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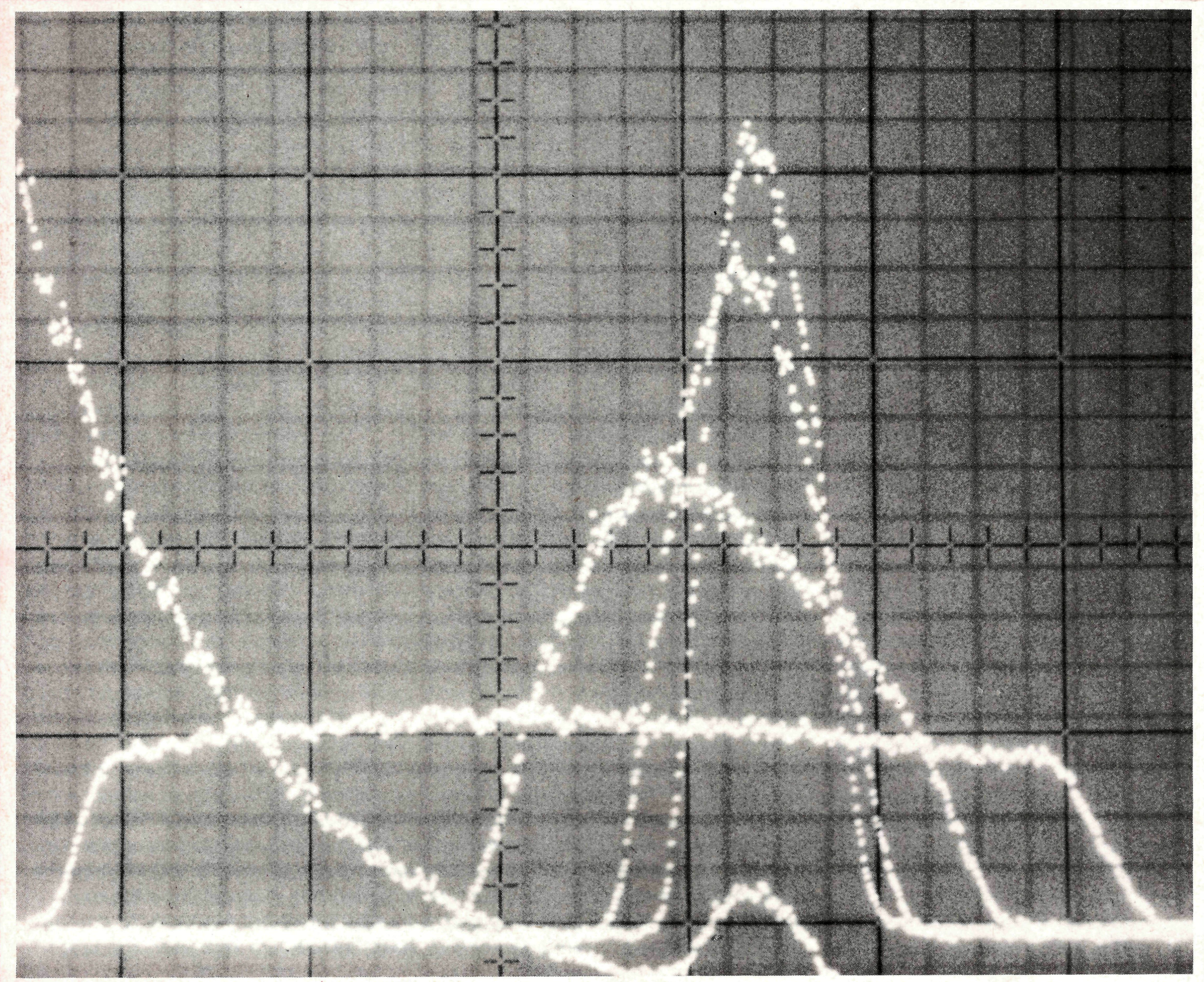

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Cover photograph: Shape of things to come. Experiments in the ICE ring at CERN have achieved the 'cooling' of a beam of about 10^7 protons, concentrating the protons around a particular momentum value by a factor of nine in three minutes. The picture shows how the lower trace, which has a broad flat plateau corresponding to a wide momentum spread, shrinks progressively to a narrow peak as stochastic cooling is applied. These results are crucial to the proton-antiproton colliding beam schemes which are the subject of the main article.

Proton-Antiproton Workshop

On 27-31 March a 'Workshop on Producing High Luminosity Proton-Antiproton Storage Rings' was held at the Lawrence Berkeley Laboratory sponsored by Fermilab and Berkeley. It reflected the great interest in proton-antiproton collisions which has welled up in the wake of the successful implementation of beam cooling schemes. The schemes could give good quality high intensity antiproton beams for the first time.

The Workshop was unusually stimulating with many participants commenting on the excitement of being involved in the development of something very new. It also attracted some eminent scientists who do not often grace accelerator meetings with their presence. Richard Feynman was there with the message 'When we have these high energies, the blurred quark-gluon picture of the hadron that we get from our present energies will become a lot simpler.' Emilio Segrè said 'We don't even need a theorist to tell us that when we increase the centre of mass energy by a factor of thirty (60 GeV at the ISR to 2000 GeV in the Fermilab Energy Doubler) we are going to see something new.'

Both CERN and Fermilab are working on cooling techniques so as to have antiproton beams in their multi-hundred GeV rings. This will make it possible to reach a new range of hadron collision energies without necessarily constructing an additional ring since both types of particle can be accelerated simultaneously in opposite directions in the same ring. The strong accelerator community at Berkeley are also interested in the ideas and are likely to be participating in the studies for the Fermilab project.

It is at CERN that most thinking and effort has been applied so far but it is recognized on both sides of the Atlantic that either Laboratory could get there first with colliding proton-antiproton beams. Bob Wilson, former Director of Fermilab, spoke only half in jest when he thanked CERN colleagues for finding solutions to problems which Fermilab would endeavour to use to CERN's dismay !

Physics possibilities with a proton-antiproton collider

Experiments with antiprotons are certainly not new. Since the antiproton was first identified at the Berkeley Bevatron in 1955, its interactions have been extensively studied but the energy and luminosity of secondary antiproton beams from proton accelerators are low, which limits the useful research which can be done.

Antiprotons are stable particles and, in principle, they could be accumulated in a storage ring. However, in practice, they are difficult to handle because they emerge from a target, bombarded with an accelerated proton beam, with a wide momentum spread. The recent developments in beam cooling techniques have opened up the feasibility of taking such an emerging beam of antiprotons and taming it for use in colliding beams.

The physics aims of a high energy proton-antiproton collider can be divided into three areas: the continuing study of the behaviour of hadrons as particles in their own right, the investigation of effects due to the small constituents deep inside the hadrons and the search for new particles.

One of the main motivations for building the CERN ISR — the world's first hadron colliding beam project — was, hopefully, to investigate 'asymptotic' behaviour at higher energies where cross-sections, impact parameters, etc., were expected to converge to some fixed limit. Earlier work had shown that the proton-proton cross-section, up to the energy range of the 70 GeV accelerator at Serpukhov, seemed to be levelling out. It looked as though the long sought after asymptotic form of the proton-proton interaction could be one of the first fruits of ISR research.

It took only a short time to show that this was not to be so. The cross-section was found to increase far more steeply with energy than would be compatible with some gentle run up to an asymptotic value which showed that there was more to be learned about hadron interactions at higher energies. The observed behaviour seems to depend on the logarithm of the collision energy and this slow energy dependence means that any asymptotic behaviour must set in at much higher energies.

Clues from cosmic rays (see September issue, page 289), indicate that with colliding beams using the highest energy present accelerators new behaviour will be seen. Multiple secondaries in particular should start to show something different. To reproduce these events in fixed target experiments would require laboratory energies of some 10^5 GeV.

The other physics areas open to proton-antiproton colliders are the study of hadron constituents and the search for new particles. The increased collision energies will facilitate large transverse momentum reactions where the constituent quark/partons inside the colliding particles come into play and proton-antiproton collisions will also open up the possibility of producing new heavier particles through annihilation processes.

The 'jet' structure, now interpreted as the subsequent release of energy by particle emission after the inner constituents of nucleons interact in violent collisions, could be studied in greater detail at the colliders. In this way more information could be obtained on the quark/partons, while new effects could be found due to gluons or other features of the quark-quark interaction mechanism.

Prompt lepton production, both singly and multiply, at today's energies has led to a number of important discoveries, including evidence for heavier quarks beyond charm. Higher energy experiments would indicate whether we are seeing the end of the spectrum of quark masses or whether there are more to be found.

One major hope is that at these energies, at last, the elusive bosons held to be responsible for weak interactions will be found. Their masses are set by the most popular theories to be below 100 GeV. If they are not seen directly, experiments will hopefully uncover important clues about the inner working of the weak interaction.

As well as the intermediate boson, the proton-antiproton colliders could give the first signs of the Higgs particles or of other unexpected states. While the discovery of weak neutral currents and charm provided impressive evidence for the gauge theory picture which unifies electromagnetic and weak interactions, one prediction of this picture is the existence of spinless Higgs bosons. If these are not found at higher energies, some re-thinking might be required.

The higher energy domain attainable with a proton-antiproton collider will probably provide the most glamorous physics possibilities, but the availability of higher intensity and better quality antiproton beams opens the door to a lot more. In particular, better antiproton beams could help augment our knowledge and understanding of what happens at presently available collision energies. By injecting antiprotons into the CERN ISR, for example, a range of new experiments will be possible, and comparison with proton-proton behaviour could provide new insights. Other antiproton investigations could study baryonium states and exotic atoms containing orbital antiprotons.

When the nature of the strong force between a proton and an antiproton is so little understood at any energy, a full programme of proton-antiproton physics using existing equipment seems to be a good investment.

The cooling schemes

All this is made possible by the cooling techniques which have emerged very abruptly over the past two years. They are of two types 'electron cooling' and 'stochastic cooling'. These were described in the December issue 1976 and here we will just sketch major features and some recent results.

The team of Gersh Budker at Novosibirsk had a project for colliding proton-antiproton beams at 25 GeV (VAPP-NAP) fifteen years ago and realized the need for some method of improving intensities of antiproton beams. They emerged with 'electron cooling' in which the essential idea is to send an electron beam, where the electrons have precisely defined velocity, along an antiproton beam travelling in the same direction at the same velocity. The two kinds of particle can exchange energy and, since the electron beam is constantly refurbished at the same energy, it cools the antiproton beam to that energy (rather like a mixture of two gases where one is constantly refurbished at a precise temperature).

The theory of the technique is fiendishly complicated and it was only after spectacularly successful demonstration at Novosibirsk of the electron cooling of a proton beam in a storage ring NAP-M (in experiments which began in 1974), that interest awoke in other Laboratories.

The main result of the Novosibirsk experiment was the cooling of an 85 MeV proton beam of up to 100 μA by a 45 keV electron beam of 0.8 A in a time of 80 ms to reach an equilibrium diameter of 0.5 mm. The energy spread was reduced to less than 10^{-5} and the angular spread to less than 5 x 10^{-5}. Important features to note are the very rapid cooling time, the great effectiveness of the cooling, the low energy at which it operated and the comparatively low beam intensity at which it operated. Further work is needed to check the technique with other beam parameters.

This is to be done at Fermilab and at CERN. At Fermilab an electron cooling ring is being built alongside the Booster for tests using the 200 MeV protons from the Linac. The building is complete, all the magnets are made and the first one is installed. The electron gun is ready and the solenoids to guide the electrons are under construction. It is hoped to operate the ring in three months' time. At CERN the emphasis has swung to stochastic cooling but it is still intended to test electron cooling.

The idea of 'stochastic cooling' came from Simon Van der Meer at CERN and was first tried on the Intersecting Storage Rings in 1975. The essential idea is to measure the density distribution of a piece of an orbiting beam and then to apply electric fields to nudge the 'centre of gravity' of the piece nearer to the desired orbit. It is a statistical method, the nudge has an unfavourable effect on some particles but a favourable effect on most. It is therefore repeated many times to achieve significant cooling of a beam.

The first tests of stochastic cooling in the ISR achieved cooling at a slow rate but still impressively enough to merit pursuing the idea. Major advances were made at the ISR during 1976 and, when the proton-antiproton ideas emerged, it was decided to test both cooling techniques in a specially built ring (revamped g-2 muon storage ring) in a project known as ICE — Initial Cooling Experiment.

At the end of 1977 both momentum and betatron cooling were achieved in ICE without difficulty. On 27 March a further test achieved the excellent performance of cooling the injected proton beam by a factor of nine in three minutes. Given the much more extensive cooling equipment which will be installed in the cooling ring for the proton-antiproton project at CERN, this performance is already close to the

The rebuilding of the muon storage ring of the famous g-2 experiment for ICE — Initial Cooling Experiment. It is here that beam cooling techniques are being checked en route to high intensity antiproton beams. Successful stochastic cooling tests took place at the end of March.

(Photo CERN 282.11.77)

level needed to achieve the design aims of the project.

The proton-antiproton projects

CERN has polished its thinking to the point where a Design Study of a proton-antiproton colliding beam facility was published at the end of January. It concentrates exclusively on the use of stochastic cooling in a cooling ring to be located on the transfer tunnel, TT2, from the 28 GeV proton synchrotron which takes beams towards the Intersecting Storage Rings and the 400 GeV proton synchrotron. Thus both the ISR and the SPS could be fed with 'cold' antiprotons. We concentrate here on the SPS scheme.

Protons will be ejected from the PS at 26 GeV and directed onto a target to yield antiprotons at 3.5 GeV/c. A higher yield could be obtained by doing the targetting after acceleration in the SPS but this would involve serious interference with the normal SPS physics programme. The 3.5 GeV/c antiprotons (2×10^7 per PS pulse) will be injected into the cooling ring where a two stage cooling process will take place. The injected particles will be 'precooled' in an outer orbit position before being moved to the stack of accumulated particles which will be kept continuously cooled. Stochastic cooling systems will be used for both processes.

It is anticipated that cooling and accumulation will go on for 24 hours before transfer to the SPS at 3.5 GeV/c down the TT 60 tunnel normally used for the ejected beam to the West Area. Allowing for losses, the transferred antiproton beam would have about 6×10^{11} particles. They will be accelerated to 18 GeV/c and injected protons will be picked up in the acceleration process at 10 to 14 GeV. At 18 GeV rebunching will be done and acceleration continued to 270 GeV where the magnet fields can be held in storage ring mode. With a low beta insertion the anticipated luminosity is 10^{30} per cm^2 per s. Detection systems and proposals for experiments are already being worked out.

