator.

But protons of 400 GeV will soon be available at CERN, and the ISR already attract many investigators interested in the highest available centre of mass energies. In order to exchange notes on past experience and future plans, the Joint Scientific Committee of the CERN-Serpukhov collaboration held an enlarged session in Geneva on July 15-19.

It was agreed that the Soviet delegation include active physicists not only from Serpukhov, but also from all other institutes of the Soviet Union engaged in research in high energy physics. The Joint Institute for Nuclear Research (Dubna) sent a delegation headed by Professor Dzhelepov. The leader of the Soviet delegation was Mr. Morosov, Vice-Minister of the State Committee.

The scientific discussions included a review of the present state of the SPS machine by J.B. Adams, a description of the beams and experimental areas by G. Brianti, and presentations of the preparations for the SPS experiments by P. Lehmann, and of the ISR experiments by H. Schopper. The proposals for 400 GeV experiments with incident muons, and neutrinos, the preparations of experiments with BEBC and with the Omega spectrometer were discussed in more detail. The Soviet delegation presented, amongst others, recent technical developments on multichannel Cherenkov counters and on high energy γ detectors (see vol. 14, p. 83) now in use at Serpukhov. Informal discussions and visits of the CERN laboratories completed the exchange of information.

It is hoped that these scientific discussions will contribute to the inception and development of new forms of collaboration.

151.7.74

Summer students

Summer courses for students are offered each year at CERN. In response to circulars sent out at the end of 1973 to Universities and Institutes of Technology in all the Member States, some 540 applications were received this year by the Fellows and Associates Service from students of physics, data handling, mathematics, electronics, electricity and mechanics. Choosing among so many was difficult, but finally over 150 students were selected and allocated to the scientific and technical Divisions of Laboratories I and II, the latter receiving students for the first time.

Their participation in the work of one of the experimental physics, applied physics, data handling or accelerator groups or of the technical or health physics services should provide highly satisfactory training for these students.

Alongside this activity a series of 61 lectures has been organized on the physics of elementary particles, accelerators, detection systems and data handling. There are two basic courses, one on FORTRAN and one as an introduction to particle physics. The first, given by Mrs. Burkhardt and Miss Kurjo, takes as its starting point this year the University of Birmingham video-tape system; the second, given by Professors Gottfried, Telegdi and Weisskopf, will be the subject of a book due to appear in about a year's time.

The value over the years of these courses, giving students the opportunity of a close insight into the work being done at CERN, is well illustrated by the fact that a considerable number of Fellows and staff members of the Organization are in fact former summer students.

Documentation for these courses is sent each year to more than 300 Universities and Technical Institutes in the Member States. If any teacher or student reader of the COURIER wishes to obtain the documentation for the 1975 summer courses, he should apply in January either to his institute, or by letter to the Fellows and Associates Service, Personnel Division, CERN, 1211 Geneva 23. It should be noted that the deadline for enrolment is 1 March 1975, and that the documentation will be available from 1 January.

Around the Laboratories

View of the double storage rings at the point, where positrons coming from DESY-Synchrotron are injected into the upper ring.

(Photo DESY)

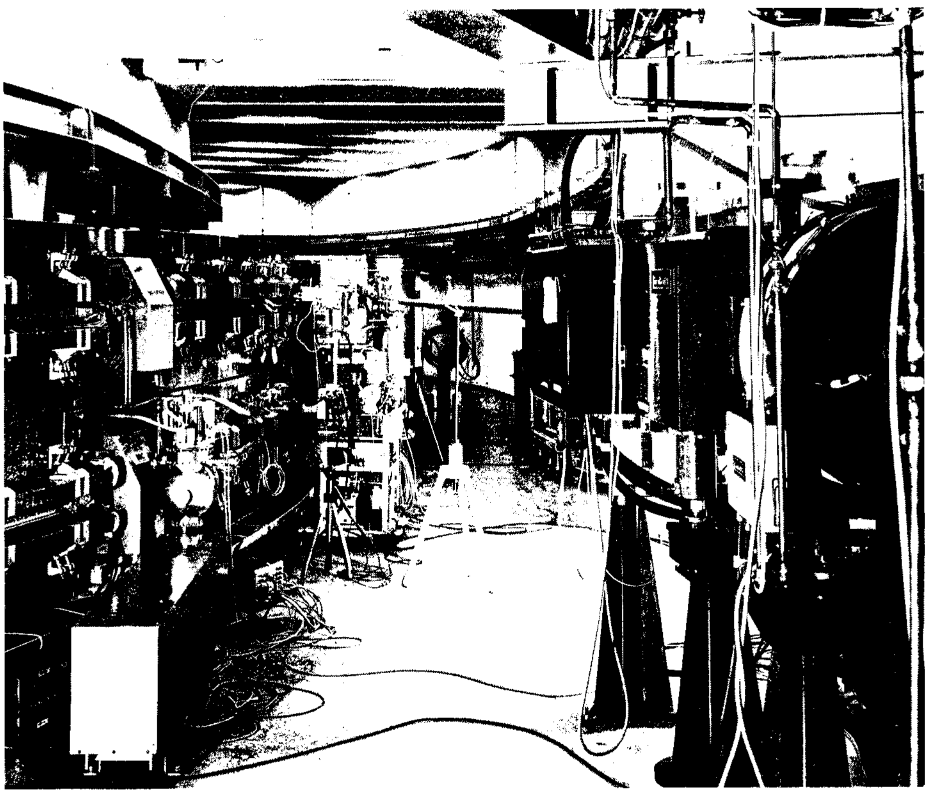
DESY
Dedication of DORIS

After four years of planning and construction and several months of test-running, DORIS, the double storage rings at DESY was ready for the dedication ceremony. This took place on June 18th. 'Typical' Hamburg weather did not dampen the enthusiasm of the physicists who came from the various laboratories where electrons hit positrons or where other particles are made to collide together so that we can look for structures in particles.

