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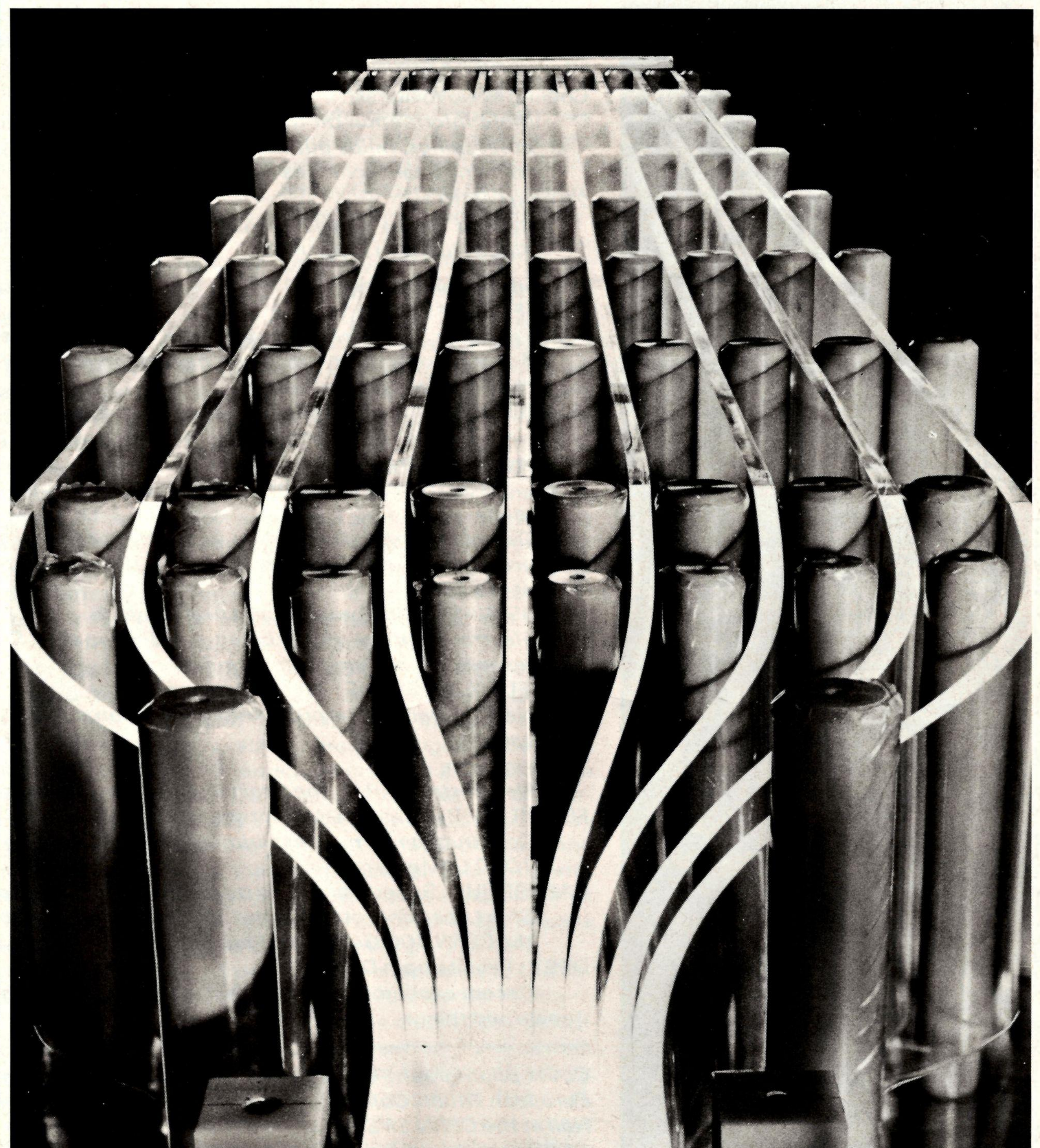

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Contents

Cover photograph: One of the 3.4 m scintillator light guides being built for the European Muon Collaboration experiment to be mounted in the North Hall at the CERN SPS. It has nine blades of the Plexipop scintillator developed at CERN and is destined for hadron detection. The design and manufacture are being supervised by the Rutherford Laboratory and Lancaster University. Other units containing six blades will be used in electron/photon detectors. They are to be made up into sets, 40 for hadron detectors and 40 for electron/photon detectors, in a 128 ton calorimeter. Construction of these light guides has required considerable skill by the manufacturers, Carville Ltd. (Photo Rutherford)

Gauge theory predictions and muon decay

In his talk at the Chicago Meeting of the American Physical Society in February, on the occasion of the award of the 1977 Dannie Heinemann Prize for Mathematical Physics, Steve Weinberg reviewed the very successful gauge field theories and their experimental implications in various energy ranges. One of these implications, concerning muon decay, received a lot of attention since preliminary results at the Swiss Institute for Nuclear Physics, SIN, seemed to be seeing such decays for the first time.

The gauge theories have evolved from the work of Weinberg and Abdus Salam in 1967 and 1968 and they explain many of the observed features of particle behaviour. Their basic equations have identical form for both the weak and the electromagnetic interactions so that these two seemingly disparate categories of particle behaviour can now be explained in the same way. The theories have been renormalized, thanks to the work of Gerard't Hooft, Ben Lee and others in 1971, and have been extended in an attempt to take in the strong interactions also.

They have had dramatic success in explaining the discoveries of recent years, beginning with the observation of the neutral current type of weak interaction at CERN in 1973 and then with the 'new physics' following the J/psi discovery at Brookhaven and Stanford at the end of 1974.

The theories make predictions about what will be found when higher energies become available. For example, they set the masses of the carriers of the weak force, the intermediate vector bosons — the charged version, W, is predicted at about 65 GeV and the neutral version, Z, at about 80 GeV. The search for these particles is one of the main motivations for the higher energy facilities, such as proton-antiproton colliding beams, which are now being mooted.

The theories also postulate a set of scalar particles in a similar mass range. Such scalar particles were considered by Peter Higgs in 1964 and are usually referred to as the Higgs bosons. He was following up a 1960 paper of Y. Nambu, which carried spontaneous symmetry breaking from statistics into particle physics and on subsequent work by Jeffrey Goldstone (with Salam and Weinberg) which predicted massless particles called 'Goldstone bosons' which were not seen. Higgs showed that Goldstone bosons would not be a consequence of the Nambu ideas if gauge theory was used and if integral spin particles were involved. These are the postulated Higgs bosons responsible for spontaneous symmetry breaking.

If Higgs bosons exist, they will affect particle behaviour at all energies. However, their postulated interactions are even weaker than the normal weak interactions. The effects would only be observable on a very small scale and would usually be drowned out by the stronger interactions.

Three phenomena, which line up with the existence of Higgs bosons, could be observable in the presently available energy ranges. The first phenomenon was seen at Brookhaven in 1964 — the violation of charge-parity symmetry in neutral kaon decay into two pions. The level of about one in a thousand, at which this symmetry breaking occurs, can be explained as due to the exchange of Higgs bosons (as was first shown by T.D. Lee).

The second phenomenon is the existence of a neutron dipole moment, the deviation of the electric charge distribution in the neutron from perfect symmetry, at the level of about 10^{-24} (as was first shown by Ben Lee). Experiments so far have just about reached this level of precision but have not yet seen a dipole moment. An experiment at present under way at the Laue-Langevin Institute, Grenoble, could achieve sufficient accuracy to see the effect for the first time.

The third phenomenon is the breakdown of muon conservation. J.D. Bjorken and Steve Weinberg have calculated that this breakdown could occur at the level of 10^{-8} (though the assumptions that are fed into the calculation could put this figure out by an order of magnitude). Up to now the observed behaviour of the leptons has put them into two distinct categories with 'electroneness' (the electron and electron-type neutrino) or muoness (the muon and muon-type neutrino). If muon conservation holds, then the muon should always decay to give a muon-type neutrino and never decay into an electron and a gamma.

An experiment at SIN is attempting to set a new lower limit to the observation of this decay —

muon → electron + gamma

Using the excellent muon beam available from the 590 MeV cyclotron, giving 5×10^5 stopped positive muons per second, they have been looking for the decay with a sodium iodide detector $16 \times 16 \times 24\,cm^3$ to spot the gamma. The preliminary data seems to have a few events which violate muon conservation to the level of a few times 10^{-8}, close to the prediction of the calculation based on the existence of the Higgs bosons. However, the SIN team stress the preliminary nature of their data. The experiment is being continued with an improved detection system. A team at the TRIUMF cyclotron is also looking for this decay. At the time of writing, they have not seen any events to a level below that of the SIN data.

Even if the 'forbidden' muon decay does not appear at the level of accuracy given by these present experiments, Steve Weinberg has enough confidence in the Higgs bosons to believe that it will be seen some day.

Cooling at Novosibirsk

In our December issue, we outlined the new accelerator techniques of beam cooling which may prove to be the most important advance in accelerator technology for many years. The techniques come in two varieties - electron cooling developed at Novosibirsk and stochastic cooling developed at CERN. We have collected some more detail on the Novosibirsk work.

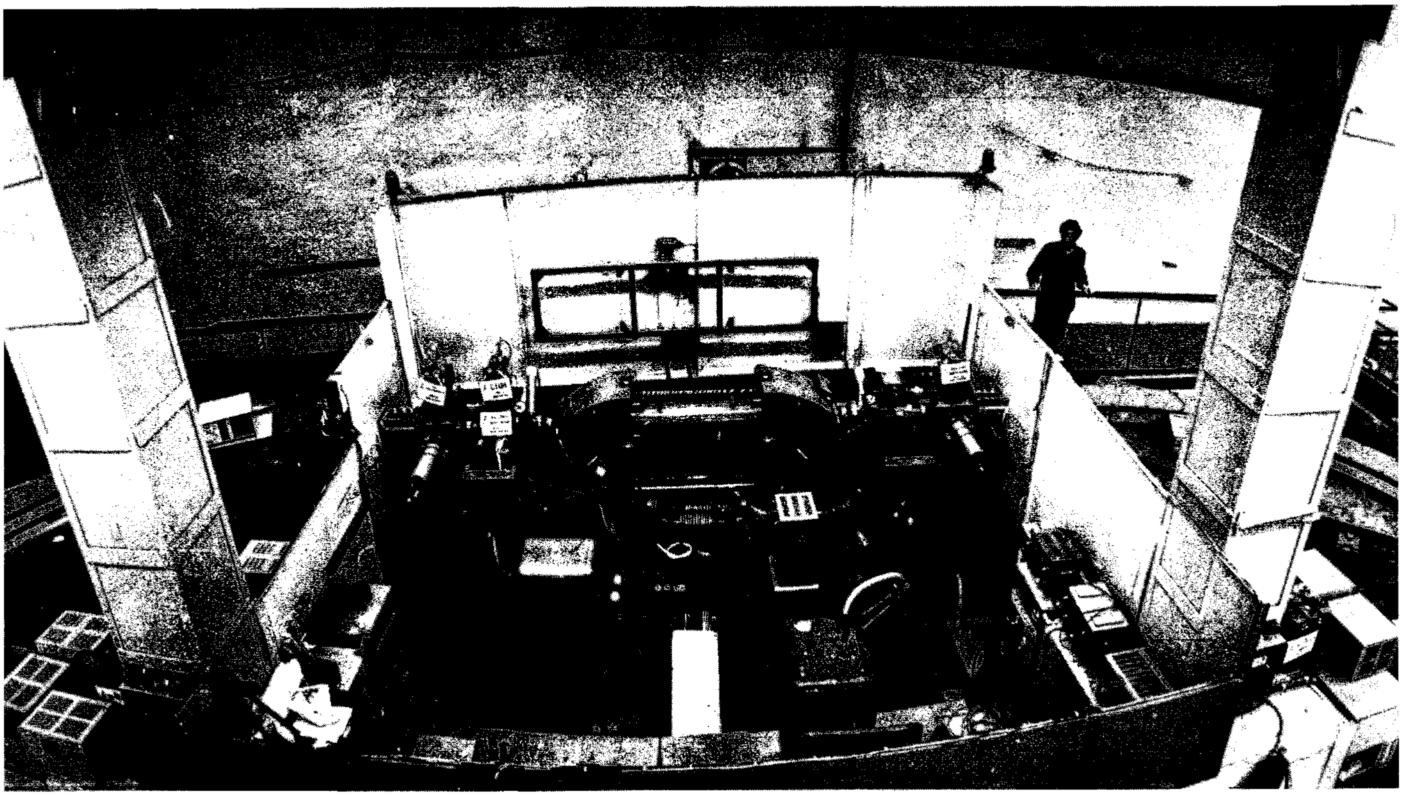
The idea of electron cooling was first proposed by Gersh Budker at the Saclay storage ring meeting in 1966. He was thinking of ways to achieve intense beams of antiprotons for a 25 GeV proton-antiproton colliding beam project known as VAPP-NAP. A reasonable flux of antiprotons can be obtained from a target bombarded by a proton beam of sufficiently high energy but the antiprotons would emerge with a variety of momenta. An attempt to hold the antiprotons in an accelerator ring would retain only a small proportion of them since the accelerator would be tuned correctly for only a small range of momenta.

If, however, the antiprotons could have their momenta concentrated around a particular value then the accelerator, or storage ring, could accept and hold a greater proportion of the initial flux and high intensity antiproton beams would become feasible.

The Budker idea is to send an electron beam along with the antiproton beam, travelling in the same direction and at the same velocity. As the two kinds of particle bounce off one another, there is an energy exchange between them which has the effect, if the electron beam has a very small momentum spread, of reducing the momentum spread of the antiprotons. Perhaps influenced by the Siberian environment, the technique was called electron cooling — the electrons cool the hot gas of the heavier particles by absorbing excess energy. The procedure is rather analogous to mixing gases at different temperatures, where they eventually reach on equilibrium temperature, except that the electron gas in the cooling scheme is extracted and constantly reinjected at the desired temperature.

Experiments started in 1974 on a small storage ring called NAP-M (NAP is the abbreviation of antiproton storage ring and M stands for model). It has the form of a square with rounded corners — the circumference is 47 m and the length of the four straight sections is 7.1 m each. After subsequent refinements (finished in January 1976) the magnetic fields are stable to better than 1 part in 10^5, the vacuum is better than 5×10^{-10} torr and the whole installation is under computer control.

One of the straight sections is used for injection of a proton beam from a 1.5 MeV electrostatic machine. The injected beam intensity is about 0.5 mA per pulse during 4 μs and the pulses are stacked to build up an orbiting



Partial view of the storage ring NAP-M, at the Institute of Nuclear Physics Novosibirsk where the electron cooling experiments have been carried out. On the far side of the ring is the cooling straight section where the electrons and protons travel together (the wedge shaped units bend the electrons in and out).

(Photo Novosibirsk)

Members of the Novosibirsk team, proudly displaying their first successful results from an electron cooling experiment in June 1974. Left to right the experimenters are I.N. Meshkov, B.N. Sukhina, D.V. Pestrikov, V. Ponomarenko, V.V. Parchomchuk and N.S. Dikansky. Other participants in the experiments are G.I. Budker, A.F. Buluchev, Ya. S. Derbenev, V.I.Kononov, V.I. Kydelainen, R.A. Salimov and A.N. Skrinsky.

(Photo Novosibirsk)

proton beam of up to 100 μA. A second straight section is used for the r.f. accelerating system. It can increase the proton energy up to 150 MeV in an acceleration time of 30 s. Most experiments were, in fact, carried out at a lower energy of 65 to 85 MeV.

A third straight section is used for beam observation. Proton beam dimensions are measured by three techniques. Aperture probes can be moved across the beam at low velocity and scintillation counters can detect protons scattered at a small angle from the probe edge. A related, non-destructive, method is to move a thin (2 to 3 μm) quartz filament rapidly across the beam and to detect the scattered protons. A third method is to fire a magnesium vapour jet across the vacuum chamber aperture and to detect and locate the electron ionization caused in the area crossed by the proton beam.

An additional beam observation method comes from the fourth straight section where the cooling is applied. The protons and electrons can combine to give neutral atoms which are not, of course, deflected by the magnetic fields and emerge in the beam direction as a beam of fast neutral atoms extremely well collimated — for example, giving a spot diameter of less than a millimetre some 10 m from the cooling straight. This long lever arm makes it a sensitive method to measure the size of the proton beam.

The electron cooling system has an electron gun able to provide electron beams of energy up to 100 keV and of intensity up to 1 A. For most experiments, with 85 MeV proton beams, it ran at 45 keV with currents around 0.8 A. The electrons are bent into the storage ring straight section and travel with the protons for a cooling length of 1 m. They are then bent out again and collected so that current is returned to the gun. In the straight section a solenoidal field caused the electrons to execute tiny spirals around longitudinal lines of force. This field is stable to better than 5×10^{-4} and the electron energy is stable to better than 5×10^{-5}. The electron energy has to be tuned so that the velocity difference between the protons and electrons is less than 1×10^{-3} before cooling occurs. The tuning process is, however, quite straightforward — the energy is adjusted until cooling is seen to occur.

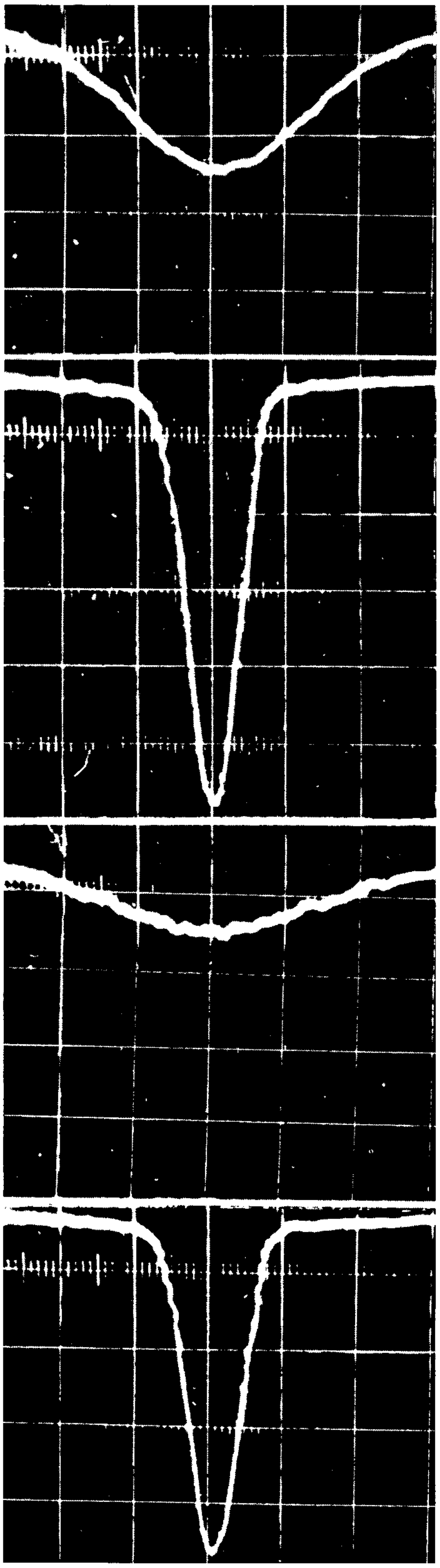
The main result of the cooling experiments is as follows: A 85 MeV proton beam of between 20 and 100 μA can be cooled by a 45 keV electron beam of 0.8 A in 80 ms reaching an equilibrium diameter of 0.5 mm. The energy spread in the proton beam is reduced to less than 10^{-5} and the angular spread to less than 5×10^{-5}. (Results reported by A.N. Skrinsky at the Tbilisi Conference in July of last year.)

