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Contents

Cover photograph: End view of a stack of aluminium vacuum vessels for the PETRA electron-positron storage ring being built at the DESY Laboratory. The profile of each chamber results from the need for four channels (for the beam, sputter-ion pumps, water cooling and bake-out elements). It is satisfying to finish our COURIER volume this year with this unusual pattern given by the DESY chambers as our cover photograph. The vigour and speed of PETRA construction has been one of the most stimulating features of the high energy physics scene during 1976. (Photo DESY)

Beam cooling — a new accelerator technique

A new technique in the handling of high energy particle beams has come into prominence in recent months. It is known as beam 'cooling'. It makes it possible to improve greatly the quality of an accelerated beam, such as protons, antiprotons or heavy ions, and holds out great potential in the use of high energy beams. (Nature has kindly given high energy electron beams their cooling for free in the form of synchrotron radiation.)

The technique has been demonstrated in two forms: 'electron cooling' which has given spectacular results at Novosibirsk and 'stochastic cooling', which is being steadily improved at CERN.

The mathematics behind the two cooling schemes are extremely complicated but, with a few generalisations, we can attempt to convey the ideas which they contain. In this imperfect world, the particles in an accelerated beam have a variety of velocities clustered around the desired velocity. We say that the beam has a momentum (mass x velocity) spread and, since it is the momentum which determines the radius of curvature of a particle in a magnetic field, this spread results in particles travelling on slightly different radii in a magnet ring. It thus contributes to the finite size of the particle beam orbiting the ring.

If it is possible to 'cool' the beam, so that its momentum spread is reduced, the beam size shrinks and the particle density is increased. There are several consequences. First of all, a beam of greater momentum spread than could be handled up to now, could be accepted into the cooling unit of an accelerator and cooled for use in the rest of the machine. This means that higher intensities and higher beam densities become possible with advantages for both conventional accelerators and storage rings. In storage ring colliding beam systems, beam density is a parameter contributing to the 'luminosity' which dictates the number of particle interactions the physicists can observe in a given time. The ability to cool beams could increase the attainable luminosity and, by avoiding any increase in momentum spread, sustain a high luminosity for longer periods. Also a cooled, smaller diameter beam can be handled in smaller aperture magnets and aperture costs money. (Aperture can, however, be required for other reasons such as the necessary beam manoeuvres for ejection.) In general, a cooled beam is a better quality beam which is easier to handle and which should give better results in many applications.

Electron cooling

The idea of electron cooling originated with Gersh Budker in 1967 and during this year, 1976, he and his colleagues at Novosibirsk have confirmed the techniques in practical tests. The method involves sending an electron beam along a section of an accelerator/storage ring travelling at the same velocity as the beam of heavier particles which is to be cooled. The electron beam travels near parallel along the section with low momentum spread. The heavier particle beam has momentum spread and when collisions occur with the electrons a relatively high amount of the momentum difference (relative to the desired momentum) of a heavy particle is conveyed to an electron. Over many turns around a ring in which there is a cooling section of this nature, the momentum spread of the heavier beam is considerably reduced.

The test system at Novosibirsk involves a 'ring' which is, in fact, more like a square in form. Protons are injected and travel around the ring with an energy of 65 MeV. A large momentum spread can be artificially introduced by giving the protons a kick with a magnetic field. Along one side of the square a beam of electrons, with an energy of 35 keV (giving the lighter electrons the same velocity as the 65 MeV protons, since this maximises the probability of the Coulomb scattering taking place), is fed in so that it travels with the proton beam up to the end of the straight section. Solenoid fields take care of the injection, guiding and ejection of the electrons while having little effect on the heavier protons. The field direction runs along the straight so that the electrons each execute tiny spirals around parallel field lines. The electron density is around 0.25 A/cm^2 and quite a modest electron gun is needed to supply the necessary currents. Also the ejected electron beam is collected and the current returned to the injection system so that the power supply has very little to make up.

With this system, Novosibirsk has demonstrated that 100 μA proton beams with centimetre cross sections can be shrunk to sub-millimetre cross sections in 83 ms. It is this extremely rapid cooling rate that has stirred up so much interest in cooling techniques during recent months.

The equation giving the cooling time contains many parameters — energy and mass of the heavy particle, electron current density, maximum and minimum beam divergencies, . . . The Novosibirsk experiments have checked most of the relationships in agreement with theory. The one mysterious, and agreeable, surprise is that the cooling rate is ten times faster than was predicted. One point worth noting is that the cooling rate depends upon the energy and is faster at lower energies.

Stochastic cooling

The idea of stochastic cooling originated with Simon Van der Meer at CERN and was first tested on the ISR in 1975. The density distribution of a cross section of a beam is measured and its 'centre of gravity' is calculated. This slice of the beam is then given a nudge by electric fields further around the ring (racing the particles around by taking signals straight across the arc of the machine) so as to move the 'centre of gravity' towards the desired orbit. It is a statistical method in that any nudge which favourably affects some particles has an unfavourable effect on others. But, by operating on the centre of gravity, the majority in that particular slice are favourably affected and there is a progressive cooling of the beam.

The 1975 tests became possible with the development of sufficiently fast electronics (GHz range). They concentrated on reducing the beam size in the vertical direction and a cooling rate of 2% per hour was achieved (see September issue 1975 for a fuller exposition). In 1976, work has extended to cooling the momentum spread of the beam and thus reducing the horizontal beam size. This was proposed by R. Palmer at Brookhaven in connection with the ISABELLE colliding beam project and the theory was developed by Hugh Hereward at CERN. Other people at CERN who have played an important part in the development and the thinking on stochastic cooling are Leo Faltin, Dieter Mohl, Wolfgang Schnell and Lars Thorndahl.

The results are in excellent agreement with theory and stochastic cooling is better understood than electron cooling. Its abilities can be considered in two regimes — with high intensity beams (tens of amperes) such as are normally handled in the ISR, and with low intensity beams. This is because the cooling rate is inversely proportional to the number of particles in the beam.

With high intensity beams there is a good signal to noise ratio and full correction of the 'error' in the beam is possible. The cooling time is comparatively long. With low intensity beams signal to noise is poor but cooling can be achieved with a correction of only one part per thousand. (In this case, the beam does not need to be raced across an arc-observation and correction equipment can be located in the same straight section.) So far the best cooling rates with 5 mA beams have been about 10% per hour and it is believed that, with the equipment available, a further factor of three improvement should be achievable. Better equipment for low intensity work will be installed next Spring. It could give another gain of a factor of ten. For high intensity work, a 4 GHz pick up and kicker system is being installed and could prove useful for beams of up to about 10 A.

The cooling rates attainable with stochastic cooling are obviously orders of magnitude away from what has been achieved with electron cooling. For microamp beams cooling times of a few minutes seem possible. An important difference between the two techniques is that they scale differently with energy. Electron cooling is at its best at low energies and may therefore be used in injection systems while stochastic cooling could take over at higher energies to sustain what has been achieved by the other technique.

Possible applications

The application of cooling (predominantly electron cooling) which is under discussion in the high energy physics field is in the production of high intensity antiproton beams. There is much physics interest in colliding protons and antiprotons since the very high energy quark (in the proton) — antiquark (in the antiproton) interactions could yield for investigation a whole range of phenomena which are predicted on the basis of the knowledge about the behaviour of matter which we have accumulated so far.

Also, protons and antiprotons could be accelerated, stored and collided in a single ring (like the familiar single ring electron-positron systems). It could, therefore, be an inexpensive route to the investigation of extremely high energy interactions by converting an existing proton ring, such as the Fermilab machine or the SPS, to provide for proton-antiproton collisions.

The problem with such schemes up to now has been that the antiproton beam intensities which could reasonably be achieved were far too low to give a usable interaction rate. The cooling techniques raise hopes again. Using electron cooling it will be possible to accept a pulse of antiprotons of wide momentum spread from a target bombarded by a high energy proton beam. They can then be cooled and stacked in a modest storage ring until an acceptable beam intensity has been built up. These possibilities have been looked at both at Fermilab and at CERN.

It is too early to go into details on possible schemes because they need input from experimental tests on cooling before they reach their final form. The general ideas are to accelerate protons to say 100 GeV, use them on a target to give a high flux of antiprotons, collect antiprotons with a fairly wide momentum spread around say 3 GeV, decelerate them to 200 MeV so as to be able to cool them by electron cooling, accumulate many cooled pulses, inject the intense antiproton beam into the big ring, accelerate protons and antiprotons together to energies of over 100 GeV, collide the beams and collect the Nobel prizes. On paper, luminosities of 10^{29} to 10^{30} seem feasible and it is the ability to take a large momentum spread of antiprotons and then to produce and store a low momentum spread beam that makes these luminosities possible.

Such a scheme has been put forward at Fermilab by D. Cline, P. McIntyre, Fred Mills and Carlo Rubbia. They suggested using the Booster for antiprotons and adding a 200 MeV 'Freezer Ring'. D. Berley and M. Month discussed cooling antiprotons by electrons at the Fermilab Aspen Summer Study in July. At the beginning of November a research proposal was submitted to the National Science Foundation for the construction of a 200 MeV proton ring to study electron cooling. The ring would probably be located at the end of the linac (on the opposite side to the Booster).

Similar schemes have been promoted at CERN particularly by Carlo Rubbia. Groups under the Chairmanship of Franco Bonaudi have looked at the physics and technical aspects of proton-antiproton colliding beams in the SPS. Simon Van der Meer is leading the technical work with a view to reaching project stage by Autumn of next year. To investigate cooling it is likely that the existing g-2 ring will be used next year for experiments on electron cooling (led by Guido Petrucci) and on stochastic cooling (led by Lars Thorndahl).

It is likely that both Laboratories will be in a position to take a decision on proton-antiproton colliding beams by the end of next year.

To conclude this presentation of cooling techniques we can mention another application which could prove extremely important. In the September issue, we described the possibility of thermonuclear fusion reactors in which deuterium-tritium pellets are bombarded by heavy ion beams. Tailoring the heavy ion beams to match the pellet dimensions seemed to be one of the more difficult tasks in such a proposal. If the heavy ion beams are cooled, this difficulty could go away.

SRFs in USA

The exploitation of the synchrotron radiation emanating from electron beams orbiting synchrotrons or storage rings has mushroomed in recent years. There are major synchrotron radiation facilities (SRFs) at Daresbury, DESY and ORSAY in Europe, and at Stanford and Wisconsin in the USA. They are serving scientists in many disciplines — physics, chemistry, biology, materials science and technology.

Except at Wisconsin, the research has been parasitic on high energy physics uses of the machines but it has proved so fruitful that 'dedicated' facilities, tailored specifically for the needs of synchrotron radiation research and used exclusively for such research, are a logical next step. Such dedicated facilities based on electron storage rings are to be constructed at Daresbury and at the Moscow Institute for Physical Problems. There are also plans to build a dedicated facility at Tokyo in Japan.

Similar projects have been evolving in the USA during the past two years and, at the beginning of 1976, the Solid State Sciences Committee initiated a study of the needs. A Panel, chaired by Robert Morse, was set up in April and has produced 'An Assessment of the National Need for Facilities Dedicated to the Production of Synchrotron Radiation'.

The Panel asserts that there is 'outstanding scientific and technological justification for a greatly expanded synchrotron radiation capability' in the USA. They give a conservative estimate of a requirement, by the mid-1980s, for 60 X-ray stations, providing radiation in the 1 to 50 keV (12 to 0.25 Å) range, and 40 vacuum ultraviolet stations, providing radiation in the 0.01 to 0.1 keV (1200 to 12 Å) range.

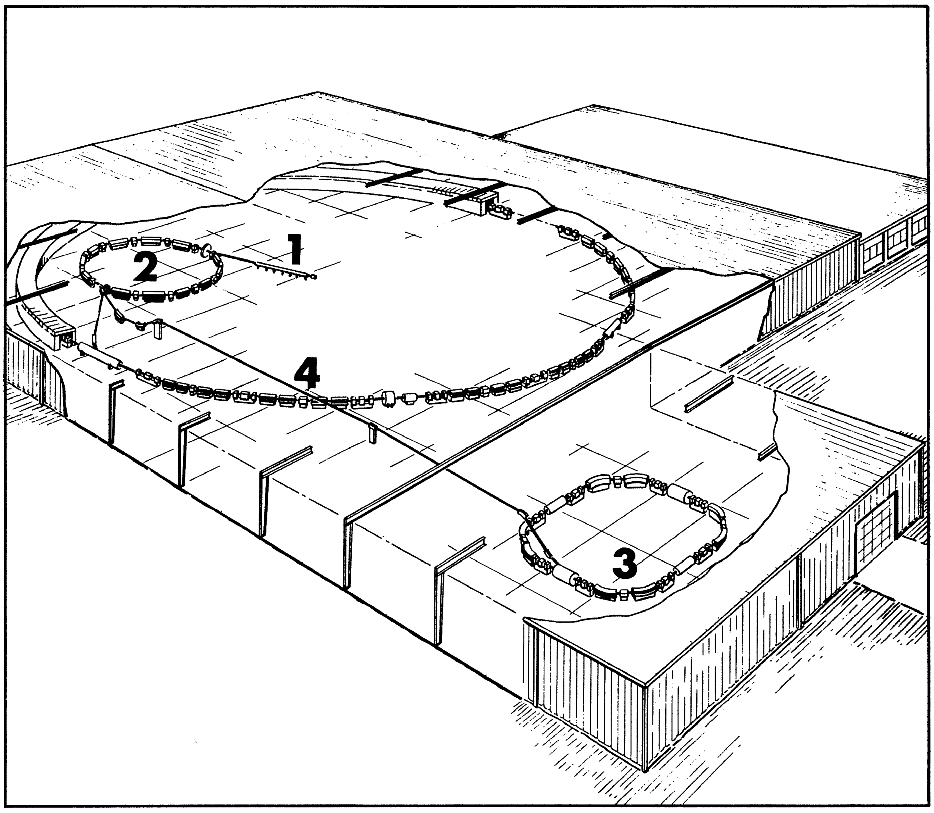
Such a number of stations could not be provided by improvement of existing facilities and the Panel recommends the construction of new dedicated SRFs geographically distributed across the USA so as to ease the problems of use by experimental groups from across the continent. Each facility is seen as a national facility.

In his introduction to the Panel report, Robert Morse remarks that the need would be satisfied by three geographically distributed major facilities at least two of which would have X-ray capability, all three having ultraviolet capability. By coincidence (of course) three SRF proposals meeting these parameters are already on the table.

Brookhaven National Laboratory, a newcomer in the synchrotron radiation field, has put forward a proposal for the construction of a National Synchrotron Light Source at a cost of around $22 million and with a target completion date of 1981 (given a start at the end of 1978). The design committee was headed by Martin Blume with the main contributions coming from Rena Chasman and Ken Green.

The design has been built around two themes. The first is that a study of the optical requirements led to a concentration on achieving high source brightness. The magnet lattice makes it possible to focus small emittance beams to a small cross section with small angular divergences. The second is that optimising both X-ray and ultraviolet capabilities is not possible in the same ring. For example, doing lower wavelength ultraviolet studies at a high energy ring could flood the apparatus with X-radiation.

The project, therefore, contains two electron storage rings — a 700 MeV ring with 16 ports for research with radiation in the ultraviolet range and a 2 GeV ring with 40 ports for research with radiation in the X-ray range. Stored beam intensities are set at up to 1 A. Superconducting 'wiggler' insertions are foreseen at several



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1. Layout of the synchrotron radiation facility proposed at Brookhaven. The elements indicated are (1) the linac, (2) booster, (3) 700 MeV storage ring light source, (4) 2 GeV storage ring light source. The booster can feed either of the rings.