In his welcome address, Prof. Herwig Schopper thanked the outside physicists for their helpful interest and the staff of DORIS for their inventive co-operation. Secretary of State Hans-Hilger Haunschild and Bürgermeister Prof. Dieter Biallas from the governments of Bonn and Hamburg, asked the physicists at DESY to regard DORIS and possible future extensions as an incentive to maintain the same high standards of research that had been achieved over the past ten years.

Chairman of the Scientific Council of DESY Prof. Wolfgang Paul, touched on the national co-operation between DESY and all those laboratories within the Federal Republic of Germany working in the field of high energy physics. Prof. Willibald Jentschke of CERN, visiting his old laboratory, emphasized the necessity for both electron and proton machines. Finally, Prof. Victor Weisskopf explained to the audience of some six hundred participants, assembled in the centre of the storage rings where they were all the time surrounded by stored electron and positron beams, why we are searching for the 'Infinitely Small'.

In the January issue (page 13) start-up experience and future plans for the machine were reported. Here we



Part of the equipment used to inject a polarized electron beam into the linear accelerator at Stanford. The system, developed at Yale University, is known as PEGGY. It uses the photo-ionization of a beam of lithium-6 atoms. In the unit with the triangular shaped upper section is the ultra-violet lamp pulsed 180 times per second. Its controls are in the box of electronics on the left. Behind the triangle is a polarization reversal coil. Nearer the camera is the beam measuring equipment.

(Photo SLAC)

will give a brief status report on the progress which has been made during the past few months.

On the technical side, the final complement of magnet power supplies has been installed, so that the energy of DORIS can now be increased to 3.5 GeV. The vacuum system has been completed, including the installation of heating jackets, and after baking out, the gas desorption rate has been reduced by roughly a factor of 10. Owing to technical difficulties the beam position monitor system is not yet operational.

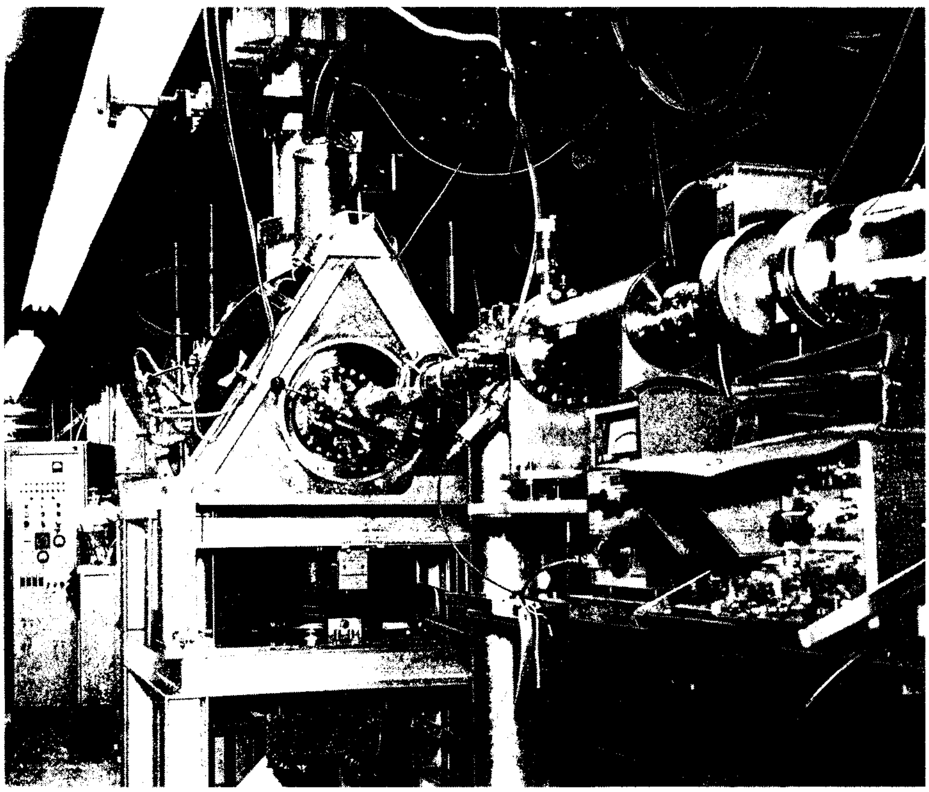
Machine studies were performed mainly at two energies, 1.5 GeV and 2 GeV. It was found that the measured and the theoretically predicted transverse acceptances of DORIS agree to within a factor two. The deviation can be explained by closed orbit distortions. For electrons an injection efficiency of 60 % was reached, and for positrons 25 %. The difference results from the fact that the beam emittance and the energy spread from the injector, the DESY-Synchrotron, is larger for positrons than for electrons. These values are valid only for injection without the multipole correction magnets in operation. Use of sextupoles reduces the injection efficiency drastically, whereas the octupoles have only a small influence. The problem of machine non-linearities is being studied.

Maximum stored currents so far are 750 mA for electrons and 160 mA for positrons. Although the same forces drive both beams into instability, it is believed that the electron currents are larger because ions in the electron ring provide some Landau-damping. On the other hand ions cause widening of the beam and careful adjusting of the clearing electrode voltages is necessary to avoid loss of particles.

The luminosity has been measured to be 2×10^{29} cm^{-2} s^{-1} with currents of 300 mA for electrons and 100 mA for positrons. This value is in agreement with calculations based on measured beam currents and dimensions. Beam-beam forces could be identified during this experiment but at these current levels are far from being destructive.