The experiments have studied the variation of the cooling effect and the cooling rate as parameters are changed. The results as they relate to betatron oscillation damping, longitudinal (or energy spread) damping, equilibrium proton beam conditions and proton beam lifetimes (which increase by a factor of over five) can be found in the journal 'Particle Accelerators' vol. 7, no 4, 1976.

The big surprise in the recent measurements has been the rapid cooling rate — much faster than was anticipated from the equations describing the cooling mechanism. The complex theory has been examined again by Ya. S. Derbenev and A.N. Skrinsky bringing in the influence of the strong longitudinal magnetic field. It remains to test the revised theory.

During the experiments, the Novosibirsk team were also able to play an accelerator physics trick which has long been talked about. By slowly raising the electron beam energy and

Signals from the magnesium jet beam observation detector showing the distribution in the vertical direction of the protons in the beam orbiting NAP-M. The scale is 1 mm per division. The top trace records the beam after acceleration. The second trace shows how the beam shrinks in size and increases in density when the electron cooling (100 mA of electrons in this case) is switched on. The proton beam rapidly reaches an equilibrium dimension of about 0.8 mm. In the third trace the proton beam has been allowed to coast for about 2 minutes after acceleration. Again the cooling is switched on, bottom trace, and similar cooled beam characteristics are achieved.



increasing the bending magnet fields in the ring in step, they were able to accelerate the proton beam by the electron beam. For example, the proton beam energy was raised from 65 MeV to 85 MeV in 200 s, corresponding to an energy gain of 0.3 eV per turn, with hardly any loss of particles.

The excitement generated by the cooling techniques centres on the possibility of producing high energy antiproton beams with intensities much higher than was conceivable before. Proton-antiproton interactions at hundreds of GeV energy could not miss uncovering more physics and the present theories predict that many as yet unseen phenomena will appear in the interaction energy range which will then become available. Proton-antiproton colliding beams also seem a comparatively cheap route to this physics since the two beams could be accelerated in the same ring (like the familiar electron-positron ring) and both CERN and Fermilab have a multi-hundred GeV ring ready and waiting.

At CERN an initial cooling experiment has been authorized. It will use the magnet ring which served for the g-2 experiment. The ring is to be rebuilt in the hall where the Gargamelle bubble chamber was housed, prior to its move to the SPS, and four 7.5 m straight sections will be introduced. Protons will be fed in from the PS. The ring will be used to study stochastic cooling of the proton beam at momenta around 2 GeV/c and electron cooling at momenta around 0.3 to 0.45 GeV/c (50 to 100 MeV energy). It is hoped that the experiment can begin at the end of this year.

Fermilab is to build a ring to the south-west of the 8 GeV Booster ring to test electron cooling. The ring could be used in that location for cooling antiprotons and it is also being designed in such a way that it could be reconfigured for installation in the Booster ring if this is called for by the antiproton scheme. The cooling ring is 140 m in circumference with 5 m of cooling straight. It will store 200 MeV protons from the linac and an electron beam, up to 20 A, will be provided by a 110 keV klystron gun (a modified version of the type used on the Stanford SPEAR storage ring). The construction of the electron gun and the magnets is scheduled to be complete by the end of the Summer.

In the Soviet Union, the Novosibirsk team have looked at the possibility of applying electron cooling to an antiproton facility for the proposed UNK (2 to 5 TeV) project. They have cooling schemes which they believe could yield luminosities in the range of 10^{31} per cm^2 per s for colliding proton-antiproton beams at 2×1000 GeV. There are also other applications of the cooling technique which are likely to receive attention in the coming years.

A good way of summing up the interest in the electron cooling technique and the proton-antiproton colliding beam possibilities that it opens up is to quote a typically pungent phrase from Bob Wilson, Director of Fermilab: 'If we physicists are sufficiently clever and manage to implement the colliding beams, then the physics that will result just boggles the mind.'

25 years of INFN

The Istituto Nazionale di Fisica Nucleare, INFN, in Italy is celebrating its 25th anniversary. A ceremony was held in Rome on 15 December 1976 at the Campidoglio in august company — Giovanni Leone (President of the Italian Republic), F.M. Malfatti (Minister for Education), M. Pedini (Minister for the Co-ordination of Scientific and Technological Research), the Deputy Mayor of Rome, Members of Parliament, of other State Institutions and of the Diplomatic Corps.

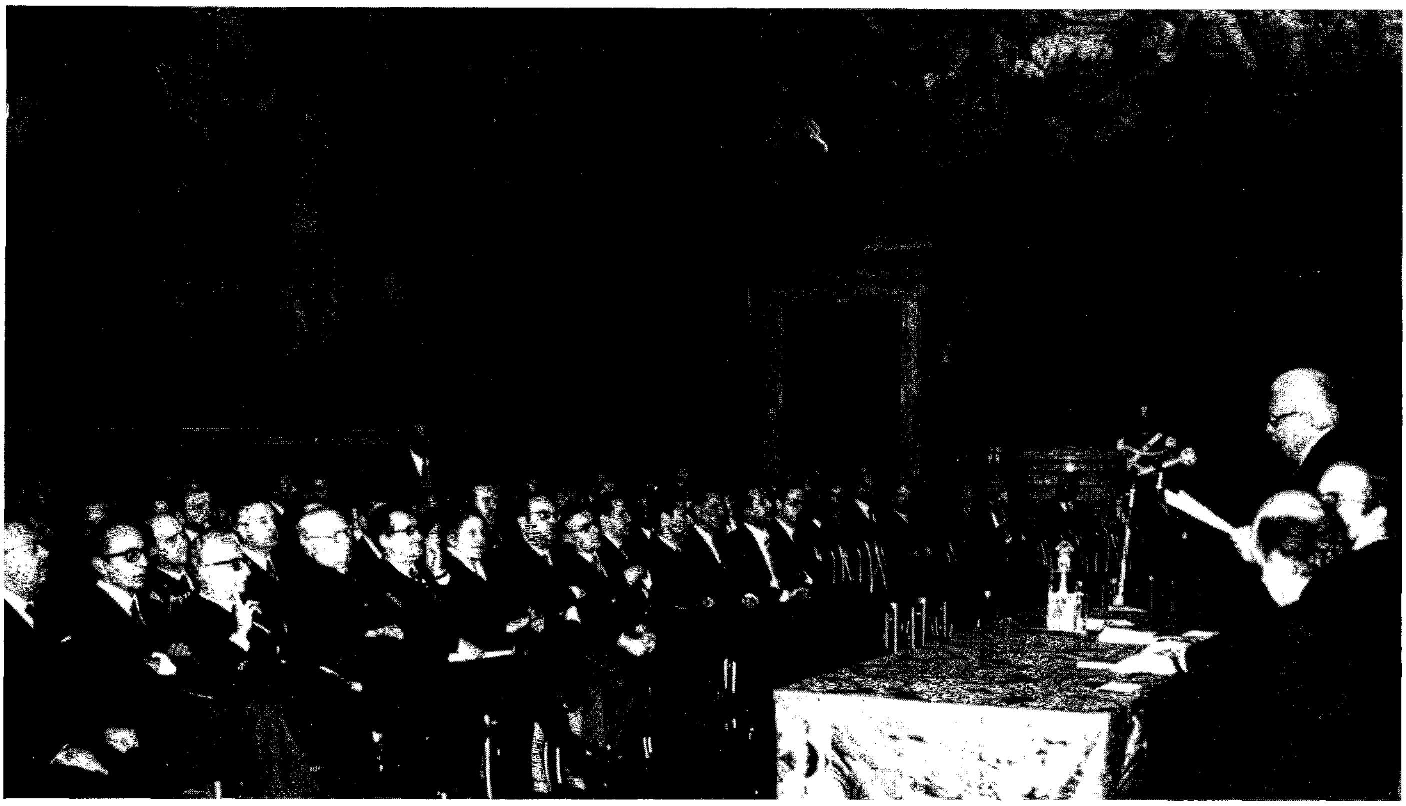
During the ceremony Claudio Villi, former President of INFN (from 1970 to 1975) recalled the work of INFN which has strengthened, both in Italy and outside, its role as the leading national research organization. He illustrated the perspectives of present research in the field of particle and nuclear physics, its impact on culture and its 'fall-out' in many other fields of research and technology.

In his reply, the Minister for Education stressed the importance of the scientific policy of INFN which operates within the Italian Universities enabling them to participate in particle and nuclear physics research at the highest levels. He gave assurance that the Government would continue to support the development of this research and the work of INFN in particular.

INFN was constituted in 1951 within the Italian National Research Council with the task of promoting, co-ordinating and performing experimental and theoretical research in the field of fundamental nuclear physics, when individual university groups could no longer cope with the increasing complexity, both technical and organizational, of experimentation in this field. The first President was Gilberto Bernardini and under his Presidency the Laboratorio Nazionale di Frascati (LNF) was founded and equipped with an electron synchrotron of 1 GeV.

During the term of office of the second President, Edoardo Amaldi (1960-1965), the INFN groups increased their activities at CERN and began construction of the electron-positron intersecting storage rings known as Adone, at LNF. The third President was Giorgio Salvini (1966-1969). In 1967, INFN became an Institution under public law in Italy and became autonomous from the Comitato Nazionale per l'Energia Nucleare (CNEN) in which it had previously been incorporated. LNF, however, remained within CNEN. During the same period, the Padua Laboratori Nazionali di Legnaro (LNL) were instituted for nuclear physics research, in the framework of an agreement with Padua University, and experiments started at Adone.

In the past six years, under the Presidency of Claudio Villi, INFN has



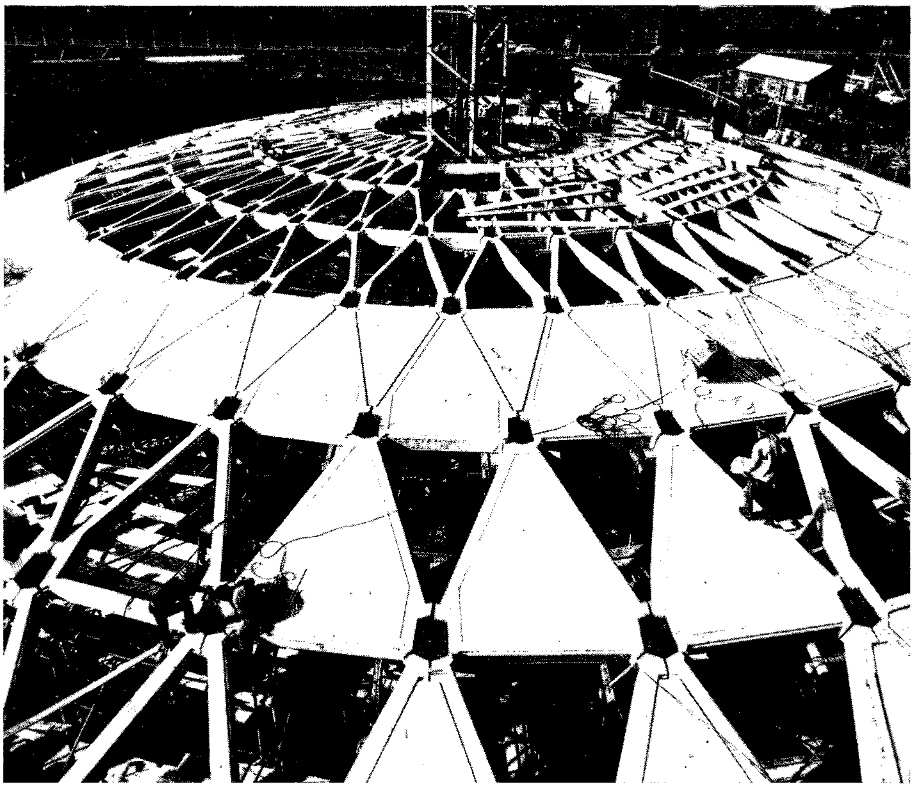
Claudio Villi, former President of INFN, speaking at the official ceremony to mark the 25th anniversary of INFN in the splendour of the Campidoglio in Rome. The President of Italy, Giovanni Leone, is in the front row of the audience third from the left.

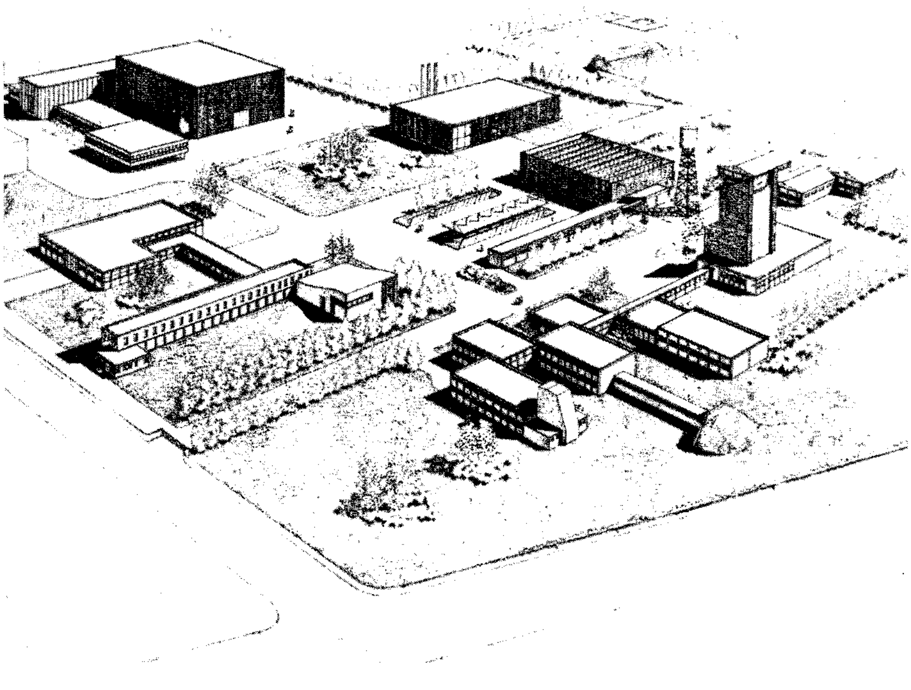
(International Press Photo)

Photograph taken in 1966 during the construction of the large dome which tops the building housing the electron-positron storage ring, Adone, at Frascati. Adone has been INFN's major national instrument for particle physics in recent years.

(Photo CNEN)

An artist's drawing of the Laboratori Nazionali di Legnaro at Padua, one of the INFN's research centres. The buildings on the right are already in occupation and the large hall, drawn top left, will house a 32 MV heavy ion tandem Van de Graaff which is part of INFN's present five year plan.





been granted complete autonomy and full recognition as the Italian public agency responsible for the research in the field of fundamental nuclear physics, both in Italy and outside. In particular INFN ensures the promotion, the co-ordination and the financing of the Italian research activities carried out at CERN.

In 1974, the Interministerial Committee for Economic Planning (CIPE) decided to transfer LNF from CNEN to INFN and approved the INFN 1974-1978 five year plan, which contains provisions for Italian participation in experiments at the CERN 400 GeV proton synchrotron, the SPS, and for the development of facilities for nuclear physics research. These are a 32 MV tandem for heavy ion beams at LNL, a 12 MV tandem at a new Laboratorio del Sud at Catania, and a polarized monochromatic gamma beam at LNF which will be produced by the interaction of a laser beam with the electron beam in Adone.

At present INFN has seventeen research units: the National Centre for the Analysis of Photograms (CNAF, Bologna), the two National Laboratories of Frascati and Legnaro and fourteen sections in the Institutes of Physics at the Universities of Turin, Genoa, Milan, Pavia, Padua, Trieste, Bologna, Florence, Pisa, Rome, Naples, Bari, Catania and the Istituto Superiore di Sanità in Rome. A research group from the University of Messina is associated with the Catania section, a research group from the Polytechnic Institute is associated with the Turin section and a research group from the Scuola Normale is associated with the Pisa section.

INFN has its operative centre at Frascati. Its decision taking body is a Council composed of the Directors of the research units and representatives of CNR, CNEN, the staff and the controlling Ministries. The Council appoints an Executive Board of four members who collaborate with the President of INFN. The President is appointed by the Italian Government with advice from the Council. Advising the Council itself there are five consultative Commissions, one for each sector of research, whose members are elected by the researchers.

The distribution of the sections gives INFN the closest possible co-operation with the Universities. It allows INFN to make a substantial contribution to further developments of fundamental physics research within the various Institutes of Physics and to promote teaching in physics with particular emphasis on the fundamental nuclear physics sector.

The direct allocations by the Italian Government for the research activities co-ordinated by INFN (including the contribution to CERN), increased from 14.8 GLire in 1970 to 37 GLire in 1976 and will rise to 51 GLire for 1977.

The INFN is now under the Presidency of Alberto Gigli Berzolari, and is beginning to evolve its next five year plan covering the period 1979-1983. It will aim to continue to contribute to the economic and cultural development of Italy.

This article was drawn from information supplied by Alessandro Pascolini, the CERN COURIER correspondent at INFN.

STANFORD
All hands talk

Professor Panofsky gave his customary 'State of SLAC' talk to the staff on the Stanford Linear Accelerator Center on 19 January. The following report is culled mainly from the talk with some additional information on the proposals for the first PEP experiments.