2. Layout of the SPEAR storage ring at SLAC with the present facilities of the Stanford Synchrotron Radiation Project, SSRP, indicated at the top around the northern arc of the ring. The proposed extensions would be around the southern arc where seven beam ports could be accommodated.

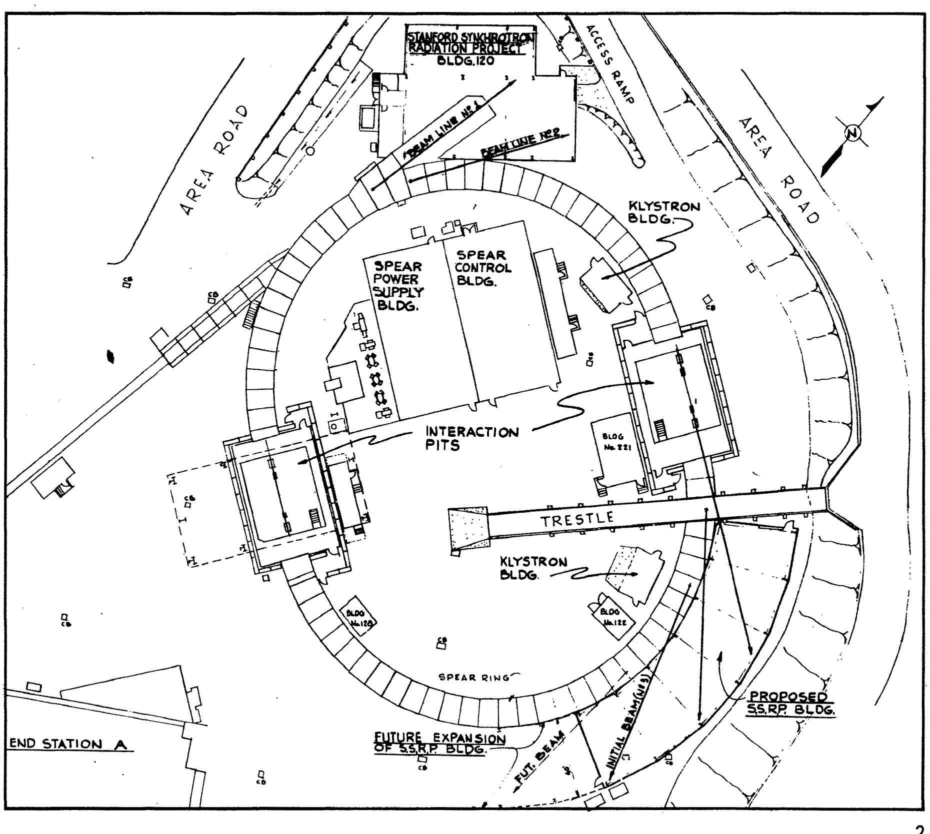
insertions in the 2 GeV ring to take the wavelength capabilities even lower.

The Stanford Synchrotron Radiation Project (SSRP) has been in operation at the 4 GeV SPEAR storage ring at SLAC since May 1974. At the end of June this year, a second radiation beam-line was brought into operation to feed four or more X-ray experiments doubling the number of available research stations. SSRP, which is funded by the National Science Foundation, currently serves about 150 scientists from 35 research centres and there is pressure for more facilities.

SSRP runs parasitically on the colliding beam high energy physics programme with SPEAR and a proposal has been submitted for the dedicated use of SPEAR for synchrotron radiation research when the emphasis of the colliding beam work moves to the 15 GeV PEP storage ring. Pief Panofsky, Director of SLAC, has already suggested that when PEP becomes available for high energy physics for half of its operating time, then half the operating time of SPEAR could be devoted to synchrotron radiation research. Herman Winnick from Stanford University represented SSRP as a consultant to the recent Panel.

The proposal for extending SSRP involves the construction of a new experimental area around the southern arc of SPEAR, providing seven more ports (feeding up to fourteen stations) and adding two wiggler insertions in the ring. The electron energy could be set between 1.3 and 4 GeV with beam intensities varying from 1.3 A at the lower energy to 0.08 A at the top energy. A three year construction period is foreseen at a cost of around $7 million.

The Physical Sciences Laboratory at the University of Wisconsin was among the pioneers of synchrotron radiation research. They have operated a 240 MeV storage ring called Tantalus I for eight years. It has nine beam ports providing what is, at present, the world's finest source of radiation in the ultraviolet region, for an extensive community of users. The Wisconsin team, led by Ed Rowe, has now proposed major extensions to their Synchrotron Radiation Centre.



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Their's is also a two ring proposal with emphasis on source brightness. The smaller ring, to cover the ultraviolet range, has an energy of 750 MeV and is fed by a 100 MeV microtron. It has 24 ports. The larger ring, to cover the X-ray range, has an energy of 2.5 GeV and has 40 ports. There is provision for wiggler insertions but they do not receive as much emphasis as in the other projects since the Wisconsin experience points more to the longer wavelengths as the fruitful areas of physics for the coming years. Each ring is designed to store 1 A of electrons.

The Wisconsin rings have been given the names of Aladdin (traditionally associated with a magic lamp) and Tantalus 2.5. The estimated cost of the full facility is $22 million over a construction time of about four years.

The report of the USA Panel making recommendations relevant to these proposals also gives a very good review of the research presently carried out at the SRFs and of the properties of the radiation associated with different machine parameters. The report is available from the Solid State Sciences Committee, National Research Council, 2101 Constitution Avenue, Washington DC 20418. Another thorough document on the present state of the art with SRFs is the Proceedings of the Quebec Summer Workshop on Synchrotron Radiation Facilities held in June. It is available (price $18) from the Centre for Chemical Physics, University of Western Ontario, London, Canada.

Around the Laboratories

FERMILAB
A track of a charmed particle

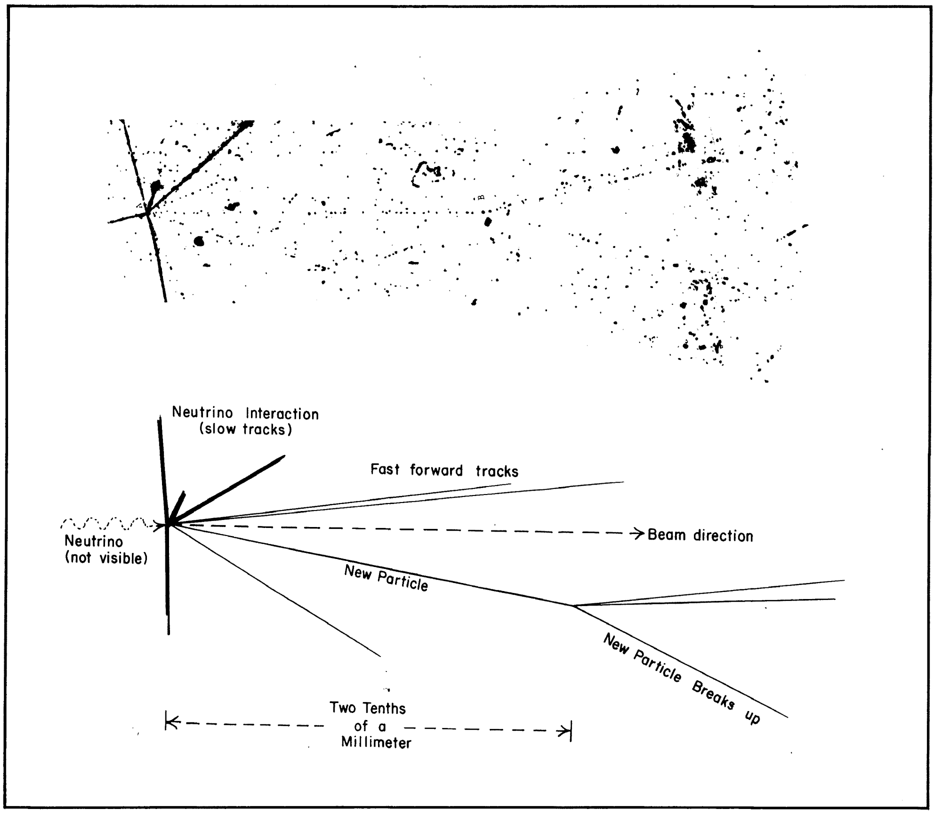
A Brussels / Dublin / CERN / Fermilab / Imperial College London / Open University / Mulhouse / Rome / Strasbourg collaboration led by Eric Burhop (who proposed the experiment) has seen a track in a high energy neutrino event in nuclear emulsion which has very probably resulted from the production of a charmed particle.

The collaboration had set up a hybrid detection system of emulsion stacks followed by a wide gap spark chamber, a shower detector, a scintillation counter hodoscope and a muon identifier, located in the neutrino beam some 30 m downstream of the 15 foot bubble chamber. Most of the detection system was developed at CERN and tested on the PS in 1975 by the Rome/Strasbourg component of the collaboration. The purpose of the hybrid system is to identify the point in the emulsion where an event of interest occurred. This avoids the near impossible task of examining the whole emulsion volume in search of events.

With a total of about 7×10^{17} protons of 400 GeV energy on target, about 250 candidates for neutrino interactions in the emulsion have been picked out by the detection system. About a third of these have been looked for and, so far, 16 interaction vertices have been found.

One of these has a track which has the characteristics expected of a charmed particle. It travels a distance of 0.18 mm before decaying to give three charged particles. It is here that the special detection ability of nuclear emulsion comes in. Only with emulsion, which has been developed and studied under a microscope, could such a short track length be observed and measured. It corresponds to a particle lifetime of around 5×10^{-13} s.

The event recorded in a neutrino experiment at the Fermilab which looks like the first observation of the track of a charmed particle. The track was found in nuclear emulsion, the only detection technique capable of seeing, directly, the passage of a particle living as briefly as a few times 10^{-13} seconds.



The possibility that the track could have been caused by a 'conventional' particle has obviously been studied but none fits the observations of decay into three charged particles, as seen in the emulsion, and a neutral particle, needed for momentum conservation reasons, after only 6×10^{-13} s. (A vertex from the decay of a neutral particle points back to the decay vertex of the probable charmed particle.) The observations do fit the hypothesis that a charmed particle was produced and decayed — for example, the charmed meson D (1.87 GeV) decaying into $K^0K^+K^-\pi^+$ or the Σ_c (2.48 GeV) decaying into $\Lambda^0K^+K^-\pi^+$.

LOS ALAMOS
Happy time for LAMPF

Louis Rosen, the Director of the Los Alamos Meson Physics Facility, opened his report to the 10th LAMPF Users Meeting on 8, 9 November with the words, 'This is a happy time for LAMPF'. The Meeting brought together 243 participants from research centres in the USA and abroad, members of the Users Group which is a formal channel for exchange of information between the scientific community at large and the administration at Los Alamos. There are currently 1000 members from more than 300 centres, such as Universities, hospitals and medical centres, plus industrial and governmental Laboratories.

Louis Rosen cited a number of milestones that have recently been achieved at LAMPF — routine operation with 100 μA production beam, successful test runs at 200 μA through all targets to the beam stop, the high resolution spectrometer (HRS) reaching its goal of better than 100 keV resolution, and all secondary beams in operation for experiments (except the

Part of the audience at the opening session of the LAMPF Users Group Meeting held at Los Alamos on 8 November. Louis Rosen, LAMPF Director, is in the foreground, with Thomas Putman, LAMPF Assistant Leader for Safety, and James Kane (on the right), Director of the ERDA Division of Physical Research, behind. Seated in the third row is Herbert Anderson from the University of Chicago a past Chairman of the LAMPF Users Group.

(Photo LASL)

pulsed beam of the Weapons Neutron Research Facility).

Plans for higher beam intensities in the future intend to have the routine operating current raised from 100 to 300 μA in the fall of 1977 and to confront the last step from 300 μA to the design intensity of 1 mA in 1979-80.

Several organizational changes were announced, reflecting an increased emphasis on experimental areas, the research programme, and the practical applications programmes at LAMPF. The budget has grown, almost in accordance with initial projections, from three million dollars in 1966 to twenty million dollars for 1977 operations. However, Louis Rosen cautioned that this steep rise is over and an almost flat budget is anticipated for the years ahead.

Don Hagerman, who heads LAMPF operations, reported in more detail on the recent operational success. Beam availability has been consistently better than 80 % during the past year. No decrease in reliability was experienced when operation with proton and H^- beams simultaneously was started in April or when the main current was raised to 100 μA in August. Activation levels in the accelerator and radiation levels in the experimental areas are low. The beam switchyard is operating with a beam halo spill of only a few parts per 10 000 and, based on the spill-free beam achieved at 200 μA, LAMPF can plan to deliver 300 μA with confidence.

The experimental facilities will be increased next Spring by the addition of a polarized beam which will be generated from an H^- Lamb shift source and will be delivered simultaneously with the high intensity proton beam. Initially it is expected to accelerate an intensity of 25 nA with 80 % polarization. The user community is very enthusiastic at the prospect of polarized beams being available for use on the external proton beam-line and with the HRS.

The high resolution spectrometer has met its design specification and has completed its first cycle of operation for physics. The spectrometer's energy loss design concept permits use of the full energy spread of several MeV in the LAMPF 800 MeV H^- beam, while giving the resolution of under 0.1 MeV which is required to see new features of nuclear structure. This design disperses the beam energy spread over the target and recombines, on a line in the spectrometer focal plane, all scattered particles having the same energy loss. Thus the event distribution across the focal plane gives a high resolution picture of the cross section against energy loss to the recoiling target nucleus.

The trick is to make the beam-line work together with the spectrometer in a fashion called 'dispersion matching' which means that the spectrometer must exactly recombine the scattered particles from the dispersed beam on target. Once the spectrometer was fully instrumented, a concentrated effort during recent accelerator cycles resulted in a successful tune. The beam-line and spectrometer use magnets of a size normally associated with the multi-GeV range of accelerators. For example, the spectrometer dipole pair and frame weigh about 330 tons and stand about 10 m high. Nonetheless, despite the size, the magnet engineering was sufficiently precise that no trimming coils were required to reach 100 keV resolution.

Instrumentation includes a scintillation counter time-of-flight/pulse height assembly and a wire chamber array for event localization and angle measurement. The on-line data system can correct energy loss for kinematic variation with the finite acceptance of horizontal scattering angle. All this machinery was turned loose for research on Saturday 6 November and one week later a happy experimental team wrapped up the first HRS production run.

