CERN COURIER

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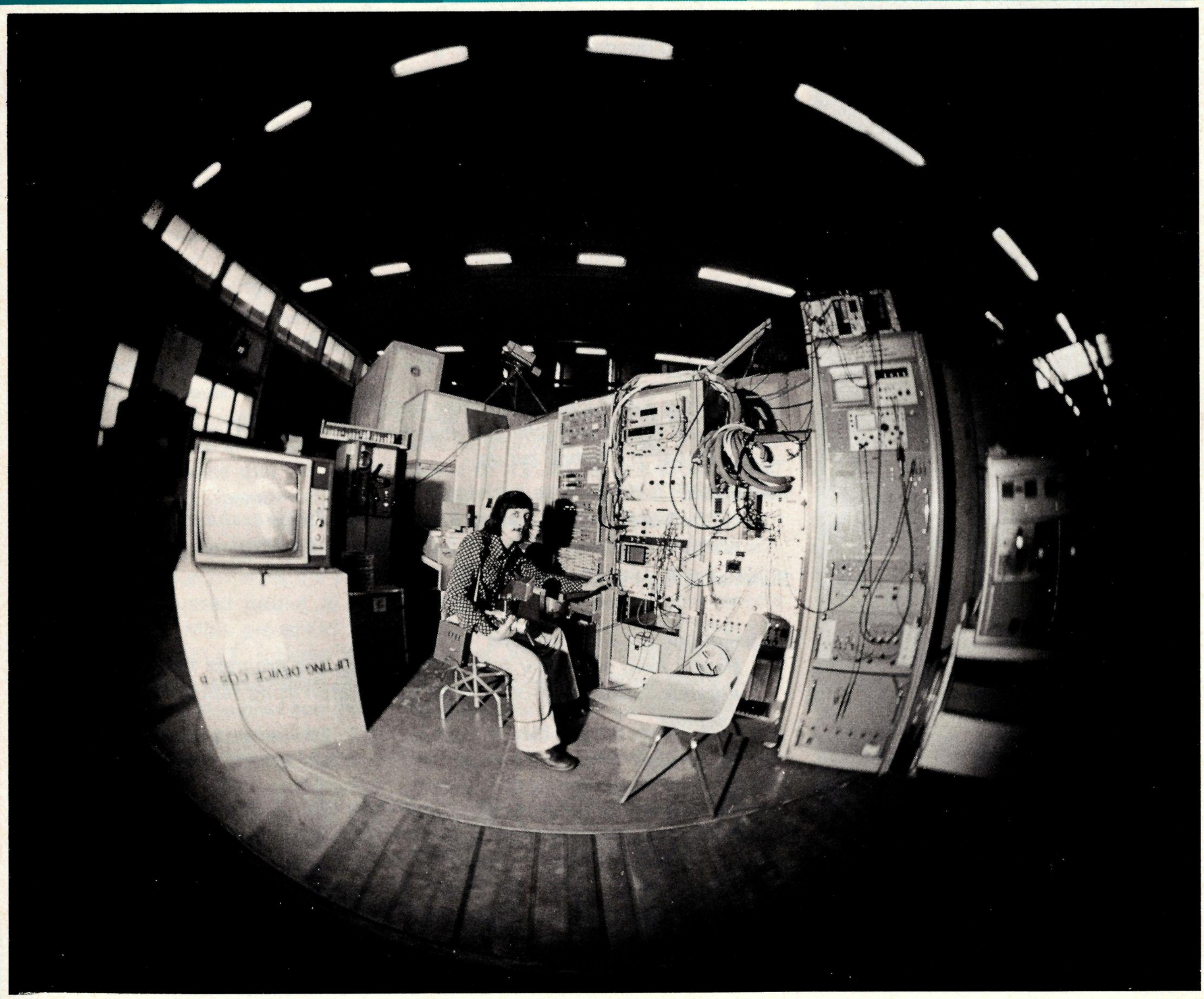

CERN, the European Organization for Nuclear Research, was established in 1954 to '... provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto'. It acts as a European centre and co-ordinator of research, 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 3000 people and, in addition, there are about 900 Fellows and Visiting Scientists. Twelve European countries contribute, in proportion to their net national income, to the CERN Laboratory I budget, which totals 382.9 million Swiss francs in 1973.

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 hundreds of 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 1973 is 188 million Swiss francs and the staff will total about 370 people by the end of the year.

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Cover photograph: Fish eye view of a local control room in the South Hall of the PS during testing of an ESRO satellite detector in a proton beam. The satellite, COS-B, will study gamma radiation in space and is scheduled for launching in 1974. To test its detection system, it has been exposed to gammas at the DESY electron synchrotron and came to sit in a CERN beam to check that signals due to charged particles such as protons would not drown the true gamma signals from the detector. *(CERN 113.3.73)*

USA Accelerator Conference

Since the International Accelerator Conference which would normally be held in the Autumn of this year has been moved to 1974 (at Stanford in May) we will devote more attention than usual to the '1973 Particle Accelerator Conference' held at San Francisco from 5-7 March. This was a conference in the 'national' series in America but, as usual, it attracted on international participation and had some papers from European and Soviet Laboratories.

The dominating topic was storage rings. This was helped along particularly by the spectacular performance of the CERN Intersecting Storage Rings and by the encouraging start of operation at the Stanford storage ring, SPEAR. W. Schnell reported on ISR operating results where design luminosity has been reached, stored currents are still rising and no fundamental limitation to performance has yet been encountered. Progress with the electron-positron storage ring SPEAR was covered by B. Richter. The ring has already achieved the highest luminosity ever recorded (over 10^{31} per cm^2 per s). Above all, these results have given confidence that we know how to build and operate colliding beam machines.

This confidence is obvious in the plans for future machines in the USA which were discussed further at the Conference. F.E. Mills presented the Brookhaven ISABELLE scheme and T. Elioff the Berkeley/Stanford PEP scheme. There was also brief comment about an electron-proton colliding beam scheme which is beginning to take shape in the minds of the high energy physics community in the UK. It is envisaged as taking over from Daresbury's electron synchrotron, Nina, and Rutherford's proton synchrotron, Nimrod, in the 1980s. Working parties from the two Laboratories plus about fifty high energy physicists are studying the project which has collected the name EPIC (Electron Proton Intersecting Complex). It is hoped to have a first presentation of the project ready by the end of this year.

The PEP and ISABELLE projects were described in vol. 11, page 279 and vol. 12, page 227 respectively. Such evolution as they have undergone since then has brought their designs closer together. PEP (Proton-Electron-Positron) is intended for high energy proton-electron and electron-positron colliding beams. It is a two ring system — one ring above the other. The top ring holds electrons and positrons up to an energy of 15 GeV. The lower ring has superconducting magnets providing fields up to 4 T so as to hold protons up to an energy of 150 GeV.

Four straight sections 200 m long are available for colliding beam experiments and the radius of curvature of the magnet quadrants is also 200 m. A particular feature of PEP is the intention to concentrate the orbiting particles into single bunches, using a three step process of r.f. gymnastics. This is intended to bring bunch size down to 13 cm for the protons and 1.6 cm for the electrons and positrons. Each bunch holds about 5×10^{12} particles and luminosities in the intersection regions would then reach about 10^{32} per cm^2 per s. Some aspects of this process (for example the possibility of azimuthal blow-up of the tight bunches) and other beam dynamics features of PEP (Q-shift, tolerable magnetic field components) have not yet been thoroughly studied by the Berkeley/Stanford team and will no doubt be thrashed out in the coming months. A four week study on PEP is scheduled for this coming Summer.

With nice diplomacy, site plans have been drawn which show PEP located at the Lawrence Berkeley Laboratory, where protons could be injected from the Bevatron, and at the Stanford Linear Accelerator Centre, where electrons and positrons could be injected from the linac.

The Brookhaven project ISABELLE (Intersecting Storage Accelerator) is for proton-proton colliding beams at energies up to 200 GeV per beam. The design has been modified to include four straight sections for experiments, two of 300 m and two of 200 m. The aim is to achieve a luminosity in excess of 10^{33} per cm^2 per s. Particular attention has been given to achieving flexibility in the intersection regions and a catalogue of possible arrangements for different types of experiment has been worked out in collaboration with the high energy physicists.

ISABELLE has been under study for longer than PEP and a number of problems have been examined in depth (for example, G. Parzen has worked out the tolerances for unwanted magnetic field components). Superconducting magnets with a peak field of 4 T would be used mounted one above another in the curved sections of the machine. The two-ring curved sections have a radius of 220 m.

The addition of an electron-positron ring to ISABELLE has also been considered. The ring is designed to give electron energies of 15 GeV with the AGS being used to inject particles at an energy of 4 GeV. The ring could either be located alongside or inside the proton rings and bypass connections would give the necessary collision straight section or sections. The luminosity is estimated at around 10^{32} per cm^2 per s.

It is well realized that, in the present climate for high energy physics financing in the USA, neither of these projects is likely to take off very soon. Nevertheless they are important in troubled times because they are keeping the art of designing accelerators

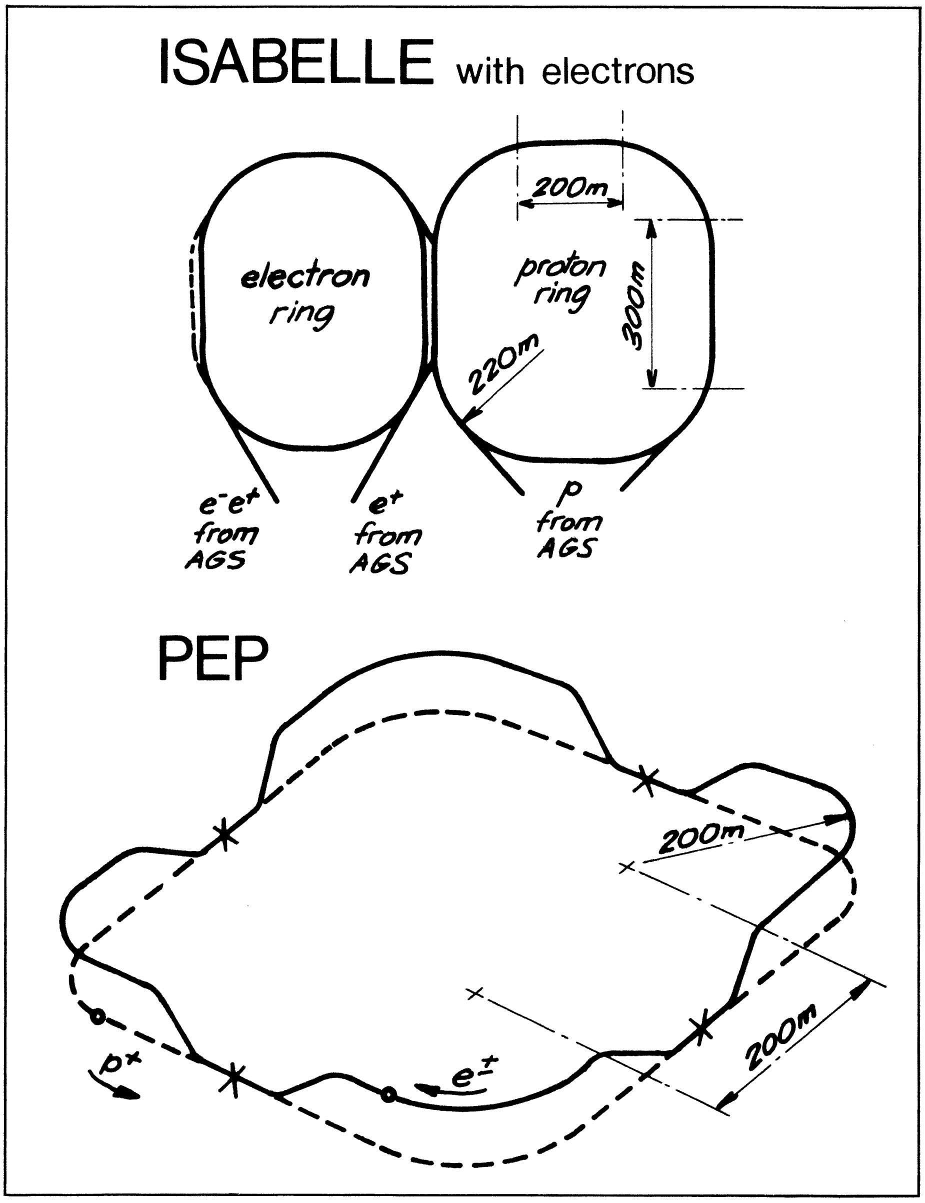
The two storage ring projects under study in the USA. ISABELLE has emerged from Brookhaven and is primarily for proton-proton colliding beams. It is sketched with a possible electron-positron addition. PEP has emerged from Berkeley and Stanford and has a single proton beam plus an electron-positron ring.

alive. The only storage ring development which is sure (since its money will be drawn from within the normal Laboratory budget) is an improvement programme on SPEAR at Stanford to take its peak energy to 4.5 GeV.

Also more time is needed to clear the way for the incorporation of superconducting magnets in accelerators. Berkeley and Brookhaven have research programmes on pulsed superconducting magnets (like the GESSS collaboration in Europe — see page 117). First measurements on a superconducting magnet which has almost the dimensions required for ISABELLE were reported from Brookhaven. The magnet has an 8 cm bore and is 1 m long (ISABELLE is planned with 3 m magnets). It uses wide ribbon conductor woven from 186 wires each containing 400 filaments of niobium-titanium. Correction windings are also built in to correct for harmonics and for iron saturation effects.

The measurements were in excellent agreement with the calculated field values up to a field of 3.9 T (corresponding to 3250 A in the conductor) when a problem with the current leads developed. When this is cured there should be no difficulty in reaching the design field of 4.5 T and it looks likely that the high quality of the field will be maintained. No training was observed.

These results look very healthy in terms of individual magnet performance but there is an important question concerning the reproducibility of superconducting magnets still to be answered. Brookhaven and Berkeley have both built sets of two 'identical' magnets. The two Brookhaven magnets were scheduled for testing at the beginning of April and the Berkeley ones should be ready not long afterwards. Their results are keenly awaited.



Among the operating accelerators in the USA the machine at the National Accelerator Laboratory, Batavia, is obviously of prime importance. D. Young presented a progress report on operation of the accelerator. Since high energy beams were first achieved just over a year ago (see vol. 12, page 120) the peak energy has doubled to 400 GeV and the intensity taken to 1.8×10^{12} protons per pulse. The accelerator runs regularly at 300 GeV and the average intensity in a recent run was 5×10^{11}.