Fermilab has different machine features influencing its proton-antiproton scheme. The first is that the Booster energy of 8 GeV is not high enough to give a healthy antiproton flux from the target. The Main Ring is therefore to be used to take protons to 80 GeV before producing antiprotons. Also the present vacuum in the Main Ring limits stored beam lifetimes to about one hour. Longer lifetimes await the completion of the Energy Doubler ring. When this is achieved, the door will be open to proton-antiproton collisions with 1000 GeV beams.

The sequence then goes: Protons will be accelerated to 80 GeV and ejected (one thirteenth of the beam around the circumference) towards a target on a line which leads to the 8 GeV Booster. A 5.18 GeV antiproton beam (10^7 to 10^8 per pulse) will be injected into the Booster, decelerated to 200 MeV and transferred to the cooling ring (an extended version of the cooling ring where the initial tests are being carried out so that the circumference becomes the same as that of the Booster). Electron cooling will be applied to cool the antiprotons. This will be repeated for many pulses collecting a cooled beam of about 10^{10} in an hour.

The cold 200 MeV antiprotons will be compressed into a small bunch and transferred to the Booster where the magnet polarity will be reversed. They will there be accelerated to 8 GeV and sent to the Main Ring. Acceleration to about 100 GeV will take place before transfer to the good vacuum of the Energy Doubler.

The normal proton injection process will then follow and a proton bunch (2×10^{12} protons) will also be transfer-

The Central Laboratory area at Fermilab in a recent aerial photograph. In the foreground on the right, alongside the 8 GeV Booster with its pond and cooling fountains, is the new building ready to house the electron cooling ring to be used to test the cooling technique for the proton-antiproton colliding beam project.

(Photo Fermilab)

red to the Energy Doubler at 100 GeV. Both beams can be accelerated to 1000 GeV and collisions can be observed with an anticipated luminosity of 2 × 10^{28} per cm^2 per s. It is believed that this 'raw' luminosity can be improved to 2 × 10^{30} by having an appropriate low beta section, by extending the storage time for antiprotons to three hours and by compressing ten proton bunches into one. At the Workshop an idea to have a 'pre-cooler' using stochastic cooling so as to accept a bigger antiproton momentum spread also looked attractive.

The Energy Doubler is essential to this project unless the Main Ring vacuum can be significantly improved. At present about seventy superconducting magnets of the Doubler type have been built, the last twenty of them being regarded as 'production' magnets. The field quality has reached the 10^{-3} level on a 1 inch radius which probably needs further improvement for performance as a storage ring. There is now capacity to build magnets at the rate of one a day and it looks as if more money for the Doubler will be made available (see page 125).

New idea from the Workshop

The above luminosity figures could be considerably affected (for the better) by an idea which emerged from the fertile mind of Carlo Rubbia in the course of the Workshop. Up to now electron cooling has always been thought of as involving low energy application (for example, Fermilab deceleration to 200 MeV/c before applying cooling). This is because the hefty electron currents which are needed are only available at keV energies given existing electron gun techniques.

The new suggestion is to use a tiny electron storage ring which could be set to energies equivalent to the proton and antiproton energies (say about 25 MeV electrons and 50 GeV antiprotons) where the particle velocities are the same. The ring would have a straight section coincident with the proton and antiproton orbits so that electron bunches and proton or antiproton bunches would briefly travel together.

The electron beam in a storage ring is very 'cold' because of its synchrotron radiation. Extremely high current densities and precisely defined momenta are achieved for free by virtue of the radiation. Thus the standard electron cooling principle, taking the proton heat into the cold electrons, could be applied at much higher energies by using a storage ring. The ring would be very small (few metres) and could thus be accommodated in both CERN or Fermilab tunnels.

The idea was too new to be checked out in detail in the course of the Workshop but it aroused a lot of in-

Around the Laboratories

terest and, if it still looks good after more careful examination, could, by achieving and maintaining higher luminosities, have a major impact on the physics potential of the proton-antiproton schemes.

Bob Wilson also pointed out that the big proton storage rings are themselves running into the energy/radius region where synchrotron radiation is noticeable. The Energy Doubler, at 1 TeV and 1 km radius, will radiate about 10 eV per turn. This corresponds to a cooling time of 30 days which would perhaps overtax the patience of the experimental physicists. Professor Wilson, never one to miss an opportunity, did add that this situation would be considerably improved when the government finally comes around to financing the 5 TeV, 8.5 T superconducting niobium-tin magnet ring which would just fit on the Fermilab site. The cooling time would then be half a day !

DESY
More light from DORIS

Until recently, scientists interested in the use of synchrotron radiation had to sit at synchrotrons or storage rings operated principally for experiments in particle physics. Today there is worldwide support — in the USA, the USSR, Japan and Europe — for storage rings operated entirely for the purpose of producing high fluxes of synchrotron radiation for spectroscopy in the vacuum ultraviolet and X-ray regions. Among the more advanced projects are the 2 GeV 'Synchrotron Radiation Source' at Daresbury, the 'Aladdin' project at Wisconsin, the National Synchrotron Light Source, (700 MeV and a 2.5 GeV storage ring) at Brookhaven and the Photon Factory project in Japan.

In the Federal Republic of Germany the government has agreed to spend some 14.4 million DM to increase the effectiveness of the DORIS storage ring at DESY as a synchrotron radiation source. A new laboratory building will make it possible to extend use of the radiation from six DORIS bending magnets. Later on a 800 MeV storage ring, situated in Berlin, will be built. Both projects will serve the growing needs for synchrotron radiation by the user community.

The research programmes making use of synchrotron radiation are becoming more and more diversified and the number of suggestions for new applications is by no means levelling off. At the Berlin facility, emphasis will be on metrology, applied research and industrial development (in the field of semiconductors and microelectronics in particular) and basic and applied research (mainly in physics and physical chemistry).

At DORIS, with energies of 3 to 4.5 GeV, X-ray physics as well as time-

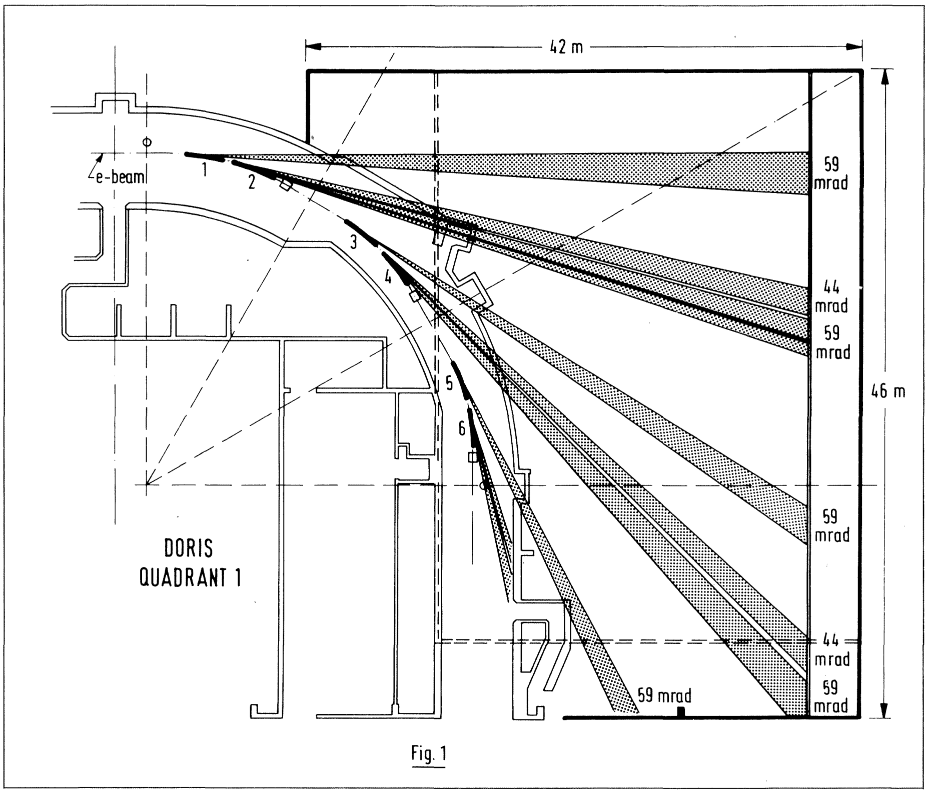


Fig. 1

Sketch of the experimental hall for synchrotron radiation experiments at DORIS. The hall smoothly links to the north west arc of the DORIS building. Several broad fans of radiation from up to six magnets will be available for experiments.

resolved spectroscopy over the whole spectral range from the vacuum ultraviolet to hard X-rays will be the backbones of the programme. With the outstation of the European Molecular Biology Laboratory, EMBL, already present in Hamburg, structural analysis of biological materials will certainly be another major topic. Other areas of research will be atomic and molecular spectroscopy in the vacuum ultraviolet as well as solid state and surface physics. Scientists working in these areas have already used DORIS with great success in the multibunch high current mode at energies below 3 GeV. They will also profit from improved conditions.

The critical photon energy to which the synchrotron radiation continuum extends is 5 keV at 3 GeV and 14.5 keV at 4.3 GeV. Thus DORIS provides high fluxes for most X-ray applications. Due to the short bunch length, the light is pulsed with pulse durations as short as 150 ps which makes time-resolved experiments possible in a spectral range where this kind of spectroscopy has never been exploited before.

Studies have shown that improved performance as a synchrotron radiation source can be obtained with some minor modifications of the beam optics. For example, the reduction of the vertical beam size by a factor of three, corresponding to 0.3 mm FWHM, seems possible. In addition extreme spatial stability at several points of the orbit is required, posing the machine experts the same kind of challenge as the demand for high luminosity in colliding beam experiments.

The quantity of radiation available for users and the ease of access to it will be substantially improved. Whereas at present only a small part of the radiation from one magnet is used, the expansion will make possible the simultaneous use of radiation from six magnets. Carefully designed new chambers within the magnets will allow the extraction of up to 30 % of the radiation from one quadrant of DORIS. Thus at least 20 experimental stations will obtain synchrotron radiation simultaneously. Presently 50 letters of intent for experiments, submitted last year, are being examined. A number of informal meetings of specialists from the user community and from the facility have been held to optimize the parameters of experimental stations and to define the requirements for each experiment. These discussions will influence the final beam-line concept.

The time schedule for the whole project is intimately connected with other programmes at DESY depending critically on the operation of DORIS as a PETRA injector and as a colliding beam machine. In principle, the new experimental hall could be ready early in 1980 with the major part of construction going on while DORIS is operating. With luck a new generation of synchrotron radiation experiments will start at DORIS sometime during 1980. The construction of the small ring PIA (see October 1977 issue, page 326) to relieve DORIS of its PETRA injection role should then allow more time for synchrotron radiation experiments.

DARMSTADT
The future of heavy ions

On 7-10 March, GSI Darmstadt organized a 'Symposium on Relativistic Heavy Ion Research' which attracted over two hundred physicists working in the field. They reviewed the physics potential and practical applications of relativistic heavy ions from existing accelerators and from those which are planned. Some of the following points are taken from the talk by Hermann Grunder, the heavy ion pioneer from Berkeley, which concluded the Symposium.

Physics with heavy ion beams, reviewed in an introductory talk by W. Greiner of Frankfurt University, had priority at the Symposium with quark matter, cosmic rays and nuclear matter under extreme conditions as the main topics.

One area of application of heavy ions is that of biology and medicine. Their use was covered in talks by E. Alpen from Berkeley (where much of the pioneering work is being done) W. Pohlit of Frankfurt and U. Schmidt-Rohr of Heidelberg. Only after a long series of clinical trials with a variety of particle beams can any assessment of the relative merits of the different types of particle for cancer treatment be made. It may well turn out that different cancers in different locations in the body respond to different treatments. Thus it is important to study the various possibilities (pions, protons, neutrons, ions) now available from accelerators in order to reach scientific conclusions.

Berkeley, Uppsala, Harvard, ITEP, Hammersmith, Dubna, Los Alamos, Fermilab, Saclay, Gatchina, Heidelberg, SIN, Harwell, Rutherford, Brookhaven... have all been involved in studying the possibilities. In the heavy ion field, one highlight is the use of carbon-11 or oxygen-15 ions which emit positrons with a definite range.

Another area of application is the use of high energy heavy ion beams to provoke inertial fusion. This topic, introduced at the Symposium by Al Maschke of Brookhaven, is comparatively new to the scene but has excited great interest particularly in the USA (see for example November issue 1977, page 364). As Hermann Grunder said, the subject is so important that the correct question to ask is not 'does it work' but 'does it have a chance?' Thermonuclear fusion seems to be the only energy source which could replace conventional sources rather than having just a modest impact on the world's energy needs.

M.J. Clauser of Sandia Labs. reviewed target problems, though

The heavies met at Darmstadt in March for a Symposium on Relativistic Heavy Ion Research organized by GSI. The Director of GSI, Chris Schmeltzer, can be seen on the front row third from the left.

(Photo GSI Darmstadt)

seemingly reverting to the information that was available prior to the Brookhaven Workshop of October 1977. Kjell Johnsen of CERN and Lee Teng of Fermilab reviewed appropriate accelerator techniques. Kjell Johnsen promotes the use of beam storage prior to injection into an induction linac in order to build up required intensities; Berkeley are trying to develop very intense ion sources to circumvent this. Lee Teng reviewed a scheme involving beam bunching going some thirty times beyond the allowed space charge limit relying on the Brookhaven experience with the AGS where bunches survived after similar treatment.

Argonne, Berkeley and Brookhaven are now attacking some of the accelerator problems and more money is being made available in the USA. In Europe, interest is growing and more effort is being applied at Rutherford Laboratory under Marshall King.

The sessions on relativistic heavy ion accelerators considered the facilities now being built or planned for the future. At lower energies there are a variety of machines such as UNILAC at Darmstadt, the cyclotrons GANIL at Caen and at Michigan, the tandems at Daresbury and Oak Ridge... In the relativistic region, the Bevalac at Berkeley has led the way with ion beams at energies of GeVs per nucleon, albeit of comparatively low intensity. An improvement programme aims to step the intensity up.

The Bevalac will be joined by two other machines following the conversion of Saturne at Saclay and the Synchro-phasotron at Dubna. Saturne II is a CEA/IN2P3 project intended to accelerate ions from protons to neon-20, up to a proton energy of 3.8 GeV, which is scheduled for first operation at the end of this year. The Synchro-phasotron could accelerate ions up to uranium-238 with an energy of 3.4 GeV per nucleon and it is intended to surround it with another ring, called the Nuklotron, which could take the peak energy to 10 GeV per nucleon.

Two other projects are well developed. One is at GSI Darmstadt itself where a synchrotron is proposed under the name of SIS, Schwerlonen-Synchrotron, to take ions from UNILAC and continue their acceleration to higher energies. In Japan, a rather similar scheme is proposed under the name of Numatron (Nuclear Matter Tron). The use of storage rings to give colliding heavy ion beams is also coming into vogue.