Other subjects at the November Users meeting were covered by James Kane (Director of the Division of Physical Research of ERDA) who spoke on the future role of basic research in ERDA, by John Domingo and Milan Locher (Schweizerisches Institut für Nuklearforschung, SIN) who spoke on research at SIN, by Reg Richardson (until recently Director of TRIUMF at British Columbia) who spoke on research at TRIUMF, by Alan Krisch (Michigan) who spoke on high energy experiments with a polarized proton beam and target, and by T.D. Lee (Columbia) who spoke on non-topological solitons. The research at LAMPF was covered in several talks: particle physics by Richard Mischke (LASL), nuclear structure by Robert Eisenstein (Car-

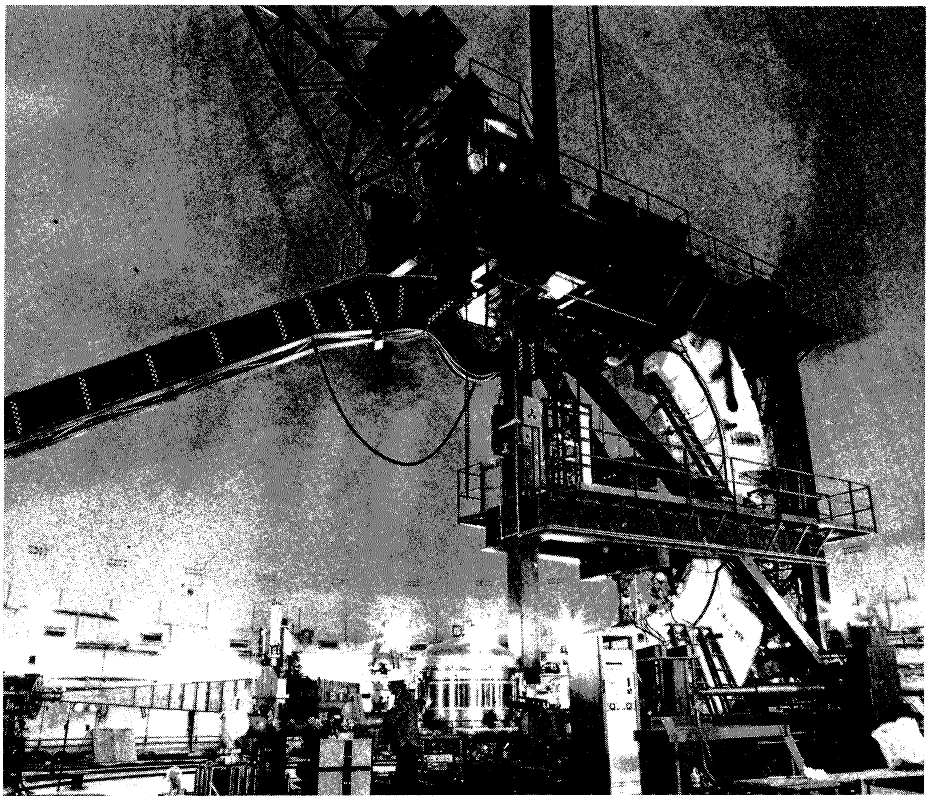
A view of the high resolution spectrometer HRS, which has begun operation at LAMPF achieving its design parameter of 100 keV resolution. The beam comes in from the left and enters the scattering chamber at the bottom of the vertical spectrometer magnets. Detectors are located on top.

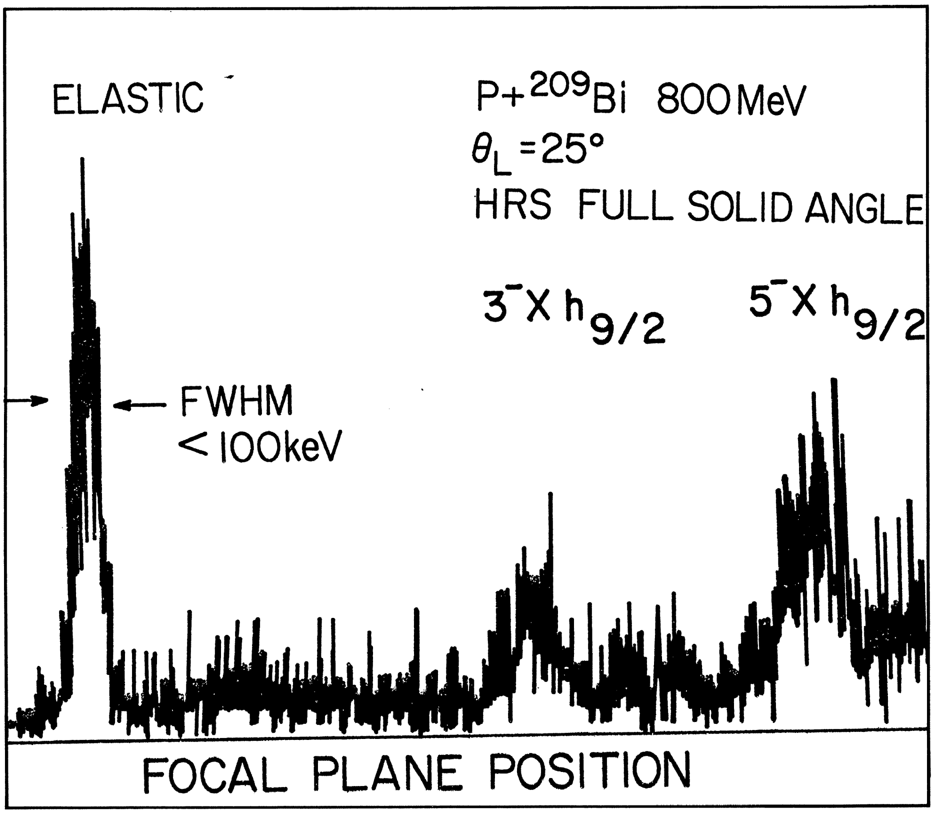
(Photo LASL)

Part of the first spectrum obtained with the HRS showing that the 100 keV resolution has been bettered in observing the scattering of protons on bismuth 209. The total range on the focal plane corresponds to 6.7 MeV.

negie-Mellon), practical applications by Ed Knapp (LASL) and biomedical results by John Dicello (LASL).

The Board of Directors of the Users Group for 1977 was elected: Chairman — Harvey Willard, (Case Western Reserve), Chairman Elect — John Allred (Houston), Past Chairman — David Lind (Colorado), Members — Ralph Minehart (Virginia), Barry Preedom (South Carolina), Glen Rebka (Wyoming) and Paul Todd (Pennsylvania State).





CERN does radiobiology at SIN

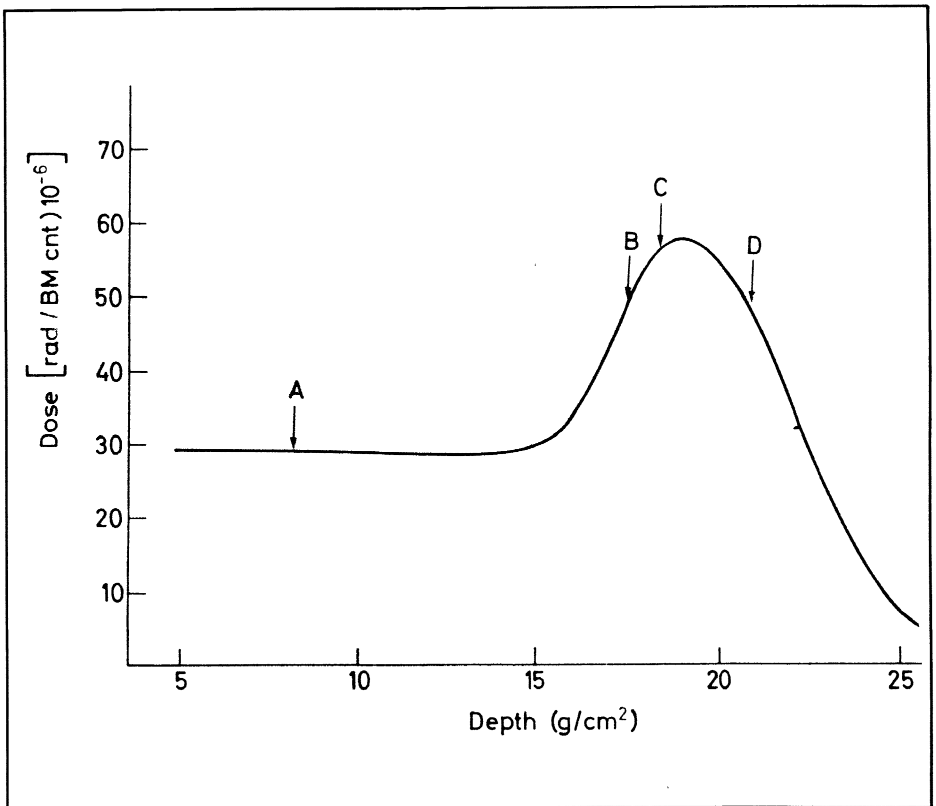
Biological effects of radiation have been studied at CERN on a small scale over the past ten years using proton, neutron, and pion beams from the 600 MeV synchro-cyclotron. The major interest has been to investigate the biological effects of strong nuclear interactions for which neutron and negative pion beams are well suited. The investigations were restricted, because of the low intensities of these secondary beams, to determining the relative biological effectiveness (RBE), using highly sensitive biological systems. Recently, the interest in this work has been stimulated with the advent of much higher intensities at the 'meson factories' and the promise of the therapeutic power of their negative pion beams.

The CERN Radiobiology Group is extending its programme by irradiations in the biomedical pion beam of the Swiss meson factory at SIN (Swiss Institute for Nuclear Research) Villigen, in the Canton of Zurich. The pion beam, with the accelerator approaching 50 % of its design intensity, is more than 50 times as intense as that available at CERN.

The interest in negative pions

1. Dose depth distribution obtained with the negative pion beam used at the SIN cyclotron by the CERN Radiobiology Group for biological irradiations. Conditions corresponding to points A, B, C and D were used in irradiating bean roots (Vicia faba) to determine the relative biological effectiveness (RBE) of the negative pions.

2. The effects on the growth of bean roots after irradiation at the four selected points on the dose depth distribution curve and with gamma rays from cobalt 60. The results for a 50 % reduction in growth of the roots show an RBE of 1.6 on the plateau A, and an RBE of 2.7, 2.6 and 3.5 respectively for the points on the peak B, C and D.



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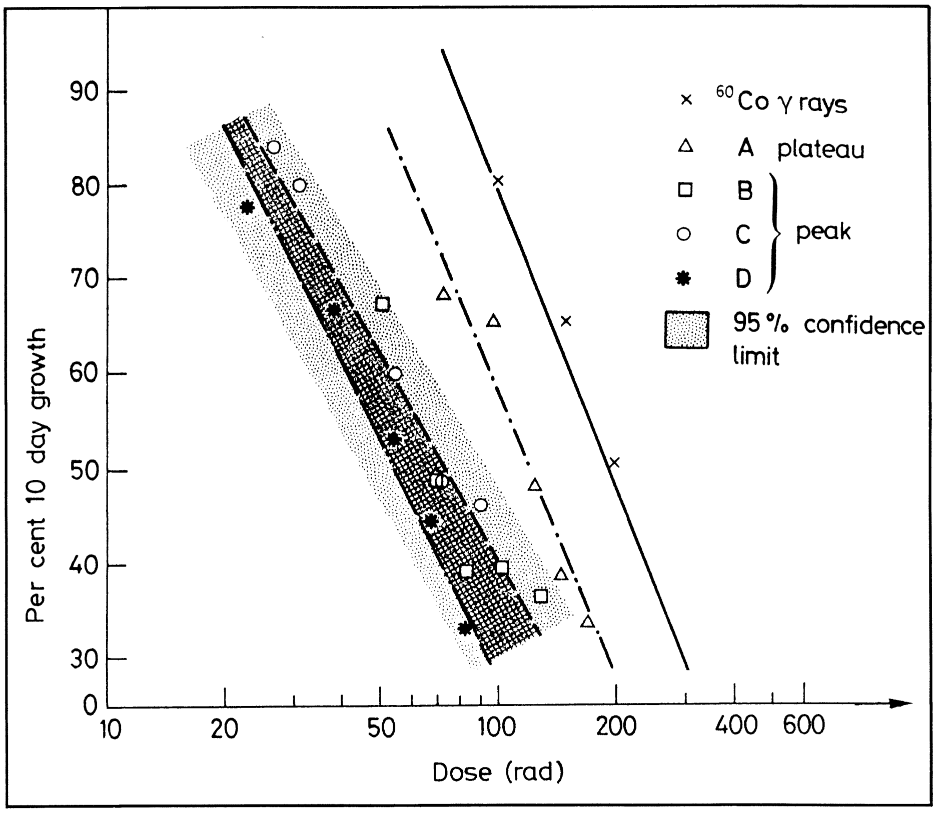

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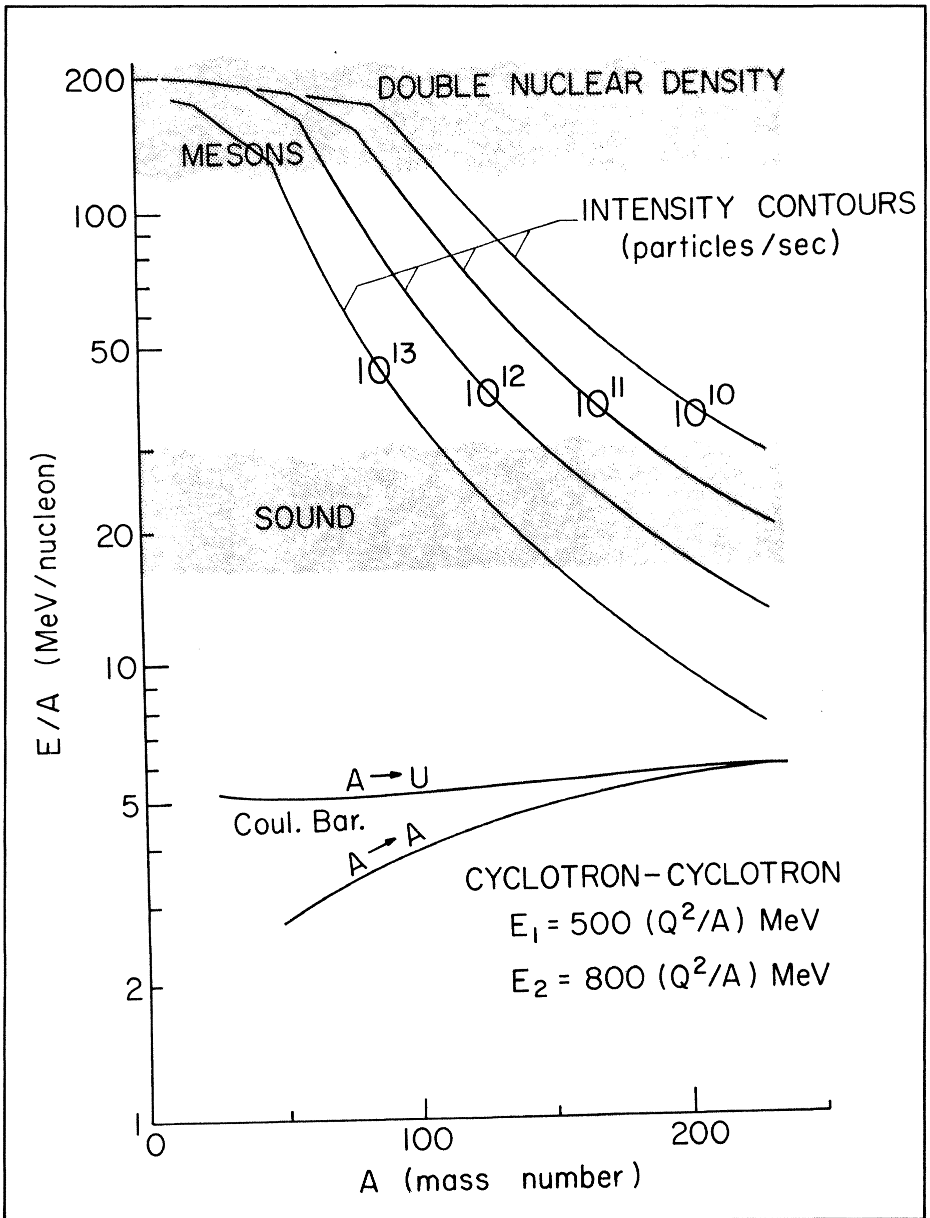
centres on the fact that the pion is annihilated when it interacts with a nucleus and a substantial fraction of its rest mass energy appears as kinetic energy of the charged nuclear fragments emerging from the interaction. These fragments in turn deposit their energy in tissue with a high specific ionisation. The pion interactions occur mostly when the pion is at the end of its range. In addition, the slowing down of the pion results in the usual Bragg ionisation peak at the end of its range. The total energy deposition rate or dose rate in the pion beam measured as a function of depth in water is shown in the Figure. As the proportion of dose from the ionisation and interaction components changes with depth, irradiations were made at a number of points along the curve to find the variation in RBE and, in particular, to look for the maximum.