The 200 MeV linac is operating with over 90 % efficiency. It accelerates 80 to 90 mA reliably, in excess of the design current of 75 mA, but the beam quality has not reached specification yet (20 % larger emittance). Improvements of the ion source and the feedback loops are to be carried out.

The Booster has run below its design figures until recently because of trouble with blocking capacitors in the r.f. system. This is now cured and 8 GeV operation with twelve pulses at 15 Hz is under way. Accelerated intensity needs considerable improvement. With single turn injection 5×10^{11} protons per pulse is usual which is a factor of eight down on the design performance. Multiturn injection has not yet led to higher intensities and the Booster beam needs more study during both capture and acceleration.

The main ring magnet problems seem to have been overcome with the use of a partially cured epoxy assembly of the vacuum chamber and coils integrally impregnated into the core. Magnets assembled in this way are replacing other magnets when they fail. A replacement takes about four hours and careful cleaning and inspection of the vacuum chamber when a magnet is cut out has cleared the trouble with obstacles in the chamber.

Performance of the main ring was mentioned above. Beam losses on injection are about 30 % and more work is needed to increase the available aperture. Fast ejection efficiencies are close to 100 % and slow ejection, using a pulsed quadrupole to push the accelerator tune into the half integer resonance, has reached about 95 % on a flat-top of 250 ms. The three experimental areas are fed with beam and beam-splitting stations enable them to be served simultaneously.

So far six experiments have published results, ten have completed data-taking, thirteen are under way, six are setting up and nine others are being installed.

There were a number of papers at the Conference concerning heavy ion acceleration. These included progress reports on the nearly completed Super Hilac at Berkeley (this will be linked eventually with the Bevatron to give heavy ions with GeV energies — see vol. 12 page 381) and on the Unilac machine at Darmstadt which we will describe in a forthcoming issue. There is also an Oak Ridge proposal for a major heavy ion accelerator facility.

Considerable attention was given to the practical applications of accelerators. Medical applications were predominent but there were also papers on such diverse topics as oil-well logging, paint-curing and even tunnelling. R.T. Avery from Berkeley reported on some research into the possibility of using intense, high frequency, electron beams to cut through rock. Such an idea is a long way from application but it is entertaining to think that the SPS accelerator might have been built using an accelerator to cut its tunnel.

Finally, a few comments on the financial situation in high energy physics in the USA, which has quite a lot to do with this burst of concern for practical applications. The budget figures before Congress for fiscal year 1974, beginning 1 July 1973, have hardly moved from those of fiscal year 1973 ($ 149 million compared with $ 148 million). In an inflationary world, this means that the funding for high energy physics is going down. Laboratory operating budgets, overall, remain the same (but since this includes the growing physics programme at NAL it means cuts elsewhere). Construction budgets have dropped considerably.

Another Laboratory is going to the wall. Following in the wake of the Cosmotron and Princeton Pennsylvania Accelerator, the Cambridge Electron Accelerator is being phased out. The Laboratory has already had its research programme at the 7.5 GeV electron synchrotron terminated and was in action only with its 'bypass' electron-positron colliding beam facility. With the coming into operation of SPEAR at Stanford, this facility also is to be closed at the end of the present fiscal year. As from 1 July, only $ 600 000 will be made available to complete analysis of bypass experiments and to close down the Laboratory. An approach has been made to the National Science Foundation to support the conversion of the accelerator into a national synchrotron radiation facility. This is a last ditch attempt to keep the Laboratory in being.

Other Laboratories such as Brookhaven have had severe budget cuts, which involve trimming the research programme and reducing staff numbers, and the immediate future does not look rosy. Nevertheless, as W.A. Wallenmeyer pointed out in his Conference review of funding, the USA physics community does have an impressive line-up of accelerator facilities: Batavia has the world's highest energy proton synchrotron (400 GeV); Cornell has the world's highest energy electron synchrotron (12.5 GeV); Stanford has the world's highest energy electron linear accelerator (21 GeV) and highest energy electron-positron storage ring (2.7 + 2.7 GeV); Los Alamos has the world's highest energy proton linear accelerator (800 MeV); Brookhaven has the world's highest intensity proton synchrotron (7×10^{12} per pulse); Berkeley has the world's highest energy heavy ion accelerator (neon up to 2.5 GeV per nucleon) which will be further improved by the now-funded Bevlac project (up to 2.5 GeV per nucleon for elements up to iron).

What is lacking is sufficient financial support to be able to use this mighty armory of research facilities at somewhere near its full potential.

Final report from 300 GeV Working Group

Under the auspices of the European Committee for Future Accelerators, a '300 GeV Working Group' was set up two years ago to look at the possibilities and the problems in carrying out experiments at energies of several hundred GeV with the SPS. Via working parties on specific topics, the interests and expertise from all sections of the European high energy physics community were brought into the discussion. Two study weeks were held at Tirrenia (see vol. 12, page 318) to pool the thinking of the working parties and a final report has now been published.

For the record, the members of the Executive Committee were: J.V. Allaby, G. Barbiellini, W. Beusch, G. Brianti, I. Butterworth, J. Drees, P. Falk-Vairant (Chairman), D.E. Fries, G. Giacomelli, F. Jacquet, E. Lillethun, I. Mannelli, C. Michael, P.G. Murphy, C. Rubbia, P. Söding, M. Steuer, J.P. Stroot, J.J. Tresher, D. Treille, R. Turlay, R.T. Van de Walle, H. Wachsmuth and E.J.N. Wilson.

The conclusions of the Committee were based on three assumptions. The first is that all three types of interaction (strong, electromagnetic and weak) will be studied at the SPS early in its experimental programme. For weak and electromagnetic physics, the ability to produce high intensity beams of muons and neutrinos of energy up to 200 GeV (compared with less than 10 GeV from the CERN PS) opens up completely new possibilities for research. Long duty cycle electron beams should also be fruitful in studying the electromagnetic interaction. For strong interactions, the SPS will fill the energy gap between the PS and ISR with the additional ability, compared with the ISR, of using several types of particle and target.

The second assumption is that the existing major detectors at CERN will be available for the SPS experimental programme. This refers to the Omega spectrometer, the 3.7 m European bubble chamber and the heavy liquid chamber, Gargamelle. The third assumption is that resources will be available to support about twelve groups involved in electronics experiments at the start of the experimental programme rising to twice this number after two years. The bubble chamber programme is expected to involve about 350 physicists.

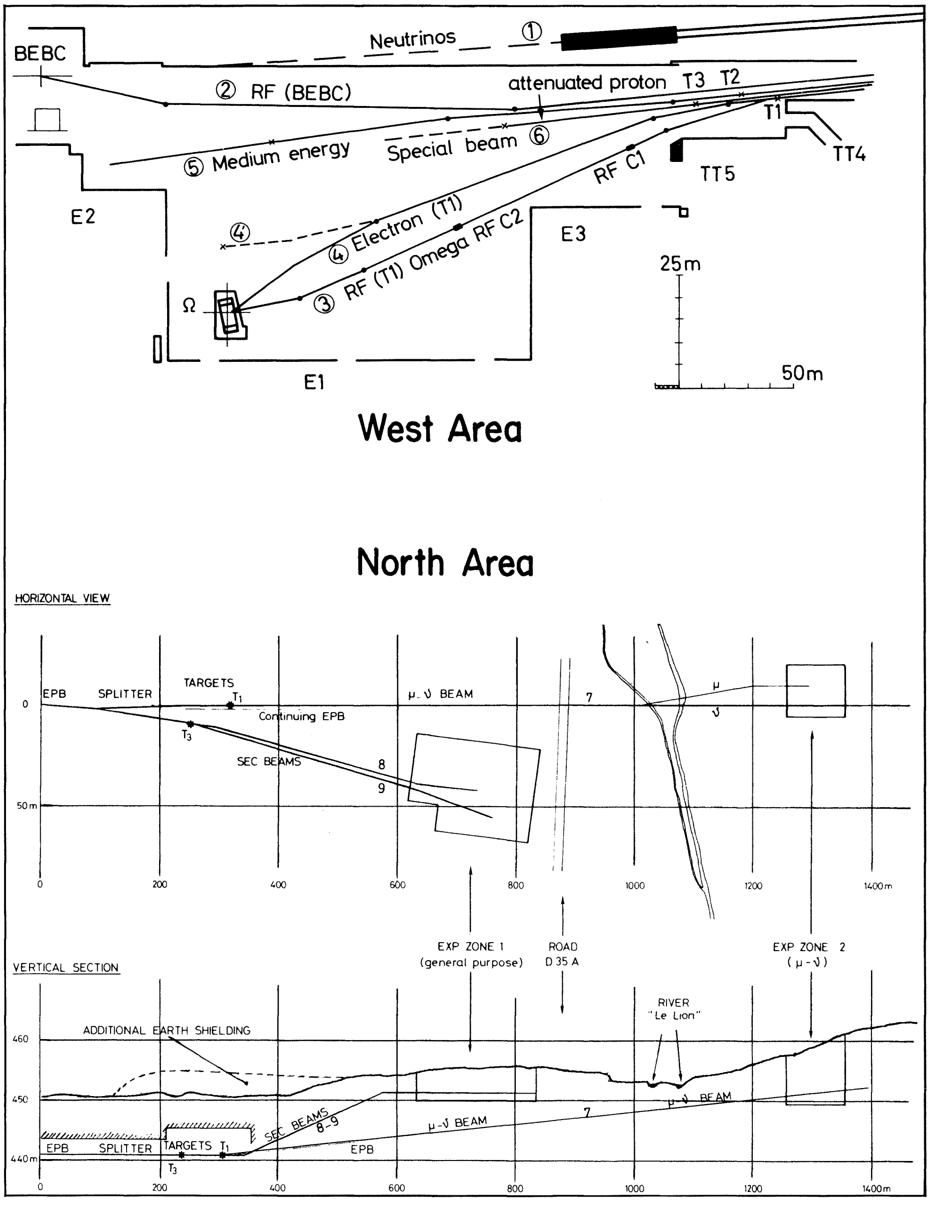
Following on these assumptions the Executive Committee emerged with the following recommendations:

1. Beams and facilities at least equivalent to those indicated in the Figure in the first two years of operation. The Figure caption details what this recommendation involves. The Committee is in favour of starting the programme with the synchrotron operating at a peak energy of 400 GeV using a full ring of conventional magnets (see the discussion on 'Schedule C' in vol. 12, page 321).
2. The use of BEBC unaided is in general difficult for energies above about 40 GeV. The Committee therefore recommends a series of developments in association with BEBC to extend its abilities to higher energies. They include the purchase of neon so as to test operation of the chamber with a hydrogen-neon mixture and the development of a track sensitive target, to be commissioned if possible before the start of the SPS (see vol. 11, page 356 for an account of the pioneering work on TSTs at Rutherford); the construction of an external muon detector for neutrino experiments; the design and construction of an external particle identifier (e.g. of multiwire proportional chamber arrays or multicell Cherenkov counters) for hadron physics and the study of the feasibility of a gamma detector behind the chamber. The Committee held back a definite recommendation on the use of Gargamelle, moved into a position behind BEBC, because other features of the initial experimental programme need to be clarified first.
3. The use of the Omega spectrometer also requires additional detectors to cope efficiently with higher energies. The Committee recommends the construction of multicell Cherenkov counters, a design study for a gamma detector behind the spectrometer and a study of the replacement of the optical chambers now installed in the Omega magnet aperture by faster multiwire proportional chambers.
4. For the North Area, the Committee recommends that a spectrometer facility be built for the start of research with the high energy high resolution beam in Experimental Zone 1. This is likely to involve major detection systems such as Cherenkov counters and arrays of multiwire proportional chambers as well as very large spectrometer magnets.
5. The Committee recognizes the need for continuing work on new particle detection techniques such as vertex detectors, relativistic rise detectors and detectors to give very high spatial resolution. High spatial resolution detectors (such as drift chambers) would be particularly advantageous since they would take some of the pressure off the spectrometer magnets. Lepton physics will require large, complex detectors (such as shower detectors for electrons and photons, hadronic calorimeters and muon detectors) and the Committee recommends that collaborations, which are likely to be needed for the construction of these instruments should begin now, under the auspices of the SPS Experiments Committee.

The buck of preparing for physics at the SPS has now passed to the newly formed SPS Experiments Committee. It has a similar task to the other experiments Committees, which make recommendations on the programme

Recommended beams and facilities for the first two years of SPS operation:
In the West Area, with the possible exception of the neutrino beam to BEBC, the secondary beams would be drawn from an ejected proton beam of 200 GeV peak energy. Beams would be — a neutrino beam for BEBC produced underground, r.f. separated beam for BEBC, superconducting r.f. separated beam for Omega, electron/photon facility, medium energy charged beam, special beam (such as hyperons or neutrals).

In the North Area, a slow ejected proton beam only is foreseen of energy up to 400 GeV feeding two zones. Experimental zone 2 would have a high energy muon beam and the possibility of using the associated neutrino flux in electronics experiments. Experimental zone 1 would have a high energy, high resolution secondary beam and another charged particle beam with enough flexibility to serve many experiments.



using the existing CERN facilities, plus the task of making recommendations on such things as beams, major detectors etc... as the situation, mapped out by the ECFA Working Group, evolves further.

The members are: J.B. Adams, J.V. Allaby, U. Amaldi, G. Brianti, R. Budde (Secretary), I. Butterworth, P. Carlson, P. Falk-Vairant, L. Foa, W. Jentschke, P. Lehmann (Chairman), C. Llewellyn-Smith, E. Lohrmann, J. Meyer, D.H. Perkins, C. Peyrou, E. Picasso, C. Rubbia, H. Schopper, P. Söding, J. Steinberger, D. Treille and R.T. Van de Walle. The first meetings of the Committee have been held and a call for 'letters of intent' has gone out as a first step towards establishing the initial experimental programme. An open information meeting on the SPS and its experimental facilities has been called for 26 April.