President Ford's budget proposal for fiscal year 1978 beginning 1 October (which it is hoped will survive the subsequent administrative changes in the USA), contains a 12% increase in SLAC's budget compared to 1977. Most of this will be eaten away by the inflation factor which this year will be unusually severe (about 10%) because of an anticipated doubling in electrical power charges, but there is, nevertheless, a budget growth of a few per cent reversing the trend of recent years. The budget growth will allow a modest increase in the experimental programme.

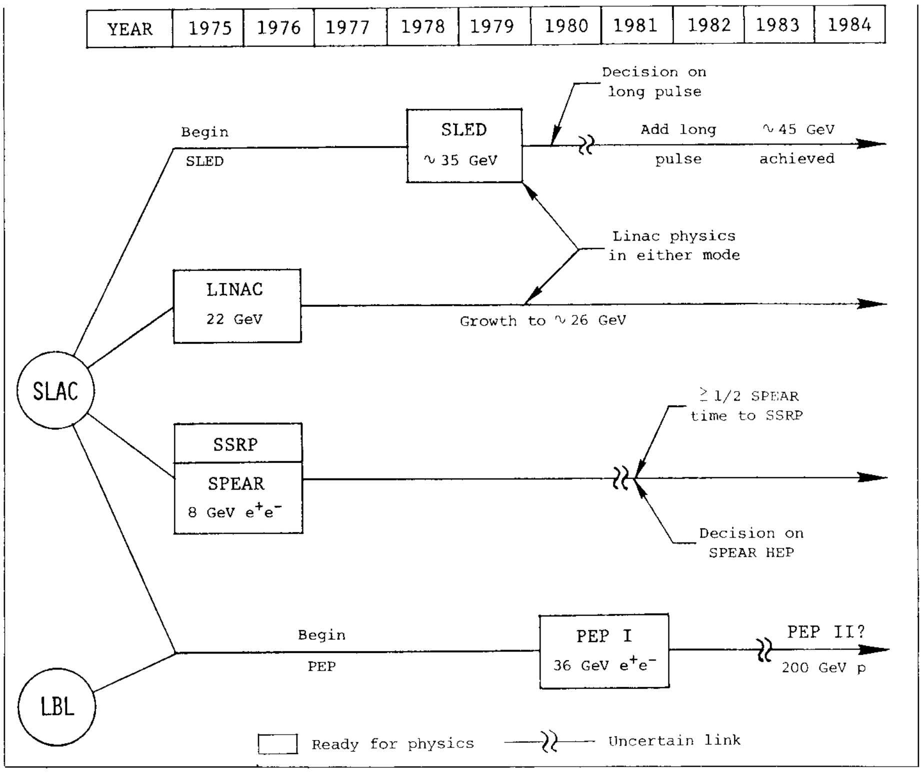
The 4 GeV electron-positron storage ring, SPEAR, will be used in a new series of experiments aiming at more detailed study of the 'new physics' which has emerged since the discovery of the psi particles. At the end of 1976, the 'iron ball' experiment was moved out of east interaction area and has been replaced by the 'DELCO' experiment (see October issue, 1976). The famous magnetic detector, Mark I, which found the psis, will be replaced by an improved version, Mark II, during a four month shutdown of the accelerator and storage ring beginning in July. In particular, the new range of detectors developed for SPEAR will have improved abilities for the observation of neutral particles emerging from the electron-positron interactions.

SPEAR is also the scene of the synchrotron radiation research in the SSRP (Stanford Synchrotron Radiation Project) which looks destined for considerable development in the coming years. The President's budget has 2.8 M $ earmarked for SSRP expansion in fiscal year 1978 with an additional $ 2.8 million proposed for the subsequent two years. There is a tentative agreement to give 50% of SPEAR time to this research when PEP begins operation and there are plans for seven new beam ports to support many more experiments.

At the 22 GeV electron linear accelerator, the large aperture solenoid spectrometer, LASS, is now in regular operation and demonstrating its voracious appetite for data. It is a general purpose facility and many experiment proposals have been put forward to use it. The hybrid bubble chamber facility, based on the rapid cycling (ten or twelve cycles per second) 40 inch chamber, also has many experiment proposals for its use in a variety of configurations. The large magnetic spectrometers still have a full list of experiments particularly with polarized electron beams. A Spectrometer Workshop is to study the future of these monsters which have been the major work-horses of the SLAC experimental programme for the past ten years.

On the linac itself, the SLED project will progressively increase the peak energy capability. The SLED scheme squeezes more power into the beam at the expense of pulse length. Over eighty SLED assemblies have been built and tested and many are installed at the linac. The present plans are to take the energy of 35 GeV but further extension would be possible if the physics calls for it.

During the long shutdown for the installation of the Mark II detector at SPEAR, construction of the tunnels for the Berkeley/Stanford 18 GeV electron-positron storage ring, PEP, will begin. The construction schedule has been advanced to take advantage



The foreseen development of the facilities at the Stanford Linear Accelerator Center. The electron linac has the SLED project to increase its present peak energy of around 22 GeV to around 35 GeV with the possibility of going higher later. The SPEAR electron-positron storage ring will continue to support high energy physics and synchrotron radiation research (SSRP) possibly concentrating on the latter in the 1980s. The Berkeley/Stanford 18 GeV electron-positron storage ring project, PEP, is scheduled to come on the air in 1980.

of the long shutdown to break into the switchyard at the end of linac for the injection tunnels. Once this work is completed, the rest of PEP construction can go ahead without interference with the experimental programme on the existing facilities.

PEP components are mostly at engineering model stage. There are models of the bending magnets, quadrupoles and a full size 500 kW klystron. Over a quarter of the aluminium extruded vacuum vessels are on site.

Nine proposals for the initial experimental programme at PEP have been received: A Berkeley/SLAC team has proposed a search for highly ionizing particles (such as magnetic monopoles) using lexan sheets. An Argonne / Indiana / Michigan / Northwestern / Purdue team has proposed a multipurpose spectrometer with a superconducting solenoid which would be used initially for production cross section measurements and a general look at hadronic events. A Berkeley / UCLA / Yale / Riverside / John Hopkins team has proposed a detector based on the time projection chamber to give excellent pattern recognition. A Berkeley/SLAC team proposes to move the Mark II detector from SPEAR to PEP for a general survey of particle production. A SLAC/Wisconsin team has proposed a lepton total energy detector using hadron and lepton calorimeters surrounding a solenoid and toroidal spectrometer. A Santa Cruz / Berkeley / Michigan / SLAC team has proposed a multipurpose detection system, known as 'Eyeball', built around a 2.5 m diameter streamer chamber. A Brown / Cal.Tech. / MIT / SLAC / Stanford team has proposed a multipurpose detection system using a three magnet array; it can explore the small angle region and could study two photon processes. A Davis / San Diego / Santa Barbara team has proposed a detection system for the forward direction primarily to investigate two photon processes.

The proposals will be evaluated by the Experimental Program Committee so as to make recommendations to the Laboratory Directors by June. Although PEP is scheduled for operation in 1980, this long lead time for the preparation of detectors is needed because of the complexity of the systems which are needed to cope with higher energy interactions.

RUTHERFORD
Polarized filter for thermal neutrons

The Rutherford Laboratory has for many years been the channel for UK University research with neutron beams at the joint French/German/UK reactor facility, Institut Laue-Langevin, at Grenoble. During this time the Laboratory has made important contributions to the instrumentation in this type of research (see, for example, the February issue 1976). Their latest contribution is a new type of polarizing filter for thermal neutrons.

The idea emerged in the Laboratory's Neutron Beam Research Unit four years ago but required the mastery of two technological problems before it could successfully prove its abilities during tests in January.

Thermal neutrons with wavelengths around 1 Å are strongly absorbed by nuclei of the element samarium and, when the nuclei are polarized, they preferentially absorb one of the two spin states of the incident neutrons. Thus the beam which passes through the samarium becomes polarized since one spin state is largely removed.

Achieving a volume of samarium in appropriate form was technological problem number one. It was prepared, using 70 % of the world's supply of the isotopically enriched samarium oxide from Oak Ridge, as a single crystal with the samarium as dope atoms in a deuterated paramagnetic salt. The resulting crystal, with an impossibly long chemical formula, is known in abbreviation as CSMN.

The second technological problem is to polarize the samarium nuclei to about 80%. This is done by locating the crystal in the mixing chamber of a helium 3/helium 4 dilution refrigerator (built by Oxford Instrument Co. Ltd.) where it experiences a temperature of 0.016 K and a magnet field of 0.5 T. As in the familiar polarized targets used in high energy physics, the polarized electrons of the samarium atoms pull the nuclei into line and give the required polarization.

Despite these complications, this new method of thermal neutron polarization has advantages over the conventional method using spin dependent scattering of protons in a polarized proton target with microwave pumping. The measurements using the CSMN filter in January were in good agreement with the theoretical predictions. The filter opens the door to a new range of experiments with high intensity polarized neutron beams.

CERN
Neutral detection with high density chambers

Many detection techniques can be applied to the observation of charged particles; their wake of ionization can be picked out in several ways. Neutral radiation (neutrons, gammas, X-rays) is more elusive, particularly at modest energies where the radiation converts to low energy charged particles which will not subsequently traverse both triggering devices and further detectors. Usually all the required information has to be gleaned from a restricted volume in a single detector.

This problem has been confronted by Alan Jeavons in collaboration with CERN colleagues and scientists from Geneva University. They have emerged with a detection technique which has potential in a wide variety of applications in high energy physics, other science disciplines and medicine. It improves the spatial resolution of neutral radiation detectors to about 1 mm and can be adapted in different configurations to give other information.

The basic principle is to place a neutral radiation converter followed by a drift region in front of a proportional chamber. The drift region has a high density material pierced with holes perpendicular to the chamber planes and an electric field applied in the same direction. The neutral radiation initiates a charged particle in the converter, it emerges into one of the nearest holes and produces free electrons by ionizing the gas in the hole. Under the influence of the field these electrons drift to the proportional chamber and give the particle position in two dimensions. The high density material prevents the spread of the ionization and can also act as converter. The spatial resolution is determined by the hole spacing in the high density material which can be of the order of a millimetre. To illustrate the various possible adaptations of this basic scheme we can consider some potential applications:

Low energy neutron beams are used for neutron crystallography in solid state studies. The detector of the scattered neutrons should ideally retain its spatial resolution for neutrons entering at wide angles. The conventionally used gas proportional chambers do not achieve this. The new detector can use a thin foil of gadolinium which has a very high absorption cross section for thermal neutrons giving a gamma which rapidly converts to an electron. The electron escapes from the thin foil into the drift space of the detector and accurately gives the location of the incoming neutron in two dimensions.

For experiments where epithermal neutrons are involved, virtually the same performance can be achieved by replacing the gadolinium by hafnium as the converter. For experiments where fast neutrons are involved, a plastic material can be used as the converter giving a knock-on proton to initiate the ionization and localize the neutron.

A small chamber (4 × 4 cm^2) has been tested with thermal neutrons at the Institute Laue-Langevin, Grenoble. A detection efficiency of 22 % was achieved (in close agreement with the theoretical figure of 21.8 % for 1.8 Å neutrons) and a spatial resolution of 1 mm. Larger area detectors (say 1 × 1 m^2) are feasible.

The range of potential applications in X-ray and gamma detection is con-

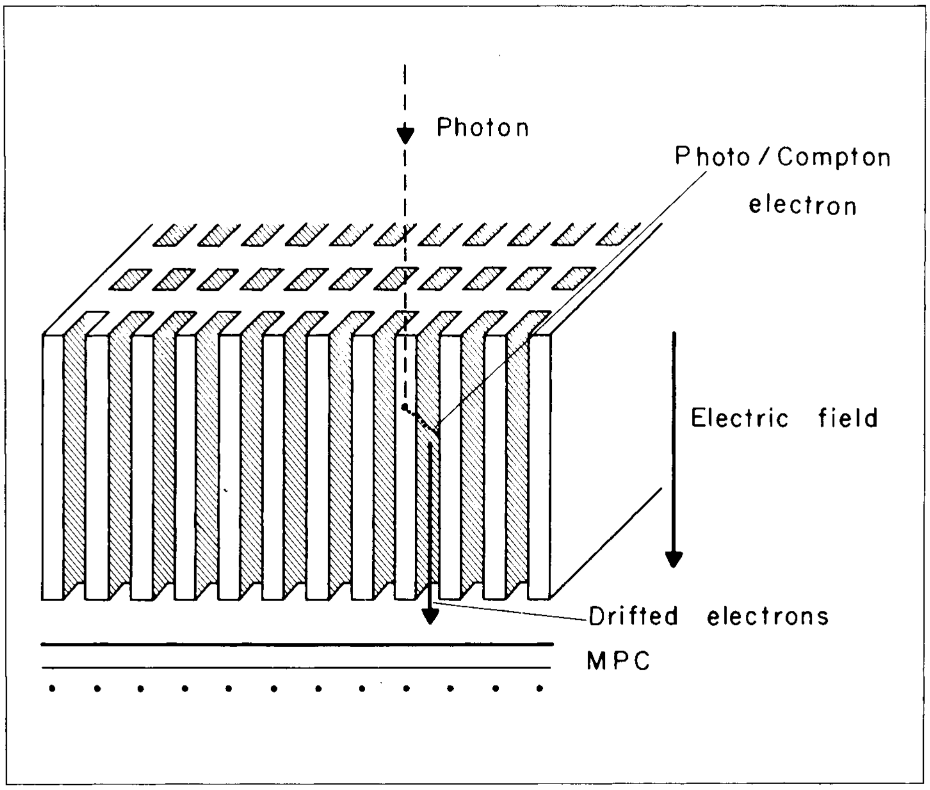


Diagram illustrating the operating principle of the neutral particle detector, indicating in this case the detection of a photon using lead as the converter. The electron initiated in the lead by the photon creates ionization in a neighbouring hole which drifts to the corresponding wire of a proportional chamber. Positional accuracies in two dimensions equivalent to the hole spacing (about 1 mm) are obtained.

siderable. Two experimental gamma chambers have been built to study 'positron imaging' (for experiments described below). They have an area of 10 × 10 cm² and a drift region comprising two overlapping stacks of 75 thin lead bismuth plates interleaved with epoxy resin sheets. A resistor chain down the plates gives the necessary electric field. They have shown good detection efficiencies and the expected spatial resolution of 1 mm.

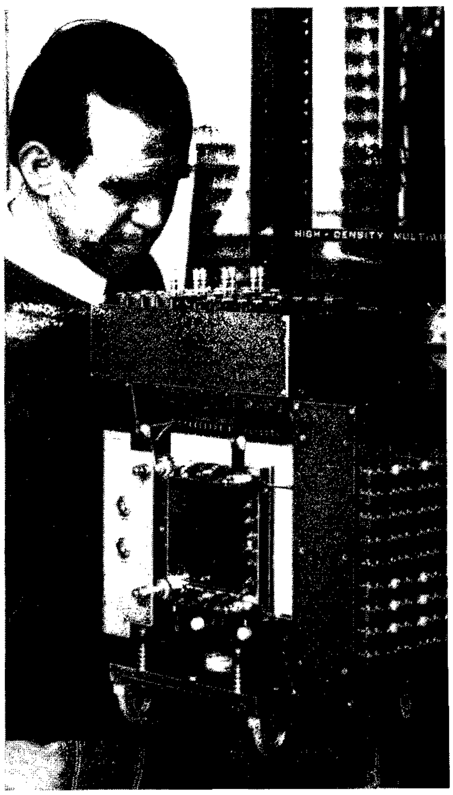
The interest in positron imaging comes from solid state physics and medicine. When low energy positrons are fired into a solid, they come rapidly to rest and annihilate with an electron. If the resulting two gamma rays of 0.5 MeV can be located with accuracy, they yield information on the atomic and electronic structure of the solid. An electron-positron annihilation at rest would give gammas emerging 'back-to-back' but because of the motion of the electron they emerge at a slight angle to one another. Irregularities in the gamma distribution can indicate defects in the crystal planes and positron imaging can thus be used in materials stress analyses, etc... In materials free from defects, the characteristic electron momentum distribution can be seen.

A test at CERN used this technique to look at the electron momenta distribution in copper with the two gamma chambers set well apart on either side of the copper to measure the gamma angles. The known distortion of the Fermi surface due to the crystal structure of copper was clearly seen.

The technique is particularly interesting for the study of alloys since it does not depend on crystal perfection like other techniques. It is also an advance over conventional techniques in giving two dimensional information and a much faster data taking rate. The two gamma chambers have been moved to the University of Geneva to pursue research of this type.

Before they were moved, a look was taken at medical applications. A skull (possibly of an unpopular group leader) was found in a cupboard at CERN. A plastic cone surrounded by a positron emitter was inserted in the skull and the gamma chambers were placed close on opposite sides of the skull. Computer analysis of the emerging gamma directions enabled tomographs to be produced (see the article on the Tomoscanner). The slices through the skull at 5 mm intervals revealed the location of the positron emitting cone with millimetre accuracy. The use of positron emitters in diagnostic work has been hindered up to now because of poor detection techniques; it looks as if that no longer needs to be a deterrent.

A medical dream is to be able to scan the heart, after injection of a positron emitting isotope such as carbon in the blood, and to image the



One of the two gamma chambers using the new detector principle. The sensitive area (10 × 10 cm²) is at the centre left of the chamber. It has been used in positron imaging tests for solid state physics and medical diagnostic applications. Standing alongside is K. Kull who led the careful construction of the detector in the CERN West Workshop.