The root tips of growing beans (Vicia faba) were irradiated and the resultant change in their growth rate was measured. In the peak region, the pions are nearly three times more effective than cobalt-60 gamma rays in producing a 50 % reduction in root growth after ten days. The maximum RBE (about 3.5) of pions appears to be at a point on the back edge of the absorbed dose peak as can be seen from the Figure. In the plateau region the radiation has only about half the effectiveness of the peak.

The high biological effectiveness in the peak relative to the plateau region, coupled with the shape of the depth dose curve, are the factors that make pions advantageous for radiotherapy since a tumour may be efficiently irradiated with minimum damage to surrounding healthy tissue. Another important factor to investigate is the dependence of the radiobiological effect on the presence of oxygen, which will indicate how efficiently anoxic cells are killed by the radiation. Experiments to determine this oxygen



Intensity contours of the proposed heavy ion facility at Michigan plotted against energy per nucleon and mass number. The facility will have two linked superconducting cyclotrons. The relationship of the design performance with areas of interest in nuclear physics (such as compression waves starting around 20 MeV per nucleon and multiple meson production starting at around 140 MeV per nucleon) is illustrated.

effect in the plateau and peak region have started.

Measurements in the pion beam have also been made with other biological systems, including spermatogonia survival in mice testes and micro nuclei production in the bean roots. Radiobiological research at CERN has always been orientated towards investigating the biological effects of high energy particles. It is hoped that the results obtained will help to clarify the physical and biological advantages of negative pions for radiotherapy.

MICHIGAN
Heavy ion project

In September, the Cyclotron Laboratory at Michigan State University submitted a proposal to the US National Science Foundation requesting $ 13 million for the construction of a Coupled Superconducting Cyclotron facility to be used for research with heavy ions. By pairing 500 MeV and 800 MeV cyclotrons, ion beams with maximum energy ranging from 20 MeV per nucleon for uranium to 200 MeV per nucleon for nuclei lighter than calcium could be achieved. With these high energies (above the constraints of Coulomb repulsion, surface interactions and normal density), new aspects of nuclei such as high density, supersonic and coherent mesic phenomena will be open to investigation.

The two proposed cyclotrons will be of similar construction. The design takes account of the large attractive force (approximately 900 tons) between the upper and lower halves of the superconducting coils and of the need for good thermal insulation for the coils. Also, a sharp magnetic field edge is needed to ensure efficient extraction. The coil design has a layered winding tightly packed vertically with a picket fence lattice between radial layers to allow for the helium cooling. The coil will be directly wound on a large stainless steel spool with a stainless steel outer cover welded on, becoming the helium can for the cryostat.

Since the cryostat cuts off most median plane access, the natural main access to the centre of the cyclotron is axially from the top and the upper part of the yoke will be mounted on a jacking system to raise the upper yoke precisely in push-button fashion. This follows the design of a similar system in use on the TRIUMF cyclotron.

The 500 MeV cyclotron will use a prototype superconducting magnet now under construction at MSU. It is made from cast 1020 steel, the yoke is 10 ft in diameter and weighs approximately 90 tons (total for five pieces). Magnetic tests of samples from the castings indicate excellent magnetic uniformity and ultrasonic tests indicate that the castings are free from voids. Coil winding has begun and the first powering is scheduled for February 1977. After magnet testing, the construction of other components will begin to complete the 500 MeV cyclotron.

An important ion source feature in the 500 MeV design is the use of automatically removable 7 inch diameter plugs in both the top and bottom of the magnet. Ion sources will be built in to one or both plugs and will be easily removable without disturbing the vacuum or warming up the cryopanels.

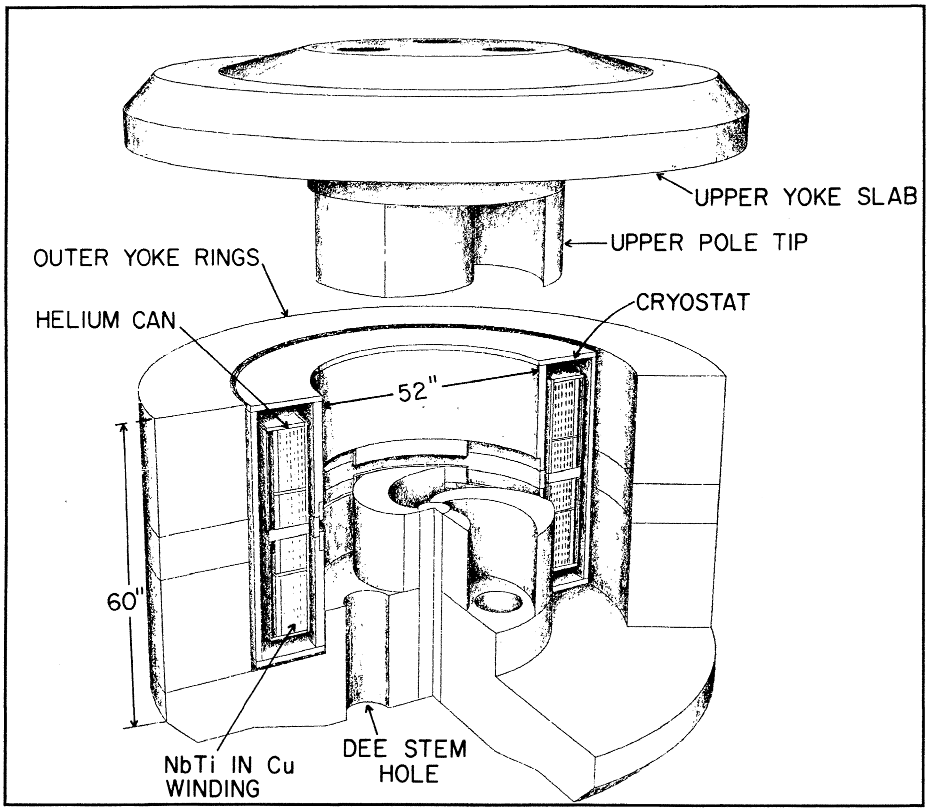
The source will be of the Phillips Ionization Gauge (PIG) type. There have recently been several important improvements in PIG sources, the most significant being the development of the 'back bombardment sputtering process', a technique which has broadened the application of this type of source to all elements. In this process, a conventional arc is main-

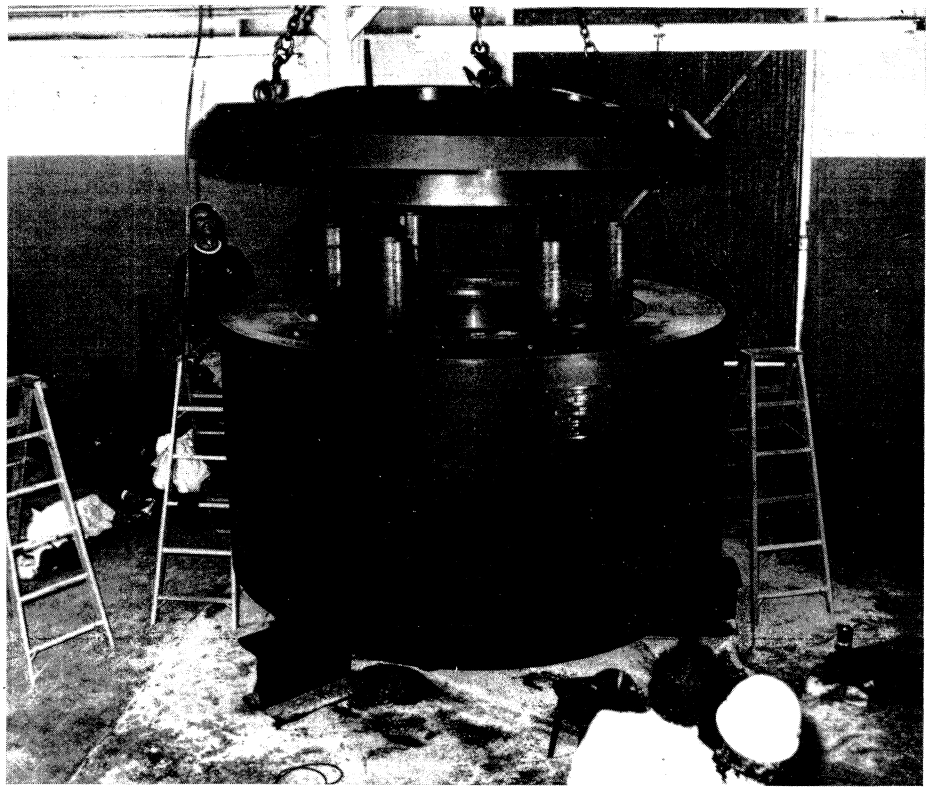
Perspective drawing of one of the superconducting magnets for the Michigan heavy ion facility. The pole face structure can be seen. Below is the magnet and cryostat for the 500 MeV cyclotron during assembly. It is scheduled to be powered early next year.

tained using a heavy gas such as krypton or xenon. Low charge state ions emitted late in the acceleration cycle move too slowly to cross the r.f. gap before the cycle is completed and decelerate in the reverse half of the cycle, eventually returning to the source in the plasma chamber. These energetic ions hit and sputter any material inserted in what is called the 'charge material pocket' at the rear of the source. The sputtered ions diffuse to the front of the source and are extracted. Relatively intense beams (in the microamp range) can be produced with this technique. Another new source feature is the construction of the cathode from a long tantalum rod which can be remotely removed axially. By simply backing the cathode out a few millimeters, it will be possible, without removing the source, to break any short circuit caused by sputtered material.

In both cyclotrons, the acceleration system is a dee-in-valley design with three dees mounted on quarter wave stems which extend up and down. Tuning of the dees is by a hydraulically clamped sliding short on the main stems with a capacitive electrode for fine tuning. Both cyclotrons will operate over the same tuning range (27 to 84 MHz) and will be driven from a single master oscillator. The injector cyclotron will operate at the 3rd or 9th harmonic of the r.f. frequency (depending on the Q/A of the ion) and the three dees therefore operate in phase and can be mechanically joined at the centre. The particle orbit coupling of the two cyclotrons assumes a three-fold increase in the orbital frequency at the transition from the 500 MeV to the 800 MeV cyclotron and operation in the second cyclotron is then on the first or third harmonic.

The extraction system for both new cyclotrons will follow conceptual guide-lines used on the present MSU

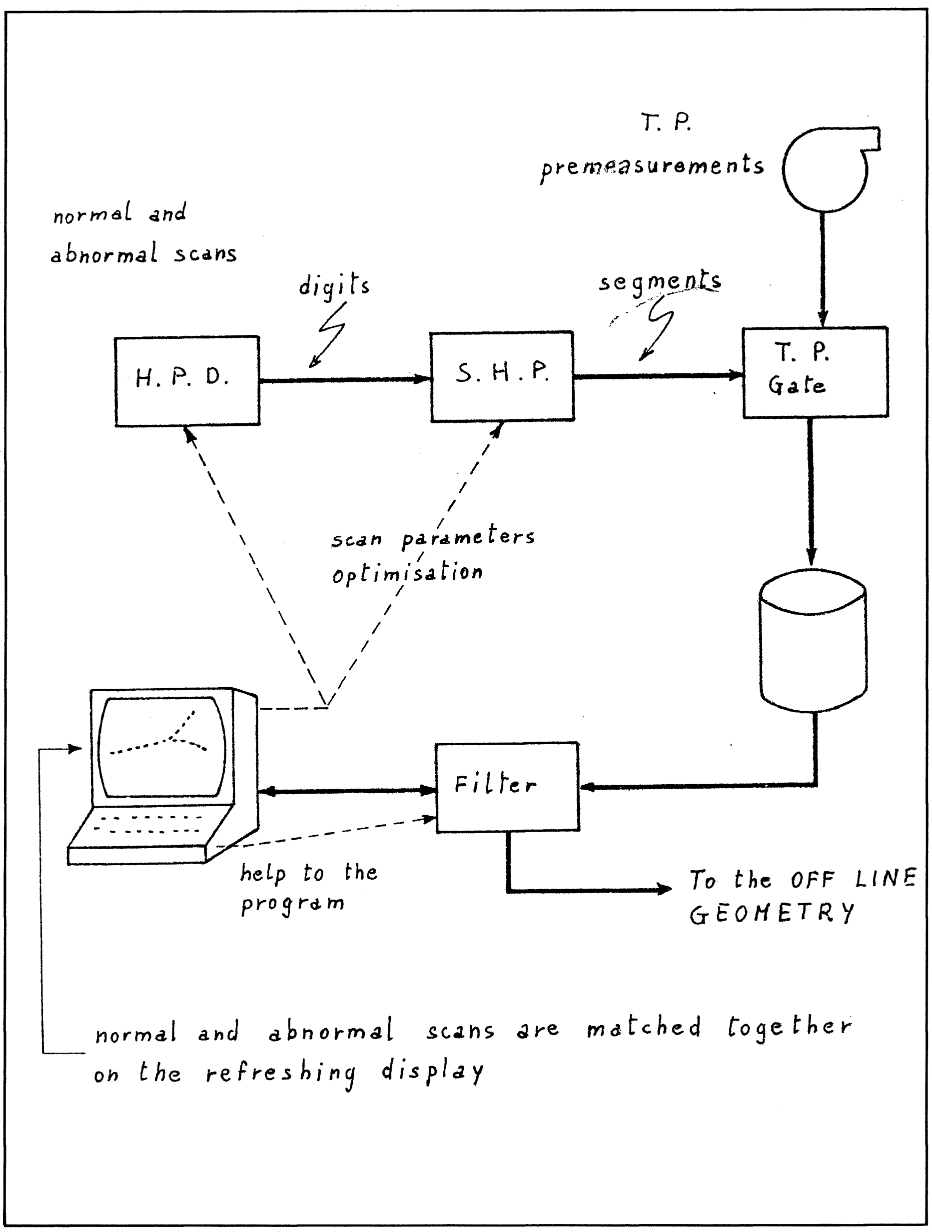


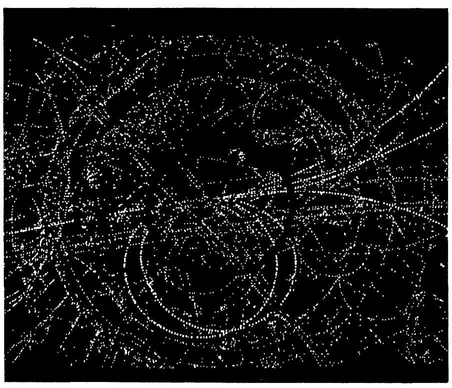


The bubble chamber film measurement system at the Centro Nazionale Analisi Fotogrammi. The Hough Powell Device, HPD, operates linked to a special hardware processor, SHP. The TP premeasurements involve position measurements of at least the vertex plus one track point per track and per view. The TP gate has an on-line program in an IBM 360/44 which drives the HPD and stores the data.

1. Display of the reduced digitization of a BEBC picture by the HPD.

2. The filtered output of the same picture produced by the film measurement system.





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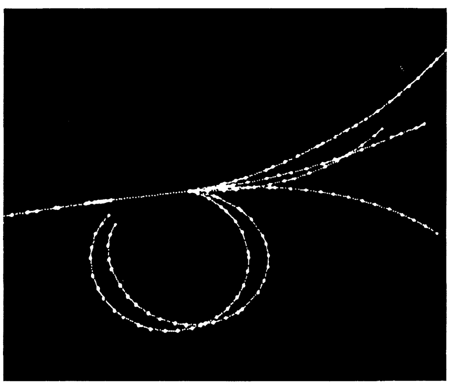

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cyclotron. Principal features include use of the integer resonance to build a coherent amplitude in the focusing oscillation (this amplitude alternately adds to or subtracts from the natural turn separation depending on the phase of the precession and gives a comfortable turn separation of about 5 mm at the deflector), three electric deflectors (operating at 140 kV/cm) to bring the beam across the magnetic field edge as quickly as possible, and three sets of iron focusing bars along the extraction path to offset the natural defocusing of the fringe field.

