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Federal Republic of Germany —
Frau I. Schuetz
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France —
Mme Detoeuf
IN2P3, 11 rue Pierre et Marie Curie, 75231 Paris Cedex 05

Italy —
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United Kingdom —
Elizabeth Marsh
Rutherford Laboratory, Chilton, Didcot
Oxfordshire OX11 0QX

USA/Canada —
Margaret Pearson
Fermilab, PO Box 500, Batavia
Illinois 60510

Other countries —
Marie-Jeanne Blazianu
CERN 1211 Geneva 23, Switzerland

Laboratory correspondents:

Argonne National Laboratory, USA
Ch. E.W. Ward
Brookhaven National Laboratory, USA
J. Spiro
Cornell University, USA
N. Mistry
Daresbury Laboratory, UK
J. Bailey
DESY Laboratory, Fed. Rep. of Germany
I. Dammann
Fermi National Accelerator Laboratory, USA
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Editor: Brian Southworth

Assistant Editor: Henri-Luc Felder

Advertisements: Micheline Falciola

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Cover photograph: 'Albert Einstein' as seen by the Soviet sculptor Sidor. The sculpture now stands in the coffee lounge at Fermilab having been presented to the Director, R.R. Wilson, by G.N. Skryabin at the USSR Academy of Sciences. Bob Wilson described the gift as 'an excellent tribute to the USA-USSR collaboration in physics, the difference being that the collaboration is very real and not abstract like the sculpture'. (Photo Fermilab)

Heavy ion route to fusion

Since the beginning of the year there has been an exponential rise of interest in the possibility of using beams of heavy ions to achieve fusion in deuterium-tritium pellets. Up to now this interest has been concentrated in the USA and, during the last two weeks of July, the Energy Research and Development Administration called a 'Summer Study of Heavy Ions for Inertial Fusion' (held at the Claremont Hotel in Berkeley) to help assess the practicality of the heavy ion ideas and judge where research and development effort is needed to test the principles involved. About sixty people, from fifteen institutions in fusion physics, nuclear physics and accelerator physics disciplines, attended the Study full time.

For some 25 years, physicists have been attempting to tame fusion as a practical source of energy. Of the two mechanisms to extract power from the nucleus, fusion (the uniting of light nuclei) is much more attractive than fission (the breaking up of heavy nuclei). It is potentially a more power productive process. It uses a fuel (hydrogen or, more precisely, its isotopes deuterium and tritium) which is in virtually limitless supply, whereas fission draws on limited resources of uranium. It is environmentally a cleaner process (probably) with less problems of safety and radioactive waste disposal.

The nuclei of elements near the centre of the chemical periodic table are more tightly bound together than their lighter or heavier brethren. To produce the lighter or heavier from the tightly bound, energy has to be supplied. Conversely, if we break up the heavier or unite the lighter, energy is liberated. Fission of heavy nuclei has proved a manageable process and is the source of energy in present nuclear reactors. Controlled fusion of light nuclei has, so far, proved to be an unmanageable process (leaving aside the use in nuclear weapons). It requires conditions of high temperature and high nuclear density, which it has not been possible to sustain simultaneously for a sufficiently long time to result in a net energy gain.

Two major routes to achieving thermonuclear fusion reactors are being pursued. The first involves magnetic confinement systems — magnet field configurations (toroidal and mirror) attempting to hold a dense hot plasma for an adequate time. The most promising versions are the Tokomak machines initiated in the Soviet Union but now being pursued world-wide. The latest examples are the TFTR (Tokomak Fusion Test Reactor) under construction at Princeton USA, the J-T 60 project in Japan, the T-20 in the USSR, and the JET project (Joint European Torus) for which a site in Europe has not yet been decided.