Back in action

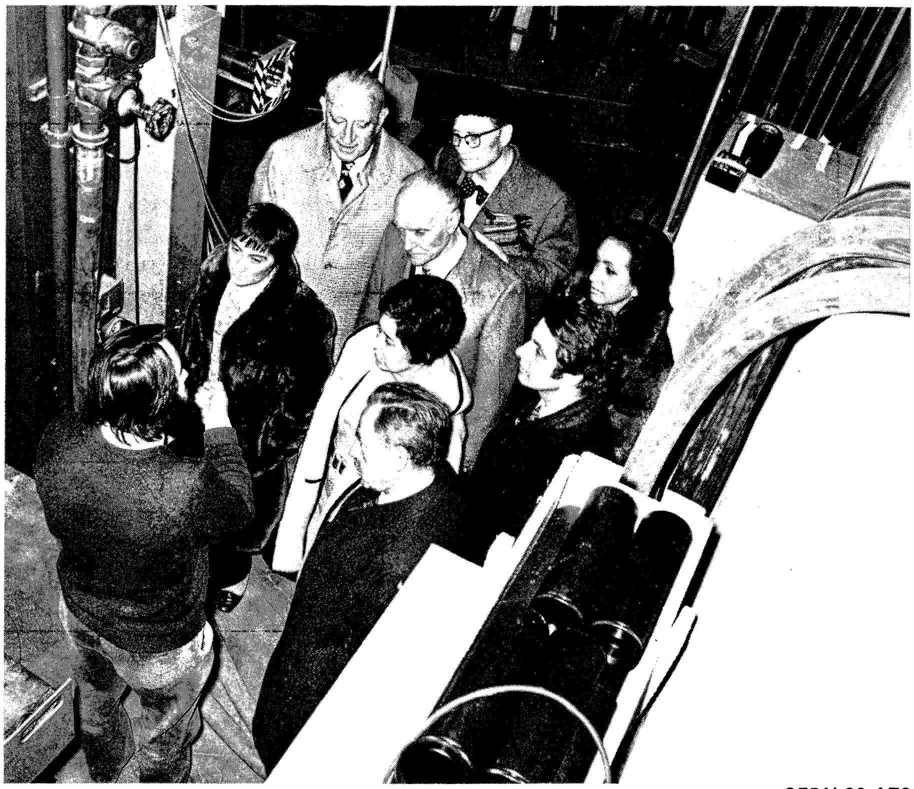
The proton synchrotron and the intersecting storage rings spent the first two months of this year in a long shutdown for general maintenance and for some important modifications. These were described in the January issue page 7. The machines have now settled down again after being switched on towards the end of February and this is a brief review of their post-shutdown performance. The information was pulled together towards the end of March so, by the time of publication, some of the performance figures which are given may be exceeded but they nevertheless give a good idea of how the machines are ticking over.

At the PS there had been considerable upheaval in the linac and modifications of one sort or another had involved tampering with half the magnet ring. Nevertheless the switch-on went remarkably smoothly. The programme leading to the scheduled time for feeding protons to the experiments went as planned. For a change, few trivial faults halted progress and the machine physicists (who described it as the most 'intellectually satisfying' switch-on yet) were able to concentrate on mastering the beam in the new magnetic field conditions. After ring components have been displaced/reinstalled/added/removed the field conditions are always slightly different and unknown; the settings of the correction elements in particular have to be adjusted to reach optimum performance again.

This commissioning was greatly helped by the stability of the beam from the linac and its reliability. It seems that the clean-up of the r.f. systems powering the linac tanks has been successful.

Traditionally the experimental programme is restricted after a long shutdown — the demands on per-

The cultural commission of the French Senate visited CERN on 4 April. About twenty visitors were welcomed by the Directors General of Laboratory I and Laboratory II. They toured the CERN site seeing experiments at the 28 GeV proton synchrotron and the Intersecting Storage Rings and also saw the work under way on the SPS site in Laboratory II. In the photograph R. Turley is describing the use of a separated kaon beam in the South Hall of the proton synchrotron to a small group from the commission.



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formance are kept modest to allow time for the machine to be brought back to its peak. But this year as demanding a programme as ever mounted began immediately with protons going to BEBC, to Omega, to counter experiments, to the 2 m bubble chamber and to the ISR. A variety of peak energies were needed; fast and slow ejection in various combinations with internal targets were in action. And with all this, the fault rate was below 5 % which is better than is usual.

To crown the success a record proton beam intensity of 2.36×10^{12} protons per pulse was reached and the average intensity during the first run was 1.73×10^{12}.

To push the intensity of the PS much higher, requires the operation of the 800 MeV Booster to provide an intermediate stage of acceleration between the 50 MeV linac and the synchrotron ring. Prior to the shutdown, the running in had been hindered by the performance of the linac — the Booster requires much more of the linac (100 mA beams over 100 μs with low energy spread) than the synchrotron ring.

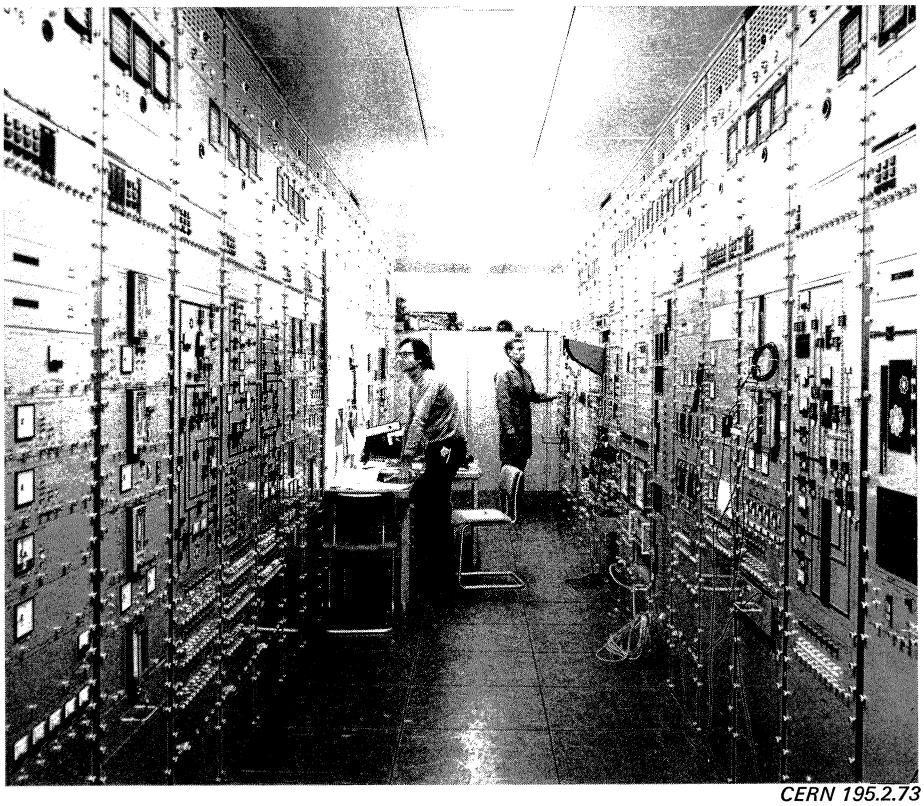
Nevertheless, in December at the very hour that the shutdown was scheduled to start, Ring 3 of the four-ring Booster succeeded, intermittently, in accelerating 2.55×10^{12} protons per pulse to 800 MeV. During the same run 1.7×10^{12} protons were fed to the PS ring. The beam quality was not very good (large emittance and longitudinal bunch oscillations) since there had not been sufficient time to optimize Booster conditions and only about 8.5×10^{11} protons in five bunches were taken intermittently to transition energy in the PS. However, this corresponds to 3.4×10^{12} if the four Booster rings had been in action to provide twenty bunches, which is a higher intensity than the PS has yet handled at GeV energies.

Much remains to be done to improve this performance, to improve reliability and to improve beam quality from the Booster. Progress seems to depend crucially on achieving the required beams from the linac and it is therefore encouraging that since the shutdown there have been several runs with good quality linac beams of low energy spread. This has made it possible to achieve stable multi-turn injection into a Booster ring. Between eleven and fifteen turns have been injected and r.f. trapping efficiencies varying between 80 and 95 % (95 % being the theoretical maximum) were achieved giving 3×10^{12} protons in a ring. It has not yet been possible to study multi-turn injection in detail because it is necessary to know the injected beam emittance and the emittance measuring station is temporarily out of action.

The high intensity beam with low energy spread also, as is to be expected, led to beam instabilities. These need to be carefully observed and this will be helped by the use of ionization beam scanners which are now being installed. The IBS will make it possible to watch the growth of an instability which is a good clue to its nature. Many correction elements exist in the Booster rings to cure instabilities.

There is now more pressure to bring the Booster into service since higher intensities would be a great advantage for the neutrino experiments in Gargamelle. Everyone is breathing heavily about a possible unification of electromagnetic and weak interactions via gauge theory (see vol. 12 page 315). One of the strong predictions of the theory is that neutrino-electron scattering should take place and a single candidate for such an event has been isolated in the photographs taken during the last neutrino experiments

A view inside part of the control room of the 3.7 m European bubble chamber, BEBC. This gives an idea of the complexity of the many systems involved in the operation of the chamber. Last month we reported the first tracks taken in BEBC. A hydrogen leak had interrupted the tests but it proved possible to repair this quickly and operation continued at steadily increasing field levels up to 2.6 T. No troublesome effects appeared due to eddy currents in the metal piston which is temporarily replacing the plastic piston. The chamber has now been 'warmed up' again to receive the last touches before the physics programme is launched in about two months' time.



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in Gargamelle. This whets the appetite but is certainly not sufficient by itself. An extension of the neutrino experiments, preferably with the highest intensity the PS can provide, is receiving high priority. It is hoped that the Booster will be able to contribute to the PS intensity before the end of this year.

At the ISR modifications and additions, which were introduced to improve the performance of the rings still further, together with new installations for experiments affected a large fraction of the machine. Despite the widespread alterations, operation was resumed without delay after the shutdown — within three hours of switching on, beams were circulating in both rings.

The major upheaval was in connection with the vacuum system. As mentioned many times before, it is the pressure rises which can occur in the rings which limit the machine performance. Prior to the shutdown the pressure had already been pushed far below the design value and this was a crucial factor on the way to achieving design luminosity in December of last year. But the phenomenon of 'pressure bumps' — local rises in pressure due to gas desorption from the chamber walls induced by ion bombardment — was still a troublesome limitation.

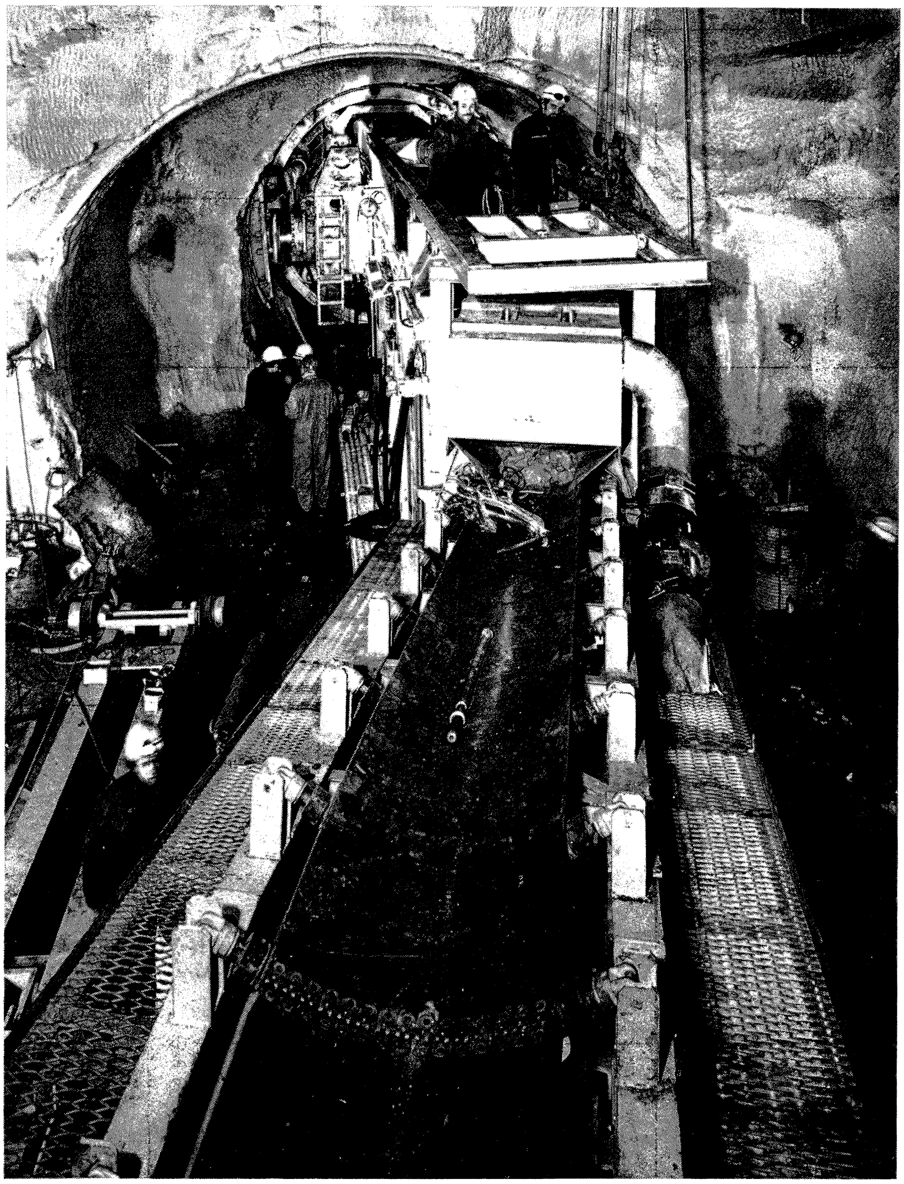
Both rings were completely fitted out with titanium sublimation pumps during the shutdown. This has improved the average pressure and has lifted the critical current for the runaway rise of pressure by several amperes. Glow discharge cleaning of chamber walls has also worked well and two new intersection chambers, at I-6 and I-7, were introduced without problem.

The benefits were immediately apparent. Soon after restarting the machine, the previous peak currents were exceeded — the record in Ring I now stands at 18.7 A (compared to 14.5 A) and in Ring 2 at 17.2 A (compared to 14.0 A). It was also possible to reach design luminosity again under different conditions to those prevailing in December (higher currents and larger beam heights) and physics runs have been possible with a current as high as 12.5 A in Ring I.

Within the first few weeks of operation the ISR, like the PS, was called upon to pull out practically all its tricks for the purposes of the experimental programme. It operated at all four standard energies, and had two runs with a 22 GeV beam in collision with a 11.5 GeV beam, and a run with beams accelerated in the ISR to 31.4 GeV. In general, performance of the storage rings is even more stable than before.