The experimental area, presently 11 000 ft², will be more than doubled, and office and lab space, presently 30 000 ft², increased by approximately 50 %. To staff the proposed facility appropriately, the operating staff of the Cyclotron Laboratory should approximately double during 1977-78 from its present level of 26. The proposed Coupled Superconducting Cyclotron will provide a front-line facility for heavy ion research in the 1980's. User access will be based on scientific merit without regard to institutional affiliation.

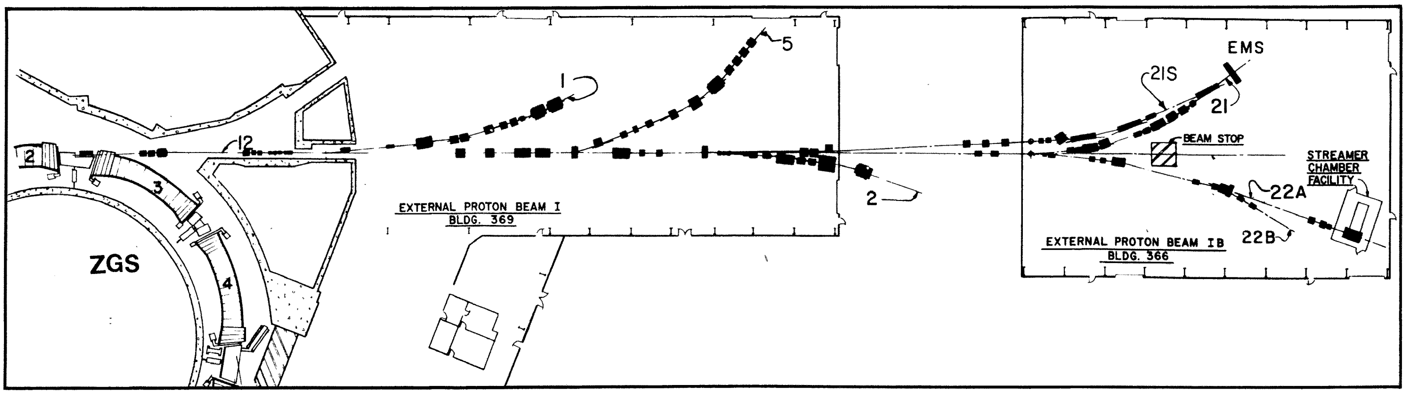
(We are grateful to Julie Eastman for the information from which this article is taken.)

Centro Nazionale Analisi Fotogrammi

At the Centro Nazionale Analisi Fotogrammi of INFN at Bologna used by Italian bubble chamber physicists, two HPDs have been running for many years, using road guidance and minimum guidance modes, measuring pictures from the CERN 2 m bubble chamber. A system has now been developed to process pictures from the BEBC bubble chamber in the point guidance mode using the same HPDs.

The new system allows human intervention during the automatic

The experimental arrangement for polarized proton beam experiments at the Argonne ZGS. After extraction, the polarized beam is split into various beam-lines and sent to the experiments designated by numbers in the figure.



analysis, while the one used up to now for previous bubble chamber film does not. As a result the rejection rate on BEBC film is very low (less than 5 to 10 %). The system uses a hardware processor on-line with the HPD, which allows data reduction of HPD digits roughly by a factor of ten. The digitizing rate for a BEBC picture (normal and abnormal scan) is nearly 10 000 words (track segments), an amount that can be quite easily processed by a medium size on-line computer, while the HPD itself gives about 100 000 words per frame.

The performances achieved are as follows: (1) Normal and abnormal scans can be performed to follow spiralling tracks. (2) The filtered data can appear on the display screen together with the track segments of the whole picture and also the premeasurement points. Any small region of the picture can be magnified at software level. At the end of the filter step, only the filter output can be seen. (3) For difficult events, two kinds of help are provided — firstly, more track points can be added through the display to see how the filter follows the track and secondly, in the event of data leak, the HPD discriminating level or hardware processor parameters can be changed and the system can ask for a new scan and filter process.

The system can, therefore, be managed in two different ways. It can follow a process without help, after which help can be provided for the rejected events. (For this second step a decision has to be made whether it is necessary to scan the film again with the HPD or not.) Alternatively, it can follow a process always with human intervention calling for help every time a rejection is detected on the film plane.

At present the Centro Nazionale Analisi Fotogrammi is processing negative pion-proton events collected at 22 GeV/c in BEBC with the following performance: About 35 fiducials per view are measured with a precision of about 10^{-6} cm^2 and, with good premeasurements (mainly related to the vertex), the rejection rate is less than 10 % with help from the operator. The overall speed depends upon many parameters. In good conditions with human help on-line, the rate is nearly 25 events/hour (for events previously scanned and premeasured).

ARGONNE Polarized proton research programme

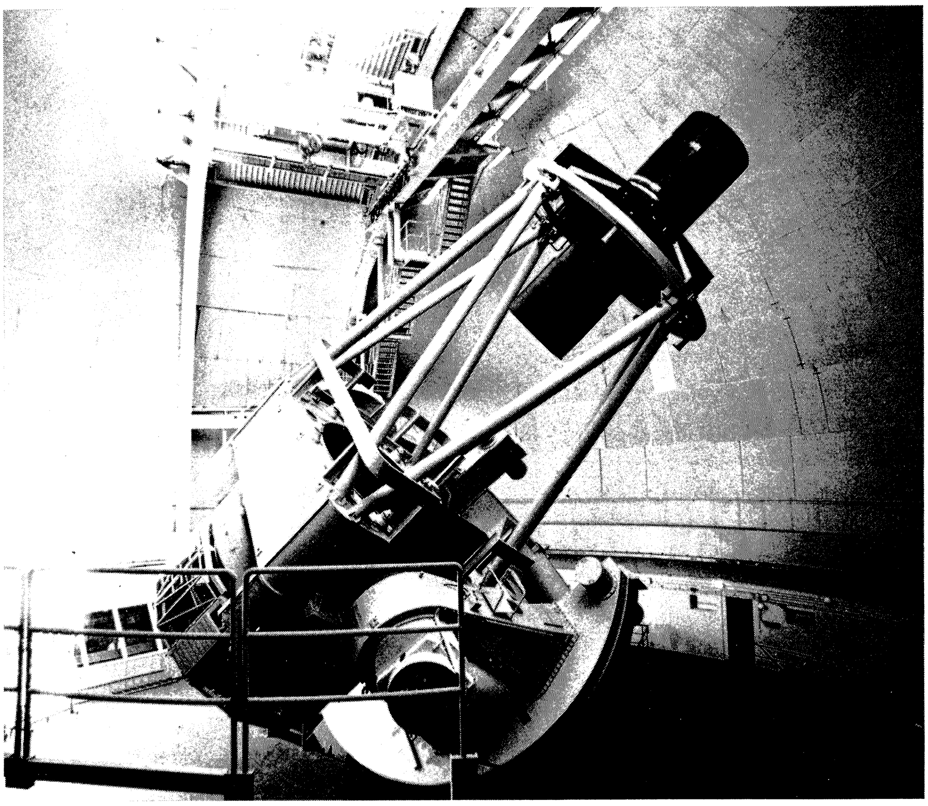
In the period of slightly over three years since polarized proton beams were first accelerated into the GeV energy range by the ZGS, a lively programme of research on spin effects in elementary particle interactions has developed at Argonne. Apart from one 300 000 picture exposure of the 12 foot bubble chamber, all of the experiments with the polarized beam have used electronic detection methods and have been arranged along one of the two extracted beam-lines.

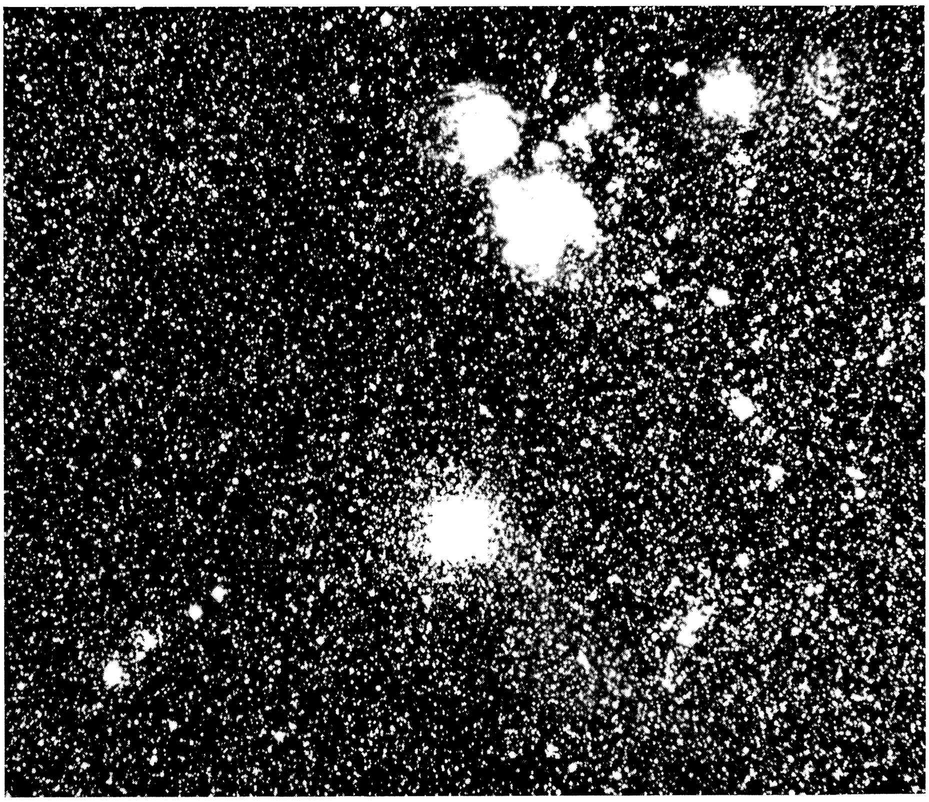
This extracted beam is split after it leaves the ZGS, a portion going into the Beam I area where the first polarized beam experiments were performed in late 1973. Experiments in this area have been carried out largely by a Michigan/Argonne/St. Louis group using a polarized target with an N-type (vertical) polarization direction. Beam intensities are typically 10^{10} protons per pulse. Differential cross sections for proton-proton elastic scattering in pure transverse spin states have been measured at 6 GeV/c and are in progress at 12 GeV/c (see May issue 1976). A set of 3-spin cross sections has been measured at 6 GeV/c to test P and T invariance at large momentum transfer, using a recoil proton polarimeter, and further measurements at 12 GeV/c are anticipated.

Measurements of the total cross section differences in pure transverse spin states have recently been made at momenta between 1.2 and 3 GeV/c by a Rice group and large differences (not yet well understood theoretically) were observed. Also in the Beam 1 area is a polarimeter, using a liquid

The 3.66 m telescope of the European Southern Observatory is now in action on La Silla mountain in Chile. The first photographs were taken on 9 November and were found to be of exceptionally good quality. Not only do they record very faint celestial objects but they are also giving images of a sharpness and roundness that indicate that the telescope is optically and mechanically near perfect. CERN has helped ESO in the construction of the telescope.

Part of a picture of the sky in the Southern hemisphere obtained with the new ESO telescope on 17 November. It shows a particularly rich area for investigation in the Western part of the large Magellanic cloud. The larger agglomerations of stars are globular clusters in the cloud and some gaseus nebula are seen. The exposure time was 30 minutes and the picture records a total of about 50 000 stars.





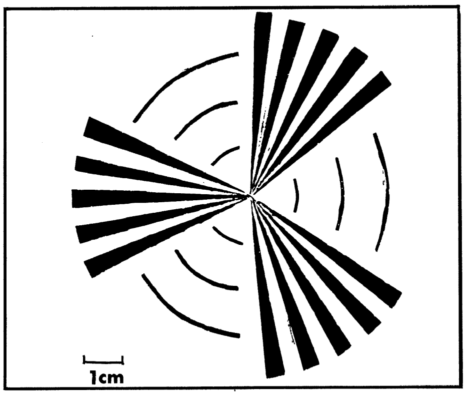
hydrogen target, where the polarization of the extracted beam is measured; it is typically 70 % at 6 GeV/c and 60 % at 12 GeV/c.

Next along the extracted beam-line is the Beam 5 area where a high resolution, large acceptance beam-line, originally designed to transport secondary particles from a production target, has been used as a magnetic spectrometer. Particles created in inelastic collisions in a hydrogen target located in the extracted beam are momentum analyzed and identified by the beam-line and Cherenkov counters. Studies of positive pion inclusive production at 6 and 12 GeV/c by a Minnesota/ Argonne / Rice group showed unexpectedly large spin-dependent effects. The depolarization parameter in $pp \rightarrow pN^*$ was also measured, using a second scattering of the produced proton. This past Summer, a UCLA/ Minnesota / Argonne / Texas group obtained very accurate data on the angular distribution and polarization in $p\text{-}He^4$ elastic scattering from 1.2 to 3 GeV/c and a sharp angular structure with a rapid energy dependence was observed.

Beam 5 has recently been modified to split off and transport a portion of the extracted proton beam. An experiment by the Minnesota/Argonne/Rice group to measure proton-proton and proton-neutron elastic scattering polarizations from 2 to 8 GeV/c near 90° in the centre of mass is in progress. Comprehensive measurements of inclusive particle production by 6 and 12 GeV/c polarized protons by an Indiana group will begin in the Spring.

Moving downstream, the next area is Beam 2, which has been used by a Los Alamos/Chicago/Illinois group to search for evidence of parity violating weak nuclear forces. These high precision experiments measure the effect of longitudinal beam polarization on absorption in thick nuclear targets. The first run gave evidence for an effect at

X ray imaging using a multiwire proportional chamber system developed at the Rutherford Laboratory.
1. The test pattern made from 0.8 mm lead foil glued onto an aluminium sheet.
2. The image of the test pattern obtained on a Tx 611 display unit when the pattern is irradiated by a gadolinium X ray source and the display is triggered by the 'escape peak' in the pulse height spectrum.
3. As with (2) but with the display triggered by the 'full energy peak' of the pulse height spectrum.



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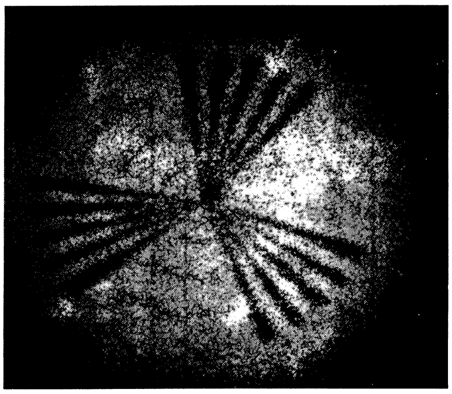
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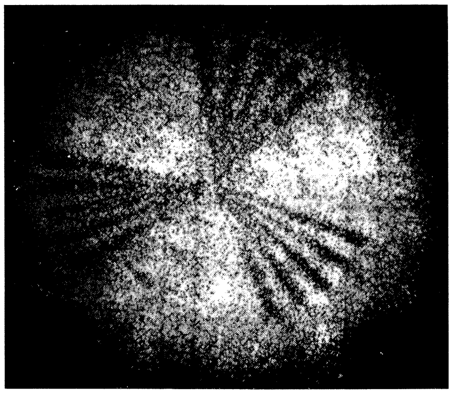
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the level of several parts in 10^6 but it was soon realized that this could result from the parity violating decays of produced hyperons. A second run with a modified apparatus is under analysis. A decision whether to press on to a level of 10^{-7} will probably be made in the coming months.