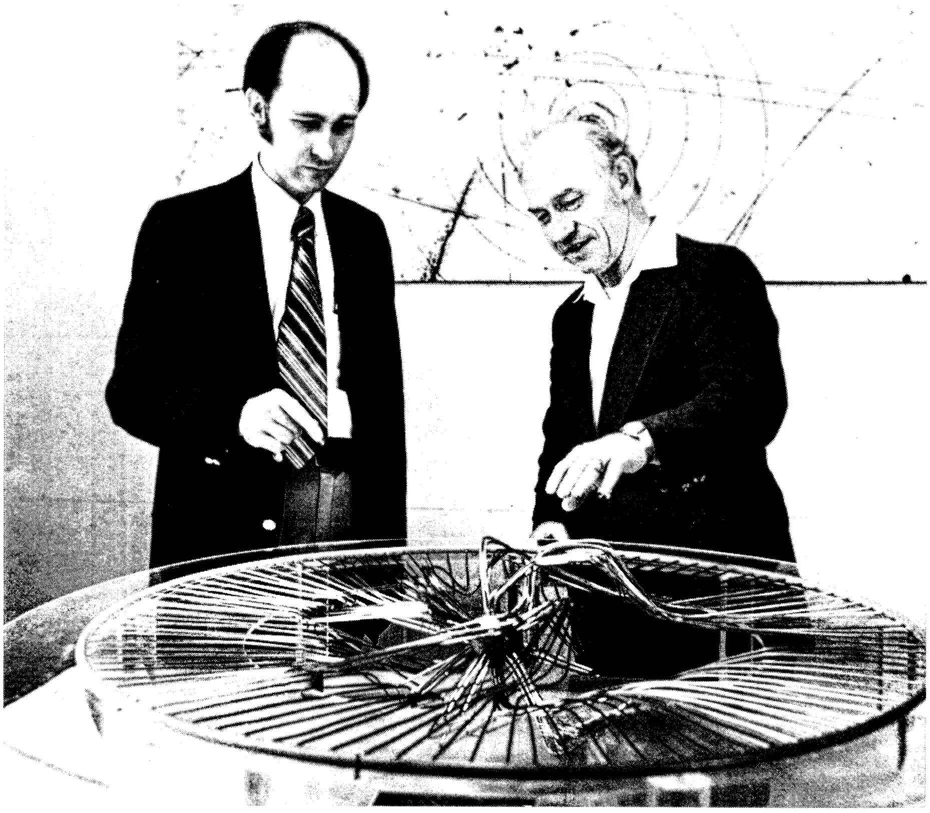
The second, more recent, route to a fusion reactor attempts to use the high power densities available from lasers to cause implosion of a deuterium-tritium (DT) pellet. Laser beams bombarding the pellet from all sides could produce the conditions within the pellet to sustain thermonuclear burn. The most powerful laser system is the Argus now being commissioned at the Lawrence Livermore Laboratory to deliver 1 terawatt (TW).

Related to the laser ideas, and pointing the way to the use of heavy ions, is the electron beam fusion technique. At Sandia Laboratories in the USA they operated a prototype, Proto 1, in 1975 and showed that with two electron beams it is already possible to crowd 2 TW into a 24 ns pulse. Experiments with pellets are now beginning and Proto II is scheduled for operation at the end of the year to give higher power by a factor of four. Money for an Electron Beam Fusion Accelerator (EBFA) has been requested for Fiscal Year 1977. At the Kurchatov Institute in the Soviet Union a 1 TW system called ANGARA 1 is being tested and a 5 MJ accelerator is planned for completion in five years.

The magnetic confinement systems have been moving progressively towards achieving the necessary temperature/density/time parameters but have some way to go. The laser systems are still well down on the necessary power densities and have repetition rate problems. It is these latter considerations that led a few hardy souls in the high energy accelerator community to take a look at the possibility of heavy ion beams doing the job that lasers and electrons are trying to do with DT pellets.

In 1975, M. Clauser of Sandia did some calculations on the use of proton beams on pellets. He emerged with 'break-even' figures (the situation where as much energy could be extracted from the system as is fed in to initiate the fusion) of 60 TW of 10 MeV protons incident on a 10 μg pellet. The ignition time was 6 ns which implies an incident energy of 360 kJ. The pellets were treated as DT in a gold shell 0.22 mm thick. The protons would penetrate only 0.17 mm into the gold so that a remaining thin shell would push inwards on the DT. (Of the incident energy, only about 8 kJ would actually be needed to establish the necessary fusion conditions.)

These figures indicate the 'ballpark' in which inertial fusion schemes need to be situated — they need beam energies around 1 MJ in a pulse length of less than 10 ns. To modern accelerator specialists these figures are not very frightening. The CERN Intersecting Storage Rings, for example, hold about 2 MJ in each ring (4×10^{14} protons at about 30 GeV). The protons, however, are not concentrated in a bunch less than 10 ns



Richard Arnold (left) and Ron Martin at Argonne survey a model of their high energy heavy ion scheme to achieve fusion in deuterium-tritium pellets. Beam lines point the ions at the pellets from all directions and the irreverent caption for this picture reads 'All that spaghetti and only one meat ball'.