Among the other modifications carried out during the shutdown we will mention only a few: In the transfer tunnels where beam is brought to the ISR there has been a substantial rearrangement of the magnet powering scheme so as to reduce the number of power supplies linked to the beam-line which will later be shared by the SPS. It simplifies the task of changing the magnet fields from pulse to pulse which will be needed when the PS is feeding both the ISR and the SPS. The new arrangement is working well. The main magnet power supplies for the two rings were also modified — new controls brought them under the ISR computer so that only the final adjustment is now done manually. This is particularly useful when accelerating beam in the ISR — the main magnets plus the auxiliary magnets can now track together to increasing fields controlled by the computer.

Finally, further beam observation equipment has been installed. A beam



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The 'mole' is on its 7 km journey boring out the tunnel for the SPS. The head of the machine is just visible where it is cutting into the rock face and the conveyor belt for removing the spoil is clearly seen since it is still in the enlarged section of the tunnel where the whole machine was assembled.

loss detection system, using ionization chambers distributed round both rings, is now available but so far has not been called into action — there is not sufficient beam loss! The system will be useful particularly in machine studies and will be linked to the computer in a few months' time. Sodium gas curtain beam profile detectors (see vol. 11, page 324) are now installed in both rings. There are problems in Ring 2 but the Ring 1 detector is in action and has given some remarkable pictures of beam profiles when the beam consisted of two or three separate stacks for spectrometer calibration.

Magnets and quadrupoles for g-2

Components of the small muon storage ring, which will be used in the third series of measurements at CERN on the 'g-2' of the muon, are now being tested. The experiment, being carried out by a CERN, Daresbury, Mainz collaboration, aims to achieve an accuracy of some parts per million in measuring 'g-2' and hence is one of the most precise ever to be undertaken. This requires great care in the design and testing of all components.

To recall the major features: The 'g-2' (or anomalous magnetic moment) of the muon is brought about by quantum electrodynamic effects. Thus its precise measurement is a refined test of the validity of the theory of quantum electrodynamics. At the same time, examining muon properties to such fine detail is a search for minute differences between the behaviour of the muon and the electron. The measurement will be done by observing the muon in the magnetic field of a storage ring 14 m in diameter. The principle of the experiment is similar to its predecessor (described in vol. 6, page 152) but with the important refinement that the muons will circulate in a nearly uniform magnetic field and will be focused in the vertical direction by electrostatic quadrupoles. The selection of a 'magic' muon energy ensures that its magnetic moment is not sensitive to the electric field. This, together with other improvements in technique, should make it possible to improve the accuracy by a factor of ten.

The magnetic field in the ring will be just below 1.5 T and its azimuthal average value should be constant to a few parts in 10^5 over the region in which the muons move. There will be an optical alignment system, a highly stable power supply, compensation windings controlled by NMR probes in each of the forty magnet blocks and a heat regulation system. But the first step is to bring the magnet blocks themselves to as near uniformity as possible.

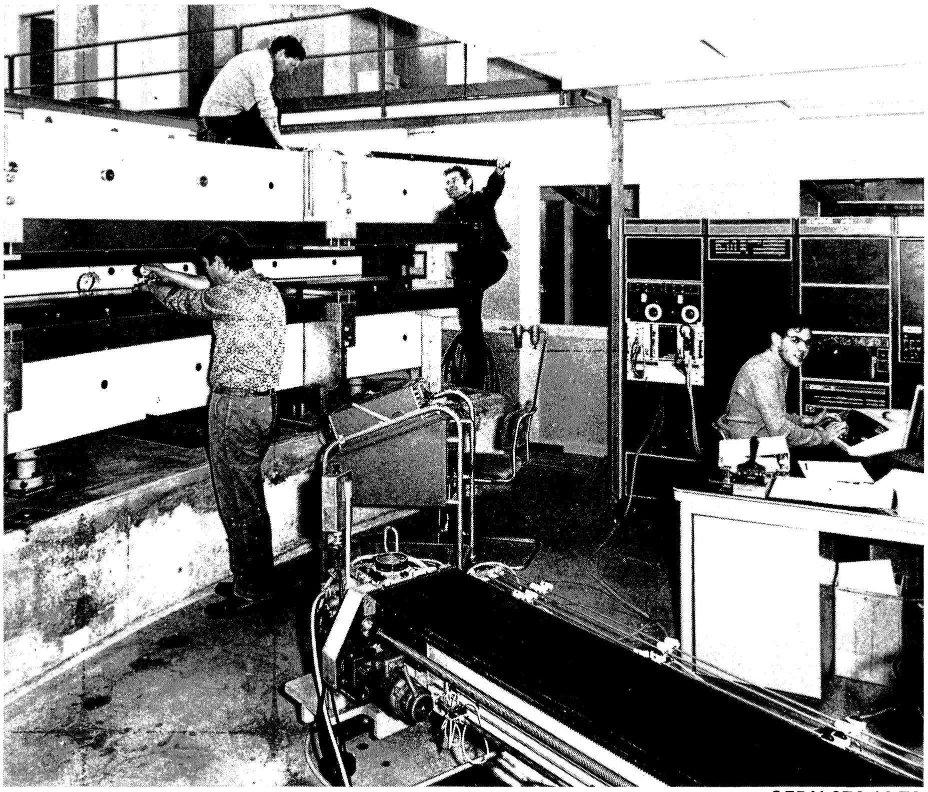
The first four magnet blocks have been delivered to CERN and have been installed in a shimming bank. The magnetic field is measured by a coil probe linked to a computer and the first series of adjustments has been completed. An air gap of about 2.5 mm has been introduced behind the pole at the centre of the magnet, wedges have been added at the ends of the blocks so as to reduce distortion of the field where the poles join together, iron plates have been added to the front and on the top and bottom of the blocks. Working patiently through these adjustments has brought the field to the desired uniformity to better than one part in a thousand.

The stage of measurement which is now beginning on the same blocks is intended to push the uniformity of the average azimuthal field in each block to better than one part in ten thousand. This will involve grinding metal off the pole faces or adding thin metal films to the pole faces. A special device has been developed to do the grinding controlled by the computer in accordance with the field measurements. After this stage the blocks will be released for installation in the ring.

Six more magnet blocks are now scheduled for delivery and blocks will continue to arrive at a rhythm of eight per month until August. Initially it is likely to take about a week to clear a block on the test rig but this pace may quicken with experience. About June the first eight will be installed in the ring. It is after installation that the final shimming to reach a uniformity of one part in a hundred thousand will be done.

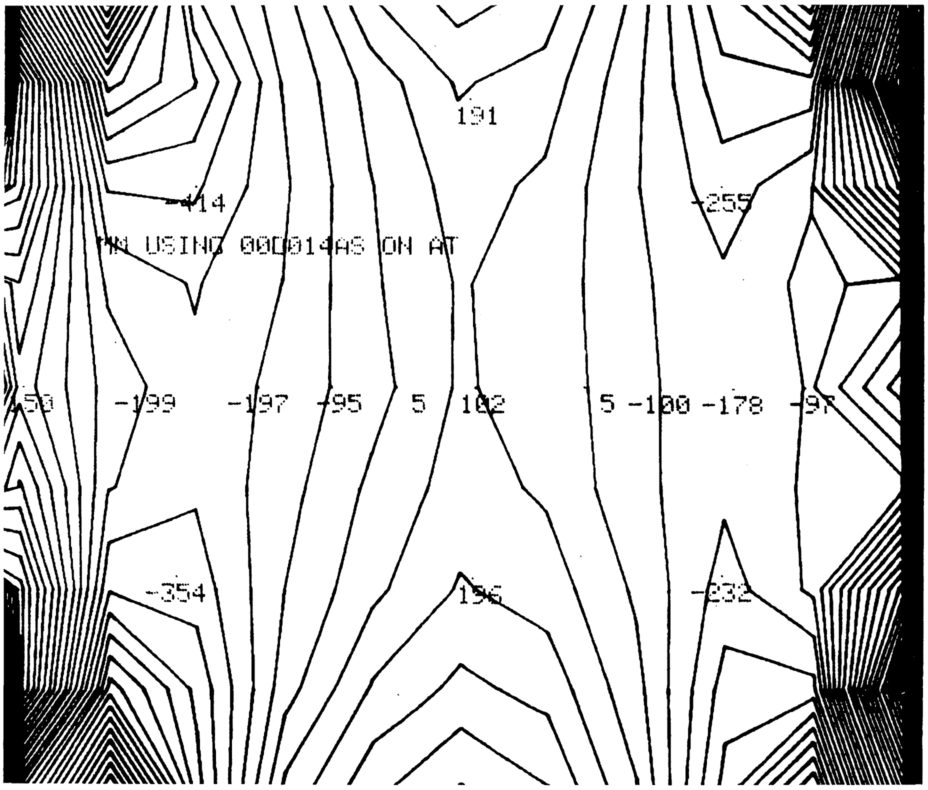
The electrostatic quadrupoles posed a considerable problem. To ensure adequate focusing of the muon beam it will be necessary to have voltages of about 40 kV on the quadrupole electrodes. With the given electrode spacing this, by itself, would not be difficult but the quadrupoles will be installed inside the magnet apertures. Quite modest magnetic fields cause breakdown at these voltage levels. The configuration of the combined electrical and magnetic fields form an excellent bottle for trapping electrons which lead to breakdown.

Research into this problem revealed, however, that it takes a comparatively long time to build up sufficient electron charge to initiate breakdown — fortunately a longer time than is needed to watch the muon. Muons will be fed into the ring at 3.1 GeV (a 'magic' energy at which their magnetic moment is not sensitive to the electric field) and at this energy their average lifetime is 64 μs. Their decays will be observed over about 600 μs. The electrostatic quadrupoles can comfortably be pulsed over 1 ms without breakdown problems. Their power supply has been perfected to give a pulse over 1 ms which is constant to better than 1 %.

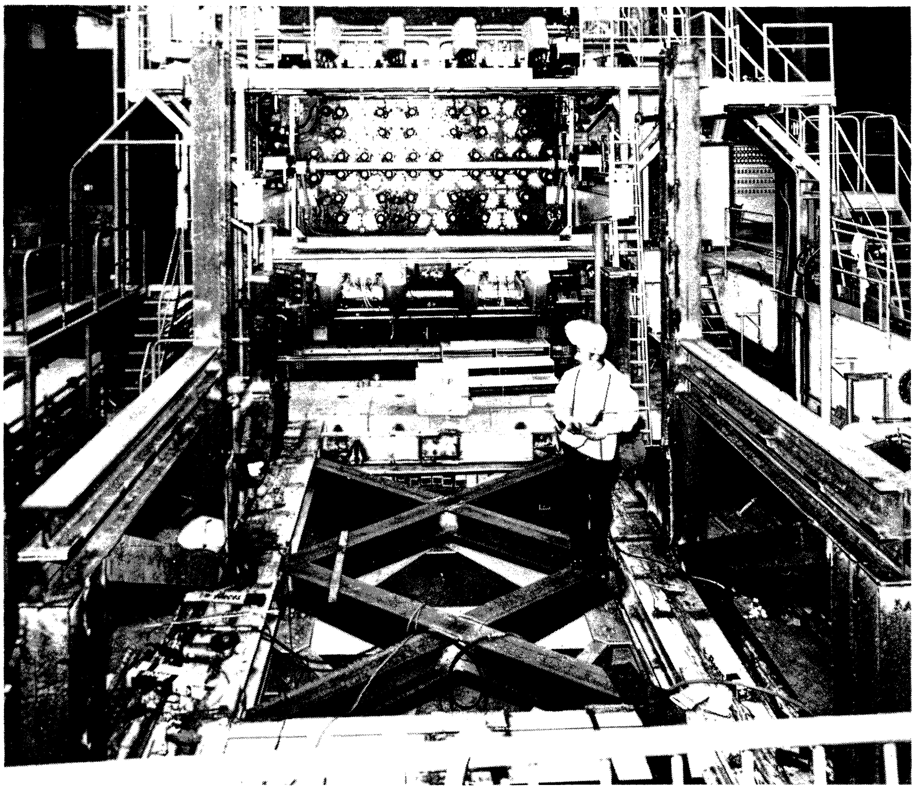


The shimming bank for the storage ring magnets which will be used in the 'g −2' experiment. Four magnet blocks (on the left) have been carefully assembled and a sequence of measurements and adjustments are in progress to bring the fields to a precision which has rarely been achieved on this scale before.

CERN 270.10.72



A radial field plot emerging from the computer linked to the measuring coil in the muon storage ring magnets. The figures printed alongside the field contour lines give the differences, compared with the reference field, in parts per million.



CERN 47.2.73

The heavy-liquid bubble chamber Gargamelle has undergone a series of repairs after factures had appeared in its expansion system. The top half of the photograph shows the magnet with its 44 expansion and recompression tubes (large white circles) and its 44 motors controlling the safety valves (small black and white circles). The chamber itself is inside the magnet. The tanks of the expansion system have now been reinstalled on the trolley in the foreground. A large number of struts have been fitted to the trolley to give it added rigidity.

Perfect quadrupole fields are obtainable in theory only with hyperbolic electrodes of infinite dimensions. In practice, truncating the electrodes can lead to the introduction of octupole field components, etc. which usually need correction. For the muon storage ring, computer calculations using a series of successive approximations has resulted in electrode profiles which give the quadrupole field to sufficient accuracy without introducing other field components at too high a level.

One quadrupole section is complete and is being tested. Seven others will be built in the CERN workshops before the end of the year. It is hoped that the storage ring can be completely assembled early next year.

Gargamelle ready to operate again

The heavy-liquid bubble chamber, Gargamelle, is being prepared for operation again — its first task will be to supply a set of photographs of neutrino interactions in freon. As reported in vol. 12, page 416, this series of experiments was scheduled for December 1972 but had to be postponed for safety reasons.

The vibrations produced during expansion of the chamber led to fractures in some of the pipework of the pressure system.

The expansion system was completely dismantled during the annual PS shutdown (January and February) and thus the necessary repairs did not cut too deeply into the experimental programme planned for Gargamelle. The trolley which carries the recompression tanks (2 × 10 m^3) as well as the expansion tank (20 m^3) and storage tanks (2 × 6.25 m^3) were all rebuilt. The girders were reinforced and the whole structure was strengthened with struts wherever possible. The trolley no longer stands on wheels but on supports set in the floor to prevent the assembly from moving during operation. Another improvement concerns the static and dynamic reactions which are now absorbed by arms resting on the edge of the pit. Also the low-pressure exhaust tanks (2 × 2 m^3) were replaced.