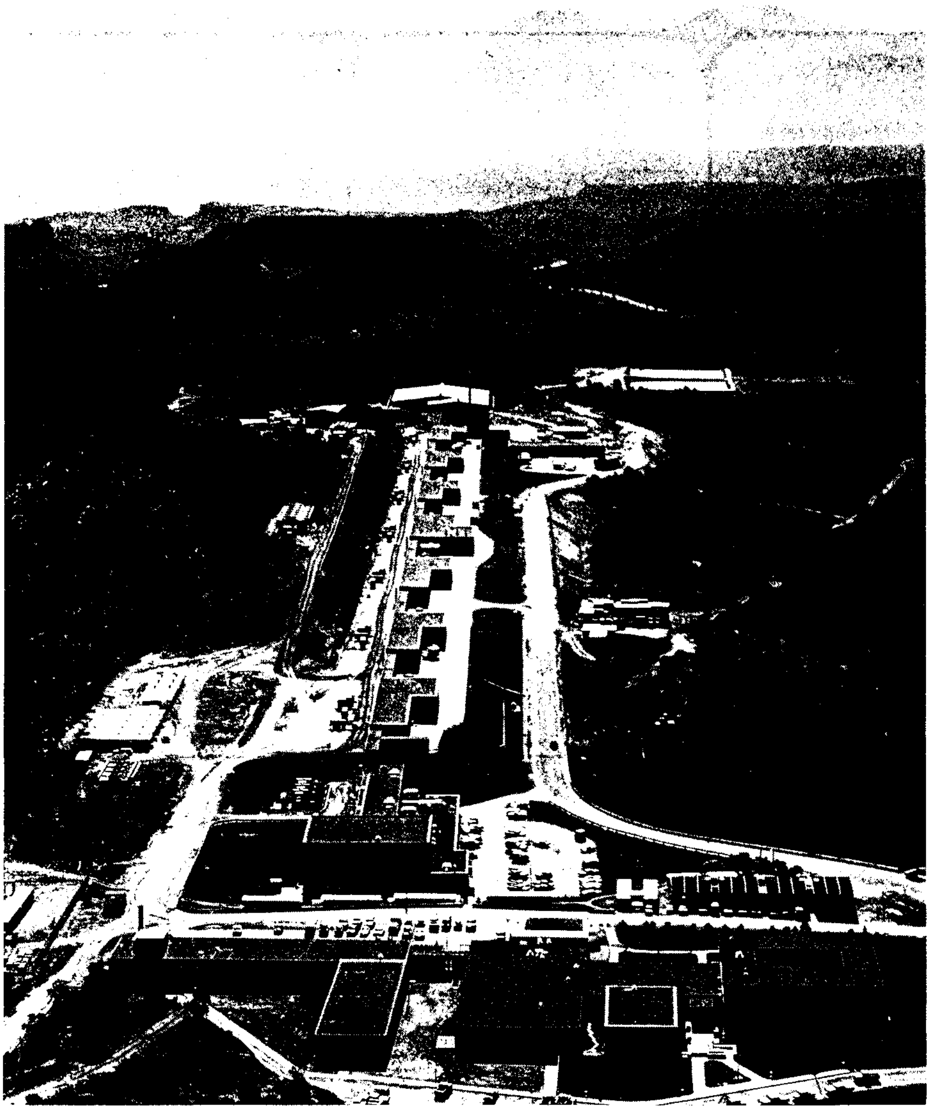
Higher values for the luminosity can be reached by storing more current or by storing the same current in fewer bunches i.e. increasing the particle density per bunch. By modifying the Linac injector to the DESY-Synchrotron it was possible to produce short bunch trains so as to fill only four adjacent buckets in DORIS out of the 480 available. In an alternative scheme which has been tried sucessfully but has not yet been studied in great detail one out of every four buckets is filled. With the short train mode the peak bunch current is limited to about 0.3 mA/bunch, but after compensating the machine's natural horizontal and vertical chromaticity (that is variation in Q value with momentum) a limit of about 2 mA/bunch was reached. Careful measurements of peak bunch current threshold versus octupole strength lead us, to conclude, together with the above observation, that the limit of 0.3 mA/bunch is given by the Head-Tail-Effect. This is the name used to describe the influence of the head of a bunch on the tail, causing it to wiggle, which of itself would not be important, but for the fact that some time later the particles in the head and tail have changed places so the effect is amplified and instability results.

The 2mA/bunch limit with sextupoles in the short train mode and the current limit when all 480 buckets are filled, are probably caused by coherent oscillations of the beam excited by spurious r.f. modes in the cavities and probably in the vacuum chamber. One can combat these oscillations by introducing Landau-damping and by decoupling the motion of single bunches, both in the transversal and longitudinal dimension, but at present the gains



Aerial view of the group of buildings housing the 800 MeV proton linear accelerator, LAMPF. The injector end is nearest the camera and the protons are accelerated along the mesa in the direction of the Jemez mountains to the experimental areas.

(Photo Los Alamos)



achieved in this manner are not high enough. For this reason a programme of locating, identifying and damping the modes which cause these single beam instabilities has been started. This programme has already been successful in so far as several r.f. cavity modes have been measured, and we are hopeful that after finishing this programme, larger currents can be stored and higher luminosities achieved.

First experiments will start in early autumn. DASP, a large equipment of double arm spectrometers, and PLUTO, a superconductive coil with 4 π-detectors, are in the process of starting work.