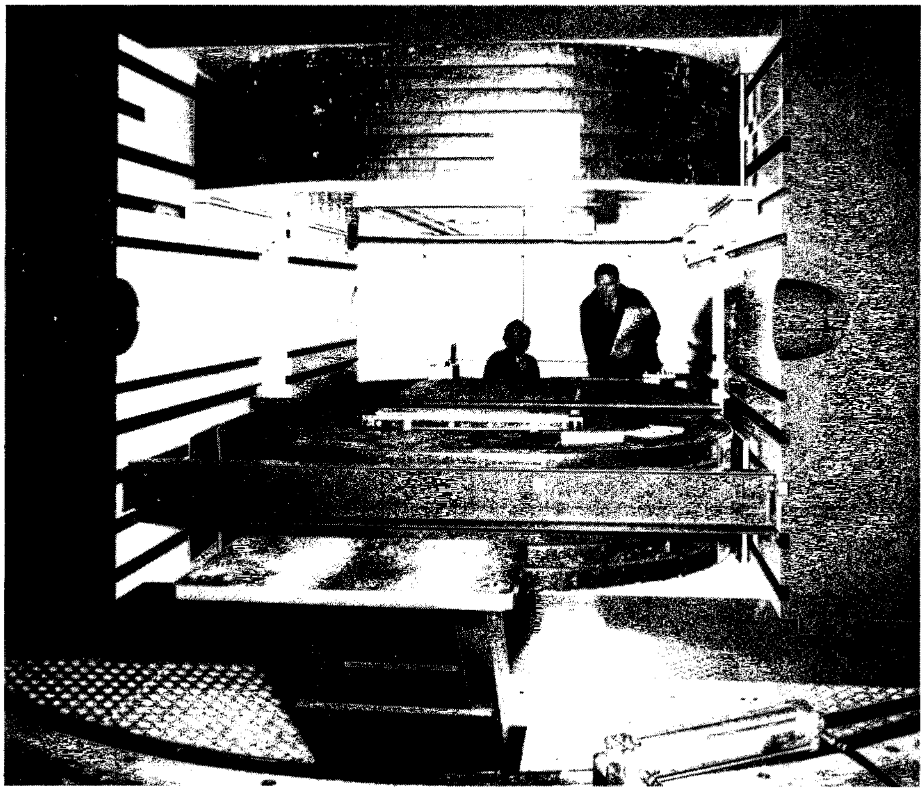
(Photo CERN 279.10.75)

A skull, with a positron emitting cone inside, flanked by the two gamma chambers. Clear three dimensional information on the cone location was obtained. To simulate the usual body environment, the skull was filled with water but unfortunately the skull was cracked and leaked. Intrepid CERN researchers carried the skull into a Geneva department store to be fitted with a bathing cap. The saleswoman insisted that the fitting took place in a curtained booth!

(Photo CERN 11.7.76)

The large aperture magnet (on loan from the Rutherford Laboratory) for Omicron, installed in the Proton Hall at the CERN 600 MeV synchro-cyclotron. A 'helium box' holding detectors will slide into the aperture and in the foreground is the platform which will hold the box while the detectors receive attention. The magnet can be rotated on a turntable to receive different beams.

(Photo CERN 41.1.77)



coronary arteries. Fast diagnostic scanning could then be used to screen people for artery constriction before heart failure manifests itself.

There are other research topics where the new technique could be useful. For example, Mössbauer spectroscopy, involving strong resonance absorption of gammas, can benefit from a position sensitive gamma detector. Electrophoresis can also benefit. This is chromatography separating ions in solution by passing them through a filter where they have different mobilities in an applied field. Filtered ions, collected on a foil, can be placed in front of the detector where the converter is normally positioned. The chamber signals will then image the radioactive ion distributions on the foil.

In high energy physics, the detector might find application for high energy gamma detection. For example, the electron shower produced in the drift region by a high energy gamma could be made to drift back in the direction of the incoming gamma. The first detected electrons would give information on the point of conversion with good accuracy, the total number of electrons would give information on total energy and the 'centre of gravity' of the detected electrons would give information on the direction of the shower. A chamber to test these possibilities has been built but not yet tried out in a gamma beam.

An exotic idea in the realm of particle physics, being worked on at Bell Labs., concerns the observation of low energy solar neutrinos. They believe that there is a comparatively high cross section in indium for such neutrinos to interact yielding two electrons in delayed coincidence. The detection technique could be applied in large arrays with indium grids and the relevant signal would be two electrons recording in the same hole (localizing the neutrino within a millimetre) within 1 μs of one another.

Omicron making ready

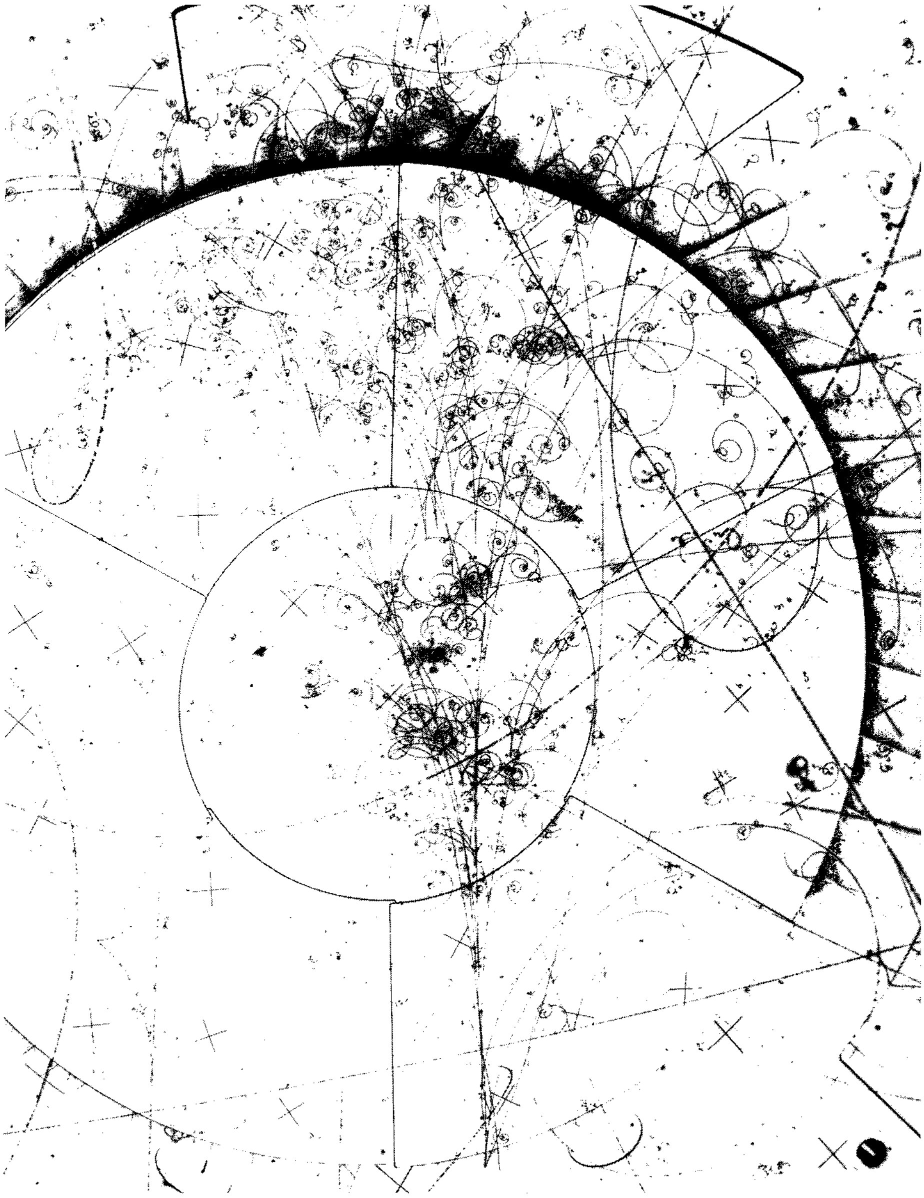
A multipurpose detection system is being built at the CERN 600 MeV synchro-cyclotron, the SC, under the name of 'Omicron'. It aims to complement the experimental resources of the new meson factories (Los Alamos, SIN and TRIUMF) by taking advantage of the special features of the SC.

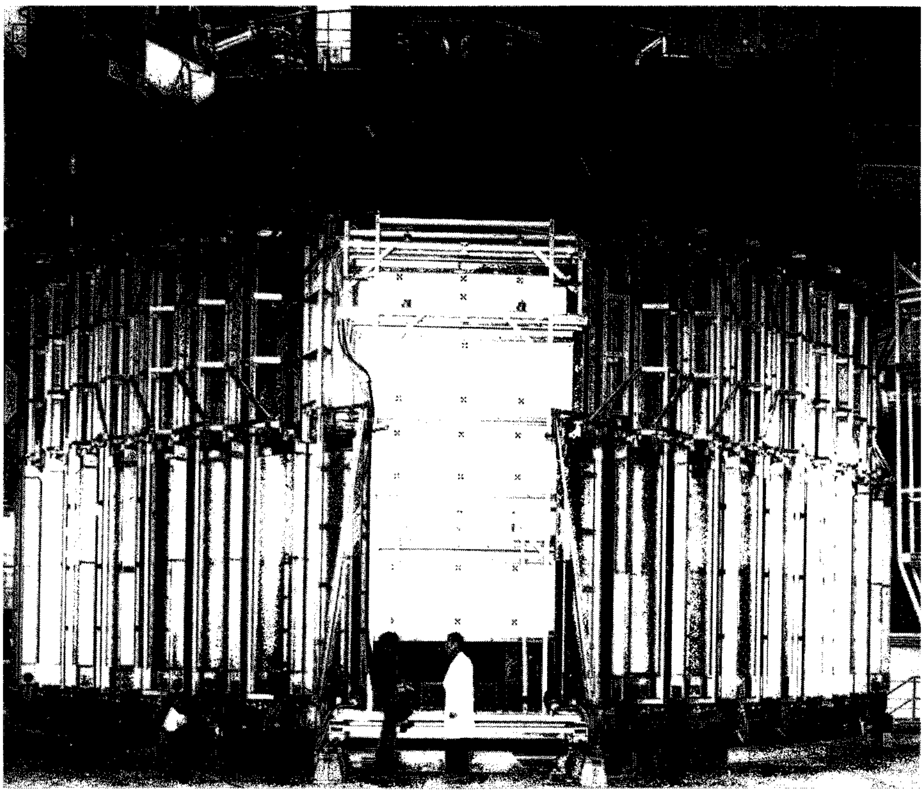
The SC cannot compete, by a long way, with the beam intensities available at the factories. Also the meson factories have single arm spectrometers of extremely high resolution making possible some precision experiments which are beyond the abilities of the SC instrumentation. However, the SC does have a much longer 'real' duty cycle. By manoeuvring with the protons at the rim of the machine while the next acceleration cycle is under way, the SC can give a structureless spill of particles to experiments with a duty cycle as high as 82 %. This is excellent for 'coincidence' experiments. The idea of Omicron is to provide a flexible instrument for this type of experiment. It will also be able to study 'backward' reactions which the single arm spectrometers find difficult. Thus Omicron, despite lower beam intensities and lower resolution, complements the experimental resources available to the factory workers.

Omicron uses a large aperture magnet (gap height of 85 cm, width of 1 m and length of 1.8 m) on loan from the Rutherford Laboratory where it had previously been used with a helium bubble chamber. The pole faces have been remade to become spectrometer-type rather than bubble chamber-type (with camera apertures) using steel from the Liverpool synchro-cyclotron. Old soldiers never die. The peak field with the presently available power supply is 1 T. The magnet can be rotated on a turn-table so as to be able to accept beams from several directions. Power and cooling water connections enter via a 'crown' at the top centre of the magnet to make these manoeuvres possible.

The detectors within the aperture will be enclosed in a box filled with helium to reduce multiple scattering which can be troublesome at the low energies of the SC. The box can slide in and out on an air cushion so that the detectors can be worked on comfortably outside the magnet. Multiwire proportional chambers, scintillation counters and drift chambers make up the initial detection system.

The first experiment will be a study of pion scattering on nuclei to obtain data on backward scattering for these interactions. The list of other likely experiments is long: studies of rare decay modes of the pion, double charge exchange over all angles, radiative capture, pion production using neutron beams (where there are few data available at present)...





This spectacular bouquet of particles was photographed in the 3.7 m European bubble chamber, BEBC, when it was exposed to high energy neutrinos generated by the 400 GeV proton synchrotron, the SPS. The primary neutrino interaction is at the bottom of the photograph.

Below is the rear view of BEBC surrounded by the curtains of wire chambers known as the External Muon Identifier. Installation of the EMI, which was described in the April issue 1976 is now complete and it is running well.

(Photo CERN 374.1.77)

The collaboration of groups which will use Omicron has the convenient acronym of COBALT - CERN, Oxford, Birmingham, Amsterdam (IKO and Free University), Ljubljana and Torino. The project has been promoted particularly by Neil Tanner from Oxford and Tullio Bressani from Turin. Brian Allardyce and Ernst Michaelis supervise its progress at CERN. The magnet is now installed in the SC Proton Hall and it is hoped to begin the first experiment this summer.

NOVOSIBIRSK
Synchrotron radiation research

On 8-10 February, a 'Second Working Conference' took place at Novosibirsk, on the use of synchrotron radiation from the storage rings of the Nuclear Physics Institute. The Conference was attended by ninety scientists from twenty-two Institutes in the Soviet Union and there were guests from France, the Federal Republic of Germany and the UK.

The Nuclear Physics Institute is the main centre for synchrotron radiation experiments in the Soviet Union. As far back as the construction days of the first electron storage rings at Novosibirsk (VEPP-1 and VEPP-2), Gersh Budker drew attention to their unique potential as a source of radiation over a wide range of wavelengths. Research using this radiation started in July 1973, after the VEPP-3 storage ring (2.2 GeV peak energy per beam) was equipped with a port to allow the synchrotron radiation out. It was X-ray structural analysis carried out by a group from the Atomic Energy Institute of Moscow.

At the beginning of 1974, X-ray spectra investigations were started by the Institute of Inorganic Chemistry of Novosibirsk on the VEPP-2 storage ring. Subsequently, the number of experimental groups increased rapidly and, at the present time, the research involves fifteen groups (about 65 scientists) from various Institutes in the Soviet Union (Novosibirsk, Moscow, Pushchino, Leningrad, Uzhgorod and Tomsk). All of the experiments requiring vacuum ultraviolet and soft X-rays are performed at the VEPP-2M storage ring (beam energy 0.67 GeV) and those requiring X-rays are performed at the VEPP-3 storage ring. The research programmes at the Institute are directed by A.N. Skrinsky.

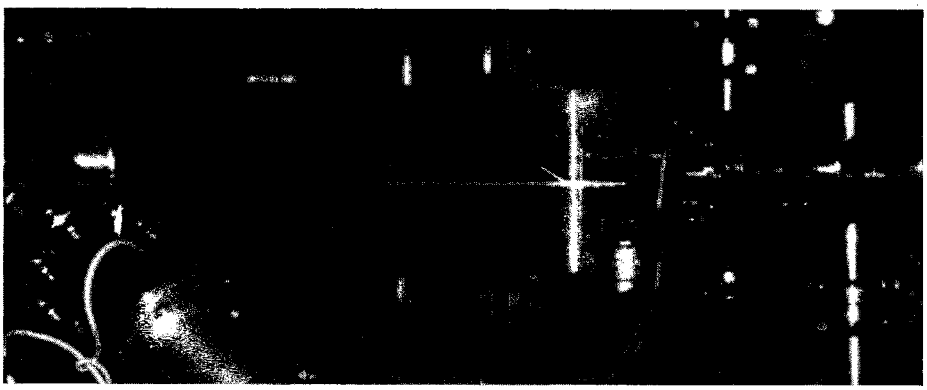
The principal parameters of the storage rings which determine their quality as synchrotron radiation sources are as follows: VEPP-2M has an energy of 0.67 GeV, a radius of 1.22 m, a revolution frequency of 16.7 MHz, a current of 100 mA, transverse beam dimensions of 1.9 × 0.12 mm^2, a bunch length of 5 cm and a lifetime of 0.5 to 10 hours. VEPP-3 has an energy of 2.2 GeV, a radius of 6.15 m, a revolution frequency of 4.03 MHz, a current of 100 mA, transverse beam dimensions of 1.5 × 0.15 mm^2, a bunch length of 20 cm and a lifetime of 2 to 100 hours. The beam characteristics of the synchrotron radiation from the storage rings which determine the qualities of the radiation sources for the 'consumer' are as follows: VEPP-2M has three or four channels 2 m long, a useful spectrum from 6 to 3000 angstroms, an irradiance (photons per cm^2 per s) of 0.2 to 2 × $10^{16} \Delta\lambda/\lambda$ and a source brightness (photons per cm^2 per steradian per s) of 1 to 5 × $10^{23} \Delta\lambda/\lambda$. VEPP-3 has one to three channels 2.5 m long, a useful spectrum from 0.5 to 6 angstroms, an irradiance of 0.1 to 2 × 10^{17} and a brightness of 2 to 8 × 10^{23}.

A feature of the channels is their short length, which, even without focusing, provides a high quantum density in the region where the experimental apparatus is installed. The Nuclear Physics Institute participates in the preparation of various experiments by providing modern apparatus, computer control systems, automation of experiments, detector development and manufacture, spectrometers, etc. The following are examples of equipment produced in the laboratories of V.A. Sidorov and A.G. Khabakhpashev:

1. A two-coordinate, 4000 channel detector for X-rays was made at the end of 1974. Data is drawn from two cathode planes of a proportional chamber. A high speed digital algorithm is used to compute (in 1 μs) the transit time with a resolution of 100 ns and a spatial resolution of 2 mm. The data is transferred to a M-6000 computer. At the beginning of 1977, a 16 000 channel detector was completed.
2. A single coordinate proportional chamber for recording quanta of energy from 5 to 20 MeV has been used since 1975 in various experiments. It has an efficiency of 100%, a spatial resolution of up to 0.1 mm, and is capable of high data taking rates (up to 2 × 10^5 per second). The detector operates on-line with a M-6000 computer.
3. A precision X-ray spectrometer, operating in conjunction with an 'Odra-1325' computer, has been used since 1975 in experiments to determine the fine structure of absorption spectra. The spectrometer consists of a computer controlled monochromator with an angular read-out accuracy of 3 seconds of arc and a detector (photomultiplier, semiconductor detector, proportional or ionization chamber) on-line to the computer. The processed data can be displayed in graphical form.