By mid-April the major repairs to Gargamelle were completed, and only a few electrical connections and some minor pipework remained to be finished before the final tests prior to operation could be carried out.

Around the Laboratories

SACLAY
Nuclear physics with Saturne

Following on from our 'nuclear physics' issue in February we have news of the nuclear physics programme which is now an important part of the work at the proton synchrotron, Saturne, at Saclay. The particular interest of nuclear spectroscopy at high energy essentially lies in the availability of high transfer momenta which make it possible to study the nuclear wave functions from a new angle — the reaction mechanisms are simplified so that more precise descriptions are possible than at lower energy.

The major difficulty is to achieve high precision. After the first experiments at Brookhaven in 1967, it was realized that this field of research requires an absolute energy resolution of the order of 100 keV, or a relative momentum precision of 6 × 10^{-5}. Measurements with this accuracy were attained at Saclay during 1972 with the commissioning of a high resolution spectrometer, SPES, at Saturne (recorded in vol. 12, page 134).

To obtain the desired precision and to take account of parasitic effects involved in the study of nuclear reactions (the predicted energy spread of the incident beam was ± 1 MeV and there are kinematic effects corresponding to variations in the energy of the recoil nucleus as a function of the scattering angle), the experimental set up was based on the use of two magnets:

- an 'analysing magnet' (radius of curvature 4 m; bending angle 64°; weight 60 tons) which, together with a set of quadrupoles, makes it possible to vary the spread and the focusing of the beam from Saturne onto the target;

– a 'spectrometer magnet' (radius of curvature 3.3 m; bending angle 97°; weight 90 tons, rotatable about the target on an air cushion system) which analyses the particles scattered by the target focusing them on its focal plane.

The analyser-spectrometer assembly is achromatic and variations in energy in the incident beam, do not appear on the focal plane of the spectrometer after particles have passed through the whole assembly. On the other hand, the energy variations coming from reactions in the target are analysed by the spectrometer magnet alone, and can be distinguished on its focal plane. The uncertainties inherent in the initial beam are thus eliminated. In addition the effects caused by the kinematics of the reactions can be compensated by changing the focusing conditions for the scattered particles (shifting the focal plane) and for the incident particles (focusing the beam upstream of the target).

Attempts were made to obtain precise optical properties for the magnets in the simplest, and therefore least troublesome, way. The precision of a magnet does not depend critically on the value of the magnetic field at all points in its aperture but on the integral of the field along the trajectories passing through it. Using constant-field magnets of the 'window-frame' type, which are easy to construct, the magnets could be corrected for good optical quality simply by sticking thin shims on to the yokes. Although it is very simple and accurate, this method has not yet found wide favour.

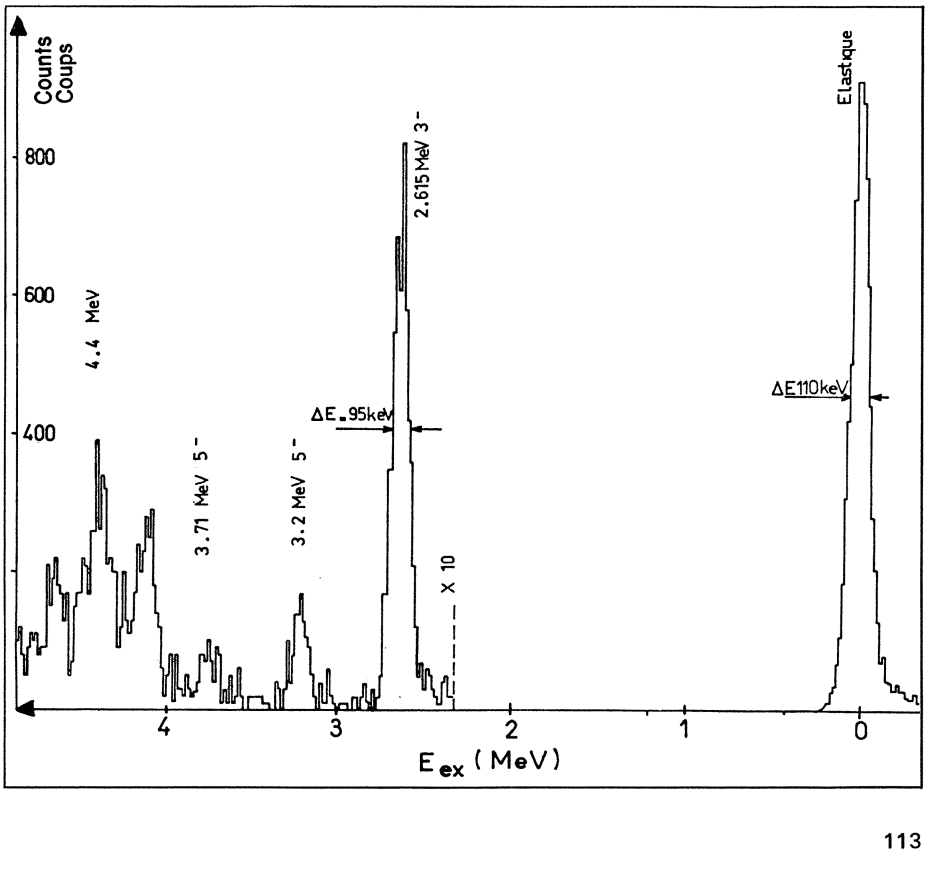
A detection system is used behind the spectrometer to measure the spectrum of the scattered particles and to reconstitute the angular distribution of the particles within the angular acceptance of the spectrometer. The local resolution of this system has to be better than 0.9 mm since the spread of the spectrometer for 1 GeV protons is 0.9 mm per 100 keV. An array of drift chambers (we shall be describing the abilities of this type of detector in a forthcoming issue) measures particle positions. The local resolution is better than 0.8 mm over a 25 cm track and better than 1.3 mm over a 25 to 50 cm track. The dead time of the chambers, during which they recover from one measurement and are made ready for another, is 5 μs. Parasitic counting can be eliminated by using several drift chambers in coincidence (the coincidence time is 40 ns for neighbouring chambers).

The spectrometer system was perfected and the elastic and inelastic scattering of 1.04 GeV particles by carbon, nickel and lead targets were studied during the ten weeks allocated to SPES in 1972. During the current year these studies are being extended to other nuclei and other nuclear reactions.

Quasi-elastic scattering

Another experiment is studying the clusters of particles which can be ejected from a nucleus which is in collision with a proton. In particular, this concerns deuteron (proton plus neutron) and alpha (two protons plus two neutrons) ejection and it is important to separate such clusters from the more common ejection of a single proton.

The experiment uses two magnetic spectrometers fitted with multiwire proportional chambers. The spectrometers analyse particle coincidences — both the scattered proton and any particle cluster ejected from the nucleus. Coincidences involving two protons, corresponding to the ejection of a proton alone from the nucleus are eliminated as far as possible from the



The spectrum of energies around 1.04 GeV of protons scattered at 10 degrees from a lead 208 target. The high precision in the spectrum, which makes it possible to separate the differer. excited states of the ^{208}Pb nucleus, was achieved using the spectrometer SPES at the Saturne synchrotron.

recorded counts by having fast E and dE measurements on the 'cluster' using two scintillators. The analysis of the E and dE information, plus a measurement of the time of flight, makes it possible to identify a cluster. The acceptance of the spectrometers (2×10^{-2} steradians) should give high statistics in spite of the small cross-sections of the reactions involving the ejection of particle clusters.

The first measurements have been obtained with a beam of 5×10^{9} protons per pulse at an energy of 600 MeV onto a lithium target. The reactions involving the ejection of a deuteron and of an alpha are clearly separated from those ejecting a proton. Much more data will be gathered and this will be helped by putting the multiwire proportional chambers (5000 wires) on-line to a computer.

Nuclear physics for astrophysics

Finally, measurements of the cross-sections and energy spectra of gammas produced in the proton-nucleus interaction are being made at energies between 500 MeV and 1 GeV in view of the new interest in gamma spectroscopy by astrophysicists.

An energy resolution of the order of 150 keV can be obtained with a spectrometer using sodium iodite detectors. This assembly has already operated in a previous experiment and the first tests on a parasitic beam for its new duties are satisfactory. During 1973 it may be possible to study the gamma production of all the main nuclei present in the galactic system.

This experiment is being carried out by a collaboration involving Clermont-Ferrand, Heidelberg and Saclay.

Saturne accelerates alphas

At the end of January alpha particles were accelerated by Saturne for the first time. Saturne already has deuterons, in addition to protons, to its credit and there is interest in a research programme with these ions.

High energy alphas are achieved in several stages: Singly ionized helium atoms are drawn from the ion source and are taken to 800 keV in the pre-injector. They are then stripped to alpha particles (doubly ionized helium atoms) by passing them through a thin carbon foil. After that they are accelerated through the linac and injected into the synchrotron. An intensity of 7×10^{10} alphas was achieved and the peak energy which can be reached is 4.6 GeV. The accelerator was however operated at 650 MeV for an experiment on radiodosimetry.

Other experiments to use the alpha beam are now possible in particle physics, astrophysics and radiobiology.

STANFORD
Rapid cycling chamber begins physics

The 15 inch rapid cycling bubble chamber at Stanford is being used in a physics experiment for the first time. The experiment, being carried out by a Purdue, Indiana, SLAC, Vanderbilt collaboration, began in March. It is a search for 'exotic' mesons with double charge which are not 'allowed' by the quark model. The quark model maintains that mesons are built up of quark and antiquark pairs. Thus, since a quark is supposed to carry a charge of 1/3 or 2/3 the electron charge, no doubly charged mesons can be built up from quarks. None has been seen to date and the Stanford experiment will be a thorough search for their existence.

The use of the rapid cycling chamber is a crucial part of the experiment. The observation of such mesons will obviously be extremely rare and a detection technique which selects only likely events will obviously save considerable time in analyzing the data. The chamber is used in a hybrid system together with spark chambers.

A beam of about ten positive pions per pulse is fired into the chamber. Interactions with the protons in the hydrogen which produce a neutron are recorded. If exotic mesons exist they could appear in the interaction as follows —

$$\pi^{+} + p \rightarrow n + X^{++}$$

The neutron, emerging in the downstream direction, is converted to charged particles which fire an optical spark chamber. Only bubble chamber events which correspond to the neutron trigger need to be examined.

It is expected that the hybrid system will be triggered once every 2000 pions, i.e. once every 200 pulses. The collaboration is hoping to collect 100 000 pictures to study. Thus normal bubble chamber operation, without the possibility to trigger the rapid cycling chamber, would require collecting and analyzing 20 million pictures rather than 100 000.

The rapid cycling chamber has the form of a vertical cylinder 37.5 cm in diameter and 14 cm high. The camera system is located below the glass window base of the chamber and three lenses bring stereo views onto a single 35 mm film. The expansion system operates from the top of the chamber and has an electromagnet drive rather similar to the coil of a loudspeaker but much more powerful.A second magnet has been built into the chamber's 'vacuum can' to give some track curvature. It is a superconducting magnet producing a 1.8 T field in the chamber volume.

The natural resonant frequency of the expansion system is 120 Hz but, to allow sufficient time for recondensation of the bubbles from the tracks of

Schematic diagram of the 15 inch rapid cycling bubble chamber which is now being used in a search for exotic mesons at the Stanford electron linear accelerator. The chamber, magnet and expansion system are all crowded into a small volume. The peak operating frequency of the chamber is 60 Hz.

The chamber body itself receiving the final touches before installation. It was successfully tested for 2 million pulses at a rate of 20 Hz before data taking started.

the previous pulse, the maximum cycling rate is 60 Hz. During January it was tested in the experimental set up at 20 Hz and operated well for 2 million pulses. During data taking it is hoped to step up to 30 Hz.