STANFORD SLED, PEGGY and Computers

A novel way of increasing the peak energy of their electrons has been cooked up at the Stanford Linear Accelerator Center. The system is known as SLED (for SLAC Energy Doubler) and was presented in a paper at the Stanford Accelerator Conference by P.B. Wilson, G. Loew, D. Farkas and H. Hogg.

The essential idea is to insert microwave networks between the powering klystrons and the accelerator. The networks, which have high Q resonant cavities, hang on to the power during most of the pulse from the klystrons and then pass it to the accelerator within a shorter time. Thus more power is crowded into a shorter pulse. The effect on the accelerated electrons is to increase their peak energy at the expense of the pulse length.

For experiments where more energy is important and where the pulse length is not crucial, SLED offers an attractive alternative to previous schemes such as the Recirculating Linear Accelerator described in vol. 13, page 10. Not least among its attractions is its much lower price (about $ 5 million for the networks, machine and switchyard modifications and new instrumentation).

If the whole accelerator is converted to the SLED scheme a peak energy of close to 50 GeV is anticipated. This would almost double the energy of 26 GeV which will become available when new 30 MW klystrons are installed. The pulse length would drop from 1.6 μs to 0.3 μs and the pulse repetition rate would drop from 360 to 180 per second, the duty cycle thus being reduced by an order of magnitude. The average current would be reduced to 13 μA (from 40 μA) but within the short pulse would be increased to 220 mA (from 70 mA). By pulse shaping, the energy spread of the emerging beam could be kept to 0.5 %.

No decision has yet been taken on whether to implement SLED but prototype networks are now being tested and it is intended soon to install one or two units on the accelerator itself for experimental studies of their effect on the electron beam.

A team at Yale University (V.W. Hughes, R.L. Long, M.S. Lubell, M. Posner and W. Raith) has been experimenting with photo-ionization of alkali atoms to study the basic processes involved and to produce a polarized beam of electrons suitable for injecting into high energy accelerators. Their work has resulted in a polarized electron source known as PEGGY which is now on the Stanford linear accelerator.

The polarized beam will be used in a scattering experiment on to a polarized proton target. Knowing the spin directions of the incoming electrons and the target protons will make it possible to pull more information from the data of the experiment. The different predictions of various models of the proton structure can be checked by these measurements. The proton target operates at 1 °K with a 5 T magnetic field and has given 70 % polarization of protons in butanol in prototype form. With the electron beam it is hoped to achieve 90 % polarization with intensities of over 10^9 electrons per pulse and a pulse repetition rate of 180 per second.

The experiments at Yale reached about 60 % electron polarization with 5×10^8 electrons per pulse from a lithium 6 atomic beam. The time available for the tests was limited and the ultraviolet lamp used in the photo-ionization process was operated at only 1 pulse per second. However a lamp has been working in independent tests at the design figure of 180 pulses per second.

PEGGY is now installed on the accelerator and is being tested. The electron beam polarization at the injection energy of 70 keV is measured by Mott scattering and, to confirm that no appreciable depolarization occurs during acceleration, the Moller scattering method (which does not involve using the polarized proton target) will be used for further measurements at about 10 GeV.

SLAC's computing power has been stepped up with the addition of two IBM 370/168s. They have joined the 360/91 which has been in action since 1968 and has become saturated, particularly owing to the new flood of data from experiments at the storage ring SPEAR and that to come from the Large Aperture Solenoid Spectrometer, LASS (itself capable of churning out 200 000 bytes per second). The three computers have a total memory bank of 8 million bytes. They are linked on-line to experiments and operate round the clock, seven days a week.

USA report on future projects

A 'Subpanel on New Facilities' has forwarded recommendations to the High Energy Physics Advisory Panel (HEPAP) concerning the future requirements of particle physics in the USA. The subpanel was chaired by V.F. Weisskopf and, after studying the problems for a week, it has urged HEPAP to transmit its recommendations to the Atomic Energy Commission so that appropriate decisions can be taken in time for the budgets of Fiscal Year 1976 (beginning July 1975).

The report draws attention to the fact that by FY 1976, eight years will have elapsed since the previous big project (the 200 GeV proton synchrotron at the Fermi National Accelerator Laboratory) was authorized and that the time is ripe, particularly in view of the present richness of the field, for new steps to sustain the success of US high energy physics.

Three recommendations have been made:

1. Authorization in FY 76 of a 15 GeV electron-positron colliding beam facility (PEP). It is felt that PEP is ready for construction on the basis of the existing design report which is founded largely on proven technology. To include provisions for proton-electron collisions in a later development would not add significantly to the cost of the electron-positron project. PEP would make possible a logical extension of the experimental programme of the SPEAR storage ring which has recently added astonishing new information to our knowledge of particle behaviour. The PEP design aims for a higher luminosity (10^{32} $cm^{-2}s^{-1}$) than has so far been achieved. The machine would be built by a joint Berkeley-Stanford team and become a national high energy physics facility. The cost estimate is $ 53 million (at 1974 prices) with $ 20 million to equip the experimental programme and $ 4 million per year for operation
2. Provision of about $ 3.5 million in FY 76 to establish procedures for the building of superconducting magnets on an industrial scale for a proton-proton colliding beam facility (ISABELLE). The aim is to follow up this prototype magnet stage quickly with a request for construction of ISABELLE with proton energies of at least 200 GeV and a design luminosity of 10^{33} cm^{-2} s^{-1}. The report further points out that the USA has at present no facility in the extremely important field of proton-proton colliding beam physics. The project requires a major step in the application of superconductive systems which would be likely to have wide impact on other areas of science and technology. A design study has been prepared at Brookhaven. The technological problems

are more difficult than in the PEP project and, in particular, it takes time to advance from laboratory prototypes to industrial prototypes of superconducting magnets. It is for this reason that one or two years more work in advance of authorization are recommended. The present cost estimate is $ 127 million at 1974 prices.