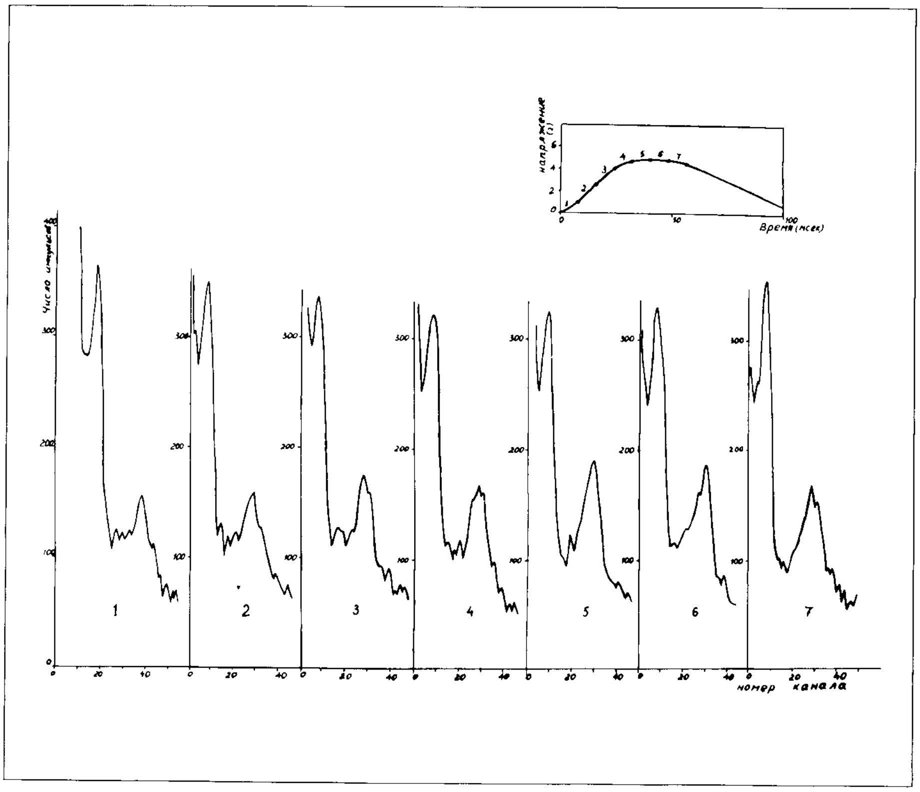
Synchrotron radiation is currently being used at the Institute for X-ray structural analysis, X-ray and ultraviolet spectroscopy, X-ray topography, trace element analysis, X-ray microscopy and lithography. The fol-

Participants at the Conference on synchrotron radiation, held at Novosibirsk in February, were photographed in the control room of the VEPP-3 electron-positron storage ring. Left to right are — Ian Munroe (Daresbury), E. Perevedentsev (Novosibirsk), Phil Duke (Daresbury), P. Dhez (Orsay) and G. Kulipanov (Novosibirsk).



The luminescent beam track of the synchrotron radiation emerging from the VEPP-3 storage ring through a beryllium foil into the atmosphere.

(Photos Novosibirsk)



Small angle X-ray measurements of muscle contraction (the sartorius muscle of a frog) taken in an experiment at the synchrotron radiation facility on the VEPP-3 storage ring. The readings were taken at intervals of 8 ms. The intensities and data taking rates which are now accessible in synchrotron radiation research are making it possible to study living organisms.

lowing three examples indicate the level of the experimental work. Biologists from the Biological Physics Institute, Pushchino, and physicists from Novosibirsk are collaborating in small-angle diffraction experiments which can study the dynamics of living muscular tissue. A special detection system has made it possible to take the first motion pictures (frame time: 8 ms) from X-ray photographs of living muscular tissue and to watch the changes in the muscle in the various phases of contraction. The first experiment superimposed data from 100 muscle contractions.

X-ray spectral analysis experiments have been carried out by the Institute of Inorganic Chemistry, Novosibirsk, in the 50 to 200 angstrom region, using a grazing-impact spectrometer with a concave diffraction lattice, and a resolution of 0.05 angstroms. Investigations were made into the L_{II-III} absorption edge of molecules composed of two or three atoms. The high resolution due to the source brightness made it possible to observe the vibrational structure of the Rydberg states.

The optical properties of semiconductors such as As_2S_3 have been studied by the Institute of Automation and Electrometry, Novosibirsk. They revealed variations in the refractive index of the order of 0.1 (with radiation of 6300 angstroms) which makes it possible to obtain a phase contrast of more than 2π for a 5 to 10 μm film. The high resolving power made it possible to obtain, by contact projection of a test specimen (using a nickel grid, with a mesh of 30 μm and strands 7 μm thick) a phase-contrasted image with a spatial resolution better than 0.5 μm.

HAEFELY/KARLSRUHE Fast neutron generator

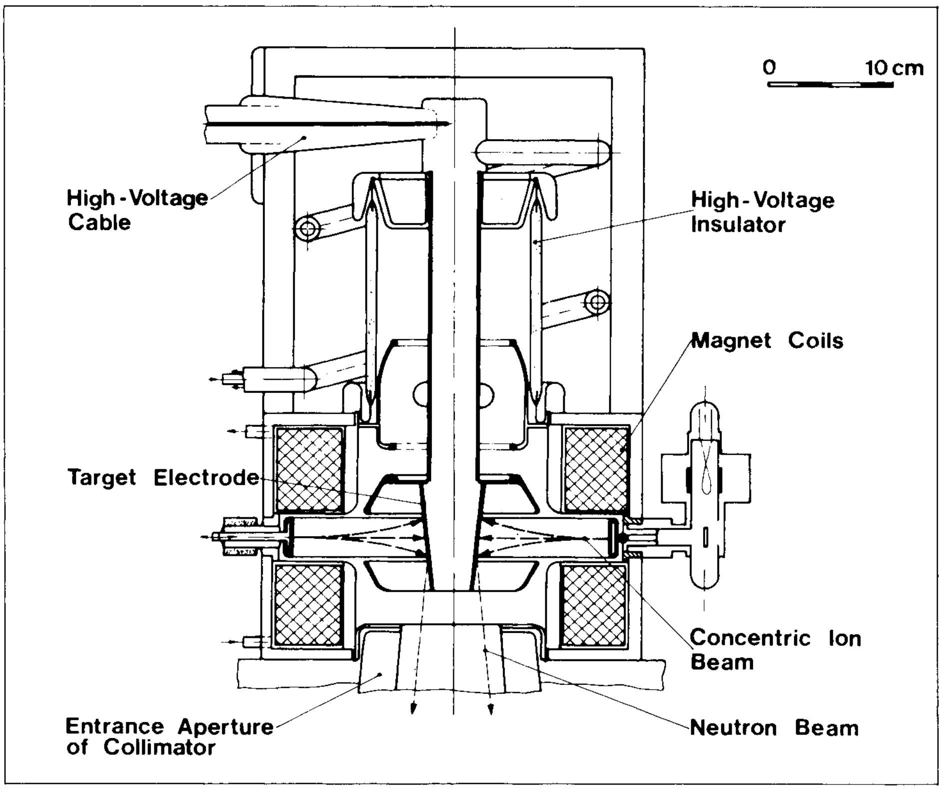
Medical applications of accelerated beams are being pursued with several types of particle. The potential of helium ions and heavy ions was considered in the article on work at Saclay last month. Several centres such as Hammersmith Hospital and Fermilab have concentrated on the use of neutrons. A new instrument for the generation of fast neutrons has been put on the market by Haefely following work at the Institute for Applied Nuclear Physics at the Gesellschaft für Kernforschung (GFK), Karlsruhe.

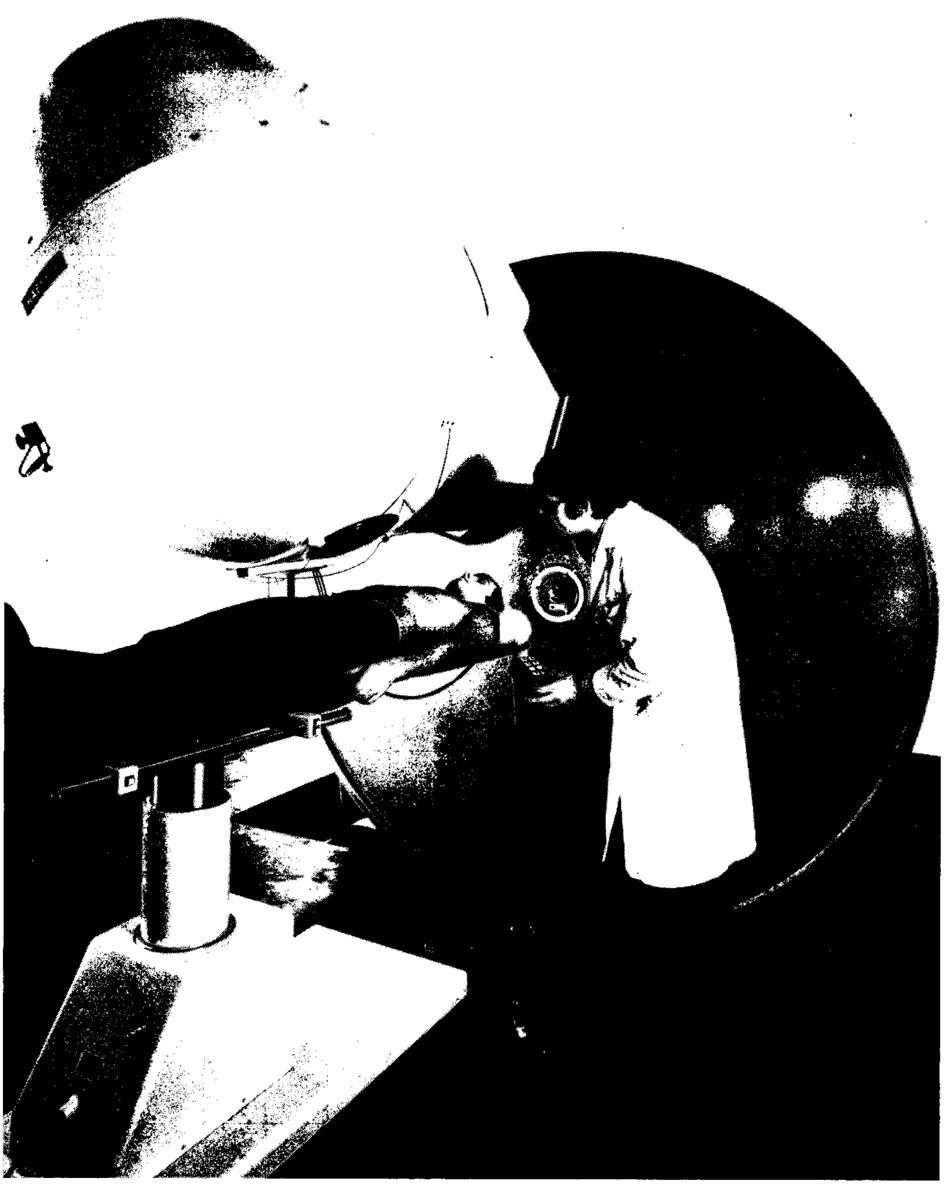
K.A. Schmidt invented a sealed high power neutron tube known as KARIN (Karlsruhe Intense Neutron generator). It accelerates a mixed beam of deuterium and tritium ions using a very compact 250 kV d.c. accelerator constructed using advanced vacuum tube techniques and operating under ultra-high vacuum. The beam, drawn from an ion source where a low pressure gas discharge is maintained fed by a tritium reservoir integral with the tube, is directed onto a target electrode coated with a thin layer of scandium-tritium-deuteride. 14 MeV neutrons emerge from the deuterium-tritium fusion reactions which result.

The use of a mixed beam reduces the neutron yield compared to conventional accelerators but serves to replenish the target tritium and thus to extend the target life so that the neutron yield does not decrease exponentially with time but stays almost constant. For example, a life of 700 hours to 1000 hours can be achieved before the neutron output decreases by 30%. Typical operating parameters are an ion current of 150 mA at 200 keV energy (beam power of 30 kW) yielding 6.5×10^{12} neutrons per second. Dose levels from the generator are 20 rads/min at a distance of 85 cm.

The tube is enclosed in a shielding source head which absorbs all the neutrons which are not emitted in the direction of the patient. The shield consists of layers of steel, polyethylene impregnated with boron carbide, and lead. The weight of the source head is about 8.5 tons and it can be rotated isocentrically so as to irradiate the tumour area from several directions. Control of the generator and monitoring of the dose rate is straightforward and operation is as easy as it is for conventional X-ray equipment.

Following the research at Karlsruhe, the German Cancer Research Centre at Heidelberg took up the development of a clinical model and also produced the radiation monitoring system. The model was installed at Heidelberg in August 1976 and clinical trials of fast neutron cancer therapy are beginning. Haefely has the license to produce KARIN generator tubes for use in hospitals, in activation analysis and in other research and industrial applications.





Schematic diagram of KARIN, the intense neutron generator tube, developed at Karlsruhe. A beam of deuterium and tritium ions is accelerated to strike a target giving fusion reactions at such a rate that the tube produces more than 5 x 10^{12} neutrons per second at 14 MeV.

The neutron generator as marketed by Haefely for use in fast neutron cancer therapy. The generator tube is surrounded by a shielding source head to absorb neutrons not directly directed towards the patient. The generator can be rotated around the patient to achieve irradiations from several directions.

(Photo Haefely)

Tomoscanner

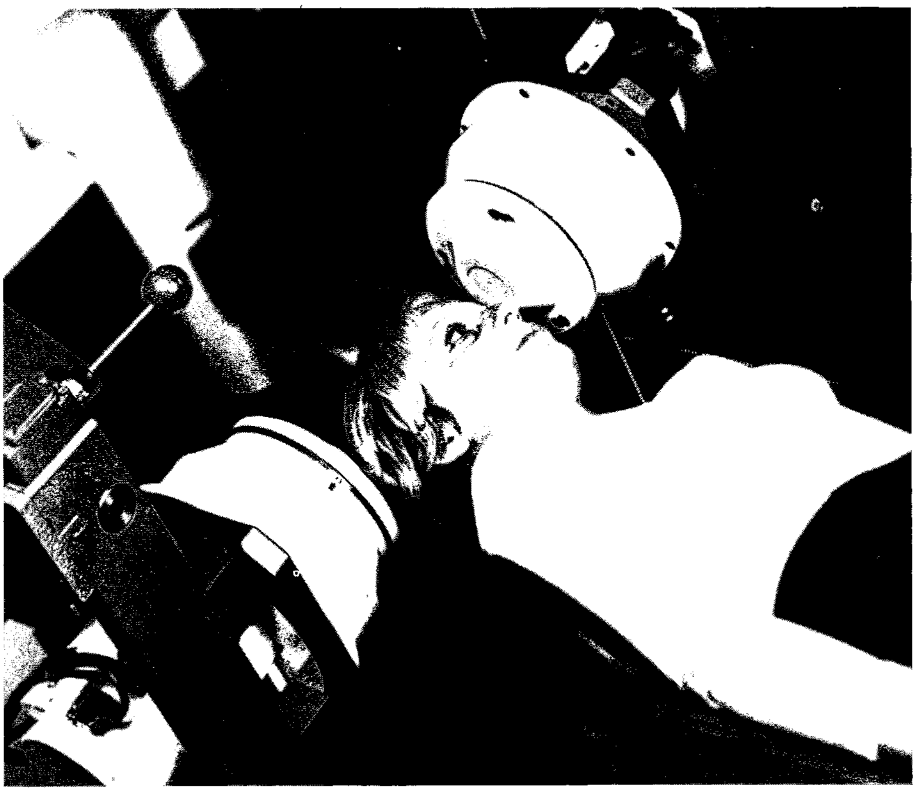
At the end of January, J. and P. Engineering, Reading, UK, announced the availability of the first isotope tomoscanner for medical diagnosis. This adds a new diagnostic technique related to the EMI X-ray scanner, which has been brought into widespread use in recent years.

The X-ray scanner detects abnormalities by measuring variations in X-ray transmission through the body. The new Tomoscanner detects abnormalities by measuring variations in radioactivity from isotopes injected into the body. Like its X-ray antecedent, the Tomoscanner rotates around the region of interest and, via computer calculations, can give information on slices through the region (from the Greek, 'tomos'- slice).

The two techniques can perform many of the same diagnostic investigations but there are abnormalities where each technique has the advantage. For example, the EMI scanner can spot lesions which will not be picked out by the other method; the Tomoscanner can spot some types of tumour which are elusive to the X-ray method. Ideally both techniques would be available.

The Tomoscanner has two detectors which are located on opposite sides of the patient and are moved around, picking up the radiation at different angles. A computer feeds a colour display of the variations in radioactivity from the region being investigated. The whole process normally takes between four and seven minutes.

The design of the Tomoscanner was initiated at Aberdeen Royal Infirmary by W. Keyes and has been developed at J. and P. Engineering by Anthony Bernard and Paul Bradstock. Anthony Bernard said that 'In producing sophisticated medical instruments such as the Tomoscanner, we value very highly the experience gained in



The Tomoscanner in use for the investigation of possible brain tumour. Experience from about a thousand such scans shows that the Tomoscanner can confirm lesions which are equivocal in other scans and can distinguish between cerebral infarcts, subdural and extradural hæmatoma.

(Photo J. and P. Engineering)

working in research physics establishments, such as CERN. The Tomoscanner is one example of the spin off from modern physics research into other aspects of life.'

The first production machine has been on evaluation at the hospital in Tübingen in Germany and has now moved to the Kantonsspital in Zurich. The first order has been received from the hospital of Essen in Germany and the company hopes that the comparatively low price of the Tomoscanner (£ 65000) will open a big market in medical diagnosis.

Sitting at present in the HiRise building at Fermilab is this model of the High Intensity Laboratory which is now under construction in the Proton Area. The proton beam entering from the left will hit a heavily shielded target and secondary beams can be drawn off at zero degrees and fed to an underground experimental hall via a beam transport system of superconducting magnets.

(Photo Fermilab)

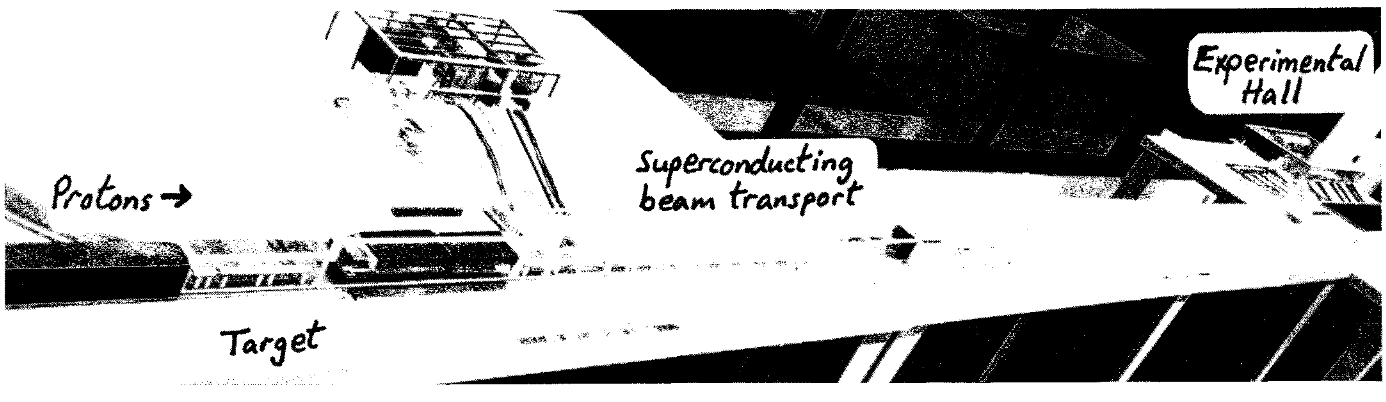
FERMILAB
Progress on High Intensity Laboratory

Construction is proceeding rapidly on the new High Intensity Laboratory in the west branch of the Proton Area at Fermilab. It will permit operation with high intensity pion and other beams and, ultimately, will be able to operate at 1000 GeV with the advent of beams from the Energy Doubler/Saver. Since ground-breaking in the middle of summer 1976, the 240 m of beam tunnel and a 70 m long experimental hall have been completed. Brad Cox, Head of the Proton Department, who has led the design and construction of this new Laboratory, hopes that the construction phase will be complete in the early summer. At present, the installation of 3000 tons of steel shielding is taking place at the target zone.