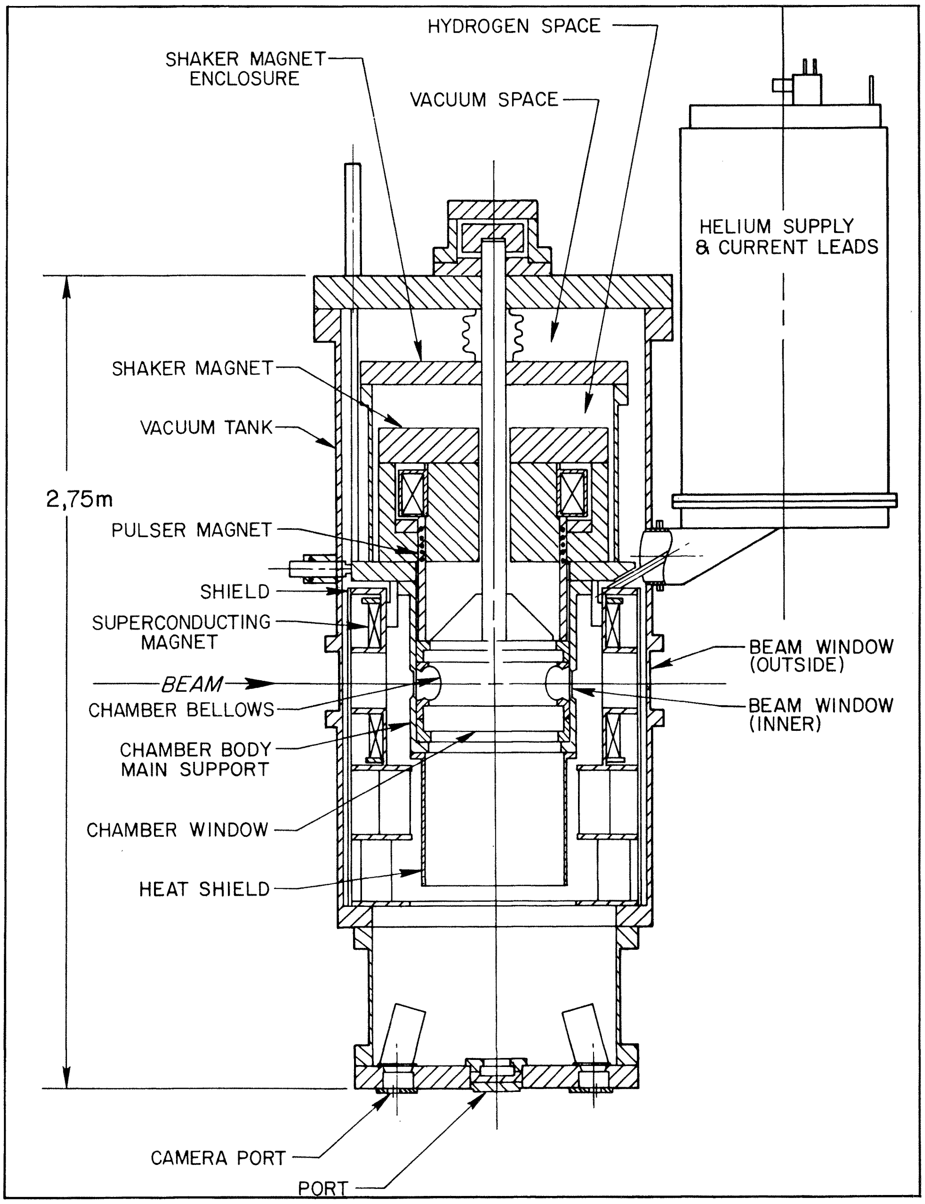
DARESBURY
K°p charge exchange

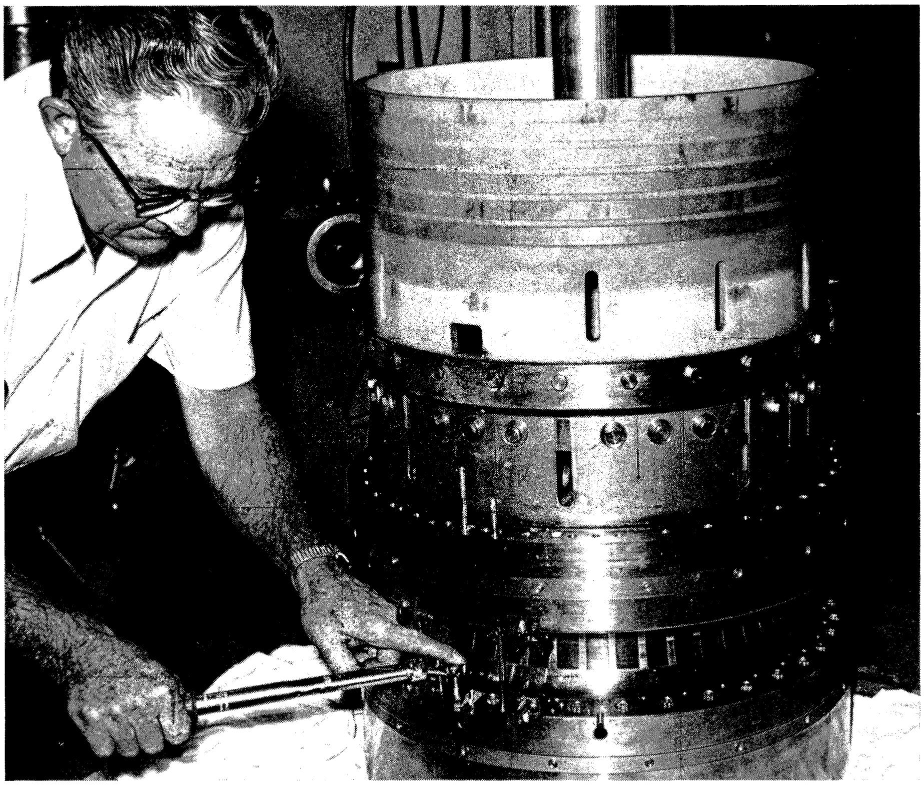
An experiment which will treble the world's data on the charge exchange reaction

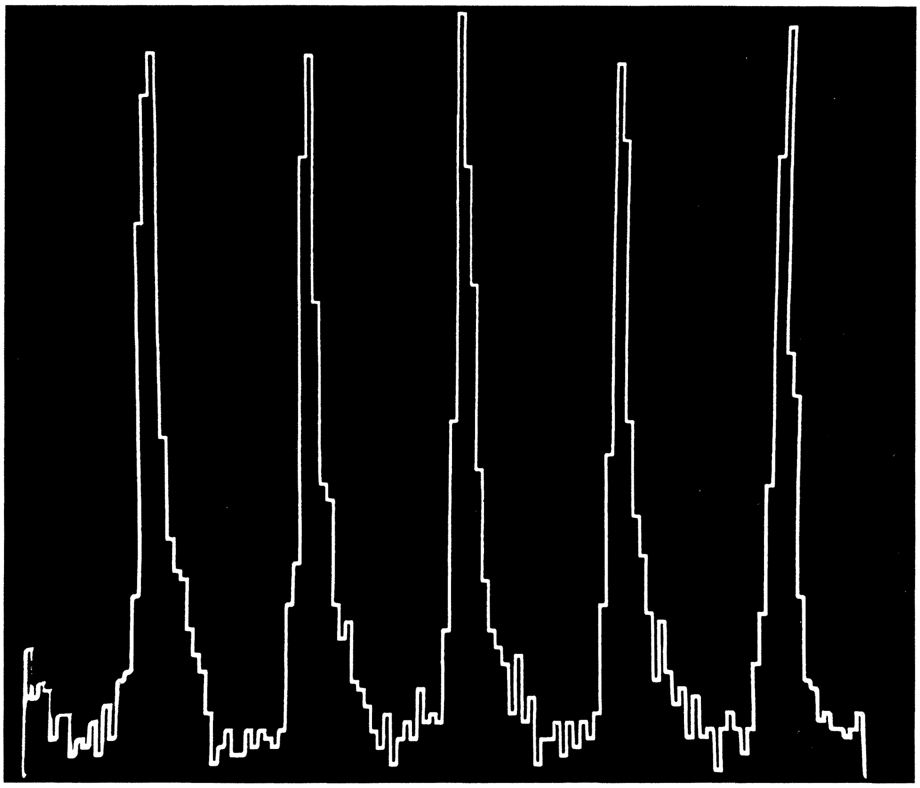
$$K^0_L + p \rightarrow K^+ + n$$

has completed half of its data taking at the 5 GeV electron synchrotron at the Daresbury Laboratory. The experiment is being performed by a Manchester/Daresbury group using a time resolved K^0_L beam of low neutron background, which spans the momentum region 0.5 to 1.5 GeV/c. Their results will provide valuable information about the kaon-nucleon interaction and throw light on the vexed question of the existence of baryon resonances of positive strangeness (Z*). Since Z*s cannot be easily fitted into the SU_3 scheme of particles, proof of their existence would have considerable repercussions. Currently, the group is re-arranging apparatus so as to optimize detection of positive kaons going backwards in the centre of mass system when neutron background will create less of a problem.

Knowledge of kaon-nucleon scattering is as necessary to our understanding of the strong interaction as knowledge of pion-nucleon scattering but kaon-nucleon studies have a long way to catch up. For example, the existence of positive strangeness baryon resonances has been conjectured for several years but is still in doubt. This is due to at least two things —







Distribution of arrival times of charged particles at counters, relative to the phase of a signal from a resonant cavity in the Daresbury 5 GeV electron synchrotron. The timing system is being used in a study of the charge exchange reaction $K^o_L + p \rightarrow K^+ + n$. The Figure shows the resolution of the detection system with several peaks at 5 ns intervals corresponding to bunch separation in the synchrotron. The full width at half height of the peaks is 600 ps.

the lower intensity of kaon beams compared with pion beams and the difficulty of separating isospin states in positive strangeness kaon-nucleon scattering. K^+p scattering presents information on the positive strangeness isotopic spin 1 state. In order to get the corresponding isospin 0 state it is necessary to study either K^+n or K^op scattering. K^+n involves the use of deuterium which introduces further difficulties. K^op also presents difficulties because of the neutron background in the K^o beam and lack of knowledge of the K^o momentum. The Daresbury experiment has a beam with a low neutron background, the momentum spectrum spans the region where structure is expected and, thanks to the efforts of the accelerator team, the beam is time resolved which allows the incident kaon velocity to be measured.

The group use wire spark chambers on either side of a wide aperture magnet to measure the direction and momentum of the K^+ produced in the charge exchange reaction. The neutron direction and time of flight are measured using an array of neutron counters. The velocity of the incident K^o is found from the recorded time of arrival of the kaon relative to a pulse generated by the accelerator r.f.

These measurements ensure that each event is 'over-determined' but the group found that more was required to distinguish the reaction of interest from elastic neutron-proton scattering. Also the cross-section for this background reaction is many times greater than for charge exchange. This difficulty was overcome by measuring the K^+ time of flight through the magnet and the pulse height it produced in a thick scintillation counter which picked out the kaon as opposed to a proton.

The r.f. structure of the beam in the synchrotron is used to time the flight of the neutral kaon. Normally the r.f. structure is a 1 ns bunch of electrons every 2.5 ns. However, modulation of the injector electron gun at 204 MHz alters this to a bunch every 5 ns. The timing method depends upon an oscillator (again 204 MHz) phase locked to the bunches; phase locking is done in two independent ways. The first method uses a signal from an idler cavity in the synchrotron to phase lock the oscillator to the circulating bunches. However, this signal dies away during extraction.

The second method uses a signal from the Cherenkov light of relativistic electrons in the bremsstrahlung beam that produces the neutral kaon beam. Conveniently, the bremsstrahlung beam has a 0.1 % contamination due to pair production in the air. Changes in phase between the oscillator (phase locked to the idler cavity) and the Cherenkov signal are measured. This is very sensitive — a change in phase equivalent to 50 ps is easily seen — and when the two signals agree to this accuracy both are almost certainly correct because they are obtained in such different ways.

Time of flight information on the neutral kaon is obtained in the following way; the positive kaon generates a start pulse for a time to digital converter. The output from the oscillator, which is in phase with the circulating bunches, is converted to a pulse train and the next pulse after the start pulse is used to stop the time to digital converter. As the bunch which produced the K^o is not identified, the measured time interval yields a series of possible K^o times of flight at 5 ns intervals. The actual time of flight can be any one of this series and the kinematics of the event is then invoked to select the correct time. (A bunch separation of 5 ns, instead of the usual 2.5 ns, is used because the kinematics is not sufficiently accurate to distinguish between bunches 2.5 ns apart.) The momentum of the incident neutral is determined to about 50 MeV/c (at 1 GeV/c) which has proved invaluable to tie down the kinematics properly and thus to reduce the background of unwanted neutron induced events.

Summer School

The Canadian Institute of Particle Physics Summer School will be held from 27 August to 1 September at McGill University, Montreal. Further information may be obtained from Miss C. Bridgman, Department of Physics, McGill University, P.O. Box 6070, Montreal 101, Quebec, Canada.

The Proceedings of the 1972 School, edited by R. Henzi and B. Margolis are now available at a cost of $ 10 Canadian from the same address.

Superconducting Synchrotrons

A Seminar was held at Saclay in February to assemble information on the progress towards the possible construction of a superconducting synchrotron. It was attended by members of the GESSS Collaboration (Group for European Superconducting Synchrotron Studies), which involves Karlsruhe, Rutherford and Saclay, and by representatives of CERN Laboratory II since the GESSS work has concentrated on detailing feasible conversions of the SPS now being built at Lab. II. This review is based on a report by J. Hamelin and J.P Pouillange which itself was inspired by the lively summary given at the end of the seminar by G.K. Green.

The possibility of taking the SPS to still higher energies by using the higher fields of superconducting magnets was emphasized in 1970 when the new version of the SPS was presented (see vol. 10, page 111). At the seminar, the ways in which this could be done were considered under two headings, each with two variants. The first would be to replace the conventional magnets. The two variants are — to slot superconducting magnets into spaces left for this purpose in the so-called 'missing magnet' lattice around the circumference of the 'conventional' machine (where magnets for only 200 GeV had been installed) or to replace a full ring of conventional magnets (where magnets for 400 GeV had been installed).

The attractions of the 'replacement' way to a superconducting synchrotron are that maximum use could be made of facilities already being built up for the SPS — the tunnel, injection system, r.f. accelerating cavities... In fact the studies have shown that some of these seeming attractions could be hindrances. Injection at 10 GeV requires a fairly large magnet aperture (around 5 cm) which requires more superconductor, sends the stored energy way up (around 700 MJ) with attendant power supply problems and would probably mean machine cycle times of longer than one pulse per 20 s. Also residual fields at the low injection energy might be beyond the acceptable field tolerances — the field quality has to be at least as good as in the conventional SPS. Beam loss in the region of the superconductor can send the conductor 'normal' and halt machine operation. This, rather than the usual radiation problems, implies exceptionally good beam control.

The other way to a superconducting synchrotron is to build a separate ring of magnets leaving the conventional ring intact. The two variants are — to build the superconducting ring in the same tunnel as the conventional ring or to build the superconducting ring in a completely new tunnel.

The attractions of the 'separate' way are that the conventional machine, at say 200 GeV, could be used as an injector. This brings the necessary magnet aperture down to around 40 cm and the stored energy to below 500 MJ. The total cycle time could then be around 15 s. Using the same tunnel would be an obvious cost saving but makes transfer of the beam from one ring to another at high energy very difficult. It could involve problems in bringing in the necessary services (cooling, etc.) to the superconducting magnets, and, during construction, would seriously disrupt the physics programme. The 'separate' superconducting ring in a new tunnel looks the optimum solution taking only machine construction and physics programme problems into consideration.

However, before any of these ways and variants can be elaborated much further, it is necessary to have fuller answers to questions on machine components such as the superconducting magnets, the cooling and the power supplies...

The studies on magnet designs in the different Laboratories have converged on a number of features. They all propose superconducting magnets which have circular aperture with the superconductor distributed in coils, closely wrapped around the aperture, so as to give the required field configuration. The coils are surrounded tightly by an iron yoke which helps mechanically in the construction of the magnet and contributes to the field (hence reducing the amount of superconductor and the stored energy). Having the yoke in this location requires that it is held at cryogenic temperatures, like the superconductor, and this introduces mechanical problems due to the different contractions of the yoke and the coils as the temperature goes down.

There are two phenomena encountered in superconducting magnets which are not met in conventional magnets and which are very important in machine design. One is the ultimate performance of the magnet by comparison with what can be anticipated from the 'short sample' behaviour of the superconductor. The other is 'training' where the performance in a superconducting magnet rises progressively to a final value during a series of quenches. Prototype magnets have now been built which show little sign of training and approach 'short sample' performance very closely. Nevertheless, the safety margin to allow for these phenomena in a superconducting machine is not clear and has a considerable influence on magnet cost and the necessary stored energy.