The fourth experimental area in use for polarized beam experiments is the Effective Mass Spectrometer (EMS). In this area, as well as in the Beam 22 area described below, beam intensities are limited to about 10^6 protons per pulse by radiation safety considerations as well as by the nature of the apparatus. Early experiments at the EMS included studies of inclusive lambda production, by an Ohio State/ Argonne/Chicago group, and studies of exclusive inelastic final states by the Argonne EMS group. Measurements of small angle proton-proton and proton-neutron elastic scattering, also made by the Argonne group, showed surprisingly large differences in the polarization between the two systems, a phenomenon not yet fully understood.

These early experiments were limited to 6 GeV/c incident beams by virtue of the beam-line arrangements. In February 1976, a 12 GeV/c superconducting beam-line (Beam 21S) was brought into operation to serve the EMS (see the March issue) so that these studies could be extended to the full machine energy. The 12 GeV/c measurements are in progress, and it is planned to continue the inelastic studies during 1977 with longitudinally polarized protons.

The last of the experimental areas used for polarized proton beam work is Beam 22, which is used primarily to serve a second polarized proton target, although the beam can be sent instead to the 1.5 m streamer chamber, where a test run of a Strasbourg group's experiment to study polarized proton diffraction dissociation by helium nuclei has been completed.

The polarized target work in Beam 22 is being carried out by an Argonne/ Northwestern group. The present goal is to determine the proton-proton elastic scattering amplitudes at 6 GeV/c in the diffraction peak region. For this purpose, the orientation of target and beam polarization directions along all three coordinate axes must be possible. Early experiments used N-type beams and N-type targets. Next, a 'spin-tipping' superconducting solenoid magnet was introduced to rotate the beam polarization by 90° around its direction of motion, thus producing an S-type polarized beam (see the October issue). With the proper arrangement of bending magnets in the beam, the S-type polarization can be converted into L-type (longitudinal) polarization. This Spring a superconducting 'R and A' polarized target magnet was brought into operation (also reported in the October issue) to provide S and L-type target polarizations. One of the first measurements made with the 'R and A' target was of proton-proton total cross section differences in pure longitudinal spin states between 1.2 and 3 GeV/c. Large structure was found in the 1.5 to 2 GeV/c region, whose theoretical explanation is still unclear.

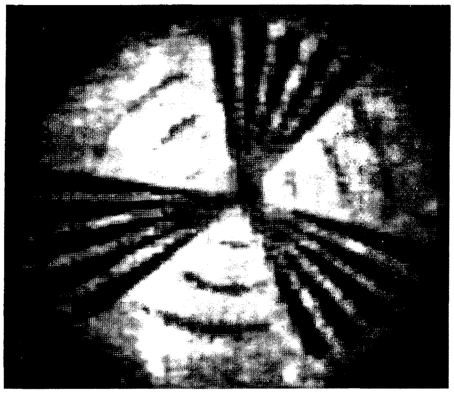
It is believed that an initial set of measurements, sufficient in principle to determine the proton-proton scattering amplitudes at 6 GeV/c, will be in hand within the next six months. Future work may well include repeating these measurements using a polarized neutron target currently under development, or else moving on to 12 GeV/c to learn about the energy dependence of the amplitudes.

In summary, the past three years of work at the ZGS have opened a new chapter in particle physics — the precision study of the role of spin in hadron interactions. Many unexpected effects have been found and much important physics remains to be done.

RUTHERFORD Detectors in biomedicine

Several Laboratories have been investigating the application of new particle detectors, developed for high

When the 'mass' image of the target object is calculated, the pictures emerging from the detection system are much clearer.
1. Conventional X ray image.
2. 'Mass' image produced using the system's computing power.



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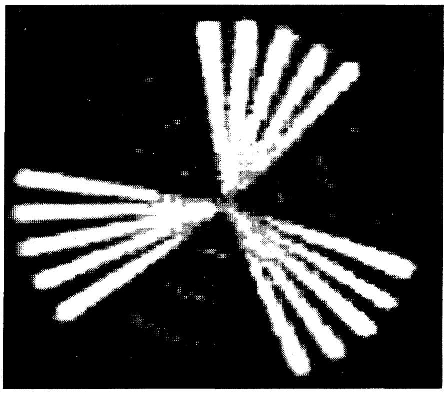

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energy physics research, in medicine. In particular, multiwire proportional chambers (MWPCs) and drift chambers, which emerged from the work at CERN in the late 1960s, offer several advantages compared with conventional techniques. Recent investigations at the Rutherford Laboratory have suggested new applications of MWPCs in biomedical studies.

A xenon filled MWPC X ray imaging detector has been developed with computer controlled data acquisition and image display. The device is intended for use in fields in which numerical data and subsequent computation are an essential feature — bone mineral estimation and lateral section tomography are typical applications. First tests with the device have concentrated on bone mineral estimation and have been performed in collaboration with the MRC Mineral Metabolism Unit at Leeds General Infirmary.

Theoretical work at Rutherford indicated that the main systematic error affecting a bone mass measurement, using the X ray absorption technique, arises from the spatial resolution of the X ray detector. To achieve the required accuracy, a spatial resolution of about 1 mm is demanded of the detector at an X ray energy high enough to penetrate the portion of the anatomy studied (usually the forearm). Further theoretical studies indicated that such requirements can be met when a monodiomatic X ray beam of about 42 keV is used with a xenon filled MWPC and pulse selection is imposed on the output pulses so as to select the so-called 'escape peak'. Experimental investigation showed clearly that unambiguous energy measurement (using the full energy peak) is quite incompatible with good spatial resolution (as can be seen in the Figures).

The performance of the imaging system is further enhanced by the computing power of the associated electronics. Normalisation of the X ray image of a target object is calculated from data runs stored on disc in the computer and an image of the mass distribution in the object can be displayed. This procedure not only displays the parameter of clinical interest (such as the bone mass) directly but it also eliminates systematic errors arising from the chamber and beam non-uniformities. The advantages of this processing can be seen in the Figures.

The MWPC performance achieved in the present work is expected to lead to a precision of about 1 % for 'in vivo' measurements of bone mineral mass which is a very considerable advance over current techniques. Application to spinal bone mass measurement and lateral section tomography also appear promising. X ray tomography, the study of sections through biological structures, has been given a boost by the development of sophisticated equipment by EMI Ltd for axial sections. The MWPC equipment for lateral work might prove considerably less expensive.

DESY
Builders treat at PETRA

On 2 December, the construction foreman symbolically smashed his glass on the last rafter which had just been put up on the SE hall of the 19 GeV electron-positron storage ring PETRA. Only a few metres of the 2.3 km of the PETRA tunnel remained to be completed and the occasion was celebrated by a visit of the site. Dr. Dieter Bialas, senator of Hamburg, and several other guests together with more than 200 builders took the opportunity to look through the ring tunnel to see what the DESY team are doing in those sections which have already been turned over to them. From outside, three quarters of the final tunnel system is no longer visible from above. One part is covered by a 3 m layer of earth, surrounding the DESY Laboratory like a city wall, while in other underground segments the only evidence is a track of fresh yellow sand.

When the visitors reached the completed experimental hall NW, they enjoyed a meal ornamented by talks and toasts of politicians, builders and physicists. Herwig Schopper, Chairman of the DESY Directorate, mentioned in his talk that particles are already waiting for their injection into PETRA. A new chopper system has been installed in LINAC II and, using this system, thirty equidistant electron bunches were stored in DORIS at a rate corresponding to a PETRA filling time of several minutes. In January

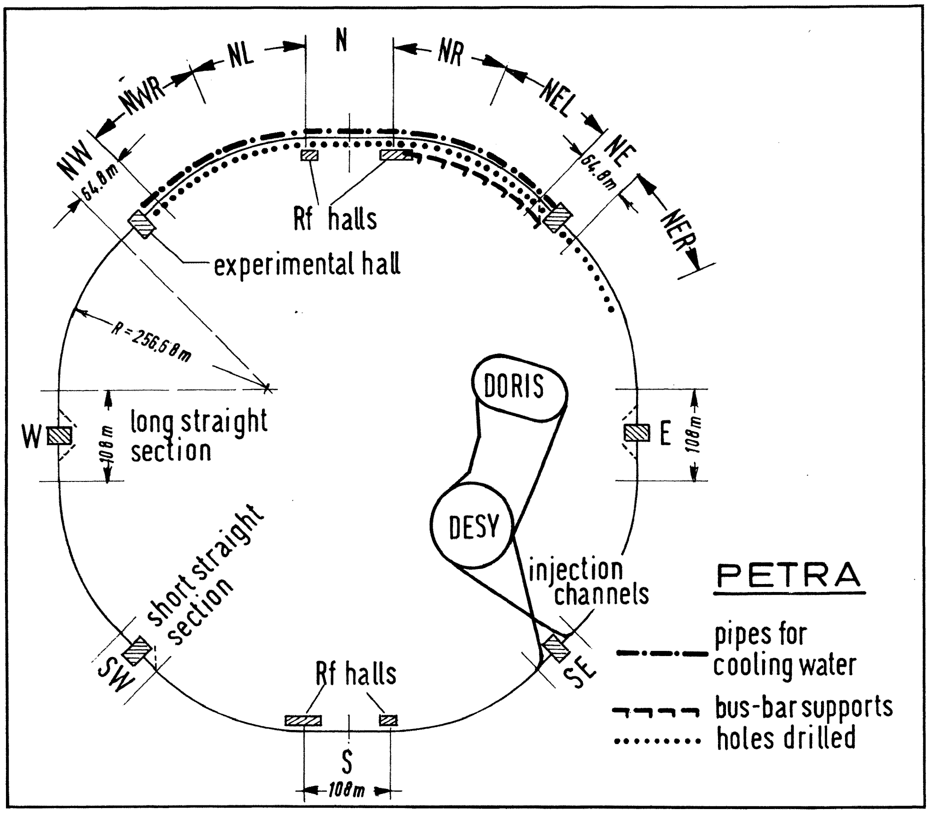
Plan of the PETRA electron-positron storage ring under construction at DESY. Construction of the tunnel is virtually completed and at the top of the ring the progress with the installation of services (cooling, bus bar supports, magnet installation settings) is indicated. The NW, NE, SW and SE straight sections are the four which will initially be used for experiments. The experimental programme was described in our November issue.

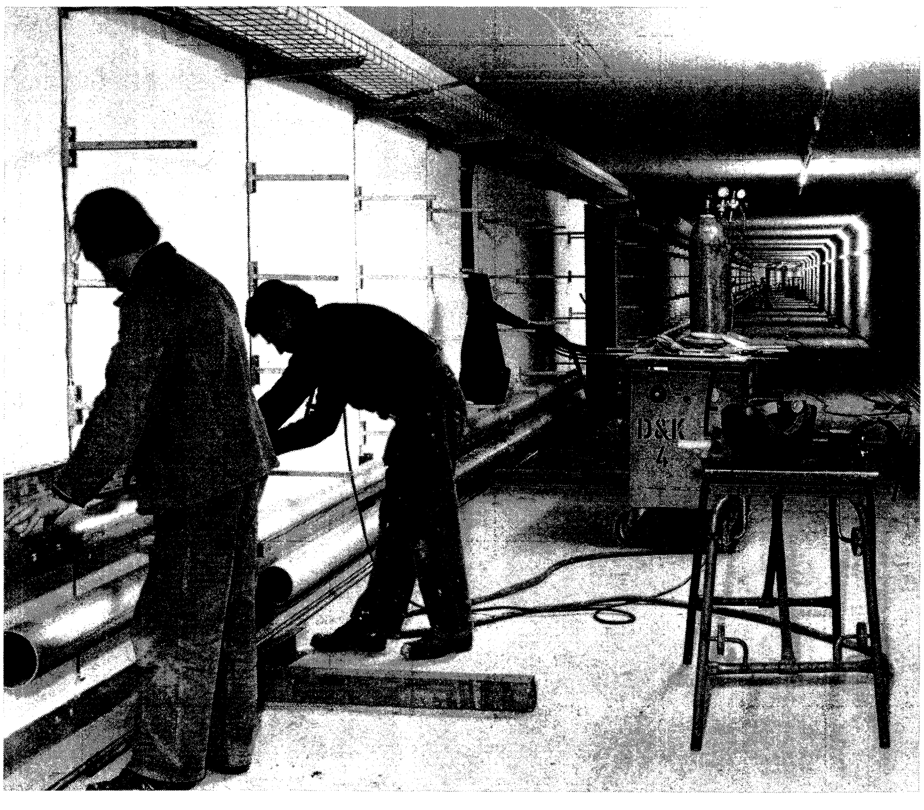
A view inside the PETRA tunnel showing the installation presently in progress.

1977, the ejection from the DESY synchrotron will be ready and installation of the 7 GeV beam transfer channels from DESY to PETRA will start. It is expected that in May the injection system plus one octant of the ring will be completed and the first particles will travel into the new machine.

In recent weeks holes have been drilled into the floor of the tunnel ready for the magnet support installation. Four bending magnet prototypes have been built to check construction techniques, establish the final pole contour and the welding procedure. In November the laminations for the first series production magnet were stamped and they are now being assembled. The production rate for the additional 231 dipoles is planned to be one per day, starting in February 1977. The first series production quadrupoles are expected this month; 304 of them will be produced at a rate of 20 per month. When they arrive at DESY, the magnets will be measured and it will be possible to check one dipole and about three multipoles per day.

To meet the special requirements for a 'smooth' vacuum chamber with low r.f. parasitic mode energy losses (see the piece on PEP in the October issue, page 348), several new techniques have been successfully developed at DESY. The standard PETRA chambers will be made from an extruded aluminium profile with four channels holding, respectively, the beam, the integrated sputter-ion pumps, the water cooling and the bake-out elements. The first eighty aluminium chambers have been received. A spark erosion technique will be used for producing about 1000 slots per chamber in the wall separating the pump channel from the beam channel. New welding techniques (see the April issue, page 138) give greater flexibility in vacuum system





design and significantly reduce the chamber production costs. A standard vacuum chamber prototype will be completed at the end of December and series production will start in February.

Prototypes of integrated sputter-ion pumps with two different cell diameters (32 and 17 mm) have been tested. Series production of the pumps has started in the workshop of the Technical University Aachen and delivery of the first elements begins this month. A new method of degassing vacuum chambers was successfully tested in which the anodes of the pumps are used to sustain a glow discharge in an argon atmosphere. This method of cleaning in situ works very satisfactorily and seems to be far superior to thermal outgassing.

Inside the tunnel, the outer wall is covered with several comblike supports that are waiting for some 60 km of aluminium busbars — the current leads for quadrupoles and sextupoles. (The dipole current will be directly carried from one magnet to the next.) Near the tunnel floor, two aluminium pipes supply the cooling water for magnets and vacuum chambers.

In the northern and southern straight sections, the ring tunnel widens to give room for 32 cavities each, which will supply the energy for acceleration and to compensate for loss by synchrotron radiation. At least 16 cavities will be installed by 1978 allowing a particle energy of 15 GeV for machine tests. At the beginning of 1979, 32 cavities will allow an energy of 17.5 GeV and, finally, 64 cavities for 19 GeV will complete installation of the first stage of PETRA. Prototypes of these five-cell cavities have been tested c.w. up to a power dissipation of 150 kW and no thermal instability has been seen. Also, no multipactoring was observed and titanium coating is not necessary. Delivery of cavities will start in January 1977. Coupling windows and tuning plungers are now being produced at DESY and the waveguide transmission-system and eight klystrons of 500 kW each have been ordered.