3. Provision of funds to support an accelerator development programme at the Fermi National Accelerator Laboratory with the long term aim of an accelerator and/or colliding beam systems in the energy region of 1000 GeV and above. An accelerator providing high energy beams to bombard a fixed target has advantages over colliding beam systems both in interaction rates and in variety of secondary particle beams. The panel considered the constuction of an accelerator in the few TeV range as the challenge for the Fermi Laboratory in the future (10 to 15 years from now) and therefore recommended support for the energy doubler and other steps towards achieving such energies. If no technical advances are found to reduce the cost of a machine to give energies of several thousand GeV an international approach might be advisable, as an expansion of the current co-operation in high energy physics, either as a USA-European effort or on an even wider scale with the inclusion of the Soviet Union and/or other countries.

The Subpanel maintains that the three recommendations can be implemented over the next ten years while still keeping the high energy physics budget for operations and equipment near $ 200 million (1974 prices). In line with the strong feeling of the USA high energy physics community, the recommendations also take account of the desirability of sustaining three strong research centres distributed geographically across the country. With these new projects — PEP on the West Coast, TeV machine in the Mid West and ISABELLE on the East Coast — diversity of physics, style and intellectual input can be sustained.

LAMPF Recent operation figures

The 800 MeV proton linear accelerator, LAMPF, at Los Alamos was operated at a peak current of 10 mA in June. With a pulse length of 160 μs there was no sign of problems from beam break-up. The average current was over 90 μA at a duty cycle of 2 % and these figures were limited only by the use of a temporary beam stop.

Beam losses in the Alvarez type section (accelerating to 100 MeV) are not a critical problem and can be accepted in high current operation. About 2 % of the beam is lost in acceleration from 100 to 240 MeV with the side-coupled cavity tanks and about a further 1 % in 240 to 800 MeV acceleration also is side-coupled cavity tanks. More than 90 % of the injected beam reached full energy within a momentum spread of 0.1 to 0.2 %. The particles of lower energy, which are not in correct phase for full acceleration, can be absorbed if necessary in a collimator near the first bend in the beam switchyard at the output end of the machine.

LAMPF is in routine operation for physics accelerating currents in the 5 to 10 μA range with a duty cycle of 5 % and these figures are likely to be held until the experimental areas can take more. As many as six independent experiments take data. We shall be returning to news from Los Alamos with a detailed report in a few months' time.

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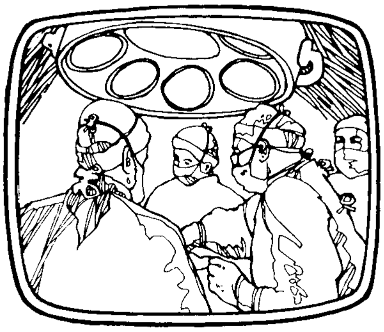

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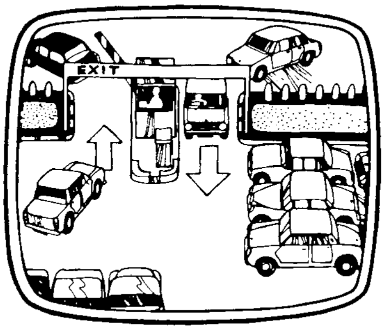

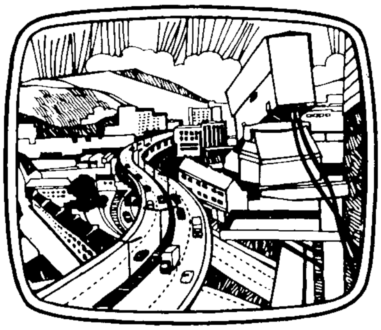

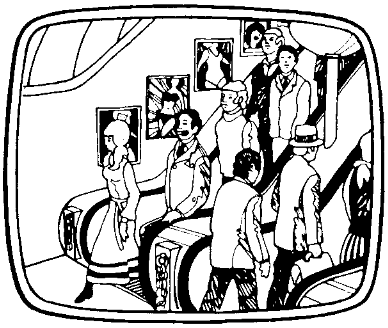

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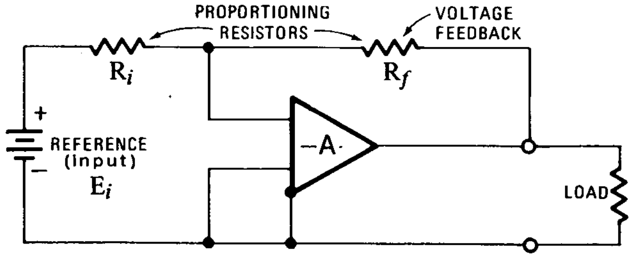

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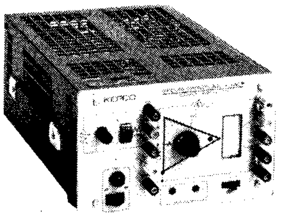

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All the world's a hadron

David Horn and
Fredrik Zachariasen

Hadron Physics at Very High Energies

Covers the rapidly developing field of very high energy hadron physics. It reviews in some detail the experimental results on elementary particle scattering and production recently obtained at the two new very high energy facilities, the Intersecting Storage Rings at CERN, and at the National Accelerator Laboratory, at Batavia, as well as data from older accelerators such as the one at Serpukhov. The phenomenological interpretation of these data in terms of the Regge pole picture are outlined and discussed. Attempts at a more fundamental theoretical understanding of these processes are also described, with the major emphasis on field theoretic and multiperipheral models. These models are described in some detail, and both their successes and shortcomings are pointed out. Other theoretical ideas, encompassed in pictures of elementary particles as droplets, in statistical descriptions of high energy production processes, and in fireball descriptions of production, are mentioned more briefly.