The provision of suitable superconductor for manufacture of the magnets seems to have been well mastered and the performance of commercially produced conductor is generally in good agreement with the theoretical predictions.

Conductor is built up of niobium-titanium superconducting filaments, with diameters typically around 7 μm, embedded in a copper matrix. The filaments are twisted to reduce losses in the conductor and an additional requirement, when many filaments are used, is to include a copper bronze resistive barrier between the filaments.

For a synchrotron magnet the coil will need to carry something like 3 kA. This can be realized by incorporating composite conductor, as described above, in transposed cable or braid compacted into rectangular shape. Strands of conductor need to be insulated from one another in the magnet coil. The normal organic varnishes have proved unsatisfactory and copper oxide is preferred. For d.c. or slow-pulsing magnets, a soft metal filling of the cable or braid completes the assembly giving good thermal and mechanical stability.

Niobium-titanium remains the best bet for the superconductor at present because of its high ductility which enables it to be drawn into filaments with ease. However the critical temperature at which it goes normal in a high magnetic field (say over 4 T) is uncomfortably close to probable helium operating temperatures. A local temperature rise of a few tenths of a degree could destroy the superconducting property. For this reason superconductors such as niobium-tin and vanadium-gallium, which have a much greater safety margin and could operate at much higher fields, remain under investigation. The mechanical problems of producing filamentary conductor from these materials have not been solved and they are unlikely to appear on the commercial scene in the next few years.

The preceding few paragraphs will have underlined the need for a reliable and efficient cryogenic system. However the cryogenic problems in constructing a superconducting synchrotron have not yet been studied in great depth. It is agreed that helium refrigeration plant and helium transfer lines can be built to ensure the necessary cooling to 4 K or below but the optimum design of such a system to ensure efficient operation, and to hold down the cost, has several unresolved questions. These relate to design features such as — number of magnets per cryostat, temperature monitoring and control ... and to machine operation features such as — minimizing the time lost due to a magnet fault which involves warming to room temperature, linking magnets and cryostats so as to simplify replacement...

Some overall features seem to be emerging. For a temperature of 4 K the estimated heat load with a 15 s cycle time in a 1000 GeV ring is around 60 kW. Refrigeration is envisaged as emanating from a central compressor house and passing via six refrigeration units, distributed around the ring, each of 10 kW or more. The compressor power would need to be around 40 MW with a reasonable efficiency factor in the cooling plant.

The 'unit cell' for cryogenic purposes is seen as a string of between five and thirty magnets each cell having separate gas and liquid helium lines. The thirty magnet subdivision is a proposed 'unit cell' also from the point of view of the power supply.

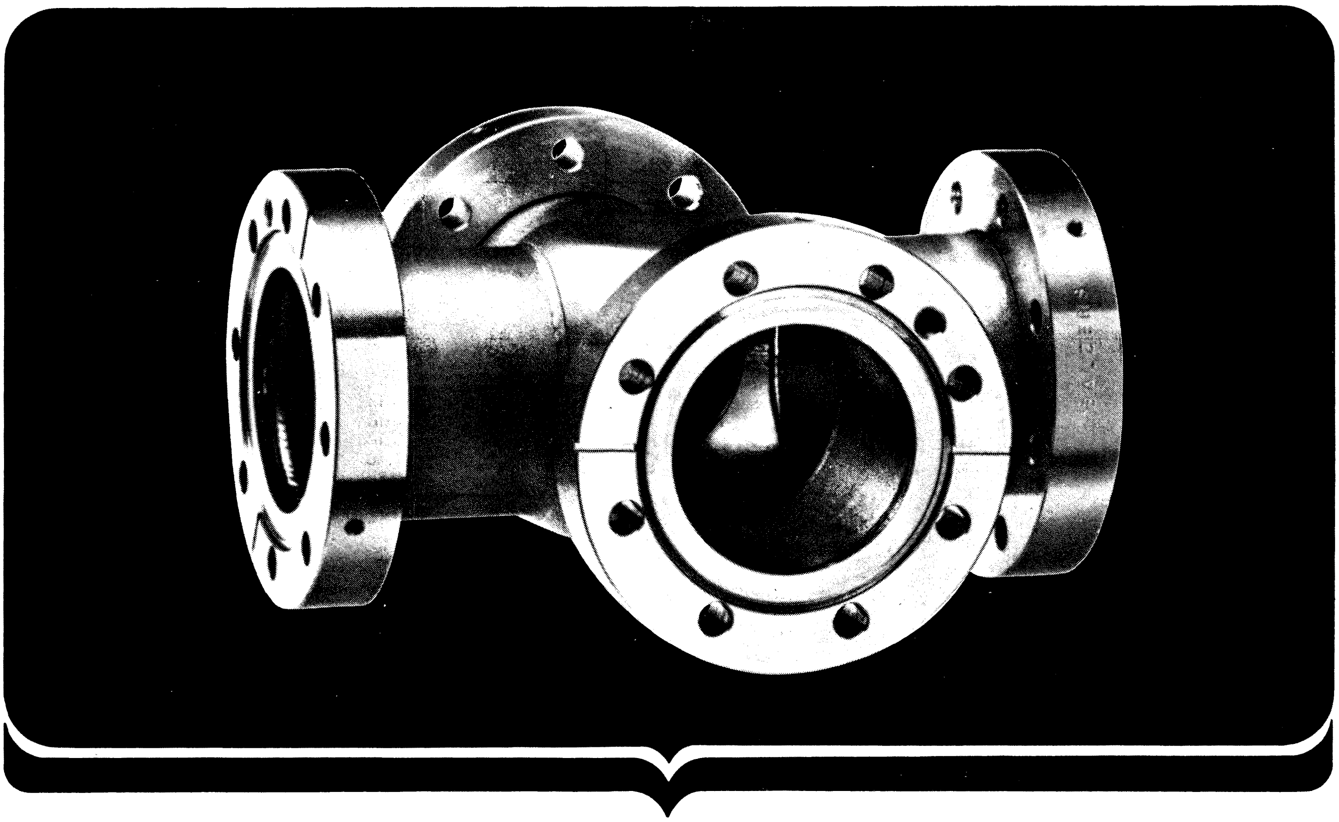
Providing the pulses of power to a superconducting synchrotron is another important feature of machine design and it poses new problems of scale. The stored energy in a synchrotron is related to its magnetic field and going to the high field levels available from superconducting magnets brings in its wake the need for much higher pulsed power. A 1000 GeV accelerator could require 500 MJ in stored energy and a peak power flow of about 150 MW.

The difficulty lies in assuring the flow of power to and from the magnets, in machine cycle times measured in seconds, while not unduly perturbing the electricity supply network. Static compensator systems could conceivably cope with the power requirements and, by 1980, the grid of Electricité de France might be able to withstand the pulsed load. Alternatively motor-generator-flywheel sets, probably in several units, could be used. Studies on superconducting power supplies (see vol. 11, page 199) are also continuing.

The seminar at Saclay indicated that most of the problems associated with the construction of a superconducting synchrotron have been overcome. The first magnet prototypes have performed satisfactorily but it remains to refine the construction techniques and to specify the necessary safety margins with more precision. The stage of magnet testing should soon be succeeded by the building of a scale model magnet/cryogenic/power section.

Appropriate cryogenic and refrigeration systems need much more study but are unlikely to throw up any major obstacle. Provision of the pulsed power is a considerable problem but it is not insurmountable — conventional motor-generator sets may not be an elegant solution but they could already be specified to meet the requirements.

GESSS is now putting the finishing touches to a report on superconducting synchrotron studies. Their conclusions on the state of progress are being taken into account in finalizing the construction programme for the SPS and the decisions are expected to be announced at the June session of the CERN Council.



Minimum outgassing of ultra high vacuum components...

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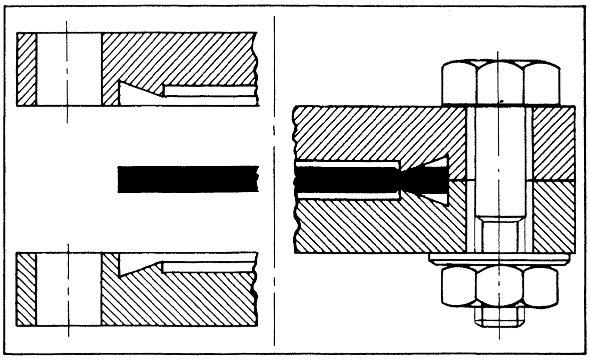

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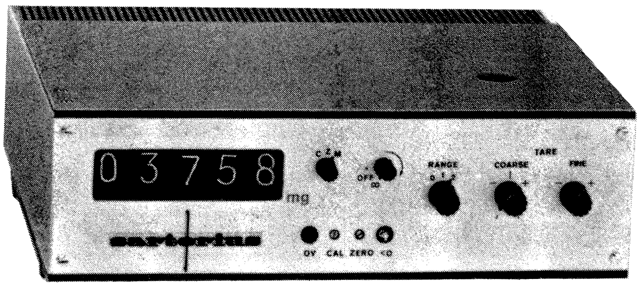

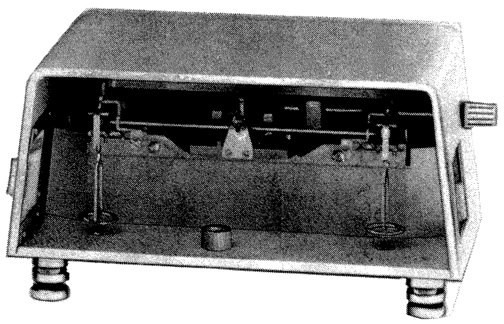

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Our 9" HIFLEX cable was developed for the constantly increasing power outputs of the transmitters.

Like all HIFLEX cables it features low attenuation and standing wave ratio, high dielectric strength, transverse stability and tensile strength.

Even with 260 mm cross section the corrugated aluminium outer conductor and the corrugated copper inner conductor guarantee high flexibility.

The illustrated cable was installed in the 500 kW German Bundespost short-wave transmitter station in Wertachtal.

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Il y a maintenant une alternative au Time-Sharing qui se rentabilise en quelques mois. Laquelle? Pour le savoir, remplissez l'encart ci-dessous.

En investissant, une fois pour toutes, quelque fr. 30000.–, vous disposez de votre propre Modèle 30, calculateur autonome et puissant, qui remplace avantageusement un terminal de timesharing.

Le clavier, de type machine à écrire, est totalement conversationnel; il permet d'accéder directement à la mémoire utilisateur interne, d'une capacité maximale de 8K octets, programmable en BASIC, et qui, par adjonction d'une série de blocs de fonction enfichables, peut atteindre 16K octets. Le calculateur peut en accepter simultanément 8; appelés par clavier, ils permettent de résoudre, par l'action d'une seule instruction, de nombreux problèmes particulièrement complexes, inversion de matrices et chaînes de caractères.

Le Modèle 30 permet également d'afficher jusqu'à 32 caractères alpha-numériques, comprend une imprimante par page imprimant 80 caractères par ligne à la vitesse de 250 lignes par minute, une mémoire incorporée à cassette avec recherche bidirectionnelle ultra-rapide sous système d'interruption et un lecteur de cartes automatique; enfin, il est connectable à tous les périphériques communs à la gamme des calculateurs Hewlett-Packard de la série 9800.

● **Langage BASIC.** Le langage BASIC, langage universel, simplifie la programmation. Il existe une vaste série de bibliothèques de programmes écrits en BASIC, testés par les utilisateurs, allant des applications scientifiques, de génie civil et de statistiques, aux travaux commerciaux courants, tels que l'établissement des feuilles de paie, la facturation ou la gestion des stocks.

Ces caractéristiques, auxquelles viennent s'ajouter la puissance du calculateur et ses possibilités de mise au point des programmes permettent au Modèle 30 de résoudre rapidement des problèmes extrêmement complexes. Il peut donc effectuer immédiatement la plupart des tâches qui, sans lui, attendraient leur tour être traitées par l'ordinateur central. Comme tous les autres produits Hewlett-Packard, le Modèle 30 bénéficie d'un réseau de 172 points de vente dans 65 pays, qui assurent le service après-vente.

Pour recevoir une documentation complète sur ce nouveau venu dans la grande famille des calculateurs Hewlett-Packard, remplissez le coupon-réponse ci-dessous.

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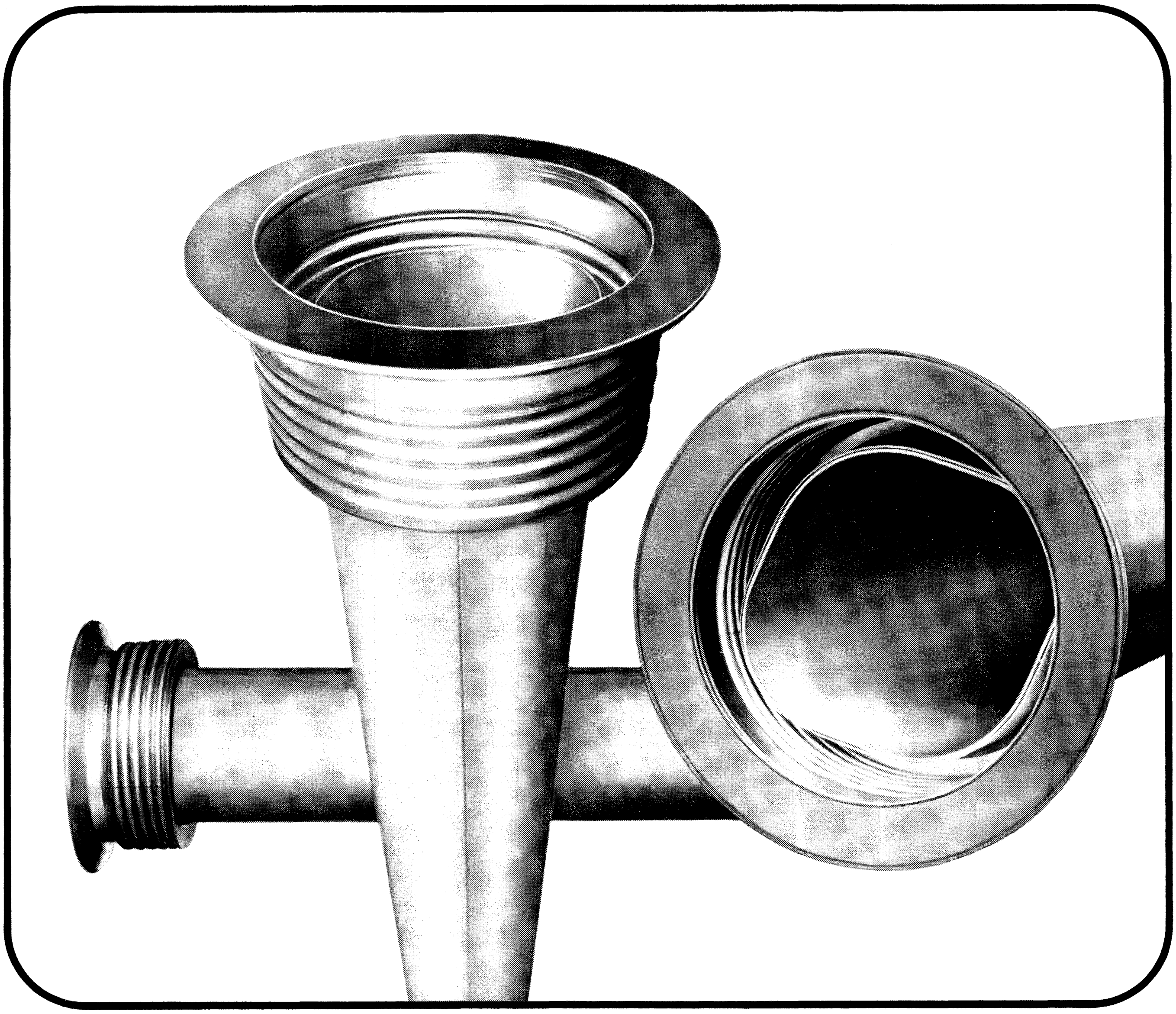

chambre pour synchrotron à protons injecteur
chamber for synchrotron booster

Calorstat

soufflets métalliques types: Hydroformés - A diaphragmes soudés - En tous métaux usuels et métaux spéciaux (TITANES - INCONELS - HASTELLOYS - etc.). - Electro-déposés miniatures en Nickel pur soudable.