Progress on the project in general is on schedule and fingers are crossed that the work which needs to be done in the coming years will go as smoothly as it has in the course of 1976. Eyes are already being raised to the future and the greatest hope seems to lie in the development of superconducting r.f. cavities such as are under attack at Karlsruhe. These cavities could make it possible to give more energy to the beam without prohibitive power costs. The PETRA magnet system will be capable of holding particles of energy up to 40 GeV and a further stage of the PETRA project would become technically feasible if superconducting r.f. cavities are mastered.

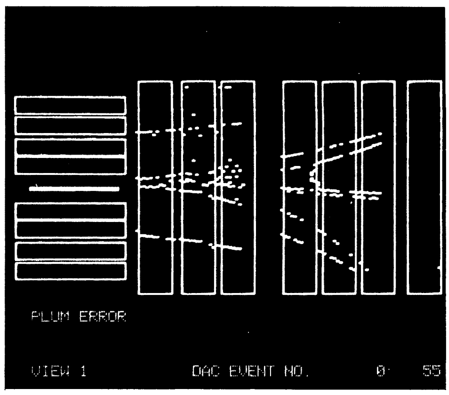
People and things

Super magnets

All four superconducting dipoles, scheduled for the high energy unseparated beam-line from the Brookhaven AGS to the MultiParticle Spectrometer, have been installed after successful tests. The magnets are each 2.5 m long with a 20 cm bore and give a 4 T bending field. Their design is similar to that proposed for use in the 200 GeV proton storage rings, ISABELLE, and the successful operation of these magnets has given added confidence to the ISABELLE team.

Future physics

In the course of 1976 three Study Groups at CERN have produced reviews of possible physics at future accelerators. The reviews are now available as 'yellow reports'. Report CERN 76-12 edited by L. Camilleri covers work on physics at a multi-TeV proton synchrotron and at 400 + 400 GeV proton storage rings (LSR-Large Storage Rings). Report CERN 76-18 covers work on physics at an electron-positron storage ring of energy up to 100 + 100 GeV (LEP - Large Electron-Positron). The group looking at the potential of LEP was chaired by Pierre Darriulat. Both reports are available from the CERN Scientific Information Service, CERN, 1211 Geneva 23, Switzerland.



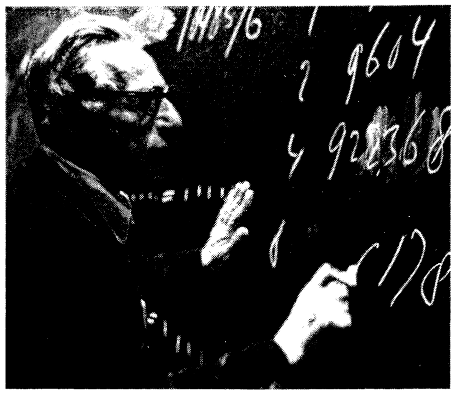
Event recorded in the Omega spectrometer of CERN during tests of the electron beam generated by SPS protons on 12 November. This is CERN's first ever high energy electron beam and the physicists were very happy to see such events appear without any tuning of the beam or of their detectors.

1. André Klein

2. Wim Klein

Opposite page:
The prototype superconducting quadrupole which has worked so well in tests at the CERN ISR Division

CERN 146.9. 76 1.



CERN 217.8.76 2.

What not to do with accelerated particles

Flutter in the dovecots of the precious stone trade in Geneva on 11 November. A large diamond, expected to attract around 3 million Swiss Francs at a Christie's auction, was withdrawn under suspicion that its yellow tint was not natural but had been obtained by irradiation with a beam from a cyclotron. Such irradiations, by affecting the crystal structure, can change the light transmission properties of a diamond. A diamond artificially tinted in this way plunges in value by a factor of ten (for some obscure reason).

50 microamp at TRIUMF

Since September, the TRIUMF cyclotron has been running 1 to 2 μA beams with 10 μA scheduled for one shift each week. Quite apart from the lack of shielding, it is still necessary to limit the average current to avoid irradiating the machine too severely. With the delivery of more concrete blocks, a 20 μA test was scheduled for 23 November. 20 microamp was achieved on the target by midnight and the current was gradually increased to a maximum of 50 μA, the limit being set by the cooling capacity of the temporary beam dump. The permanent dump (which is also a neutron source) will be installed next Summer in preparation for the first 100 μA runs by the end of the year.

Power from accelerators

The fertile mind of Bob Wilson, Director of Fermilab, has looked again at the possibility of accelerators becoming energy producers, via the nuclear fission route, in the light of the reduced power requirements for accelerator operation using superconducting magnets. Construction of the Fermilab superconducting Energy Doubler is the obvious source of this rethink. The necessary sequence would be to use high energy protons to generate neutrons which would be absorbed in uranium or thorium yielding fissionable material, like plutonium, to burn in a reactor. Some collections of accelerator parameters (energies, intensities, etc.) could make this sequence productive by generating more power than is used to accelerate the protons. Professor Wilson accepts that there are better ways of producing plutonium but points out that the necessary proton beam intensities in any device such as he outlined would make a truly magnificent neutrino source.

On people

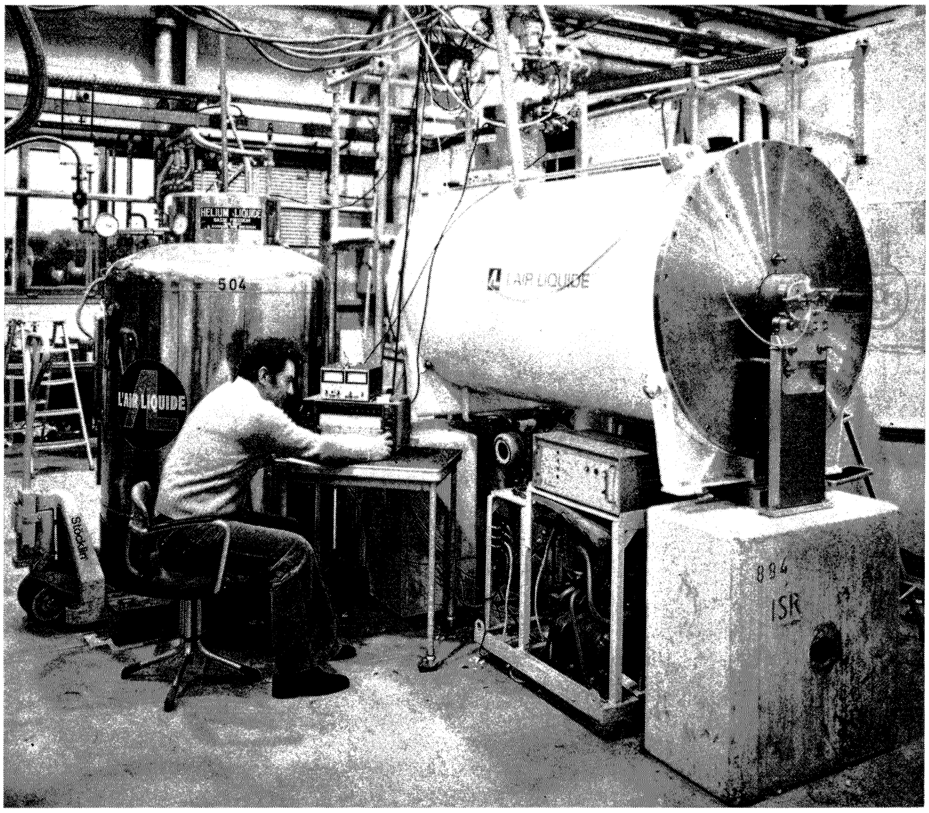
By coincidence, CERN is bidding farewell at the same time to two prominent staff members bearing the name Klein. André Klein has returned to the upper echelons of French administration after five years at CERN during which time his main task was as head of administration at the SPS project. In that role he did a great deal to smooth relations with the two host countries, France and Switzerland, during the complicated negotiations involved in the major extension of the CERN site. Wim Klein, the human computer, has retired after eighteen years in the Theory Division. His phenomenal abilities at mental arithmetic are legendary — there cannot be many people around who could even understand the complication of mentally extracting the 37th root of a 220 digit number in a few minutes! His departure was marked with a 'Farewell Show' in the CERN Auditorium on 10 December when his prowess was obviously undimmed.

Frank Cole of Fermilab has joined John Blewett of Brookhaven as co-editor of the journal 'Particle Accelerators' published by Gordon and Breach. John, who has edited the journal since it was started, intends to retire as editor in July of next year.

New appointments at Fermilab: Drasko Javanovic becomes Associate Head of the Research Division. Linc Read becomes Head of Research Services. Dennis Theriot and Dick Lundy swop places becoming Head and Associate Head of the Neutrino Department.

On the occasion of their 30th Anniversary, the Associated Universities Inc. which operate the Brookhaven Laboratory, honoured I.I. Rabi and Franklin A. Long with commemorative plaques for many years of distinguished service on behalf of Brookhaven and the National Radio Astronomy Observatory.

The Program Advisory Committee at SLAC has five new members for a term extending to 1978. They are Joe Ballam (SLAC), Robert Cahn (Michigan), John Kadyk (LBL), James Pilcher (Erico Fermi Institute) and Stanley Wojcicki (Stanford).



CERN 222.11.76

Superconducting quadrupole of ISR quality

A prototype superconducting quadrupole such as could be used in a high luminosity insertion at the CERN Intersecting Storage Rings has emerged with flying colours from a series of tests and magnetic measurements in its own horizontal cryostat. (The first tests in a vertical cryostat were reported in May, page 185.) Very stringent tolerances on field gradient allow a maximum error of only 2 parts per thousand over the beam aperture of the magnet and this has been achieved at the design peak field gradient of 40 T/m with a maximum field of 5.1 T in the superconducting magnet windings. The magnet is of such a quality that its installation in the ISR could be envisaged with confidence—there is no higher criterion in the accelerator world.

COURIER progress

With this December issue we complete the first volume of CERN COURIER in which we have attempted to extend our information coverage to be more representative of the world-wide community of high energy physics. Thanks to the splendid collaboration of the correspondents based in the Laboratories (see the list inside the front cover) our aims have been largely achieved. There remains, however, a great deal that can be done and, in the coming year, we hope to be able to invest more effort at the editorial end so as to realise more of the potential of the communications system that has been established in the course of this first year.

A word of thanks should also go to those who take such good care of the distribution of the journal in several of the larger countries. After a few teething troubles, the new distribution chains seem to be operating efficiently (though we have still to establish the distribution system in France). Finally in our list of appreciations, we should like to thank Presses Centrales Lausanne who have printed CERN COURIER for the past four years. Their high competence and enthusiasm eased the task of the Editor considerably.

The COURIER will move to a new printer at the beginning of 1977 and it has been decided to open the year with a combined January/February issue. This will avoid the problems of producing an issue in the first days of January (problems which mainly stem from postal delays immediately after the turn of year festivities). The issue will appear mid-February and, given the continued excellent co-operation that we receive from so many people, we hope to serve the high energy physics community better in the course of 1977.

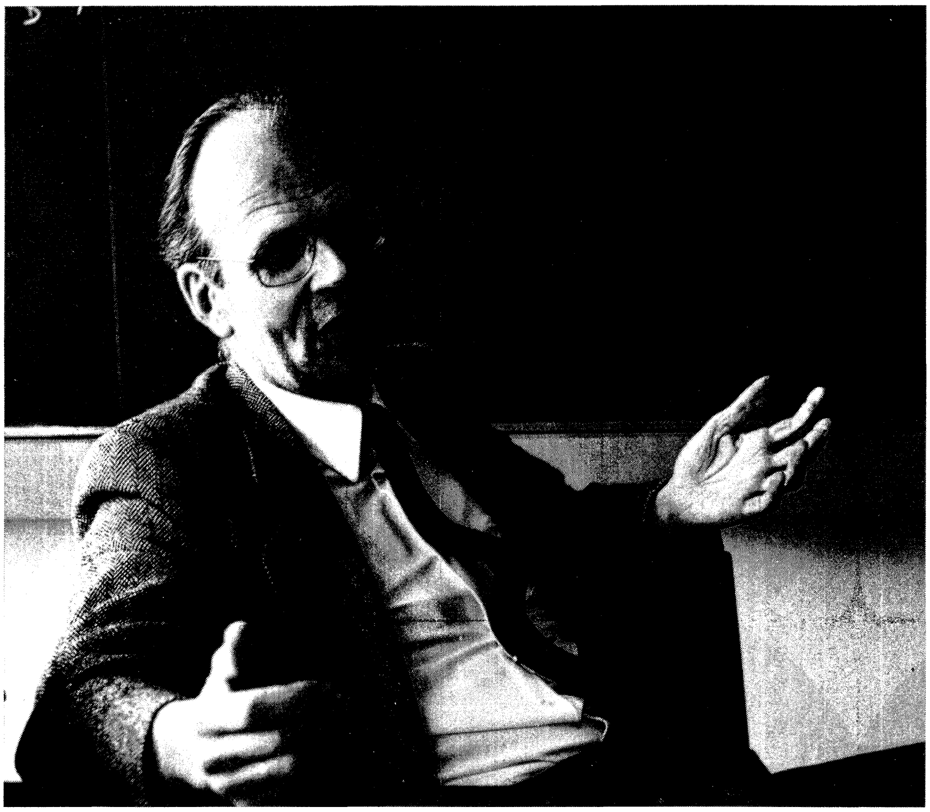
A Point of View

Leon Van Hove, Research Director General at CERN, gave the closing lecture at an International School of Particle Accelerators held in Erice from 10 to 22 November. The title of the talk was 'What do physicists expect from higher energies?' Giving his personal evaluation of the high energy physics outlook, Professor Van Hove concluded with the following comments about the need for a strategy concerning the selection and exploitation of future large accelerators.

The recent developments have made it overwhelmingly clear that much new knowledge can be expected from higher energy machines. The interest of the phenomena to be investigated and the advances being made toward unified theories leave little doubt about the scientific validity and vitality of high energy physics. One can therefore hardly see any reason why a reasonably strong level of support would not be continued for this branch of physics, which is obviously quite fundamental and in a state of constant progress. The problem is not so much whether new high energy accelerators will be built in the future. Right now in fact, new electron-positron storage ring facilities are under construction at DESY and SLAC, and Fermilab is building an energy doubler to accelerate protons to 1000 GeV (1 TeV).

The problem is rather to ensure, through a proper strategy for future accelerators, that the world resources allocated to high energy physics be spent for the greatest overall benefit and advancement of science. Two circumstances play here a dominant role, firstly the evidence that the progress of physics demands various complementary types of machine, secondly the fact that the cost of each of them is likely to saturate the financial possibilities of a whole continent for many years.

Leon Van Hove,
CERN Research Director General



It is therefore of great significance to adopt a new, more systematic approach toward a world-wide co-ordination of future large accelerator projects, somewhat analogous to what was done in Western Europe in the early 60's with the creation of the European Committee for Future Accelerators, ECFA. Following a recommendation of an interregional study group concerned with the possibility of a 'Very Big Accelerator' on a world-wide scale, the Commission for Particles and Fields of the International Union for Pure and Applied Physics decided in July 1976 to create an Interregional Committee for Future Accelerators, ICFA. It should sponsor discussions and studies on future large-scale efforts between the various regions of the world engaged in high energy physics research. The contribution which ICFA could make is very great indeed, just as ECFA played a crucial role for the successful development of European high energy physics.

Looking more concretely at the situation in the three main regions of the world operating large accelerators, the following picture seems to emerge. The USSR high energy physicists, who are mainly using the 70 GeV proton synchrotron at Serpukhov, are making plans for a new machine of the same type in the energy range 2 to 5 TeV. It is hoped that the new synchrotron will be built in the 80's and will be supplemented by an electron ring for the study of electron-proton collisions.