1973, xvi, 378 pp.;
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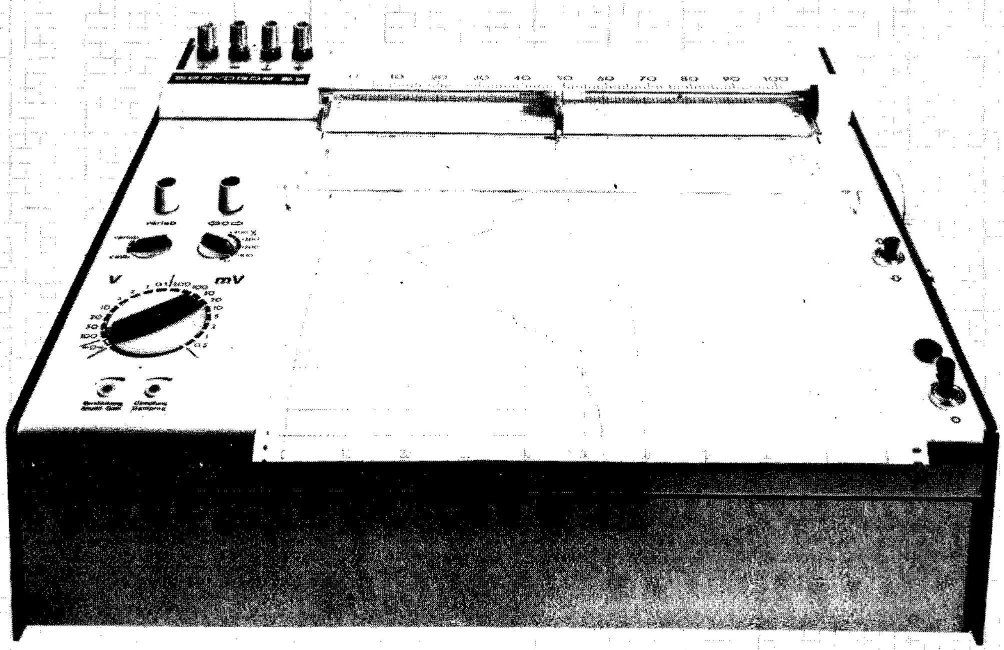

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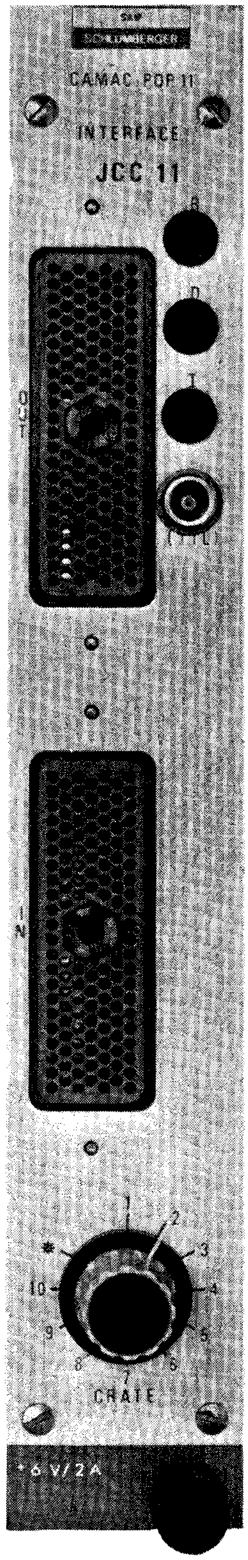

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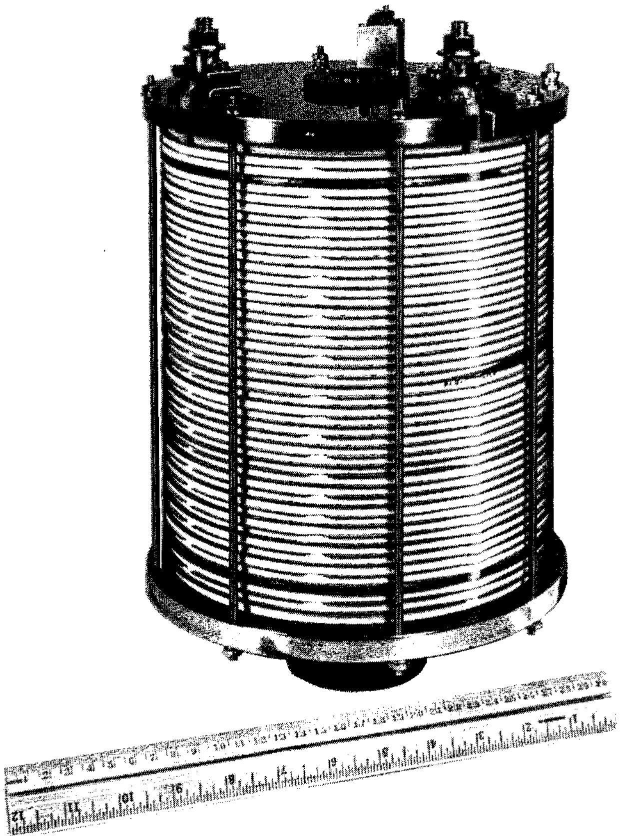
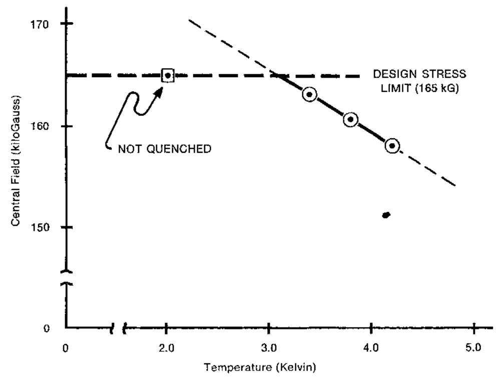