Hermann Grunder emphasized that detectors should also receive attention since, in general, detection systems had been poor in heavy ion research. He concluded with the remark that 'with relativistic heavy ions we are sailing towards new shores where the probability is high that something very exciting will turn up.'

ARGONNE
Preparing for polarized deuterons

A beam of polarized deuterons will be accelerated into the GeV energy range this summer by Argonne's ZGS, the first time such a beam has been available to high energy physicists. This new beam will supplement the ZGS programme to study high energy spin effects, carried on in recent years with polarized proton beams, by permitting experiments in which the neutron in the deuteron serves as the projectile in nucleon-nucleon collisions. The momentum of the beam will range up to 12 GeV/c and intensities of at least 5×10^9 polarized deuterons per pulse are expected for the initial runs.

The first requirement is the availability of a polarized deuteron source. To provide this, a third r.f. transition unit will be added to the polarized proton source. By selectively inducing spin flips of the deuteron in the atomic beam in the source, these transition units will modify the populations of the atom's various magnetic substates so as to produce a net polarization. Three transition units allow pulse-to-pulse changes in the polarization direction and the proportion of tensor to vector polarization in the beam. The maximum vector polarization is expected to be 60%, and the maximum tensor polarization 85%. Since g-2 for the deuteron is 13 times smaller than for the proton, the delicate problem of retaining the polarization during acceleration, which the polarized proton programme has fought and solved, does not occur with deuterons. The lowest order intrinsic depolarizing resonance would occur at 23 GeV/c !

The techniques required for accelerating deuterons have been investigated in recent accelerator research periods. Over 3×10^{11} unpolarized deuterons per pulse have been brought to full energy, within a factor of two of what is believed possible, despite only a short time being available for tuning the linac and the synchrotron.

Accelerating deuterons in the 50 MeV proton linac is difficult because the deuteron charge to mass ratio is half that of the proton, causing much larger beam losses. The final deuteron energy is only 25 MeV, so that deuterons are injected into the ZGS at half the velocity of protons. Since the velocity after acceleration is still near that of light, the r.f. frequency swing in the ZGS would have to be twice that for protons which is not possible with the present r.f. system.

Instead, the beam is captured on the 16th harmonic and accelerated to 1.2 GeV/c where the ZGS is flat-topped. The beam is debunched and then rebunched on the normal 8th harmonic and accelerated to full energy. A minicomputer-based control system had to be developed to carry out these r.f. gymnastics. The ZGS operators were pleased to find that only 10% of the beam was lost during the rebunching exercise.

The success of these acceleration tests led to the scheduling of physics runs in September and October of this year. The first month's run will be at relatively low energy, with two experiments by a UCLA / LBL / Argonne / Minnesota collaboration studying forward and backward elastic scattering of deuterons off a liquid hydrogen target around 3 GeV/c incident momenta.

The forward scattering experiment is designed to measure the d-state mixture in the deuteron. The backward scattering experiment is intended to identify a possible N* (1688) component in the deuteron ground state. The experiments require the ZGS to deliver various combinations of tensor polarization, vector polarization, no polarization, up polarization, down polarization, left polarization and right polarization ! The last two require the use of two 2 m, 60 kg superconducting spin rotating solenoids in the deuteron beam.

The second physics run will follow in October, with two experiments sharing the beam at 12 GeV/c. Both will use the deuteron beam incident on polarized proton targets to study neutron-proton elastic scattering in pure spin states. A Michigan / Argonne / Abadan Institute of Technology collaboration will concentrate on the large t region, and a Rice / Argonne / Illinois group will look at smaller t scattering.

These experiments are tightly enough constrained to minimize the effect of the spectator proton, as well as the usual carbon-produced background from the polarized target. No data of this type exists at high energies and comparison of the results with proton-proton measurements already obtained at the ZGS may shed light on the many surprisingly large spin effects observed at high energies, including the unexpected differences between proton-proton and neutron-proton collisions that persist up to the highest ZGS energies.

VIENNA
Wire Chamber Conference

About two hundred detector specialists gathered in Vienna in February to discuss developments in the technology and applications of wire chambers and their associated electronics. The Conference was organized by the University of Vienna, the Institute for High Energy Physics of the Austrian Academy of Sciences and was opened in the presence of the Austrian Science Minister.

Georges Charpak, inventor of the multiwire proportional chamber, in full flight during his talk at the Vienna Wire Chamber Conference.

The first plenary talks were by G. Charpak and A. Jeavons from CERN who covered the use of proportional chambers in fields outside high energy physics (particularly in various branches of medicine). Their spatial accuracy and fast data taking rates can far exceed the capabilities of conventional X-ray cameras. The ability to give X-ray images in three dimensions and to localize gammas and neutrons are major applications. Other pioneering work on some of these topics is being led by V. Perez-Mendez at Berkeley.

Most of the Conference was devoted to the present status and development of detectors in high energy physics. The major review talks were by I. Veress (Budapest) on multiwire proportional chambers, and by J. Heinke (Heidelberg) on drift chambers, showing the enormous progress of these techniques in the last decade. A number of invited talks and many contributions covered existing large detectors, such as the two neutrino experiments at the SPS and the Split Field Magnet at the ISR.

Another aspect of the conference was the discussion of new trends in detection technique. Due to the rapid progress in electronics, pulse height measurement on each channel becomes feasible. This leads to ultimate limits in precision and the determination of energy loss. The relativistic rise in ionization can now be used for particle identification. The External Particle Identifier (EPI) is the first operating large-scale detector of this generation.

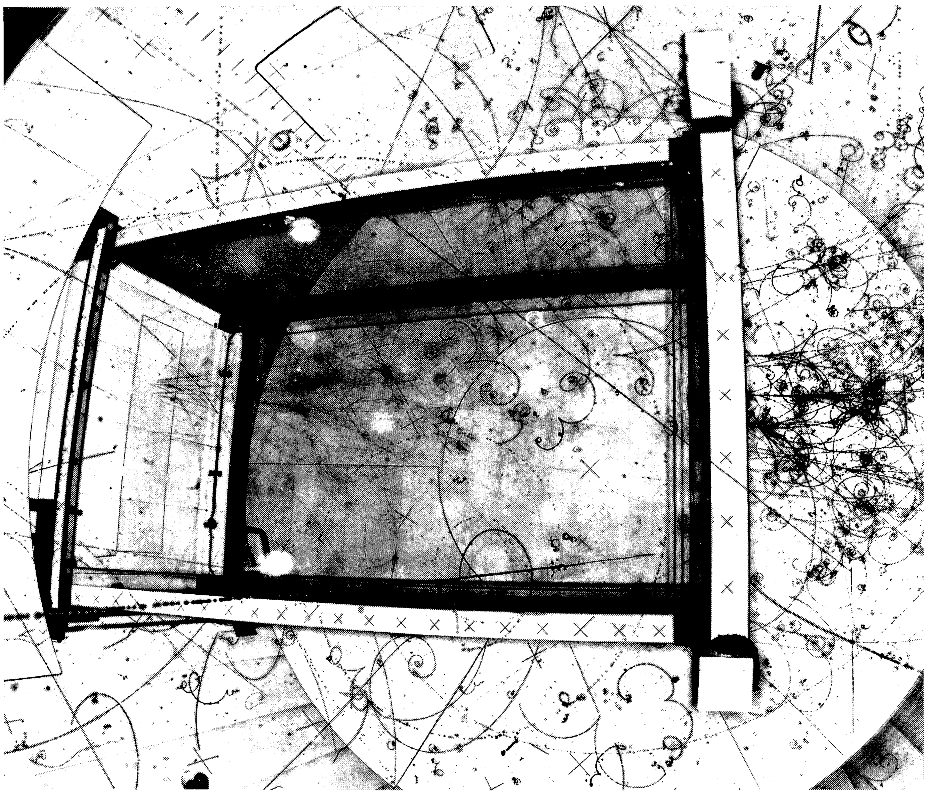
It was obvious that multiwire proportional chambers and drift

The PEP storage ring, now under construction at Stanford, has been baptized by heavy downpours. The photograph shows interaction region, IR-8, which is signposted Lake Rees (elevation 273 feet) in recognition of Project Director, John Rees. Dry sense of humour?

(Photo Joe Faust)

chambers are now well-mastered detection techniques. We are not, however, at the end of finding applications for the remarkable abilities that they have in comparison to their predecessors.

As a social highlight at the Conference the organizers (W. Bartl, F. Bensch, G. Neuhofer, M. Regler) invited the participants to a traditional 'Henniger' at Grinzing.



The new BEBC TST in operation as seen by one of the four bubble chamber cameras. Particles first traverse the TST, leaving very fine tracks due to the relatively high temperature of the hydrogen (29.3 K). These tracks are difficult to reproduce in printing. The outgoing tracks which traverse the neon-hydrogen mixture are about four times thicker. Most of the background tracks are cosmic rays.

CERN

TST in and working

In the first experimental period of the CERN SPS in 1978, the 3.7 m bubble chamber, BEBC, was equipped for the first time with a track sensitive target (TST) and the first 42 000 pictures were taken with the new target configuration. Measuring 2.4 m in the beam direction, 1.4 m across and 1 m high and containing three cubic metres of liquid hydrogen or deuterium, the new TST is the world's largest, 75 times larger than the one used in the Argonne 12 foot bubble chamber and 3 times larger than the complete 2 m chamber at CERN which was recently closed down.

The aim of the TST technique, invented by H. Leutz, is to combine the advantages of hydrogen and heavy liquid bubble chambers. Hydrogen filled chambers provide free proton targets for the incoming beam (deuterium also allows the behaviour of neutron targets to be studied) but have a low efficiency for converting the gamma rays coming from the decay of the otherwise invisible neutral pions. A heavy liquid bubble chamber, on the other hand, is better suited to detecting gamma rays, but events are more difficult to interpret due to the presence of complex nuclei.

In the TST approach, successfully demonstrated by a CERN/DESY collaboration in 1966, a plastic box transparent to particles and to visible light is filled with liquid hydrogen (or deuterium) and placed inside a bubble chamber filled with a mixture of liquid neon and liquid hydrogen.

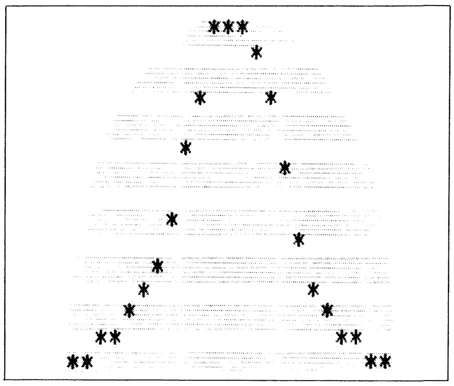
The new TST for BEBC is made from Lexan, a thermoplastic polycarbonate manufactured in the US in sheets ¼ inch thick. The TST requires Lexan plates several times thicker than this and with good optical properties. Such plates are obtained from commercially-available Lexan sheets by 'press-polishing' them between highly polished chromium plates at 170° C and a pressure of up to 70 atmospheres.

The TST plates are optically coated by vacuum evaporation with quarter-wavelength thicknesses of magnesium fluoride to reduce the reflectivity of the surfaces and so improve the quality of the final bubble chamber pictures.

The most difficult problem is the assembly of the Lexan plates into a box which is optically perfect and which can survive millions of expansions near 29 K and accidental pressure differentials of several 100 grams per cm^2. Special techniques have to be used to stick the plates together (see February 1976 edition, page 48). The TST is a passive device with no expansion system of its own and a minimum of additional equipment inside the bubble chamber. There is only a cooling loop and a heater to enable the liquid in the TST to be maintained at a different temperature to the neon mixture in the main chamber. The instrumentation is limited to a vapour pressure thermometer and eight strain gauges to monitor the TST shape.

The net buoyancy of the filled TST in BEBC containing its neon-hydrogen mixture of 78 % amounts to 1.7 tons, and this force is supported by strong springs. The operating conditions are still being adjusted to match as closely as possible the sensitivities of the chamber and the TST. At present the TST is run at 29.3 K which yields tracks of 10 to 12 microns on the film; the chamber is 0.2 K warmer with tracks of 40 to 50 microns.

Three initial experiments are lined up for the TST. A Bari / Birmingham / Brussels / Ecole Polytechnique / London / Rutherford / Saclay collaboration will study high energy neutrino interactions. The other two experiments will look for prompt leptons coming from hadron collisions, with a Bologna / Glasgow / Rutherford / Saclay / Torino group using a 70 GeV/c negative pion beam and a Brussels / Helsinki / Liverpool / Mons / Stockholm group using antiprotons at the same energy. The neutrino experiment and at least one of the hadron experiments are expected to be run simultaneously, with BEBC being operated in 'double-pulsed' mode, with neutrino and hadron TST photographs being taken on alternate expansions. Equipped with the TST and its external particle identifiers, BEBC now provides an impressive range of detecting capabilities for physics at SPS energies.



The muon beam profile recorded at the entrance of the muon experimental hall, EHN2, in the North Area of the CERN SPS. The beam intensity in this first run was about 5×10^6 muons per pulse and the profile is recorded by a wire chamber where each wire is separated by 4 mm. The vertical axis is a measure of the muon intensity falling on each wire.

Muons in the North

Since the CERN machines came back into action after the end of year shutdown, the 400 GeV proton synchrotron, the SPS, has been working very well. At the beginning of April, average accelerated beam intensities (obviously with a very good feed from the PS injector) were topping 10^{13} protons per pulse and machine reliability was around 85%.

Up to now the SPS beams have been used in the West Experimental Area, with 200 GeV protons to the counter experiments in the West Hall and up to 400 GeV protons for counter and bubble chamber experiments with neutrinos. The West Area had a flying start in the SPS project since the Hall and some detection systems were already in existence. A completely new area, the North Experimental Area, has also been built and it received its first beam on 31 March. This was the muon beam which has received a lot of emphasis in the SPS programme as one of the major experimental facilities.

The ejection system towards the North was tried on 7/8 March and, with some tidying up, rapidly gave protons onto targets T2, T4 and T6, almost a kilometre from the ring. These targets feed six beam-lines — four into the Hall EHN1 for hadronic experiments, one to the high intensity Hall EHN3 which is yet to be completed, and one conveying muons to experiments in Hall EHN2. Even on 7/8 March, when these beam-lines were not powered, some muons were creeping through from the targets and were spotted by the detectors in EHN2.

On 31 March ejected protons were steered onto target T6, source of the muon beam-line. A series of quadrupoles gave efficient capture of emerging pions which were guided through some 600 m of decay pipe, 20 cm in diameter. A beryllium absorber 9 m long, halted remaining pions while causing minimum disturbance to the muons which had come from pion decays. In the first test, pions of 220 GeV/c were collected and the muon section of the beam-line was tuned for 200 GeV. Another long transfer channel brought the muons to the experiments.