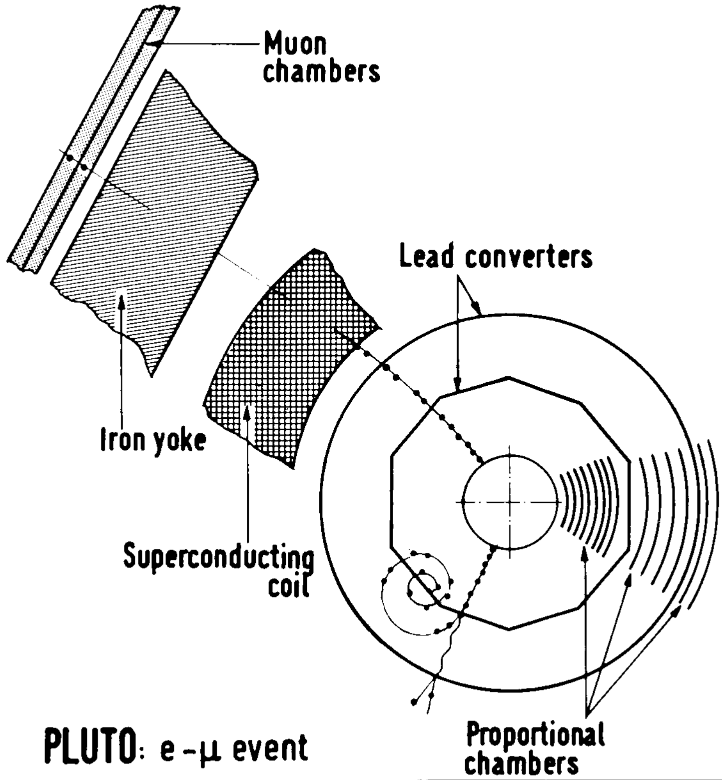
The design of the superconducting magnets and helium refrigeration systems for the beam transport into the High Intensity Laboratory is under way in the Proton Department. The magnets will be particularly important in handling 1000 GeV beams. Installation of the first of these magnets will take place in late summer and a 400 GeV beam transport system is scheduled to be in place by the summer of 1978 when the first experiments should begin. At that time it will be possible to draw both neutral and charged particle beams at zero degrees from the proton target. High intensity charged particle beams (up to 10^{10} pions per 10^{13} protons on target) will be provided by the sextupole corrected beam transport system. In addition, experimentation with high quality and high intensity antiproton and electron beams is planned for this new Laboratory.

KARLSRUHE
Superconducting quads for SPS experiment

In 1974, CERN and the Laboratories of the GESSS collaboration (Karlsruhe, Rutherford and Saclay) decided not to pursue the development of pulsed superconducting magnets for the SPS. Instead, the Labs. tackled other projects for CERN where superconducting magnets were desirable. It was



Drawing of an electron-muon event as seen in the PLUTO detector on the DORIS storage rings at DESY. They have added important evidence for the existence of heavy leptons.



decided within GESSS (Group for European Superconducting Systems Study) that Karlsruhe would construct and install two quadrupole magnets for the SPS experiment WA2 which looks at the leptonic decays of hyperons.

Two quadrupoles are required in the beam line to match the characteristics of the hyperon beam emerging from a target bombarded by the primary proton beam to the acceptance of the experiment's spectrometer. Due to the short lifetimes of the hyperons, their path lengths need to be kept short and this calls for the use of high field superconducting magnets wherever possible. By avoiding iron pole tips, the quadrupoles provide focusing for hyperons up to 150 GeV/c with a peak field gradient of 160 T/m in magnets of overall length 1.4 m and 1.1 m. The useful aperture is 3 cm diameter with the bore at liquid helium temperature.

Each magnet has four coils with 288 superconducting turns. The cross section of each coil is a rectangular block whose position is chosen to minimize field distortions in the useful aperture. The coils are mounted on a central support tube which serves as a mechanical reference. Radial forces are taken up by aluminium rings that are shrunk onto the coil assembly and the magnets are shrink-fitted into cylindrical iron yokes to contain the magnetic field.

Considerable training was observed during the test period and about 200 quenches were required to achieve the short-sample critical current. The number of quenches was proportional to the length of the magnets and further studies are being pursued to check the conjecture that the training may be primarily due to the metallurgical properties of the conductor itself rather than to its thermal or mechanical surroundings. Both magnets were trained to their short-sample limit and are operated at 90% of critical current.

Compact design of magnets and cryostats has kept the outer (warm) diameter to 24 cm in the end parts, which can thus slip between the coils of neighbouring normal dipole magnets. In this way, the effective length required for focusing in the beam is below 2 m.

Coolants come from 500 l vessels of liquid helium and nitrogen and their regular refurbishing is the only task necessary during operation of the magnets. Following commissioning in November 1976, the quadrupoles have worked continuously. 500 l of liquid helium, supplied via about 14 m of transfer lines, are sufficient for 60 hours of operation.

DESY
Results from DORIS

Results from the two spectrometers PLUTO and DASP at the DORIS electron-positron storage rings were reported at the Coral Gable Conference in January and at the Chicago APS meeting in February.

The most exciting result, obtained using PLUTO, is strong evidence for the existence of heavy leptons (see also page 68). PLUTO studied two-prong events with no other observed particle at energies between 4 and 5 GeV. One particle is identified over a large solid angle (43 % of 4 π) as a muon with only a small probability (less than 3 %) for hadron misidentification. It seems that the only way to explain this class of events by the reaction is in terms of an interaction in which the electron and positron give a pair of heavy leptons which then decay to the known leptons. The production cross section has a threshold around 4 GeV indicating a lepton mass of about 2 GeV. If the interpretation is right, some of the two-prong events should contain an electron rather than a muon and indeed about 24 clean muon-electron events were found. The electron spectrum agrees (within the still meager statistics) with the expectation for a heavy lepton with a branching ratio of about 20 % for each leptonic decay.

The electron spectrum differs considerably from the much softer electron spectrum which was observed last year for the decays of charmed mesons. Additional evidence against an explanation in terms of charm decays is obtained from muon-electron events with multiprongs. For charm decays a relatively large number of such events is expected from kaon decays which should accompany the lepton emission but the observed number is much too small.

New facets can be added to the charm picture by results from both PLUTO and DASP. The theory predicts that the charm quark decays preferentially to a strange quark and kaons should therefore be produced abundantly in decays of charmed mesons. A threshold in kaon production has now been detected, simultaneously, by PLUTO (for neutral kaons) and by DASP (for charged kaons). Also, a remarkable anomaly was found — at the 4.4 GeV peak, the production rate is comparatively low which seems difficult to understand in terms of present theories.

Recent theoretical papers have speculated about the existence of charmonium molecules made up of two pairs each consisting of a charmed quark-antiquark. If this were true, a particular decay mode involving a rearrangement of the four quarks ('charm burning') would yield about 10 % of J/psi particles. PLUTO measured the inclusive J/psi production at 4.4 GeV and saw a yield of less than 4×10^{-3} which speaks strongly against the idea of charmonium molecules.

Further interesting results were obtained for charmonium states by PLUTO. An analysis of events giving two gammas and a J/psi taken at 3.7 GeV produced further confirmation for the 3.454 GeV intermediate state which has not been seen in hadronic decays. A few more decays into J/psi and a gamma have now been observed. More statistics from DASP on the J/psi decay into three gammas gives three kinds of information. The existence of the X(2.8 GeV) state was corroborated; the total width of the three photon decay is compatible with 2/3 charge of the quarks (but not with integer charge); the branching ratios for $J/\psi \rightarrow \pi\gamma, \eta\gamma, \eta'\gamma$ were found to be in the ratio 1 : 11 : 30. Inclusive spectra for separated pions, kaons and anti-protons between 3.5 and 5 GeV show scaling with energy at large momenta whereas at low momenta the cross section increases with energy. This implies that the rise in total cross section at higher energies is associated with high multiplicity events.

It becomes more and more obvious that the energy range between 4 and 9 GeV is an extremely rich field for further investigations and the Scientific Council of DESY recommended on 1 March that DORIS should be operated for particle physics for many years to come avoiding if possible a reduction of utilization after PETRA comes into operation.

People and things

Bits and Pieces

The book of the film 'The Key to the Universe' — the television programme by Nigel Calder and Alec Nisbett on the new physics — has been issued by BBC Publications at a price of £ 5.95.

The cold box and engines of the prototype satellite refrigerator for the Energy Doubler/Saver at Fermilab were successfully tested at the end of January. Twenty-four of these units will be distributed around the accelerator ring to cool the superconducting magnets receiving liquid helium from a central plant.

An 'Informal Report' has been issued at Brookhaven (BNL 22160) entitled 'Beams at US High Energy Physics Laboratories'. It gives the parameters of the beam lines in operation, or planned for the near future, at Argonne, Brookhaven, Cornell, Fermilab and SLAC.

The Cancer Therapy Facility at Fermilab now has 45 patients on its books and 38 of them have already received neutron irradiations. The Facility draws beam from the linac for about 60 hours per week and a third of this time is used for patient treatment.

Herman Winick has written a comprehensive, readable account of synchrotron radiation research in the February issue of the 'SLAC Beam Line'.

The Proceedings of the 1976 DUMAND Summer Workshop held in Honolulu in September of last year are available from the Physics Department at Fermilab (P.O. Box 500, Batavia, Illinois 60510) price $15.50 surface mail, $17.50 Europe air mail, $24.00 USSR, Far East air mail. The Workshop investigated under ocean detection systems for neutrino and muon interactions with energies above 10 TeV.

U becomes less unknown

Further data from the electron-positron storage ring, SPEAR, at Stanford supports the contention from earlier experiments that a heavy lepton exists, with a mass around 1.9 GeV. Two blocks of concrete absorber interspersed with muon detectors were added on top of the famous magnetic detector that saw the first sign of heavy leptons. This has improved the muon signals, and more data has been collected in three energy ranges. Each time anomalous muon signals with no conventional explanation were seen.

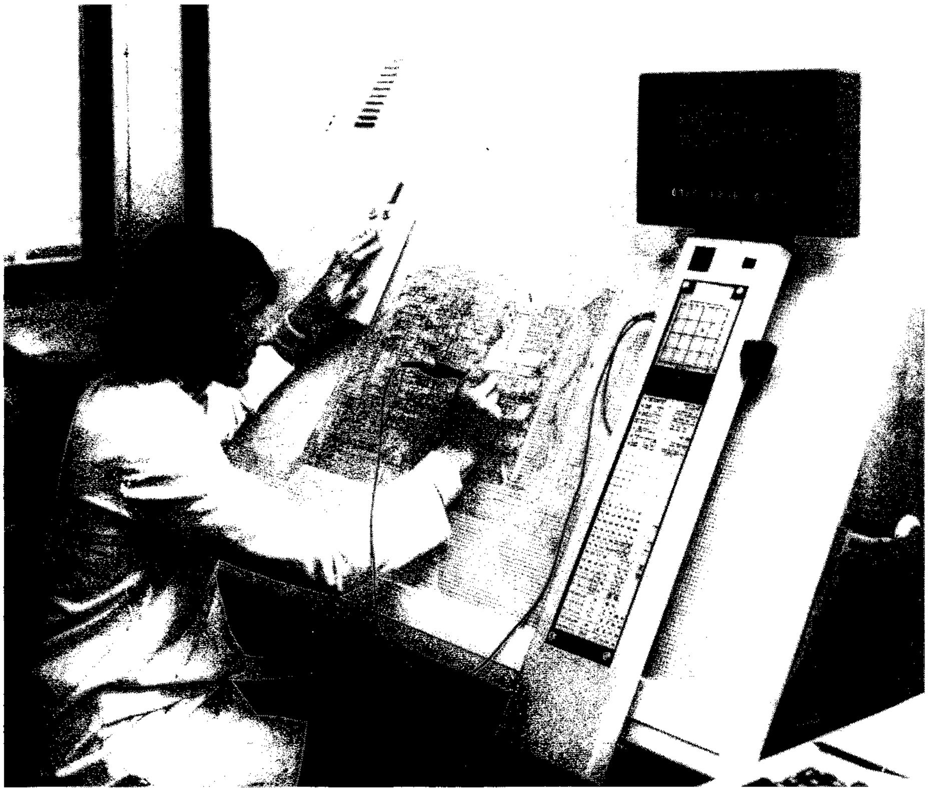
The earlier data was of electron and muon events which could result from the decay of leptons named U^+, U^- (U for unknown). The latest data adds more weight to this interpretation. Information from the DORIS storage rings at DESY on the same topic is presented on page 67. At a time when a lot of particle physics seems to be coming together, with the 'scent of a new grand synthesis in the air' (Gell-Mann's words), the U particle has the niggling quality of the pea (or should we say the Perl) under the mattress. It could be a clue to lepton spectroscopy and lepton structure which has not been foreseen as part of the grand synthesis. Martin Perl prompted the first heavy lepton analysis and G.J. Feldman led the team from SLAC and Berkeley which has provided this additional data.

Future of the ZGS

Present indications are that the Zero Gradient Synchrotron at Argonne will continue operation until the end of 1979, as recommended by the 1976 ZGS Study, so as to continue the research with high energy polarized proton beams which is unique to this machine. The other components of the research programme are likely to be

The Quest system which automates the design and production of printed circuit boards.

(CERN 107.12.76)



closed down during this year. This will include closing of the 12 foot bubble chamber which is at present in operation with a track sensitive target. Some European groups in the collaborations involved in the TST experiments have moved to the CERN programme with the 3.7 m bubble chamber, BEBC, and the remaining groups are collaborating on a final 500 000 picture experiment, with a 45 % neon-hydrogen mixture surrounding the TST, using 4.1 GeV/c antiprotons. This experiment began in March following completion of a run with stopping antiprotons for Japanese groups.

Notes from TRIUMF

The Users Executive Committee of the TRIUMF cyclotron for 1977 has the following members: M.D. Hasinoff (Chairman), J.-M. Poutissou (Associate Chairman), P. Kitching, P.L. Walden and A.W. Stetz. It is hoped to achieve a 100 µA proton beam in TRIUMF by the end of this year. The addition of an isotope separator on-line facility at the cyclotron has been approved by the Experiments Evaluation Committee and the possibility of moving the TRISTAN facility from the Ames reactor in Iowa is being discussed. It would be mounted in an additional building adjacent to the present main experimental hall. The hoped for operation date is September 1978.

Circuits from Quest

The large volume of electronics which is involved in so much of CERN's work requires large volume design and production of printed circuit boards. Three systems for digitizing and plotting the layout of PCBs have been acquired from Quest Automation Ltd. and, after a running in period since May of last year (both for the systems themselves and for the operators), are now in operation in the ISR, SPS and Data Handling Divisions. They halve the time necessary to produce PCB masters, since no 'scotching' is necessary, and allow a greater density of lines on the board. Each system has a digitizing table, a teletype, a NOVA computer, a pen plotter, a perforator and a photoplotter. The designer at the digitizing table can interact with the system in a flexible way. Two tapes can emerge from the computer — one can be used to produce the master for the PCB and the other to guide an automatic machine for the drilling of the holes in the printed circuit board. The systems are now operational and have speeded and improved PCB production. Further information can be obtained, for example, from G. Leroy, ISR Division.

ISABELLE

The 200 GeV proton-proton storage rings project, ISABELLE, at Brookhaven is receiving a second allocation of CP and D (Construction, Planning and Design) money from ERDA to continue the thorough evaluation of the design. A new design proposal is to be submitted in April with a redesign of the magnet lattice to give six intersection regions. Work on the development of the superconducting magnets has the construction of a 'half cell', consisting of two bending magnets and a quadrupole to be operated together, as its next major step. The half cell will be assembled in the old Cosmotron building where a model section of the ISABELLE tunnel has been assembled. Preparations for the industrial manufacture of the superconducting braid and coils are well under way. Jim Sanford, who is leading the project, initiated an 'ISABELLE Newsletter' at the beginning of this year to convey general information about how the project is progressing including preparations for the experimental programme.

Evidence for superheavies losing weight

In June of last year a group from Oak Ridge presented evidence for 'superheavy' elements 116 and 126 from X-ray emission spectra of inclusions in monazite crystals. Since then a series of experiments at several Laboratories have attempted to duplicate the results without success. An Oak Ridge group has recently published results which seem to have completely contradicted the original findings. They used monochromatic synchrotron radiation, from the SPEAR storage ring at Stanford, to stimulate X-ray emission in the same monazite crystals as gave the earlier results. This technique is much more sensitive than the proton stimulation used in the first

1. J.B. Adams

2. H. Schopper

experiment. No sign of emitted X-rays corresponding to what is expected from nuclei of superheavy elements was seen. The experiment should have spotted such nuclei down to concentrations of 5×10^9 atoms per inclusion whereas the earlier data suggested concentrations of 2×10^{11}.

On People

On 3 March, John Adams, Executive Director General of CERN, received the Faraday Medal awarded by the UK Institution of Electrical Engineers for his 'outstanding contributions to the design and construction of high energy particle accelerators'. John Adams led the teams building the CERN 28 GeV proton synchrotron (PS), which achieved design energy in 1959 when it was the first machine of its type to come into operation, and the CERN 400 GeV proton synchrotron (SPS), which produced its first beams last year.

Herwig Schopper, Chairman of the DESY Directorate, has been elected new Chairman of the AGF succeeding K.H. Beckurts on 17 February. The Arbeitsgemeinschaft der Grossforschungseinrichtungen (Association of Major Research Centres) was founded by ten German centres in 1970 to coordinate the work done in various research fields. The work of the present twelve member centres covers a wide spectrum.