New IGC magnet breaks the 150 kG barrier



CENTRAL FIELD AT "QUENCH' VERSUS MAGNET TEMPERATURE

An IGC superconductive magnet has decisively penetrated the long-standing 150 kG barrier for commercial superconducting solenoids. Built for the Mullard Cryogenic Laboratory of the Clarendon Laboratory, Oxford, England, the new magnet produces 158 kG at 4.2 K and 165 kG at 3.0 K. This record performance was made possible by IGC's modular approach to magnet design, combined with the superior properties of IGC's stabilized Nb_3Sn conductor.

Unique in its characteristics, the new magnet has an outer diameter of only 231 mm and weighs only 66 kilograms. It is also extremely stable, performing to 150 kG in less than 30 minutes on its first run, and in less than 10 minutes on subsequent runs.

From a mechanical stress standpoint, the new magnet was designed to perform to 165 kG. As the inset graph shows, however, the results suggest that IGC Nb_3Sn magnets may be capable of fields in the range of 170 kG at temperatures near the helium λ point (2.18 K).

Superconductive magnet performance to fields above 180 kG at 4.2 K may also be made possible by this major advance. Such magnets will use V_3Ga superconductor (now available through IGC) in the regions of the winding space where the field is greater than 150 kG.

This is one more reason to consider IGC, whatever your requirements—superconducting materials, ultrahigh field magnets, or complete turnkey systems. Rely on the one company with across-the-board capability . . . Intermagnetics General Corporation. For more information, write or call: Paul Swartz, Vice President of Marketing and Sales, Charles Industrial Park, Guilderland, New York 12084. Telephone: (518) 456-5456. TWX No. 710-441-8238.

TABLE OF PERFORMANCE SPECIFICATIONS

Quench Field at 4.2K	158 kiloGauss
Quench Field at 3.0K	165 kiloGauss
Clear Bore Diameter	25.7 mm
Outer Diameter	231 mm
Length	262 mm
Operating Current at 150 kG	126 Amperes
Field Homogeneity at 150 kG	3×10^{-4} in a 5 mm DSV
Time to 150 kG (Virgin Run)	Under 30 minutes
Time to 150 kG (Subsequent Run)	Under 10 minutes
Weight	66 kilograms
Average Current Density in Winding Space at 165 kG	15,500 A/cm^2

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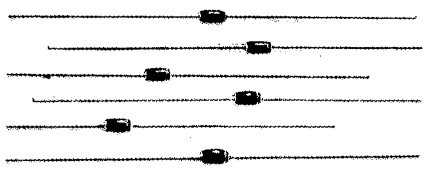

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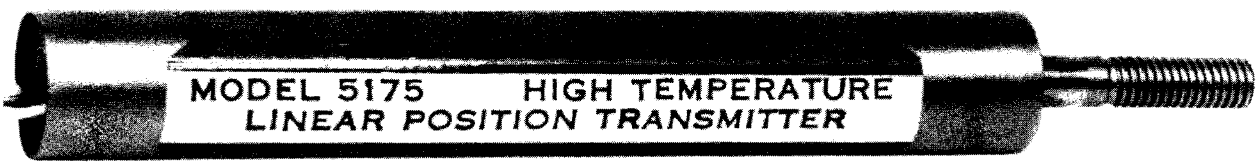

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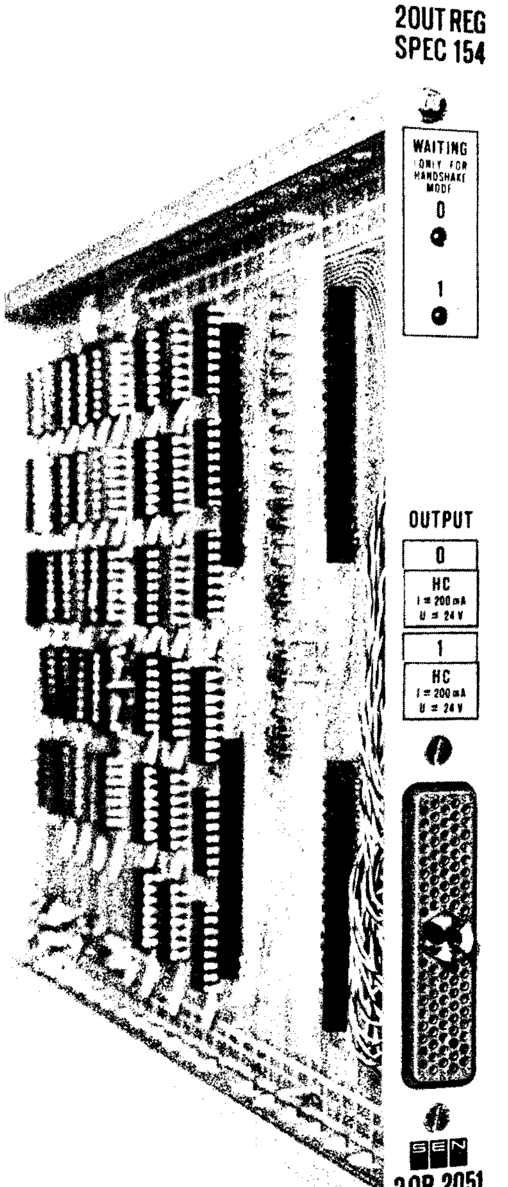