At the end of the channel a scintillator hodoscope with very good resolution (5 mm, 0.1 ns with up to 10^9 muons per second) will be able to measure the momentum of each muon passing to the detectors. The peak momentum will be 300 GeV/c and the intensity will be around 10^8 muons per pulse.

In the first test, some 5×10^6 muons (from 5×10^{11} protons on the T6 target) reached the detectors in excellent agreement with the prediction. It is already the highest intensity high energy muon beam in the world.

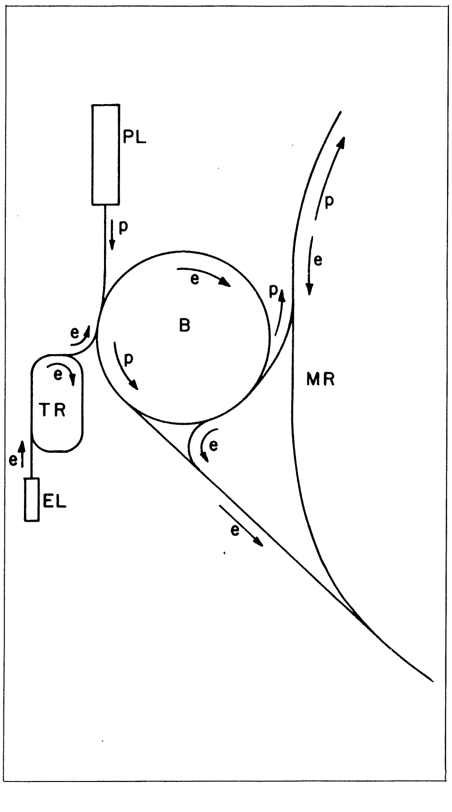
FERMILAB
An ep scheme

In addition to the proton-antiproton scheme covered in the main article in this issue, the construction of the additional ring for the Energy Doubler opens other colliding beam possibilities at Fermilab. One of these is electron-proton collisions whose physics interest has been the subject of lively discussions during the past year (see for example November 1977 issue, page 364). In the USA, Stanford (PEP) and Brookhaven (ISABELLE) have not closed their eyes to this physics and in Europe both CERN and DESY have been examining what would be needed at the SPS (a scheme called CHEEP) and PETRA (a scheme called PROPER) respectively.

The electron-proton possibility at Fermilab was promoted at the Aspen Summer Study in 1977 and has since been investigated. A. Ruggiero reported progress in the February issue of the Fermilab Report. The aim is to collide electrons of up to 12 GeV with protons of up to 1000 GeV.

The scheme has a 75 MeV, 400 mA electron linac feeding the cooling ring (where the electrons are taken to 750 MeV), feeding the Booster (where the electrons are taken to 4 GeV), feeding the Main Ring with several pulses (where acceleration to 12 GeV is completed). Protons follow their normal route and finish up stacked for ten pulses in the Doubler ring to give a circulating current of 1.5 A.

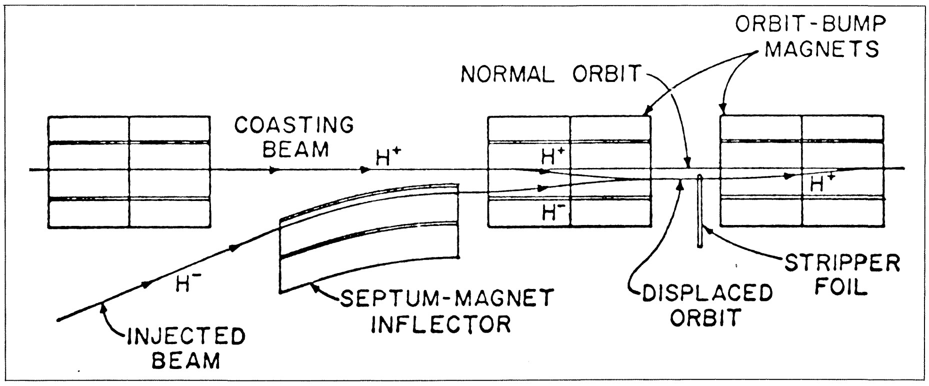
Most of the necessary equipment either exists or will exist for other colliding beam schemes. Additions would be the electron linac, more shielding, power supply in the cooling ring and a low beta insertion for the experiments.



The electron-proton colliding beam scheme studied at Fermilab. The addition of an electron linac (EL), the use of the electron cooling ring (TR) and of the Booster (B) gives electron beams into the Main Ring while protons follow their normal route to the Main Ring and can be stacked in the Energy Doubler.

1. A diagram of the negative hydrogen ion injection scheme into the Fermilab Booster which has been tested very successfully.

2. Multiturn injection of negative ions during a record intensity run when fifteen turns of 24 mA of ion beam were injected. Each step of the staircase is 2.8 µs long and indicates the increase of circulating charge as successive turns are added. The total number of protons injected per booster batch is 6.4 x 10^{12}. A small loss of beam can be seen following injection. Most of the losses occur during the first 4 ms of the cycle.



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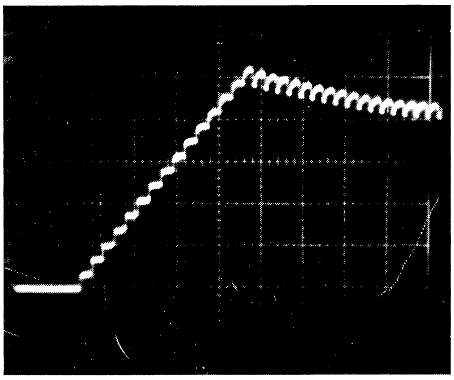


2.

The estimated luminosity is 10^{31} per cm^2 per s with the main limitation being the vacuum pressure which can be sustained in the presence of synchrotron radiation. 10^{-7} is hoped for which would restrict beam life-time to about an hour.

A report on the scheme is being prepared on completion of the studies at the end of March.

Positive results with negative ions

A record Booster intensity of 3.46 x 10^{13} protons per Main Ring cycle was achieved on 4 March at Fermilab. This intensity, well above the previous record 3.06 x 10^{13}, was attained eight days after starting trials of negative hydrogen ion injection into the Booster. The injected beam (about 6 x 10^{12} particles per Booster batch) consisted of fifteen turns each of 24 mA negative hydrogen ions from the Linac. A Main Ring cycle consists of thirteen Booster batches.

The rapid success testifies to the essential simplicity of the injection method and follows two years of careful preparation by the Linac and Booster groups. Work is continuing to refine the techniques.

A negative hydrogen ion consists of two electrons bound to a proton. This combination has unique advantages for beam injection since the negative charge makes the ion bend with the opposite curvature to a proton in a magnetic field, so that the incoming ions can be injected on a path that overlaps the orbit of circulating protons. Where the trajectories coincide, the ions pass through a carbon foil which strips off the two electrons, leaving protons which add to those previously injected. The intensity can be built up by injecting for many turns, without the growth in beam size typical of other multiturn injection methods which stack beam side by side. The multiturn capability allows modest Linac currents to be used avoiding the instabilities and beam growth typical of high current operation. The specialists know the scheme as a way of beating Liouville's theorem.

The technique of charge exchange injection is usually associated with the name of Gersh Budker, late Director of Novosibirsk who was its strongest proponent in the late '50s. The idea was raised also by others in different contexts. Milton White of Princeton (now Chairman of the URA Board of Trustees) spotted the possibilities while working on a cyclotron extraction scheme in the 1930s. Rolf Wideroe looked at it also in 1943 and there were comments on negative hydrogen injection into storage rings from R.L. Walker and Milt White in 1955.

The primary goal of the negative ion project is to produce more protons for the high energy physics programme but, at Fermilab, other advantages are expected. Changing the intensity in response to varying needs can be accomplished more easily with ion injection by changing the number of turns injected into the Booster. The ions also provide flexibility for the Linac, which serves not only the high energy physics programme but also the Cancer Therapy Facility and, in the future, the Electron Cooling Ring. When two or more of these programmes are operating simultaneously with different intensity requirements, the needs can be met by varying the length of the Linac hydrogen ion beam pulse.

At the Booster end, the 200 MeV line was modified to transport the ions. A complete replacement for the injection apparatus in the first Booster long straight section was installed. The carbon stripper to undress the negative ions consists of a foil about a micron thick inside the accelerator and since these foils are delicate, a belt arrangement permits up to 115 foils to be moved into the beam in turn. There is, however, no serious damage to the foils from the beam. Carlos Hojvat working in conjunction with Chuck Ankenbrandt, head of the Booster Group, developed the new injection straight section for the Booster. Dave Cosgrave was responsible for much of the mechanical design and installation.

Physics monitor

The weak way to quarks

Since quarks were first proposed fifteen years ago as the basic ingredient from which all strongly interacting particles are built, physicists have tried hard to isolate them. While there are occasional reports of quark sightings (see for example May 1977 issue, page 154), most quark searches see nothing at all. Over the years, the diligence and imagination of many talented experimentalists have failed to find reproducible conditions for catching free quarks.

Meanwhile, the indirect evidence for the existence of quarks has grown considerably and, with the discovery of corpuscular effects deep inside nucleons, now seems to be overwhelming. There is definitely some structure inside the nucleon, and therefore presumably inside other hadrons, but whatever is responsible for this inner structure refuses to reveal itself as free particles.

The acknowledged way out of this dilemma is to adopt a 'quark confinement' philosophy, which says that quarks are there but are doomed to perpetual imprisonment inside the hadrons. Under this philosophy, the binding mechanism of the quark is such that the more strenuous the efforts to prise it loose the more strongly it becomes bound.

In all the painstaking and sometimes bizarre quark searches carried out so far, one approach has not yet been tried — that involving weak interactions. In the view of some physicists, this is an oversight which should be remedied. Now, after a short pilot experiment in the neutrino beams at the CERN SPS, a major quark search using neutrino beams is to be carried out by a CERN/Bologna collaboration, led by Antonino Zichichi.

'Strong interactions are soft, while weak interactions are hard' says Zichichi,,pointing out that in the very high momentum transfer collisions where the interior of hadrons is really being probed, the nature of the strong force can disperse the total momentum transfer over many individual interactions. In this way the momentum transfer in individual quantum exchanges is limited and is insufficient to probe the quark core of the hadron target.

On the other hand, leptons can transfer large amounts of momentum transfer in one go, and the small coupling constant for weak interactions guarantees that any large momentum transfer has come about by a single interaction with the exchange of just one quantum. Multiple exchanges, such as occur readily in strong interactions, are automatically damped. According to Zichichi, the weak interactions do supply the large momentum transfers to pierce through to the deep interior of the nucleon.

Neutrinos, with no strong interaction or electromagnetic affinities, can penetrate the outer cloud of hadronic matter and seek out the point-like quarks within. A neutrino interaction with an inner quark could supply enough sideways 'kick' to free the quark from its hadronic straitjacket so that it emerges from the interaction as a free particle. Zichichi believes that point-like neutrinos could be the ideal tool to seek out the quarks.

However, it seems unlikely that a quark could be produced from these reactions accompanied by just a few other particles. In high energy, high momentum transfer proton-proton collisions, the production of secondary particle 'jets' is widely seen and is believed to be a result of the energy released as the inner quarks are excited.

If a quark were freed from a nucleon, it is likely that a similar amount of energy would be released and the quark would emerge along with a jet of other particles. If so, it would be difficult using counter techniques to pick out the quark from the remainder of the secondary particles. For this reason, the new CERN/Bologna experiment will use a streamer chamber to help identify any fractionally charged particle produced along with large numbers of conventional particles.

In the pilot quark search using the wide and narrow band neutrino beams at the SPS, the CERN/Bologna team used coincidence counters to search for relativistic secondary particles correlated with the bursts of neutrinos and showing signs of fractional charge. Out of 22000 triggers, not many events survived the selection processes.

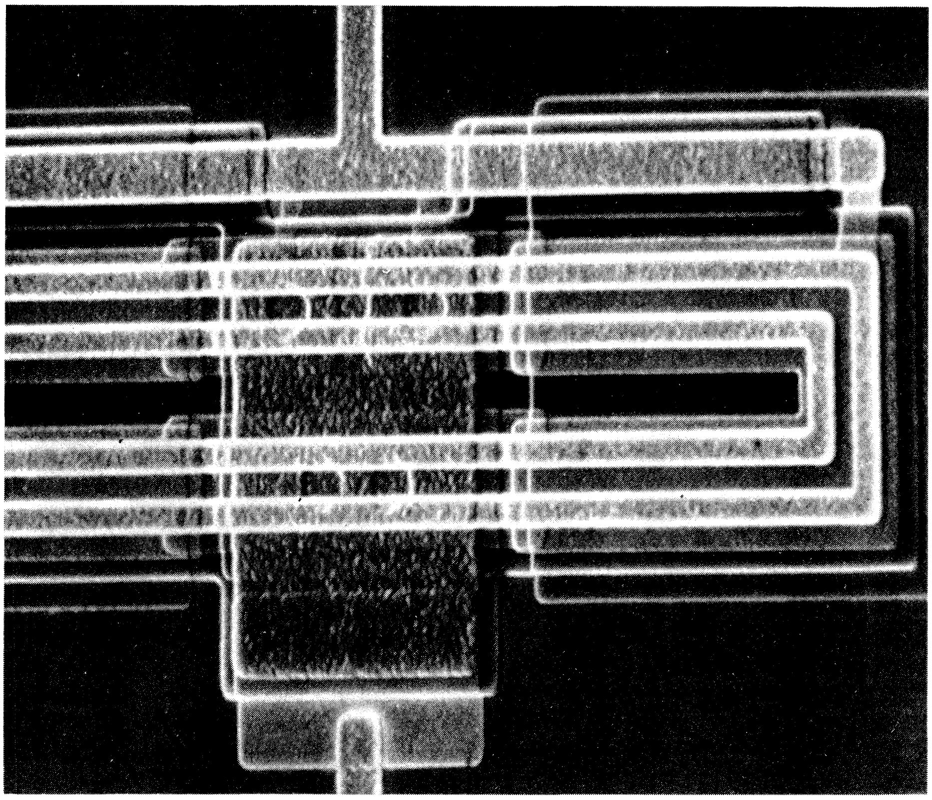
Comparing the pulse heights of these accepted events in the different counters gave a 'scatter plot', which was then compared to a simulation of the possible effects which could be produced by fractionally charged particles.

With the wide band neutrino beam, two events were obtained which fall inside the region of the scatter plot expected to be populated by fractionally charged particles. However, neither event is in the most probable region predicted by the simulation. At this stage, the experimenters prefer to use these results to infer an upper limit on quark production in neutrino interactions and eagerly await the day when a more thorough study can begin.

The CERN/Bologna experiment will be the first to use a new experimental hall for neutrino work, now being built in the neutrino beam in the West Area at the SPS behind the building which houses the Gargamelle bubble chamber.