Torlief Ericson from the CERN Theory Division, who is among the best known theoreticians in the field of nuclear physics, has been made Doctor Honoris Causa at the University of Lund in Sweden.

The new membership of the Experimental Program Committee which will vet experiments for the Berkeley/Stanford storage ring project, PEP, is as follows: Carl Albright, Karl

1.

Berkelman, Owen Chamberlain, Norman Christ, Jim Cronin, Fred Gilman, David Leith, John Peoples, Nick Samios, Frank Sciulli, S.J. Stuart Smith, Mahiko Suzuki, Bob Tripp, Paul Tsai and Bob Walker, with Gerry Fischer as Secretary. They will be making recommendations on the first experiments by June.

Moves at Fermilab: Tim Toohig has succeeded Charles Brown as Head of the Meson Laboratory. Peter Koehler has succeeded Frank Nezrick as Head of the Physics Department with Ed Blesser as Assistant Head. Dick Carrigan has become Assistant Head of the Research Division.

A Memorial Fund has been established in memory of Professor J.G. Rutherglen from Glasgow University who died in a car accident in Geneva last August while over at CERN preparing for an SPS experiment. The Fund will be used to endow an award to a postgraduate student in high energy physics. Subscriptions may be forwarded to K.M. Smith, Department of Natural Philosophy, University of Glasgow.

ECFA looks at future accelerators

At the end of February, ECFA organised a long week-end study at DESY to look at possibilities for future accelerators. About 80 physicists took part. Carlo Rubbia discussed protons

2.

and antiprotons in the SPS, Bjorn Wiik electrons and protons in the SPS and Giorgio Salvini and Burt Richter the physics interest of a large electron-positron ring (about 2×100 GeV). The Chairman of ECFA, Guy von Dardel, in his concluding talk promoted optimism about future accelerators. He recalled that two years ago PETRA was only at the project stage and now DESY is surrounded by its tunnel. He said that if miracles can still happen in Hamburg they could also still happen at CERN.

Sam Ting's speech

By popular request, here is a translation of Sam Ting's speech at the Stockholm Nobel prize ceremony reproduced in the original in the January/February issue:

'Your Majesties, Your Royal Highnesses, Ladies and Gentlemen,

Professor Burton Richter and I wish to thank the Nobel Foundation and the Royal Academy of Sciences for the great honour which has been conferred on us.

Having grown up in the old China, I would like to take this opportunity to emphasize to young students from developing nations the importance of experimental work.

There is an ancient Chinese saying 'He who labours with his mind rules over he who labours with his hand'. This kind of backward idea is very harmful to youngsters from developing *countries. Partly because of this type of concept, many students from these countries are inclined towards theoretical studies and avoid experimental work.*

I hope that awarding the Nobel Prize to me will awaken the interest of students from the developing nations so that they will realize the importance of experimental work.'

Summer Study on Fermilab colliding beams

A Summer Study on aspects of colliding beams at Fermilab will be held at Aspen, Colorado, from 27 June to 15 July, 1977. The three week Study will cover both proton-proton and antiproton-proton interactions. The use of the Energy Doubler/Saver beam in collision with the Main Ring beam for proton-proton collisions will be explored as well as the use of the Main Ring (or ultimately the Energy Doubler/Saver) for antiproton-proton collisions.

The purpose of the Study is to examine the designs of the intersection regions, experimental areas, techniques to obtain high luminosity, possible detection systems and physics objectives. Working groups will be set up to study these individual topics and any others which seem appropriate. Participants will be expected to be supported by their home institutions and, because of the limited facilities available, the number will have to be restricted. Those desiring to participate should contact Jim Walker, of the Colliding Beams Department at Fermilab as soon as possible, indicating their specific fields of interest.

Baryonium

A Max Planck Institute Heidelberg/University of Heidelberg/CERN team has studied the proton-antiproton interaction and has evidence for a narrow resonance near 2 GeV which could be an example of a baryonium. Such systems are well known for the leptons — the electron and positron are capable of living together for a short time in orbit around one another in the system known as 'positronium'. More recently the psi family has been interpreted as a charmed quark and charmed antiquark system in the various energy states of 'charmonium'. In analogy to these systems the proton-antiproton resonance has been called 'baryonium'.

There was already evidence for such a resonance in this energy region in two other experiments. The experiment at the CERN PS used an antiproton beam onto a liquid hydrogen target. A narrow resonance appeared in both the elastic scattering of the antiproton and in the decay into charged mesons. The good resolution of the detection system pinned the resonance down at 505 $\pm$ 15 MeV/c corresponding to a centre of mass energy of 1939 $\pm$ 3 MeV. Its width is less than 4 MeV.

Quark physicists interpret baryonium as a diquark-diantiquark system. The narrow width may result from the mysterious Zweig rule. Nuclear physicists interpret baryonium as a proton-antiproton system bound by a nuclear force.

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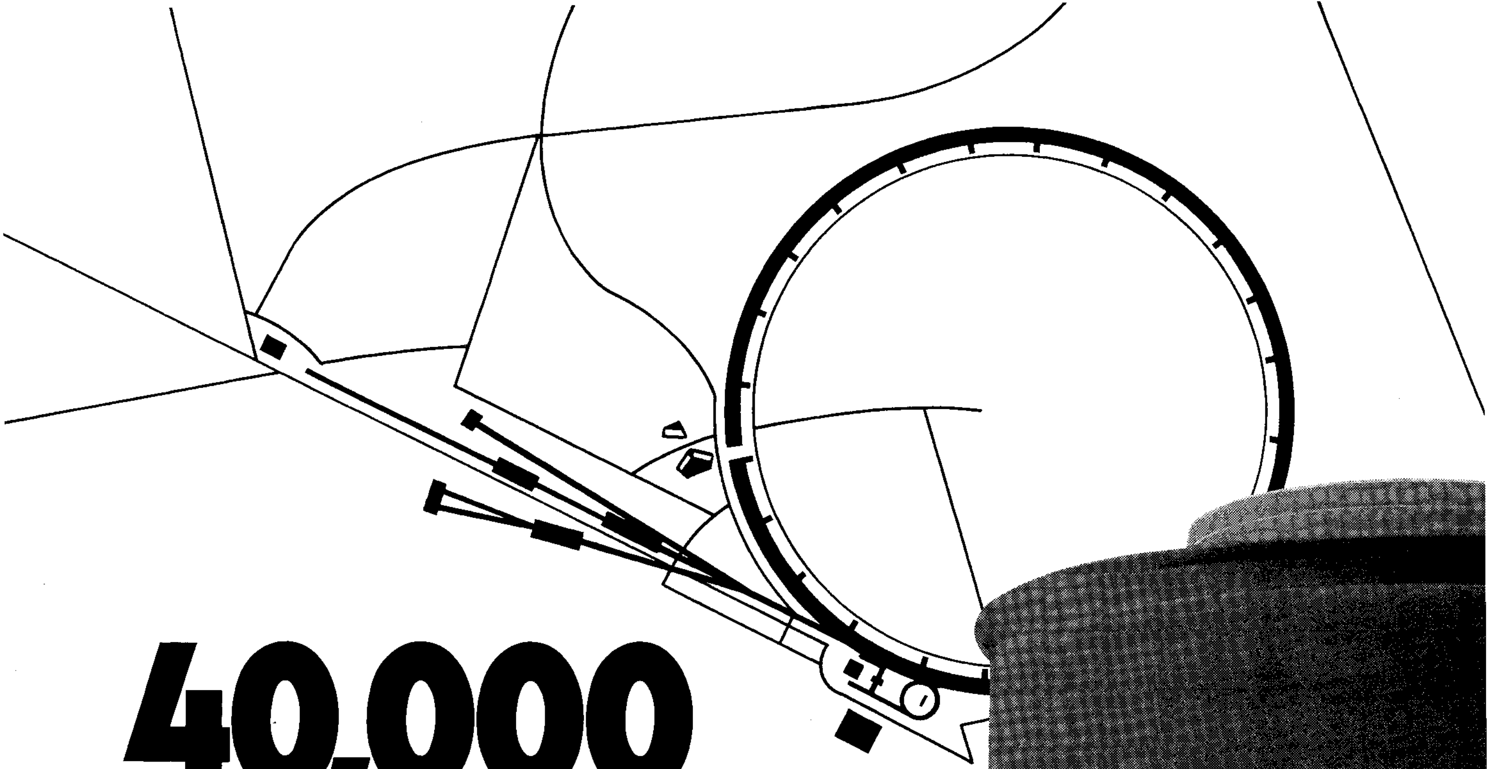

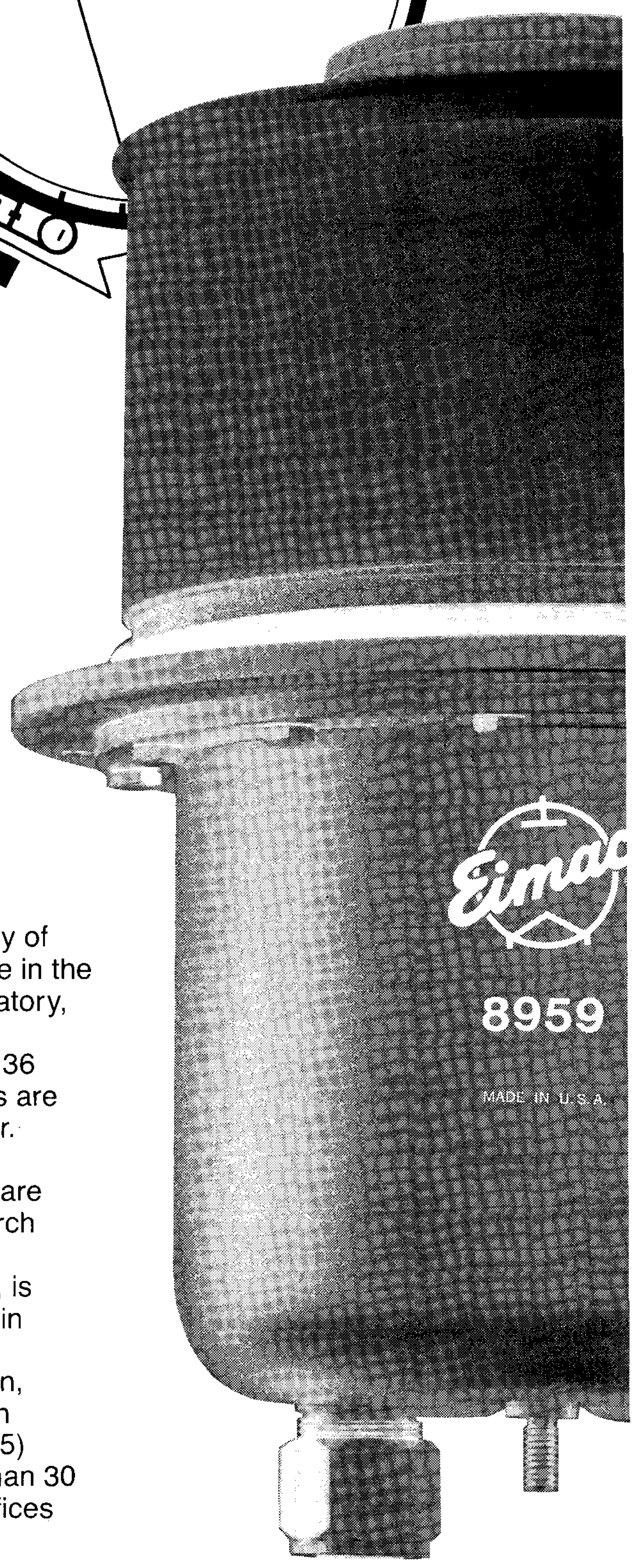

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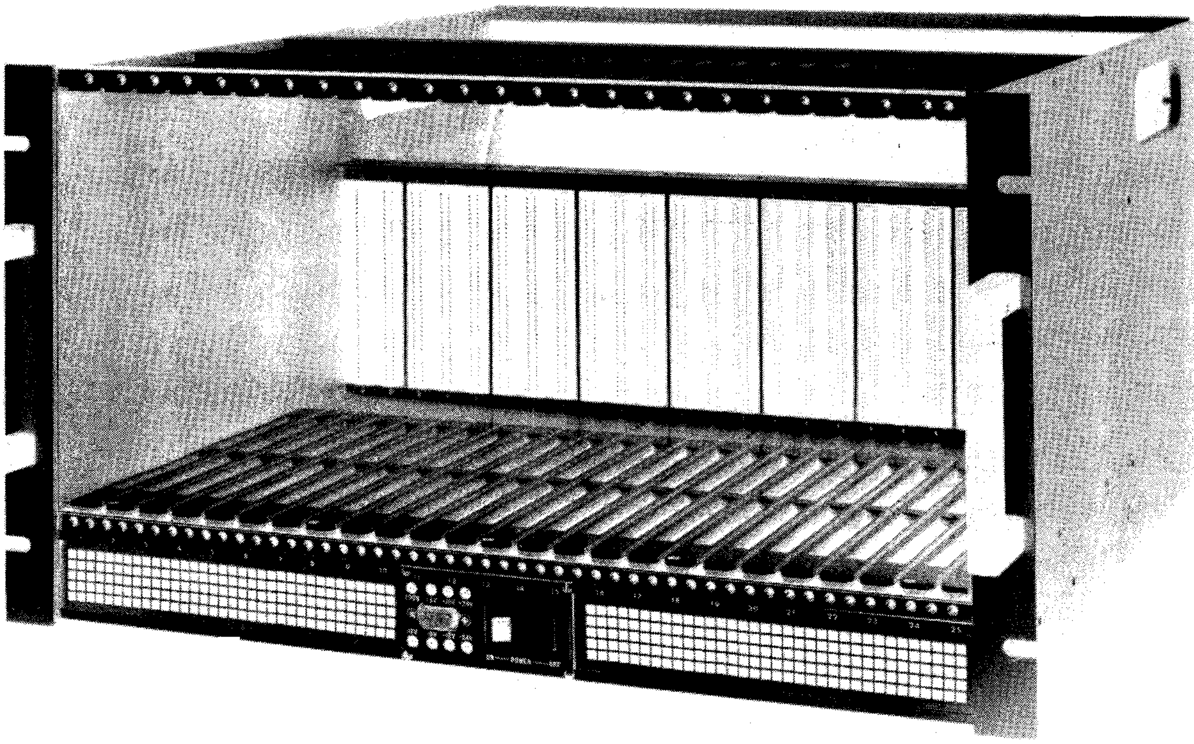

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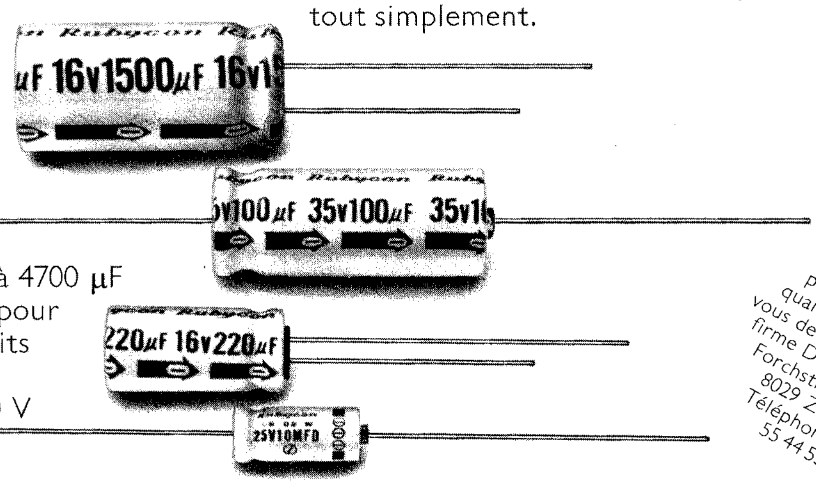

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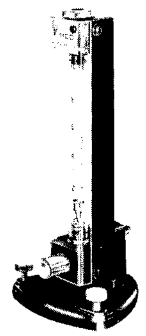

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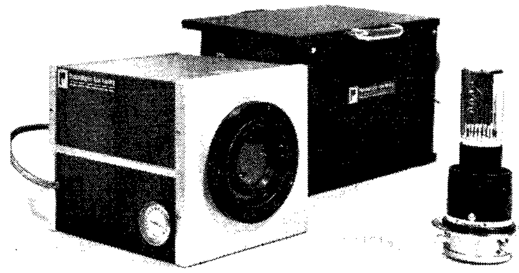

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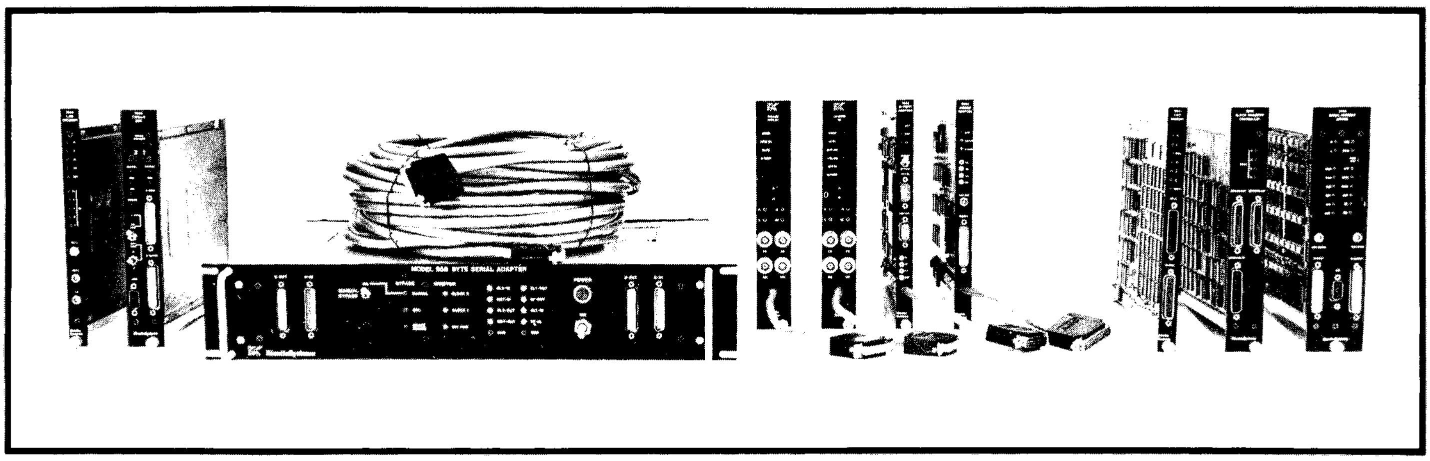