In the USA, the 400 GeV proton synchrotron at Fermilab is exploited for physics since 1972 and a 1 TeV energy doubler is under construction, which is intended to be used also in a proton-proton colliding beam mode with the ring of the existing accelerator *). The electron-positron storage ring PEP is being built at SLAC, and two possible projects of very high energy proton-proton rings, ISABELLE and POPAE, are under study.

In Western Europe, CERN is completing the construction of its 400 GeV proton synchrotron, and work has started on the electron-positron storage ring PETRA at DESY. Preliminary studies are carried out on various storage ring projects, each one having its proponents *). Among the possible options, a number of physicists show particular interest in the choice of a very high energy electron-positron facility as a future large European enterprise.

If each of the trends mentioned above would materialize, one would have an example of a reasonable sharing of work between the various regions of the world for the high energy physics accelerators of the coming decades. While other forms of sharing are of course possible, it should be borne in mind that duplication of one of the very large projects contemplated may mean that another of the desirable machines would not be built, at least for a very long time.

But intercontinental collaboration in high energy physics has developed rapidly in recent years, in particular with the exploitation of the ISR at CERN and the large proton synchrotrons at Serpukhov, Fermilab and CERN. It may, therefore, not be too optimistic to hope that a reasonable co-ordination of regional plans will be achieved, aiming at an efficient use of necessarily limited resources for the further progress of high energy physics, and paving the way to a more integrated world-wide collaboration in one of the most fundamental branches of science.

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*) *Both Fermilab and CERN also study the possible utilization of their existing accelerators for proton-antiproton colliding beam experiments.*

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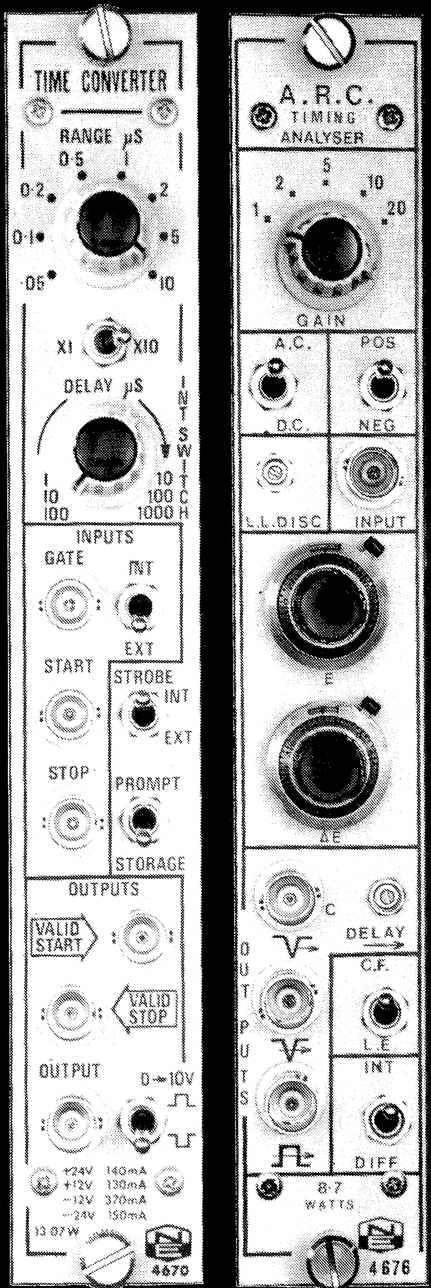

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March 2, 3, 4, 8 and 9	Polarization analysis in high-energy experiments, by L. Michel (Institut des Hautes Etudes Scientifiques, Bures-sur-Yvette)
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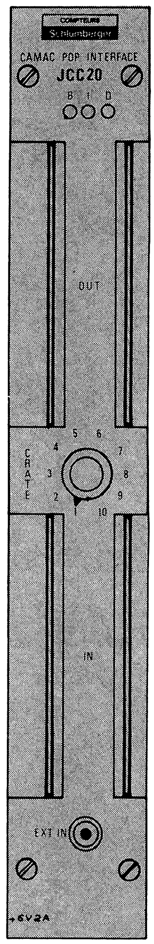

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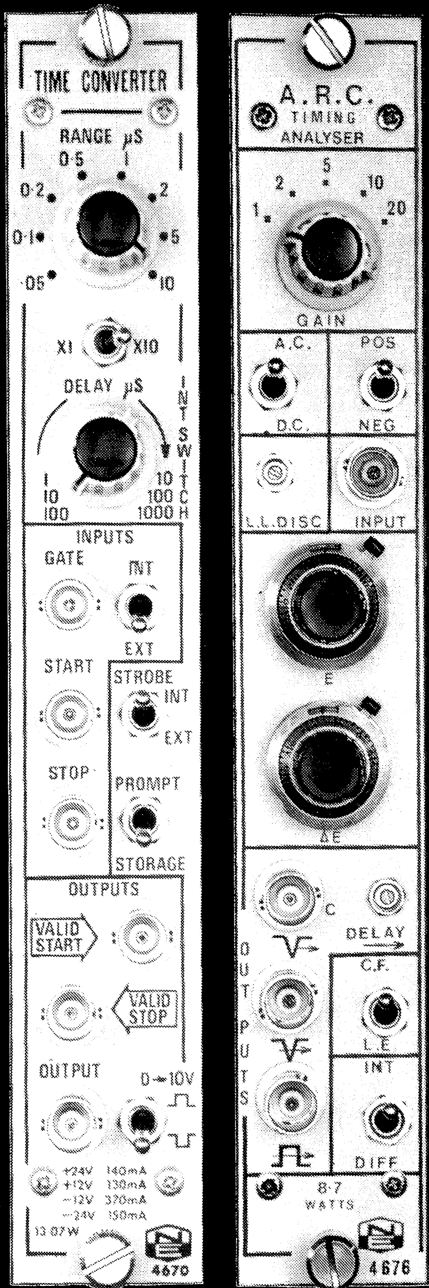

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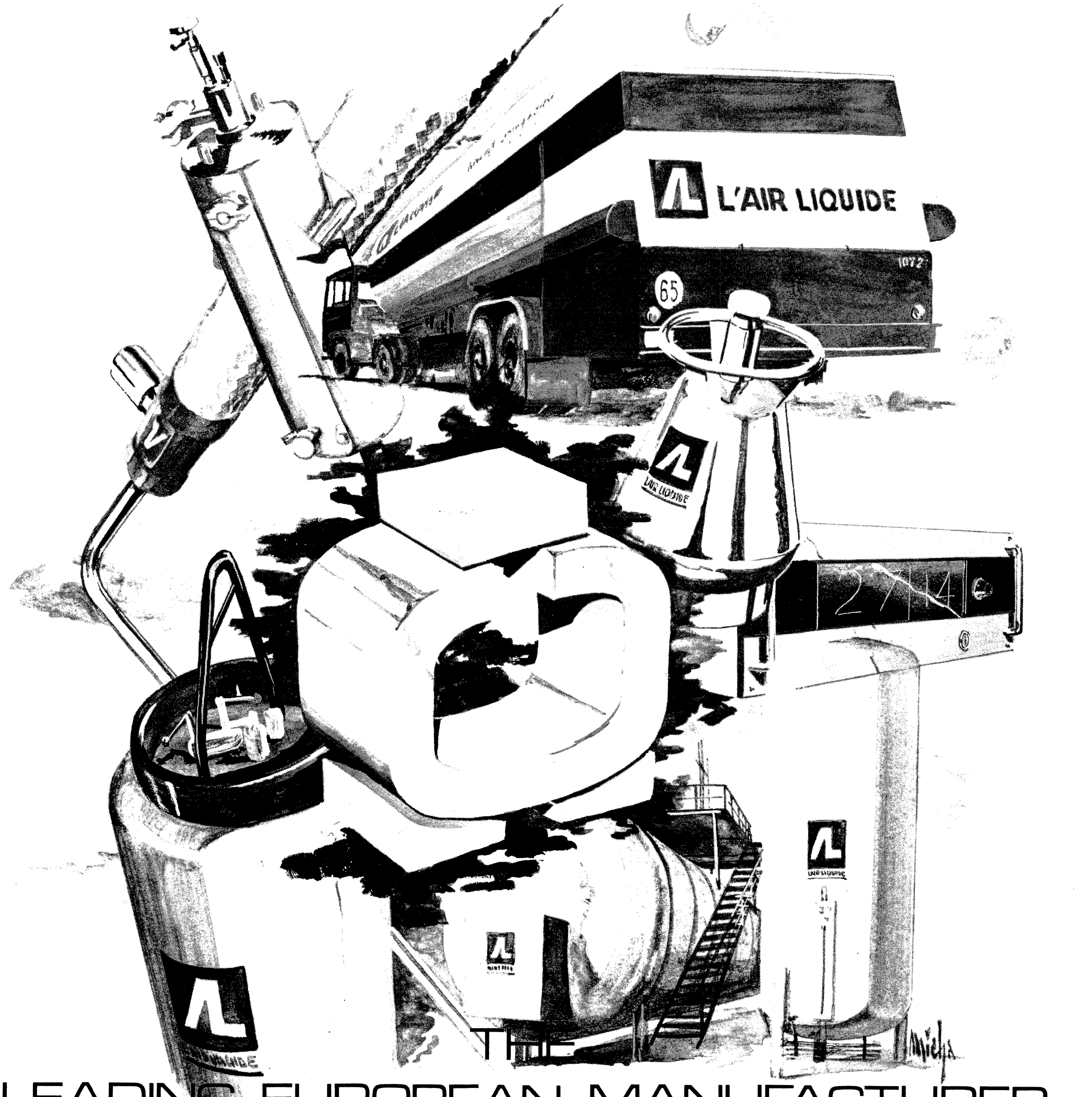

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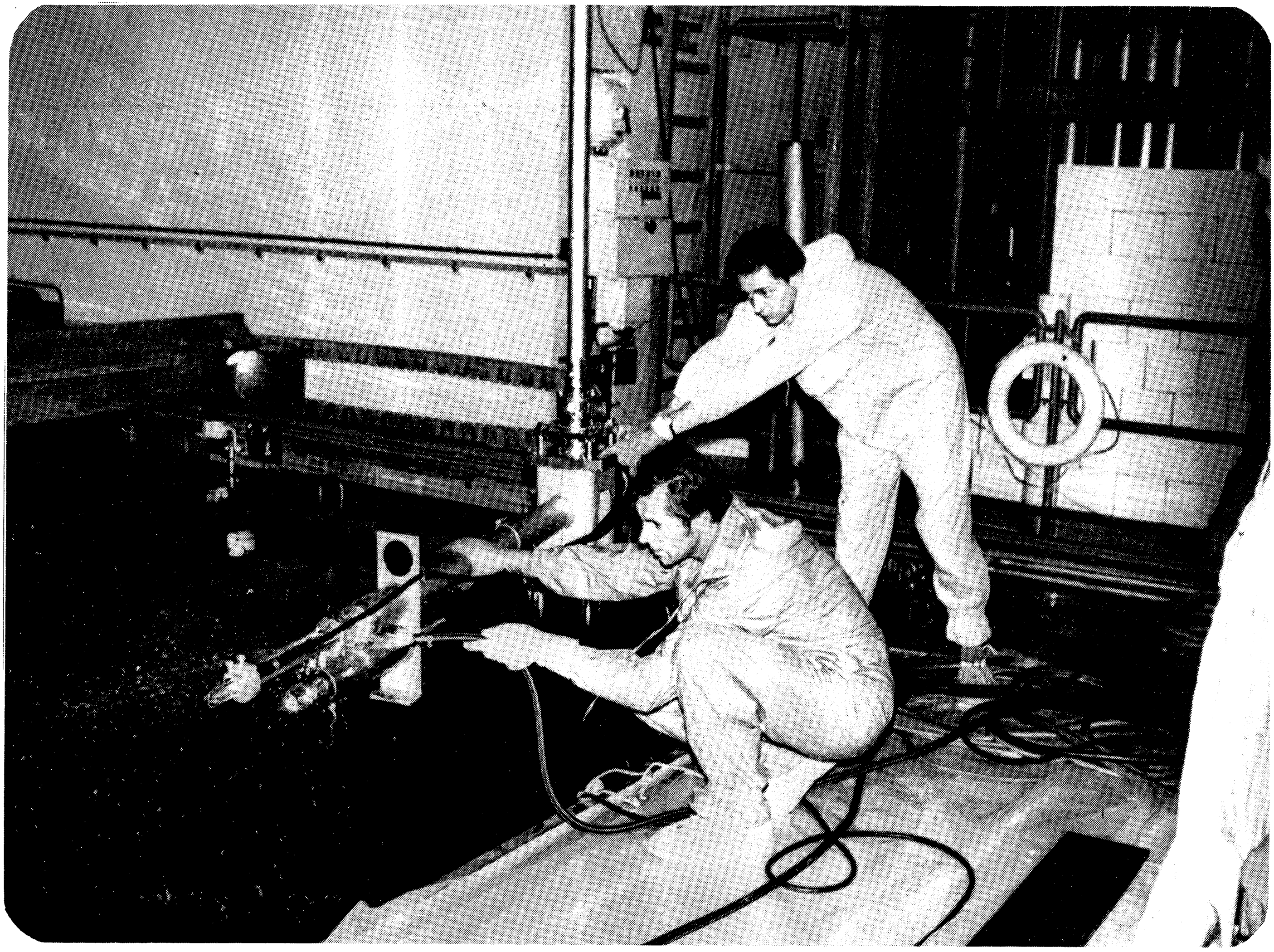

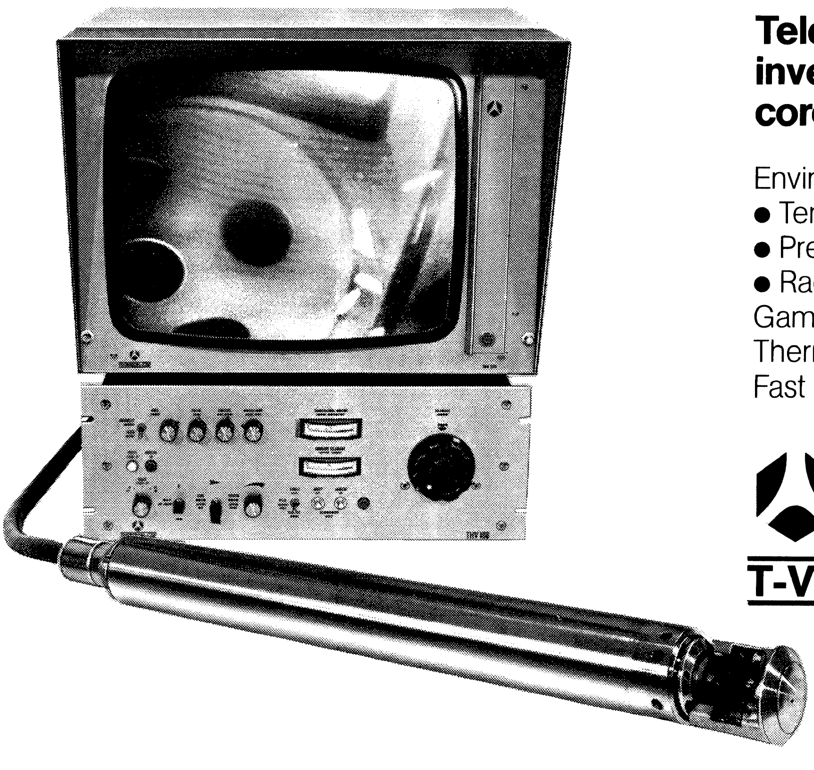

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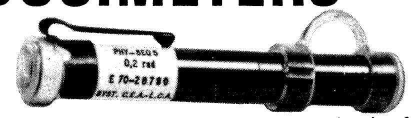

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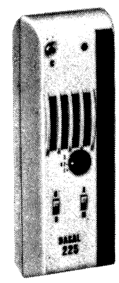

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