Cryogenic computers

The prospect of new computers, faster and more powerful than before, could have a significant impact on the high energy physics scene in the late 80s,



The computer equipment of the future? Part of an electron microphotograph of an 'OR' circuit using the superconducting Josephson effect. This circuit, made at IBM's Research Center at Yorktown, New York, has a response time of less than 50 ps.

(Photo IBM)

especially as by then large new machines may be in use, producing more and more particles at higher and higher energies.

Just sixteen years after it was first predicted, and only twelve years since it was first observed and studied, the so-called 'Josephson effect' has been incorporated by IBM scientists and technicians into logic circuits and memory units presumably aimed at a new generation of superconducting computers. Within the next decade, these techniques could result in tiny cryogenic processors, faster and more powerful than the impressive arrays of equipment which cram modern computer rooms.

In 1962, solid state physicist Brian Josephson boldly predicted that electron pairs could quantum mechanically tunnel across a junction between two superconducting materials and give rise to a tiny superconducting current. Subsequent experiments verified his predictions and showed that the currents were very sensitive to current density and applied magnetic fields.

Being quantum mechanisms, these effects happen much faster than those exploited in present semiconductor technologies, while the voltages and currents are down in the millivolt and milliamp regions. As a result, the new circuits are faster and require about a thousand times less current than conventional solid state components.

This in turn implies that heat generation is reduced drastically, so that components can be packed together much more tightly, making for more compact computers. It also means that electrical impulses have to travel much shorter distances, so reducing response times still further. Even using prototype equipment, IBM estimates that a memory of 100000 bits of information could be fitted into a square centimetre and would consume only about a milliwatt of electrical power.

However, if recent trends in the development of silicon-based microcircuitry continue, the cost and performance of 'conventional' computer equipment will continue to be attractive for some time to come. This means that a real breakthrough in performance and power will be required from equipment using the new Josephson circuitry to outweigh the necessary investment in a helium refrigeration plant.

While cryogenic equipment would not be an attractive proposition to, say, an insurance company, a particle physics laboratory already making widespread use of superconducting apparatus might find cryogenic computers easier to swallow.

Solitons – great solitary waves

In August 1834, the British engineer and natural philosopher John Scott Russell saw a strange phenomenon, which now, nearly 150 years later, has important implications for both classical and quantum physics as the underlying mechanisms become better understood.

In Russell's own words, which poignantly reflect the more leisurely tempo of nineteenth century research into natural phenomena, 'I was observing the motion of a boat which was rapidly drawn along a narrow channel by a pair of horses, when the boat suddenly stopped — not so the mass of water in the channel which it had put into motion; it accumulated round the prow of the vessel in a state of violent agitation, then suddenly leaving it behind, rolled forward with great velocity, assuming the form of a large solitary elevation, a rounded, smooth and well-defined heap of water, which continued its course along the channel apparently without change of form or diminution of speed.

'I followed it on horseback,' Russell continued, 'and overtook it still rolling on at a rate of some eight or nine miles per hour, preserving its original form some thirty feet long and a foot to a foot and a half in height. Its height gradually diminished, and after a chase of one or two miles I lost it in the windings of the channel.'

What Russell saw was a 'soliton', although this name was not adopted until 1965, when the phenomenon was rediscovered in the numerical solutions of plasma wave equations. Russell had called his discovery the 'wave of translation' or 'great solitary wave' and developed empirical formulas to describe its motion. He strongly believed that these phenomena were of more than passing importance, but over 100 years went by before his extraordinary foresight was confirmed.

Ordinary 'solitary waves', as opposed to solitons, are found as solutions of linear dispersionless wave equations and are pulse-like disturbances which travel along a particular direction without changing their shape. The introduction of nonlinear effects and dispersion immediately makes things more complicated.

In particular, nonlinear wave equations have no simple superposition principle, so that two different solutions of the equations cannot easily be added together to obtain another solution. In practice, this means that the solitary waves 'scatter' off each other without creating any new disturbance and continue on their way with their original shapes and velocities. These highly stable solitary waves are solitons.

Gravity waves in shallow water are a good example of such a system of nonlinear dispersive wave propagation and the solitary wave solutions of the relevant wave equations correspond to the phenomenon observed by Russell. Similar nonlinear dispersive systems are encountered in other branches of physics, including ionic collisions, acoustics, meteorology, plasma studies, lasers, magnetism and elementary particle theory. Soliton-like phenomena can appear in a wide variety of disguises.

One good classical example of wave behaviour in nonlinear systems is given by an array of vertically-suspended rigid pendulums moving with large oscillations. (In the usual school treatment of simple pendulum theory, the oscillations are considered to be small, so that the equations of motion are linear). If such an array of pendulums is inverted, it has a highly unstable equilibrium position and the slightest nudge to one pendulum makes it swing down and begin to oscillate about a downward vertical. This nudge is then transmitted along the line of pendulums, making each one in turn fall and begin to oscillate below its point of suspension.

This transmitted effect or 'kink' can also travel in either direction along the line of pendulums, giving 'antikinks' as well as kinks. A similar effect is found in ferromagnetism in the Bloch wall which separates domains of opposite magnetization. When one of the stable spin configurations is nudged, it flips over to lie in the opposite direction and this kink is transmitted through the ferromagnetic material. These kinks and antikinks travelling in opposite directions can produce soliton-like 'kink and antikink pairs' and effects due to such states have been observed in spectroscopy.

A different arrangement of coupled oscillators provides an example of a true soliton. Instead of vertically suspended rigid pendulums, imagine a line of rods joined by a horizontal torsion wire, each rod securely fixed at its middle to the wire. In equilibrium, these rods rest horizontally about the wire. If one of the rods is given a sharp nudge, this nudge is transmitted through the torsion wire to each rod in turn. The wavelike movement through the line of rods is a soliton.

One striking property of classical solitons is that, although they derive from a nonlinear field theory, they behave very much like particles — they are localized, they have a distinct energy and they are stable. This makes them interesting to particle theorists looking for new explanations of particle behaviour but the quantization of the necessary nonlinear field theories can be troublesome, so that the implications of quantum solitons are still to be explored fully.

In the meantime, solitons provide theorists with an additional method of assessing different quantum field theories and another framework for developing methods to overcome the limitations of field theory techniques.

People and things

Fermilab budget

We reported in the March issue the resignation of Professor R.R. Wilson as Director of the Fermi National Accelerator Laboratory in protest at the 'inadequate' funding of the Laboratory. Since then the Subcommittee of the USA House of Representatives has added substantial amounts to the budget submitted to Congress by President Carter. The changes are believed to include an increase from $ 39 million to $ 50 million for the Energy Doubler construction with $ 20 million, rather than $ 10 million, to be available in the 1979 Fiscal Year and $ 30 million for 1980. A further $ 24 million has been tabled for 1981 for completion of the Tevatron project.

Overall there has been strong reaction to the President's budget proposal of $ 295 million for the Department of Energy high energy physics programme (plus about $ 25 million via the National Science Foundation) which is below the 'Low Budget Case' reviewed by the HEPAP Subpanel chaired by Jack Sandweiss in 1977. The Subpanel described this as follows:

'The consequences to the program would be a drastic reduction or termination of the lower energy fixed target and colliding beam programs, and a reduction in the level of support and number of university groups. In addition, levels of use of the new electron colliding beam facilities, of Fermilab, and of the proton colliding beam facility will only be at about 50 percent level. Further, the provision of equipment necessary to exploit these facilities will be substantially slowed. This funding level on a long term basis is close to that which would require a drastic revision in the long range program and probably is not adequate to keep the United States in a world competitive position in this field.'

In our February issue we carried a photograph of a block of leadglass which had come to grief in a very artistic way at Fermilab. CERN's contributions to modern art include a disintegrated bubble chamber window. Two pieces of this glass have been specially decorated by Mario Bellettieri, under the guidance of Eliane de Modzelewska, as mementos for retiring Council members J.H. Bannier and W. Gentner.

1. Antonino Zichichi, newly elected President of the European Physical Society.

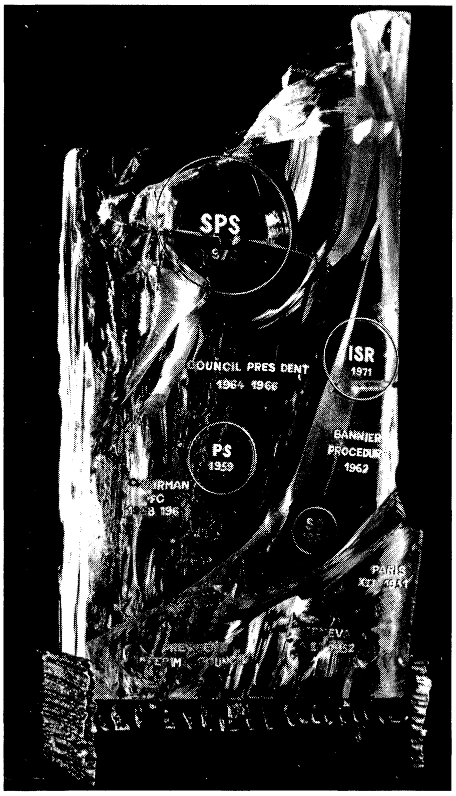
2. Accelerator specialists from China (left to right: — Ho Lung, Han Tsien, Fang Shou-Hsien, Tsao Tsan) on an introductory tour of the CERN site with Eddie Powell of the Visits Service. They are at CERN for several months working on the design of their 30-50 GeV proton synchrotron.

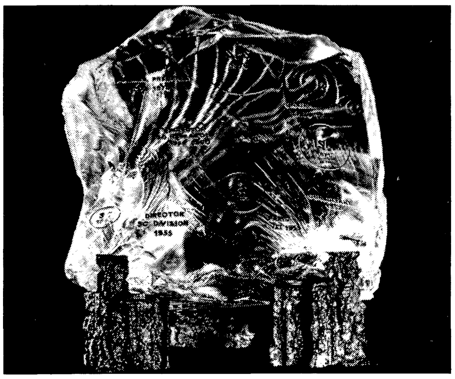
(Photo CERN 2.4.78)

European Committee on SRF

The European Science Foundation has organized a look at the scene in Europe with regard to synchrotron radiation facilities. The synchrotron radiation user community has grown so dramatically in recent years (see also the report from the DESY Laboratory page 115) that a broad look at present and future needs seemed desirable. The ESF has issued a report 'Synchrotron Radiation — a Perspective View for Europe' encouraging continued use of all existing facilities and urging that they be supplemented by facilities dedicated exclusively to this research. A particular recommendation was the building of an electron storage ring to provide beams of hard X-rays.

A Committee has been set up to consider the design of such a facility. Two sub-groups (on the machine, chaired by D.J. Thompson of Daresbury Laboratory, and on the instrumentation, chaired by D. Buras of Riso National Laboratory) met at the CNRS headquarters in Paris on 8 March. They are working towards producing a design proposal for an X-ray source by the end of 1979 so that the machine could be built as a joint European facility in the 1980s. The sub-groups will meet regularly at the various synchrotron radiation Laboratories in Europe.





Neutrons at Argonne

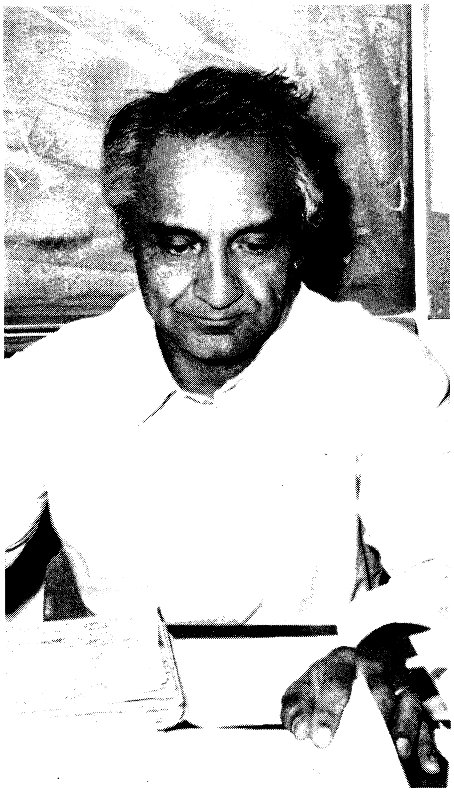
The USA President's budget for Fiscal Year 1979 included $6.4 million construction money for the first phase of the intense pulsed neutron source (IPNS) planned at the Argonne National Laboratory. A year ago, the Laboratory received $ 0.4 million to plan the facility. In a first phase, the 500 MeV proton synchrotron, Booster II, will be used providing 5 x 10^{12} protons per pulse at 30 Hz. Construction could begin in 1979, given Congressional approval, for completion in 1981. IPNS-II could follow using a 800 MeV High Intensity Synchrotron succeeding the ZGS which is scheduled to close down as from the end of Fiscal Year 1979. If construction begins in 1980 completion is expected in 1985. Another high intensity spallation neutron source, SNS, is to be built at the Rutherford Laboratory following the closedown of Nimrod in June of this year.

Accelerator history project

A project to gather information and material on the history of accelerators is under way at Fermilab with the aim of assembling historical material on particle accelerators and on Fermilab in particular. Several other institutions have already done some work in this area, notably at the American Institute of Physics' History of Physics Center in New York and the Bancroft library project at U.C. Berkeley. Paul Forman's work on the history of accelerators exhibit at the Smithsonian Institute in Washington has also developed a great deal of interesting material. The Fermilab project hopes to draw upon the experience of these activities and complement their efforts.

Significant documents in the accelerator area including reports, photographs, drawings and pivotal log and data books are being collected. Equipment artefacts of reasonable, and even unreasonable, size are being gathered. At present there is a search for a Wimshurst machine, preferably one with a certain stylishness and an elegant contribution would be suitably acknowledged. Collections of personal notes and records of significant contributors to the field may also be incorporated. A room adjacent to the library has been set aside for a document centre. Artefacts will be displayed in the Central Laboratory Building and elsewhere around the site.