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Frightened away by the high cost of starting a CAMAC system?

Used to be, the most basic CAMAC system required an investment of $10,000 to $12,000. This amount would cover the crate, power supply, terminator module, cable, Type A-1 crate controller, and branch driver. The last item alone accounted for the lion's share of the cost.

While the branch driver is unquestionably the most practical and versatile computer interface for large and complex CAMAC systems, we have blazed trails to develop a less costly alternative that would satisfy the needs of 70-80% of all CAMAC users.

Frankly, the result exceeded our expectations.

You can see it in the extreme right-hand station of the CAMAC crate in the photo. This module, called the DC-011, is dedicated to performing the dual role of controller and computer interface. You can use several of them in multi-crate systems. The DC-011 has a number of functional advantages—fast data transfer, flexible interrupt structure, software options for point address incrementing, etc.—but none are as likely to impress you as its low price.

Thanks to this breakthrough, we can now supply a complete basic CAMAC system like the one shown here—powered crate, cable, and DC-011 (everything you need except the PDP-11 computer)—for less than half of what you'd pay for a comparable system using a branch driver and Type A-1 crate controller.

For full details, contact your nearby Ortec representative or EG&G/Ortec High Energy Physics Products, 500 Midland Road, Oak Ridge, Tenn. 37830. Phone (615) 482-4411. In Europe: Ortec Ltd., Dallow Road, Luton, Bedfordshire. Phone LUton 27557. Ortec GmbH, 8 München 13, Frankfurter Ring 81, West Germany. Phone (0811) 359-1001.

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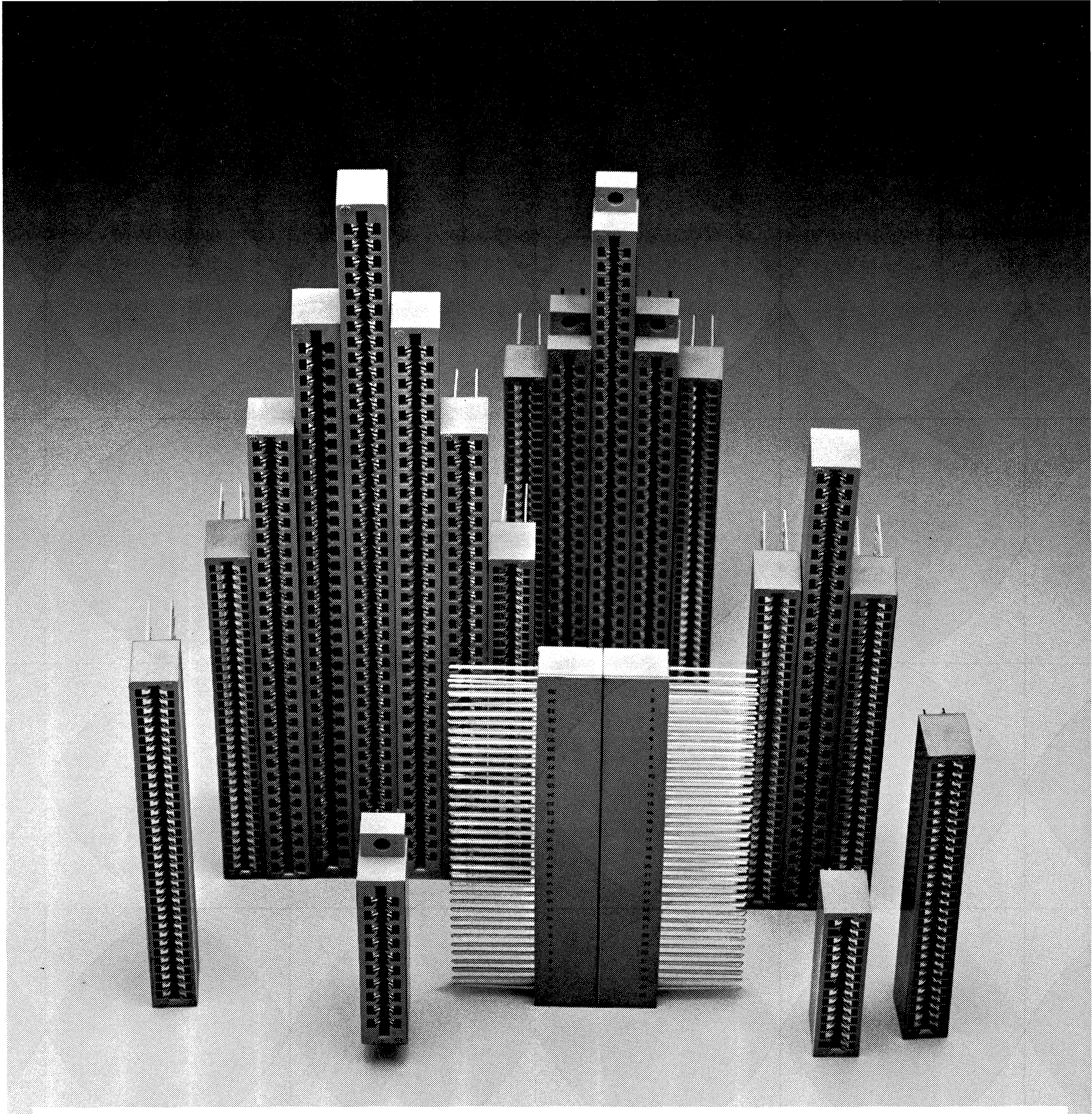
HIGH ENERGY PHYSICS

Our basic CAMAC system: crate, power supply, DC-011, unibus extension cable.

5540 B



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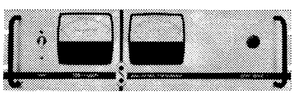

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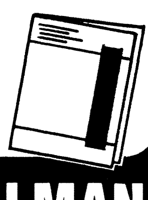

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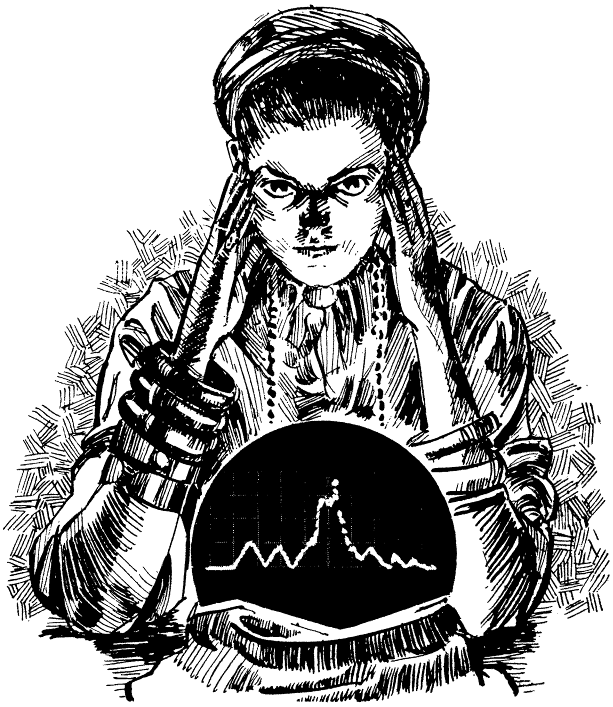

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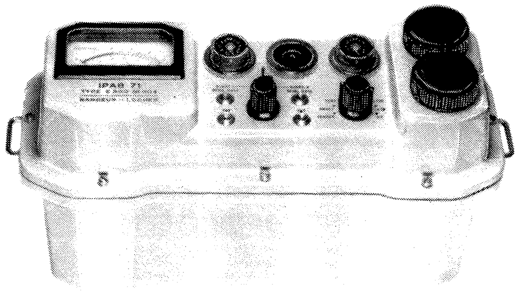

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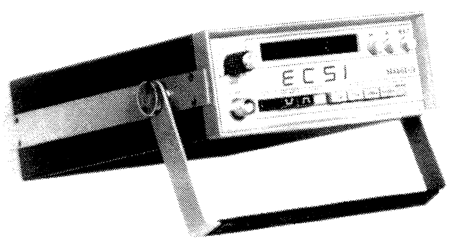
- Précision : meilleure que 5%
- Limites de température : - 10° C + 50° C
- Seuil du discriminateur : 1 volt
- Capacités équivalentes : GM - PM : 0,6 pF
  CPA - BF3 - diodes 0,04 pF

COMPTAGE



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- Prétemps : 1 - 10 - 100 - 1000 s (précision 10^{-3})
- Temps de résolution : < 5 µs (fréquence 200 KHz)
- Impulsions à l'entrée : polarité positive ou négative durée ≫ 100 ns
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- Température de fonctionnement : - 10° C + 50° C

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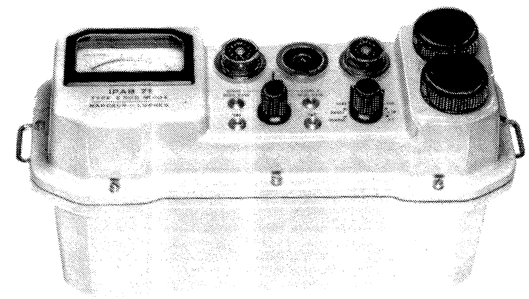
Usine : 37600 Loches - FRANCE

RADIO PROTECTION



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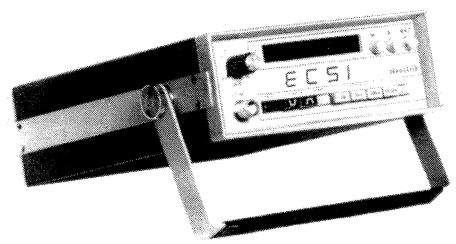
- Discriminator threshold : 1 volt
- Equivalent capacities : GM - PM - 0.6 pF
  CPA - BF3 - semi conductor detectors 0.04 pF

COUNTING



ELECTRONIC COUNTING SCALE

E. C. S. 1 Réf. E.521

Portable, self-powered, six decades

ELECTRICAL CHARACTERISTICS

- Pretime : 1 - 10 - 100 - 1000 s (accuracy 10^{-3})
- Resolution time : < 5 µs frequency > 200 KHz)
- Input pulses : positive or negative, duration ≫ 100 ns
- Threshold adjustement : 0.1 à 10 V
- Input impedance : 1000 Ω
- Working temperature range : - 10° C to + 50° C

NARDEUX

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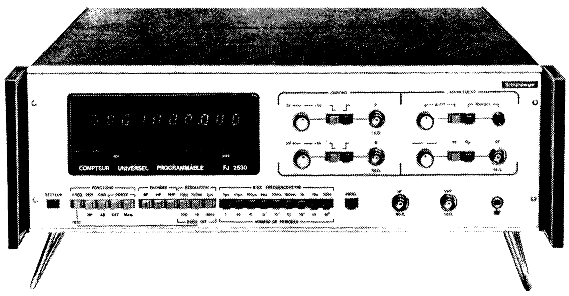
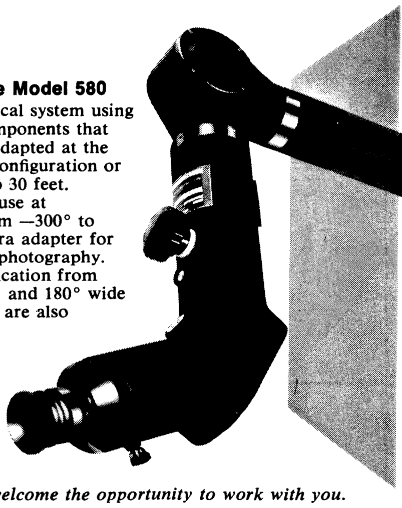
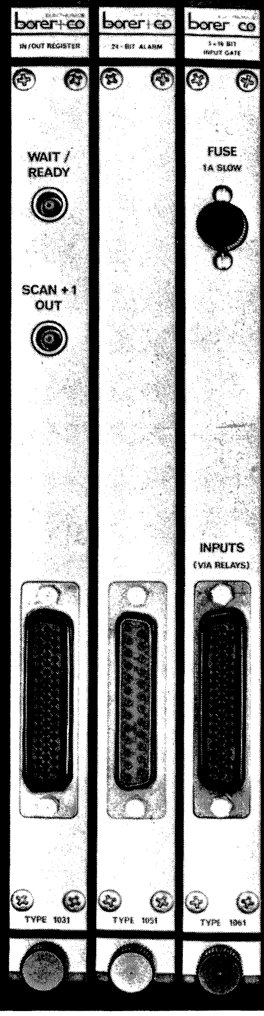
Usine : 37600 Loches - FRANCE





Camac inputs made easy



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