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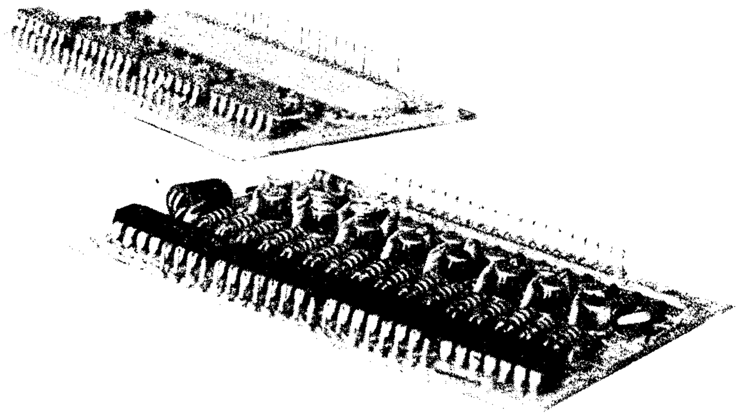

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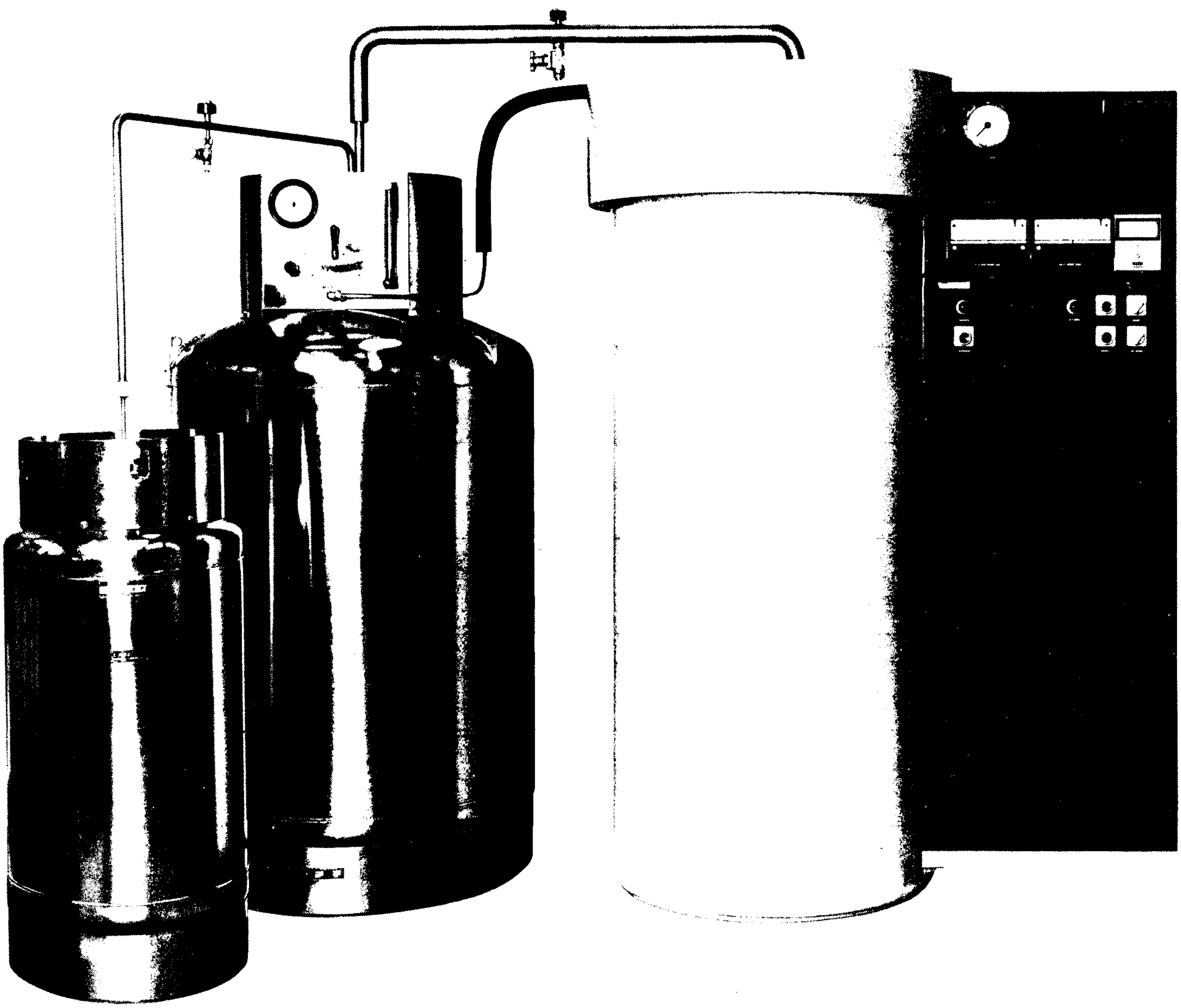

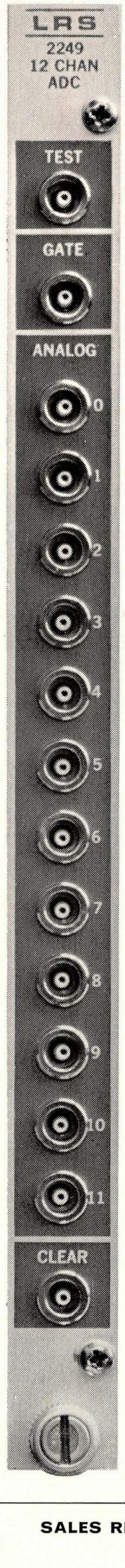

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