Another phase of the project is to collect the reminiscences of some of the individuals who have played an important role in the development of particle accelerators. In-depth oral histories have become a highly developed art in the last years but this type of interview requires a well prepared historian as interviewer. At Fermilab a complementary approach is being followed. Historical figures are invited to the Laboratory to lecture on the developments with which they were associated and also attend a luncheon



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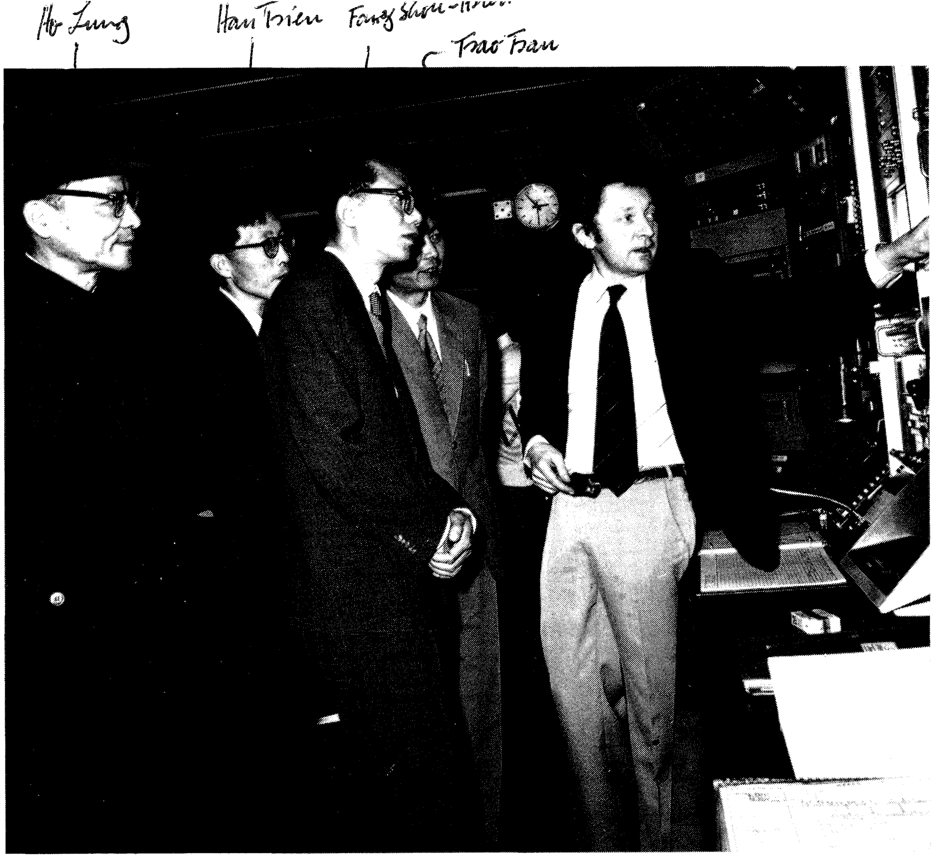

2.

with scientific colleagues. The luncheon conversations and the lectures are recorded on tape. William Brobeck, Herb Anderson and I.I. Rabi have recently been 'documented' in this way.

Lillian Hoddeson (a physicist, interested in the history of modern physics) has joined the project for a stint as Resident Archivist at Fermilab. She has recently reviewed the development of solid state physics at Bell Laboratories in Physics Today. She is working on a similar project at Los Alamos and coordinating all of these activities with the American Institute of Physics project.

Members of the guiding committee welcome advice on this project. The committee includes Bob Wilson, Dick Carrigan, Frank Cole, Ned Goldwasser, Drasko Jovanovic, Dick Lundy, Lee Teng and Roger Thompson.

On People

Professor Antonino Zichichi, INFN and CERN, became President of the European Physical Society on 1 April. The Vice-President is Professor Sergei Kapitza from the Moscow Institute for Physical Problems.

A misinterpretation of a communication led to the February issue carrying the information that Giorgio Bellettini has become Director of the National Laboratories of Frascati. Professor Bellettini has been Director of Frascati but that post is now held, since November 1977, by Professor Renato Scrimaglio. Our apologies for any embarrassment caused by this error.

Henry Bohm has been elected President of the Argonne Universities Association which operates Argonne National Laboratory. He is a solid state physicist of Austrian origin, now Professor of Physics at Wayne State University. He has worked in industry, at the Universities of Cornell, Purdue and Lancaster and with the Science Research Council in the UK.

The recipient of the 1978 Dannie Heineman Prize is Elliot Lieb of Princeton University who, together with Walter Thirring of Vienna University, in 1975 simplified the proof of the stability of matter in bulk, and had previously (in 1969 with Joel Lebowitz of Rutgers Univeriesty) described how matter in bulk obeys the laws of thermodynamics.

John Polkinghorne, Professor in the Department of Applied Mathematics and Theoretical Physics at the University of Cambridge, is giving up physics next year at the age of 48. He plans to spend some time at a theological college before entering the Church. He is the second distinguished Cambridge theoretician to give up particle physics in recent years. His former colleague, Richard Eden, now concentrates on energy research.

A group of four accelerator specialists from the Institute of High Energy Physics at Peking arrived at CERN at the beginning of April to study accelerator construction problems during stays ranging from two to four months. The group is led by Ho Lung, Head of the Accelerator Division at the Institute, and includes Fang Shou-Hsien (accelerator theorist), Tsao Tsan (looking after magnet design and measurement) and Han Tsien (looking after injection and ejection systems). China has recently announced its intention to build a 30 to 50 GeV proton synchrotron near Peking which could later be used as injector for a higher energy machine.

On the morning of 23 May, a ceremony in memory of Bernard Gregory will be held at the Ecole Polytechnique under the Presidency of L. Leprince-Ringuet. Speakers will be H. Curien, A. Astier, X. de Nazelle and I. Solomon.

A.N. Skrinsky has been appointed Director of the Institute of Nuclear Physics at Novosibirsk. Professor Skrinsky has been Acting Director since the death of G.I. Budker and has been a prominent scientist at the Institute for many years.

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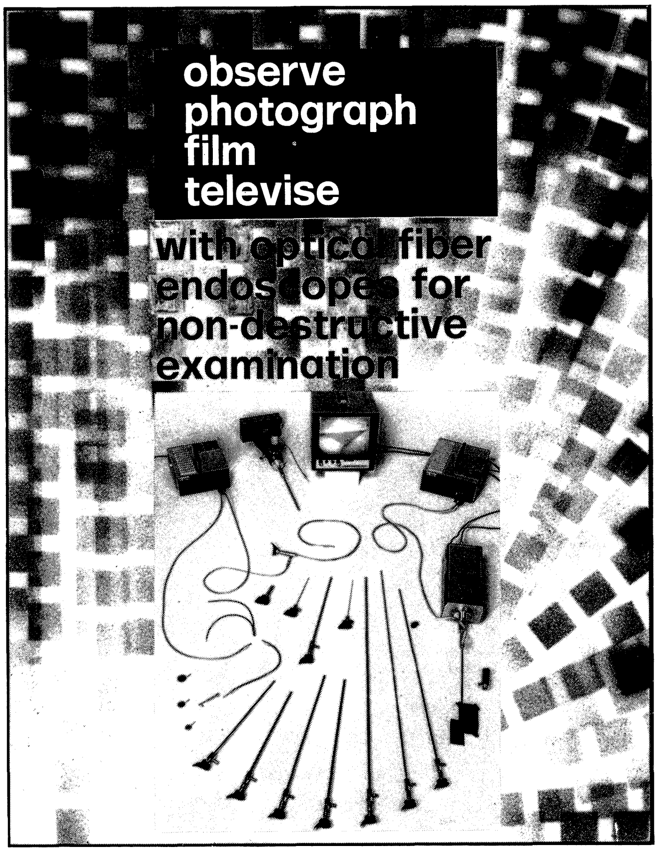

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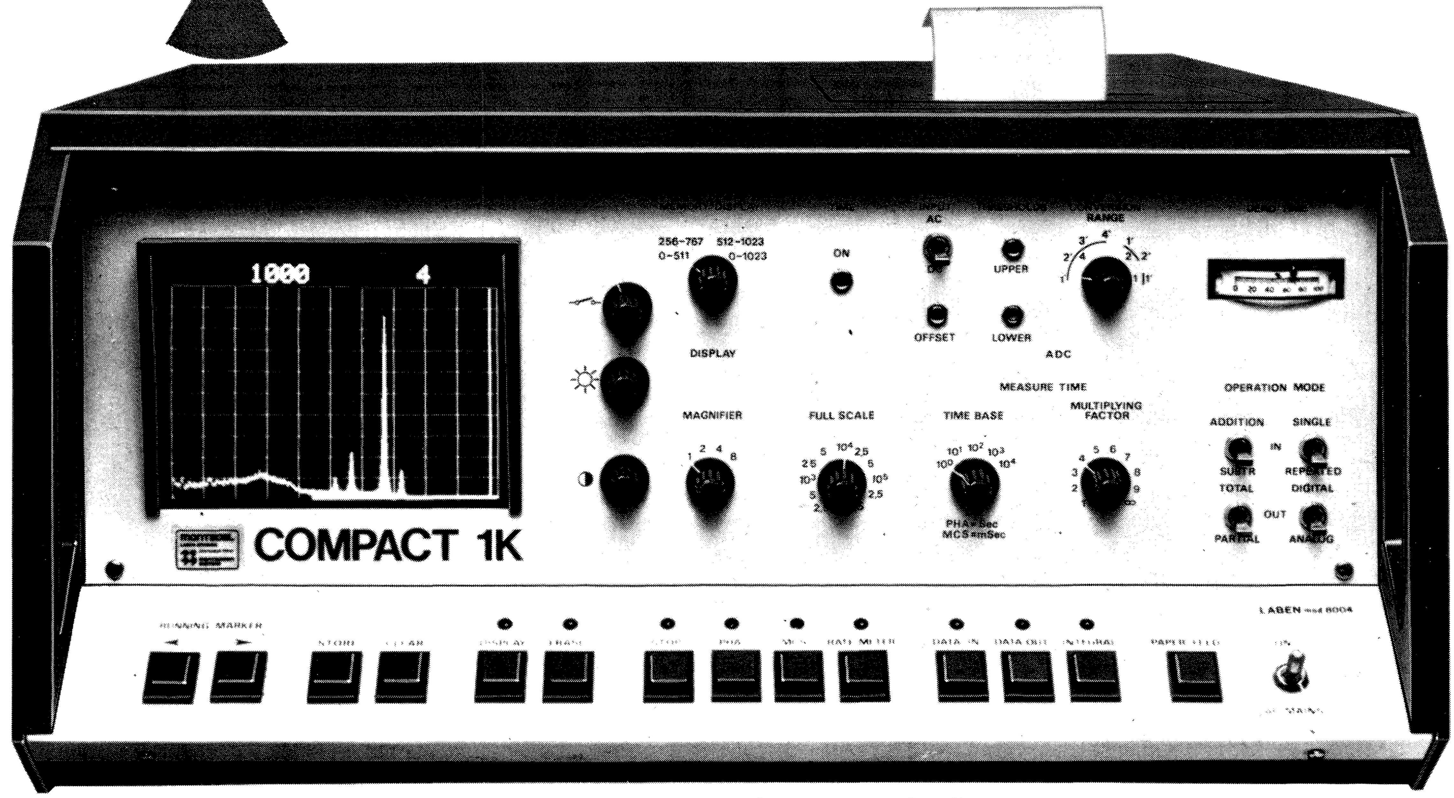

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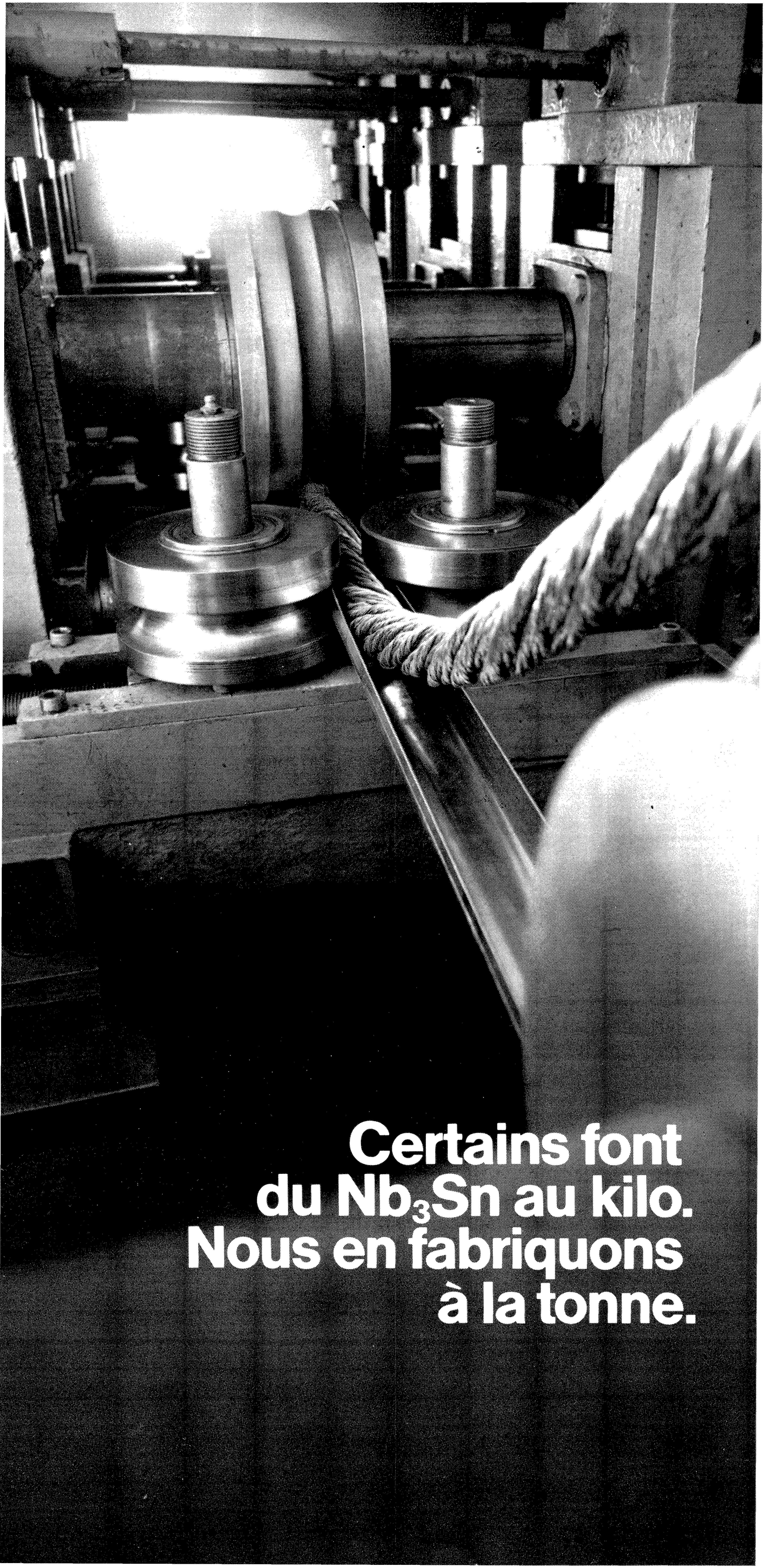
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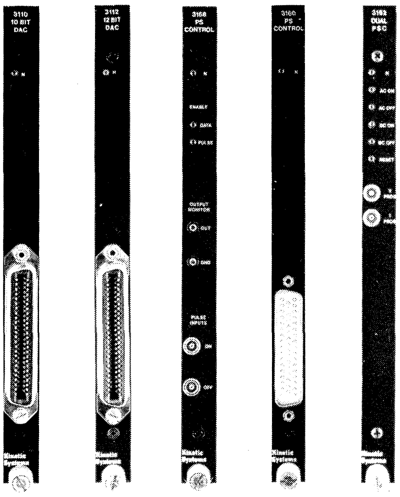