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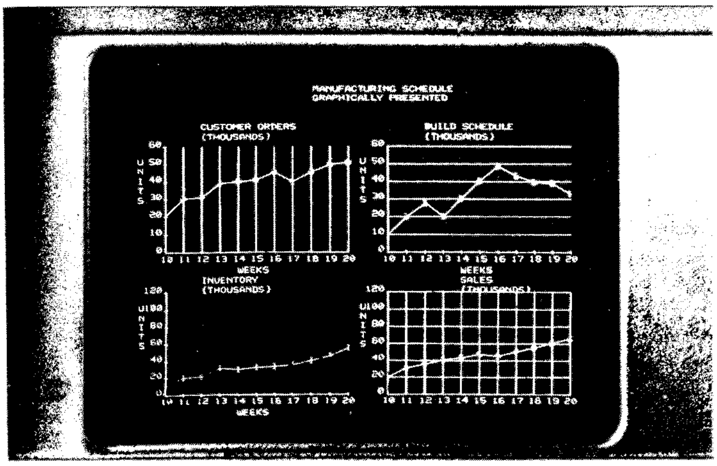

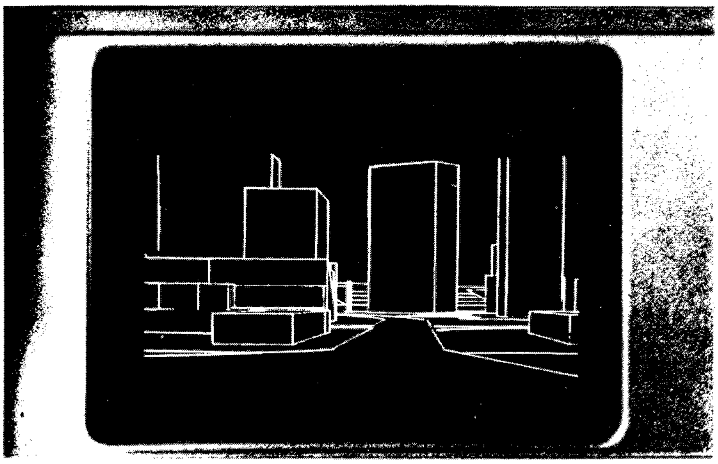

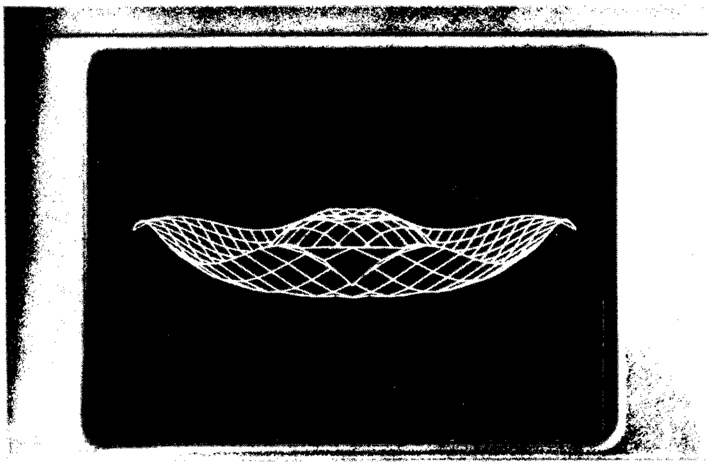

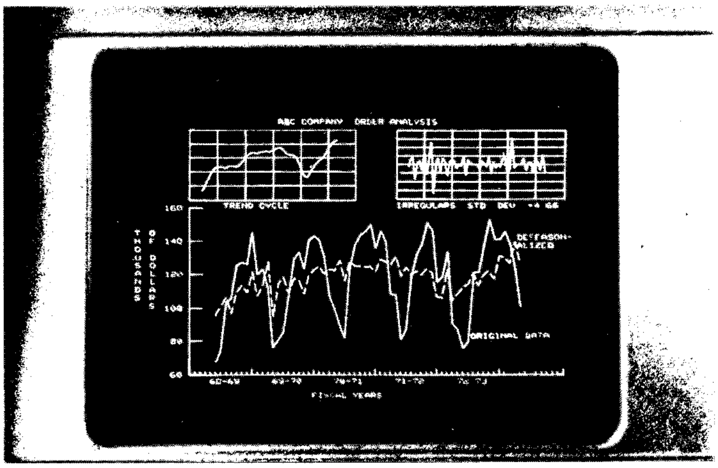

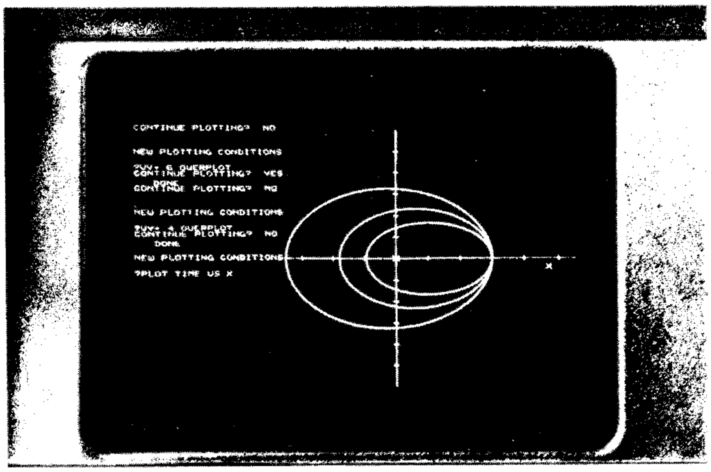

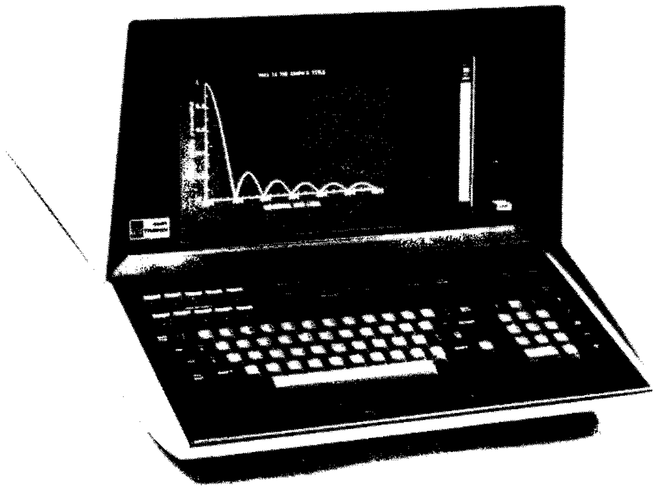

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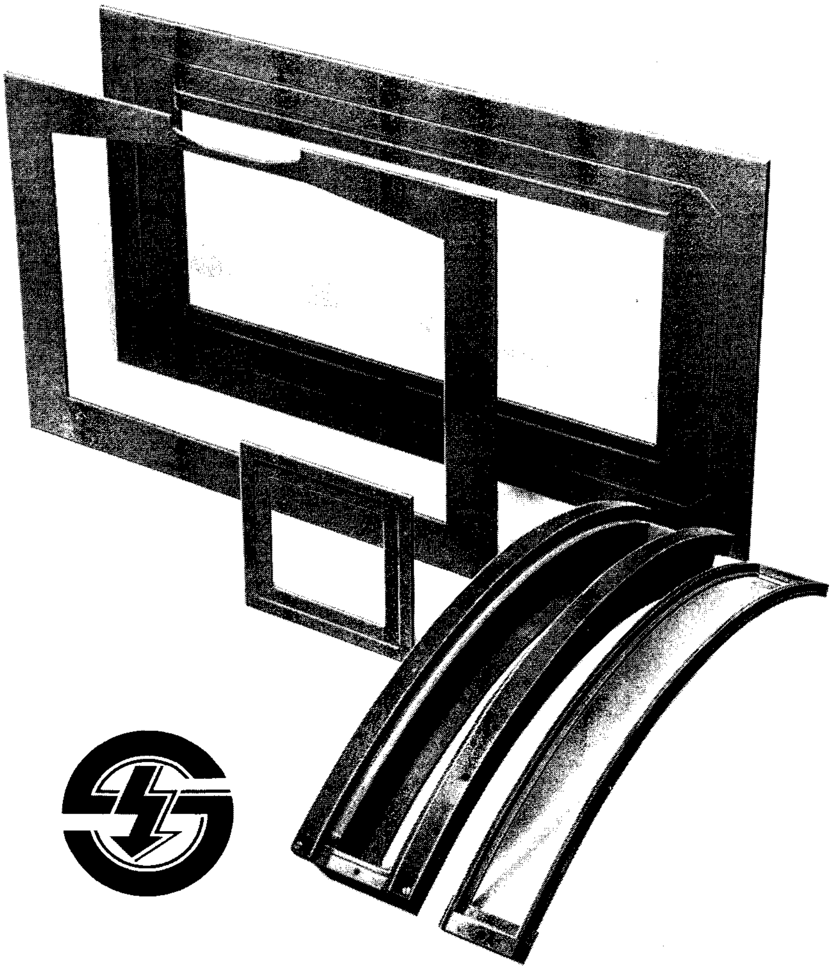

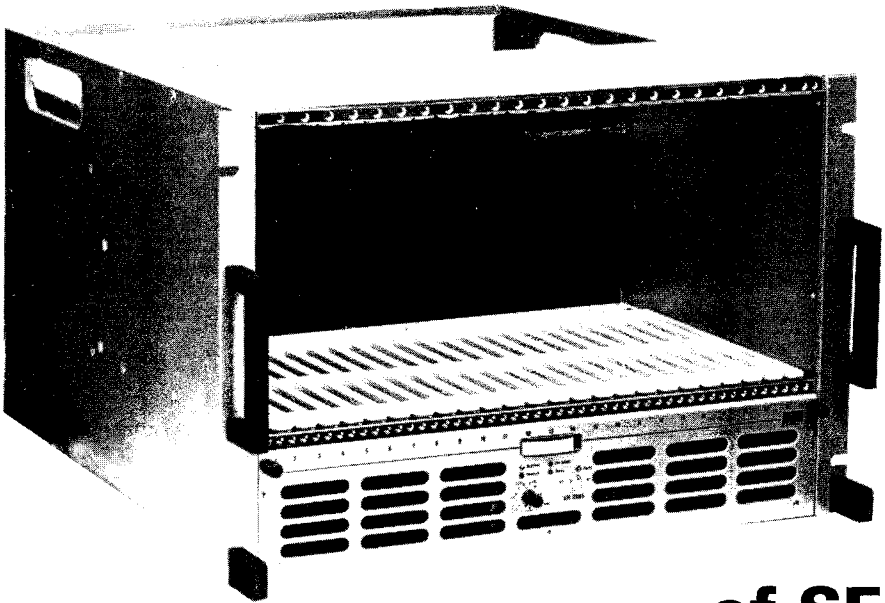

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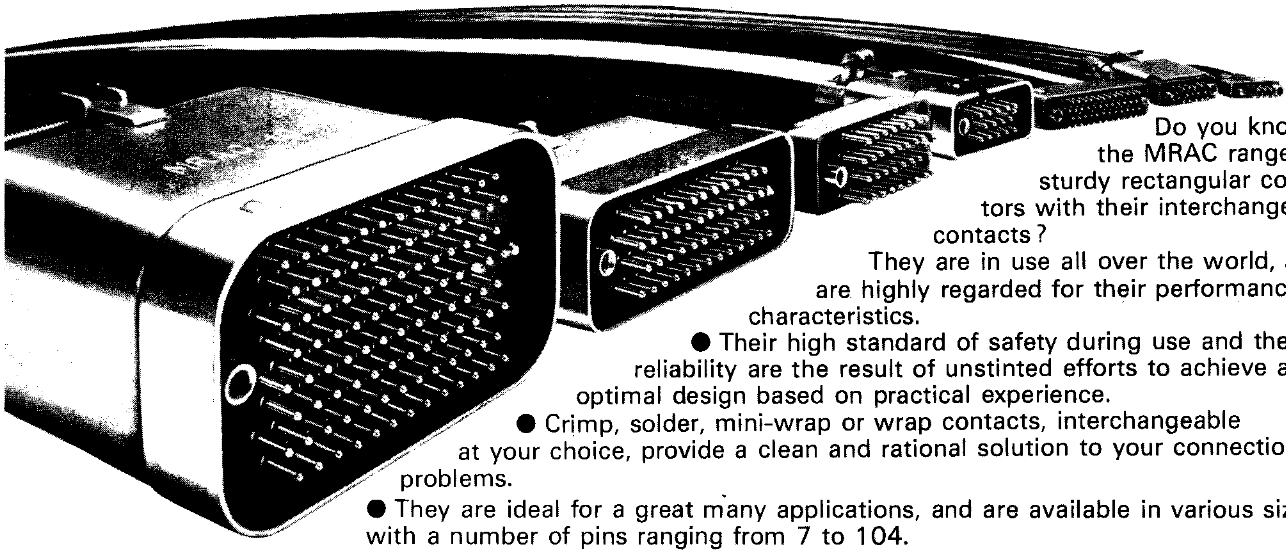

Do you know the MRAC range of sturdy rectangular connectors with their interchangeable contacts?

They are in use all over the world, and are highly regarded for their performance characteristics.

- Their high standard of safety during use and their reliability are the result of unstinted efforts to achieve an optimal design based on practical experience.
- Crimp, solder, mini-wrap or wrap contacts, interchangeable at your choice, provide a clean and rational solution to your connection problems.
- They are ideal for a great many applications, and are available in various sizes, with a number of pins ranging from 7 to 104.

Ask for further details of this line and of the other types of connectors in the LITTON programme.

Don't settle for less — Choose MRAC

Litton

LITTON PRECISION PRODUCTS
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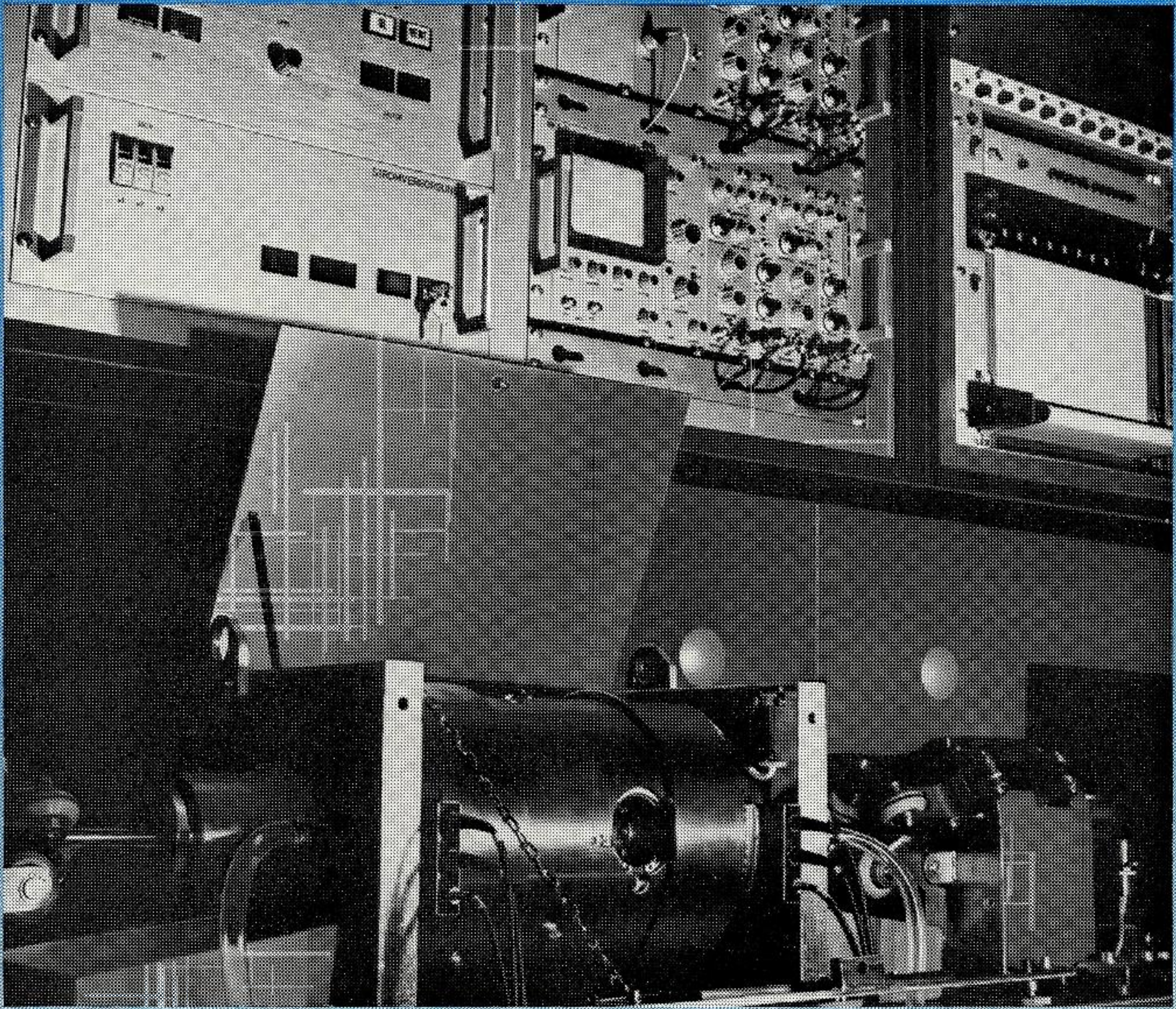
Confidence is good-control is better.



The stringent and, to a great extent, new quality demands made by the nuclear industry require reliable measuring and testing devices of topmost accuracy. For this, NUKEM has developed its own measuring, testing and control systems, transferring the reactor-technique know-how to the nondestructive testing. Take, for example, the ROTA 40 DIM ultrasonic tube-testing equipment, suitable for dimensional control of quality tubes. Thanks to the modular construction of the electronics employed, it can be made to meet individual test requirements and, in addition, be upgraded to become a fully automatic system with go/no-go sorting facility, with or without a processor. Our delivery programme also features installations for the testing of tubes with diameters ranging till 220 mm. All installations are equipped with the new NIM-technique plug-in units. The plug-in system is modular, has a superior mechanical stability, is space saving and is being used all over the world. **We help you improve your quality assurance.**

NUKEM

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