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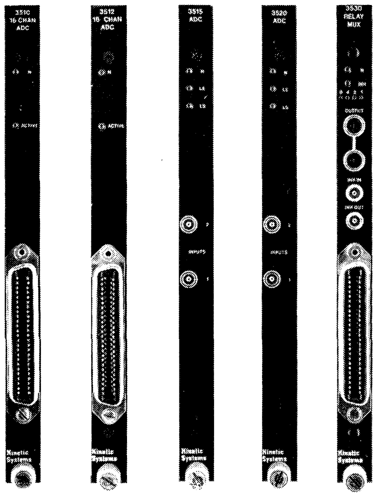

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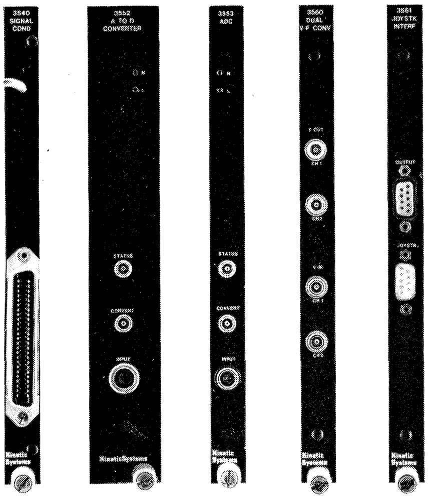

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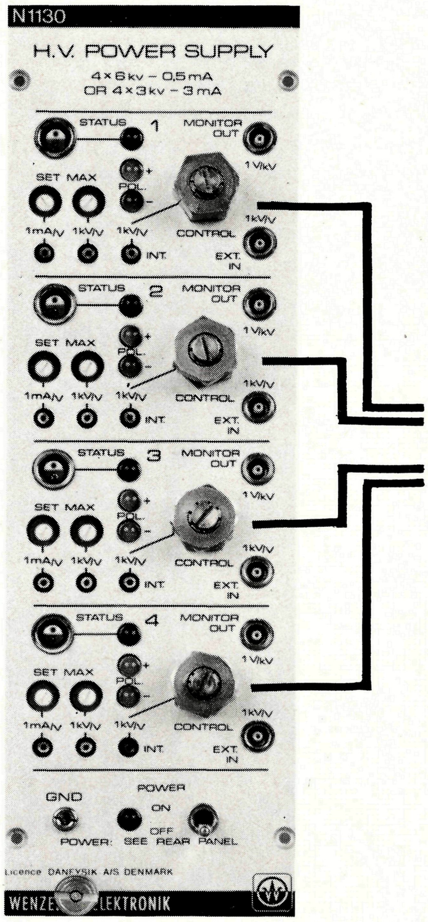
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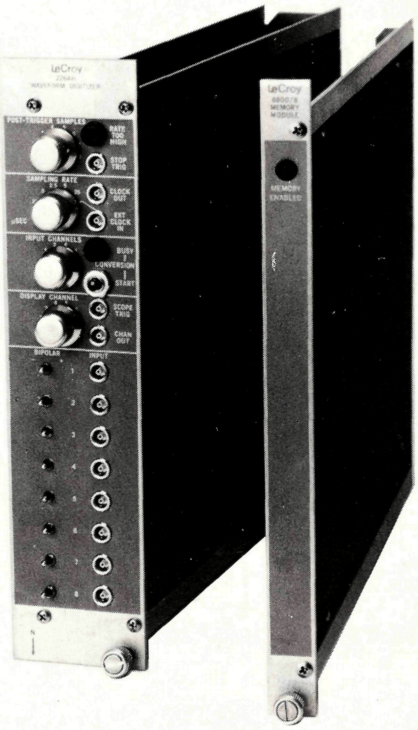
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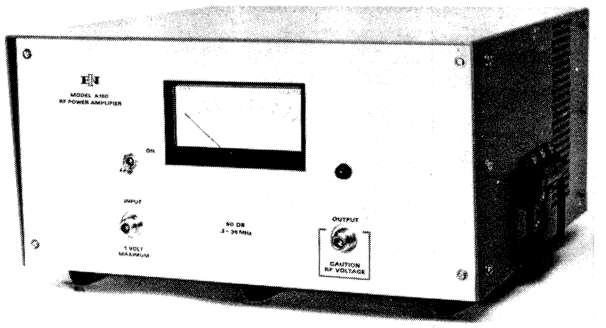

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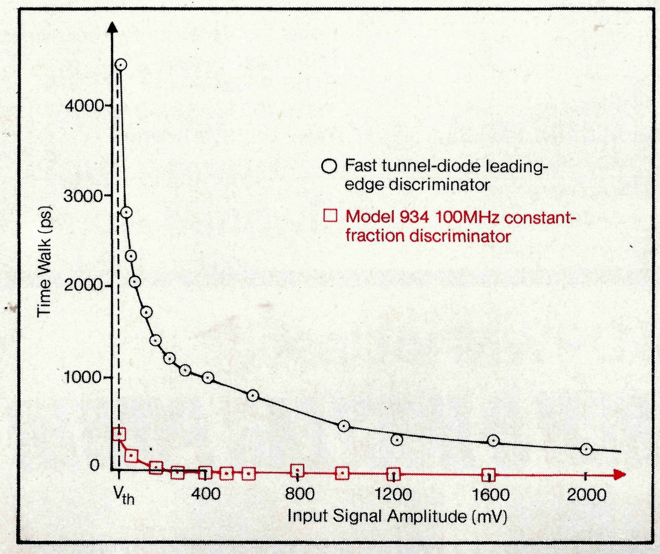

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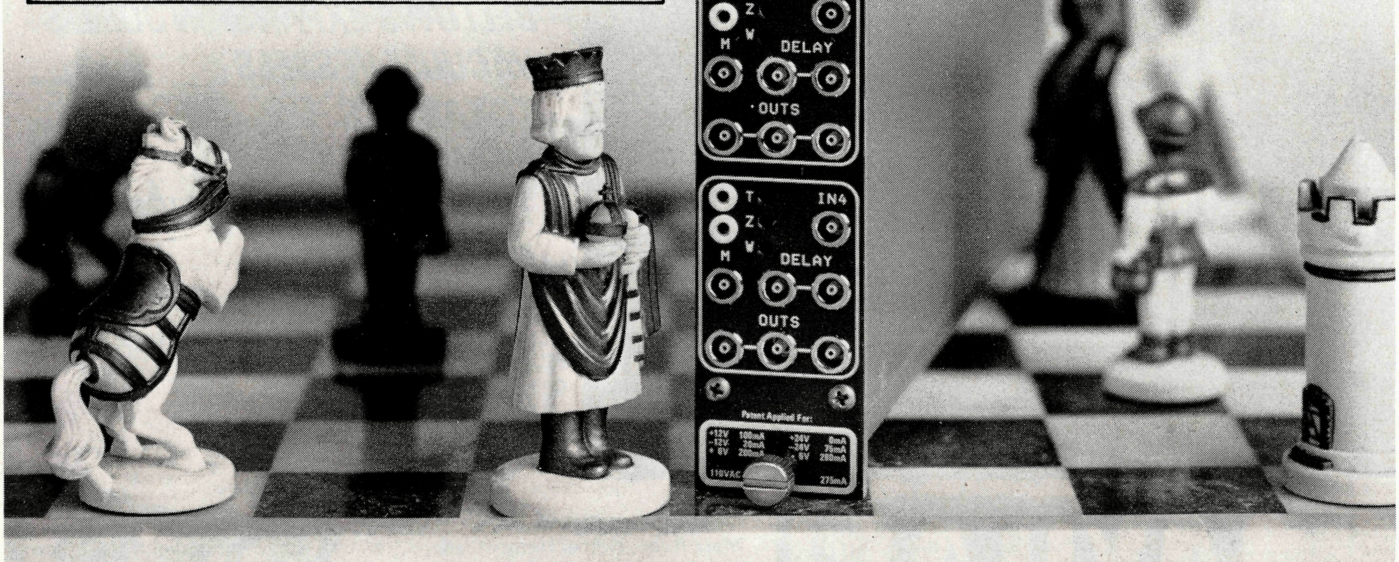

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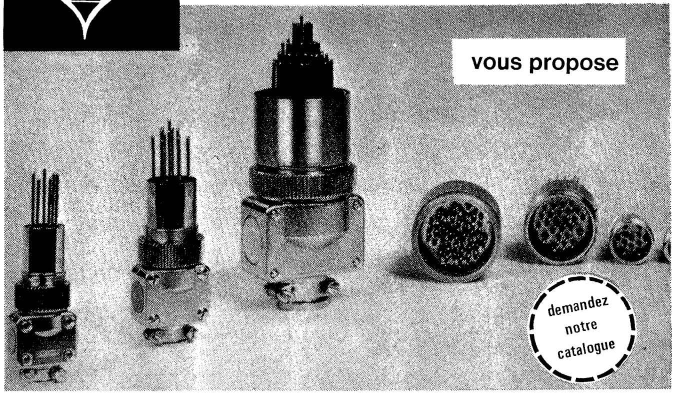

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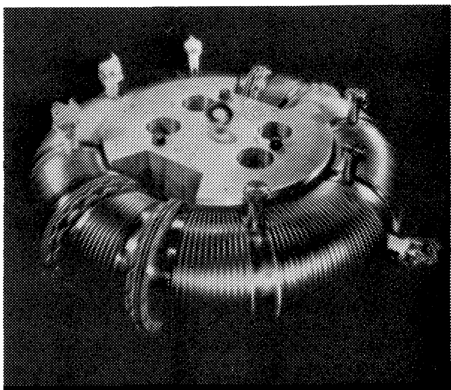

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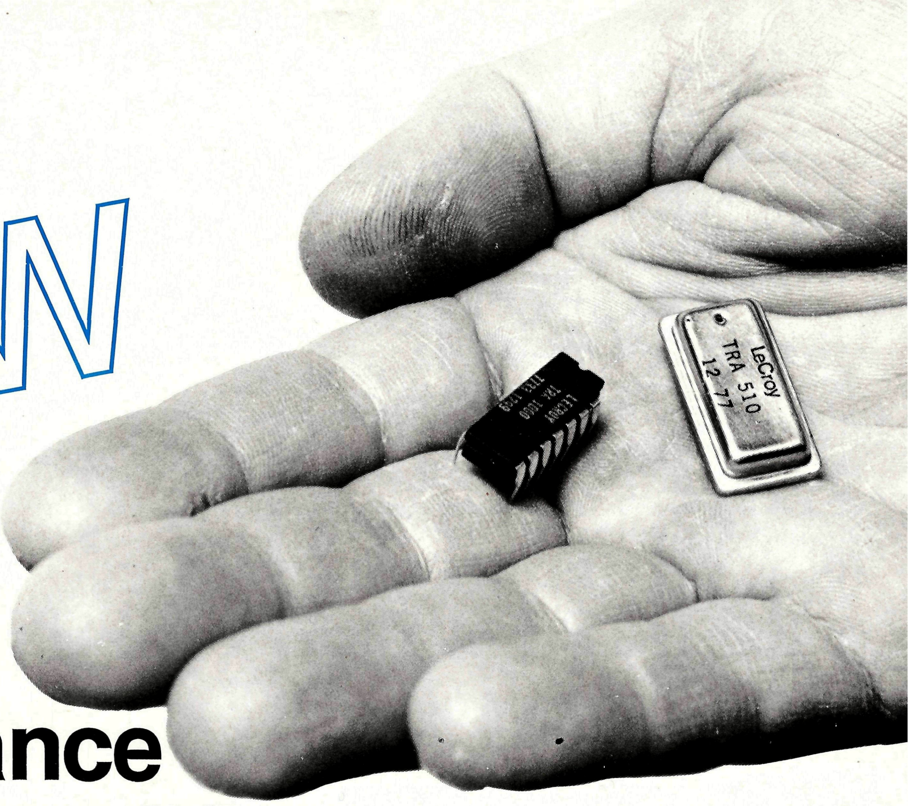

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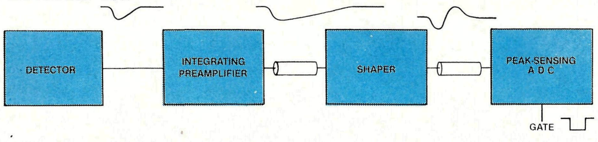

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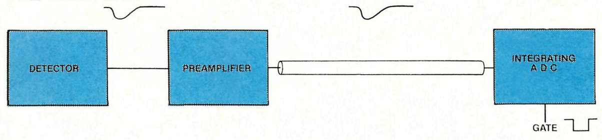

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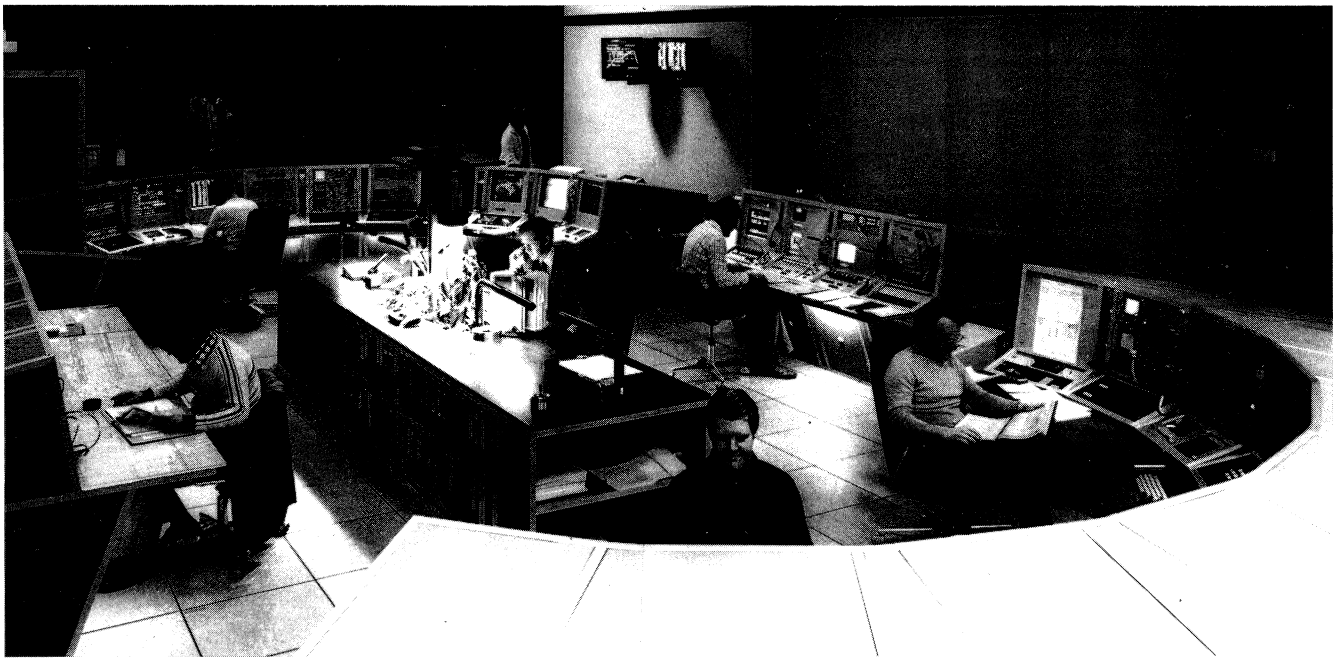

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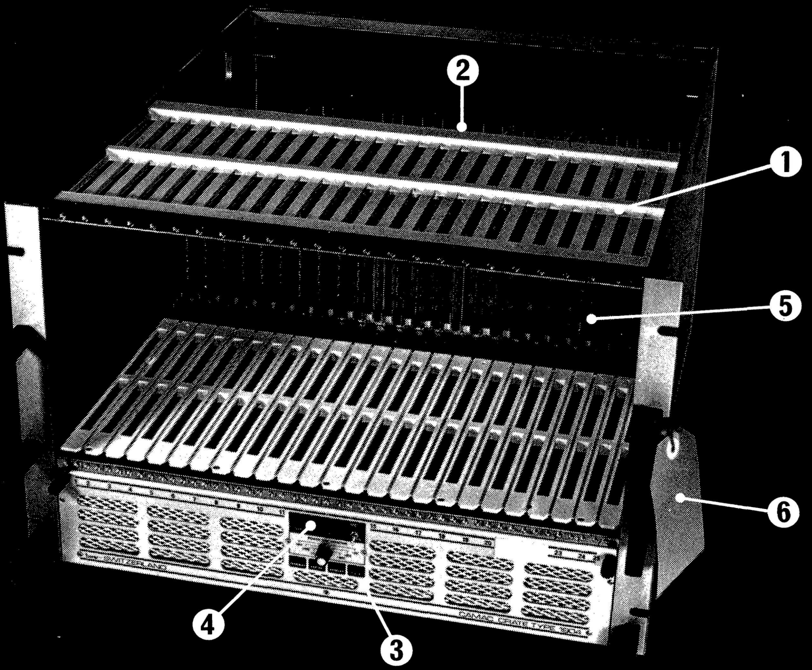
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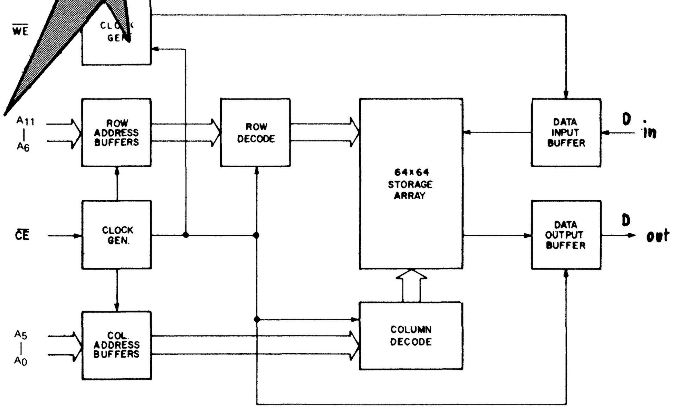
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A6
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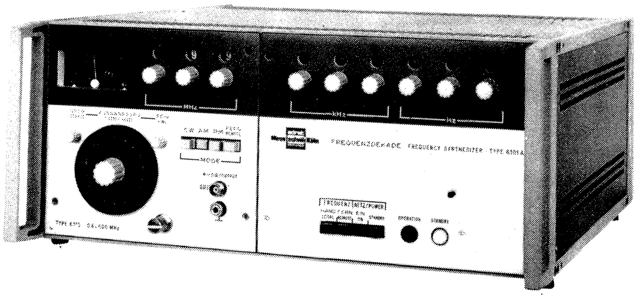

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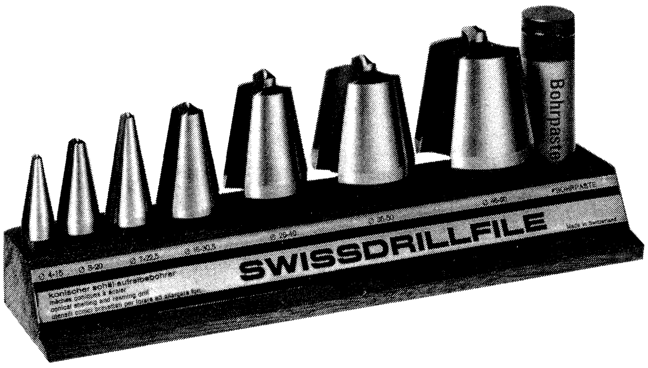
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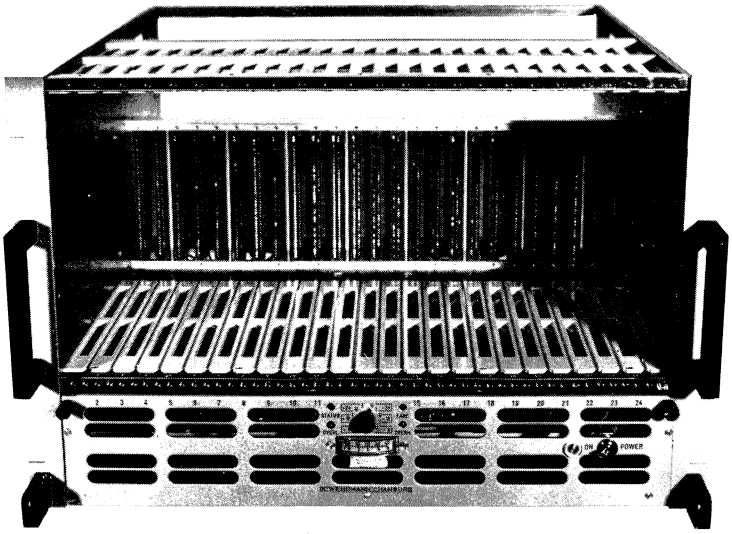

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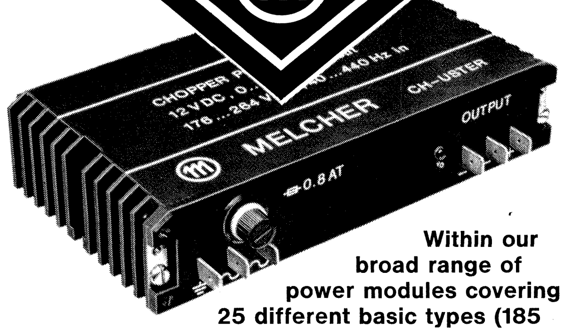

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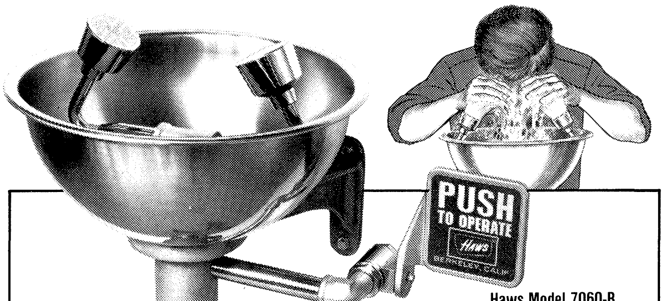

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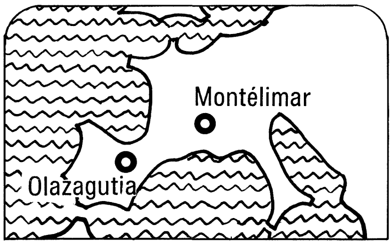

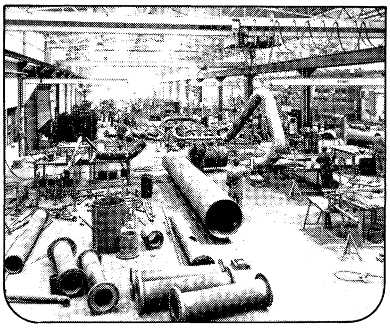

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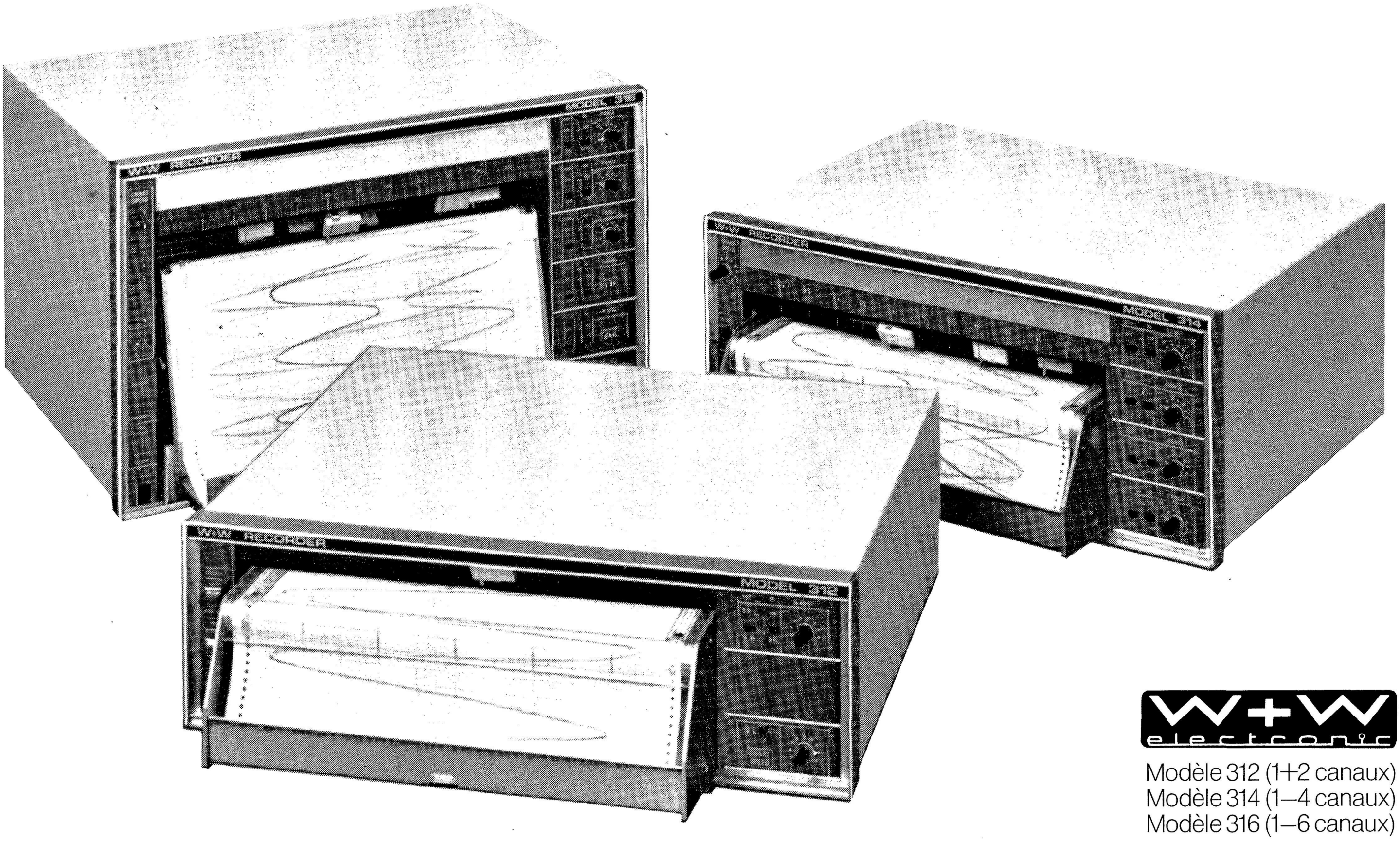

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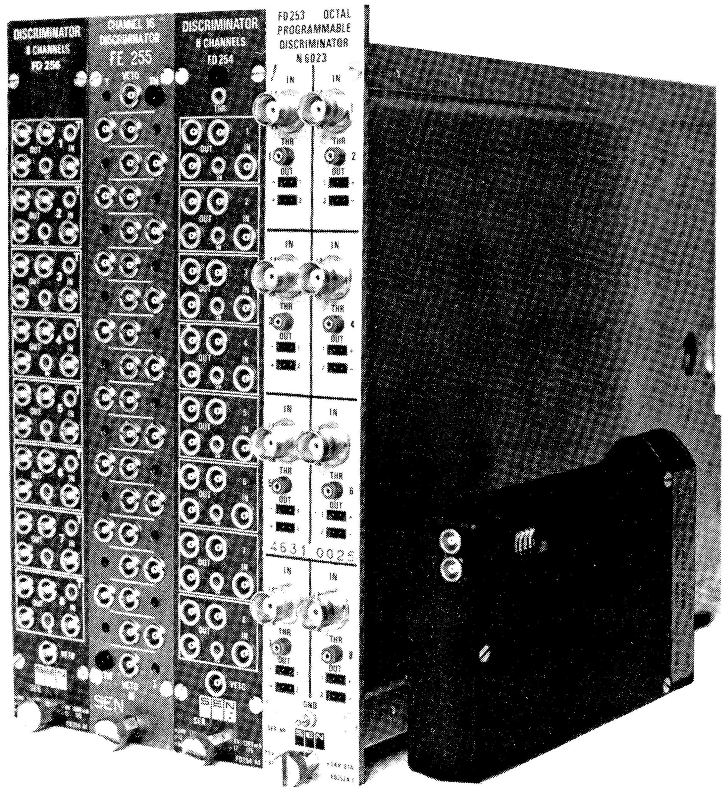

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Updating	yes	yes	yes	yes
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Output width (ns)	5 to 35 computer controlled*	<5 to >40	<5 to >40	<5 to >40
Nb of outputs	2	3	1	3
Fast veto	no	yes	yes	yes
Typical rate (Mz)	100	100	100	100
Double pulse resolution (ns)	10	⩽10	⩽10	⩽10
Time slewing (ns)	⩽1	⩽1	⩽1	⩽1
Input connector	BNC	Lemo	Lemo	Lemo
Output connector	AMP	Lemo	Lemo	Lemo
Input-output delay (ns)	19 to 34 computer controlled*	⩽20	⩽20	⩽20
Output level	MecL	NIM	NIM	NIM

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