(Photo Argonne)

long! To get megajoule energies concentrated in a few nanoseconds, several high energy heavy ion schemes have emerged.

The main ones have come from A.W. Maschke of Brookhaven who has been working with people from the Lawrence Livermore Laboratory, from R. Martin and R.C. Arnold of Argonne, and from D. Keefe of the Lawrence Berkeley Laboratory who has spent some time at the Princeton Plasma Physics Laboratory. Al Maschke has considered uranium ion accelerators of 100 GeV, both synchrotron and linac configurations. Ron Martin and Richard Arnold have considered a hydrogen-iodide ion accelerator/ storage ring of 40 GeV. Dennis Keefe has considered a uranium ion linear induction accelerator of 25 GeV (drawing on the Berkeley experience with such very high current machines during the Electron Ring Accelerator programme).

Although these schemes have been worked out in some detail there is not much point in fuller description here since a lot of work will need to be done before any preference among them becomes clear. It is important to say, however, that much of the accelerator technology involved is already mastered. Ion sources to give adequate currents still require some work but they will probably be developed without great problems — for example, Oak Ridge already has a 1 A uranium ion source and, in July, Berkeley achieved 10 A from a xenon ion source. The synchrotrons, storage rings and beam transfer systems are not dramatically different from our existing machines. Beam emittances, space charge limits, beam instabilities, multiturn injection, bunching requirements and multi-beam transport seem manageable.

But there are some vital questions to be answered regarding the accelerator systems. The major ones concern the cross sections for charge exchange between the ions in the intense beams and between the ions and residual gas molecules in the machine vacuum. The proposed schemes attempt to hold, for example, triply charged uranium or singly charged hydrogen iodide ions. If charge exchange occurs, the ions involved would be lost from the beam.

If the cross sections for charge exchange interactions in the beams are large, they would limit the time for which it would be possible to hold high intensities. This would dictate the choice of fast acceleration and storage schemes rather than slower versions. Also high intra-beam cross sections would suggest going to the multiply charged ion schemes (for which these cross sections would be less) provided the space charge forces do not get too high. If the cross sections for charge exchange interactions with the residual gas are large, they would dictate stringent vacuum requirements (though with the ISR behind us this is not a major concern). It will not be easy to simulate the necessary conditions in order to answer these questions, though some extrapolation may be possible from work on machines such as the Berkeley Bevalac and Darmstadt Unilac.

A lot of development remains to be done on target pellet and reactor design — no-one has yet demonstrated an efficient fusion implosion. One of the problems, which has worried the people attempting inertial fusion using lasers, is the preheating of the deuterium-tritium. Unless the laser light pulse gives 90% of its energy in the last 10% of the pulse, too much energy would reach the DT in advance of the major shock wave. The heating that this would cause would create conditions making the DT resistant to implosion. The same worry applies also to heavy ion bombardment.

Target specialists, however, have high confidence that appropriate pellet designs can be produced. Much of the thinking on such designs has come from the laser work, particularly at the Lawrence Livermore Laboratory.

Some ways need to be found to carry out 'proof of principle' experiments on the concepts of high energy, heavy ion induced fusion at a reasonable cost. One strong sentiment at the Summer Study was that, if the outstanding questions are answered positively, then the accelerator community would come in with a system which would work, accompanied by reliable cost estimates. Probably more than any other profession they have proved that they are masters of their technology and can accurately predict the costs involved.

Before then a tremendous amount of detailed work would be required. It is far too early to talk money but it is worth emphasizing already that it is unlikely that energy from high energy, heavy ion induced fusion would be cheaper than is available, at present, from other sources. Perhaps a fusion power plant with several reactors fed by a single accelerator system would cost around $1000 million. But controlled thermonuclear fusion has the advantages that we cited at the beginning of the article and, long term, is man's greatest hope as a source of energy.

It is surprising that in a matter of a few months so much interest and enthusiasm has been generated on the topic of heavy ions for fusion. It is even more surprising that the ideas have survived a two week investigation by experts from the fusion and accelerator fields and have emerged stronger than when the study began. There is considerable optimism that the concepts are correct and that the necessary technology is feasible. The subject is so important that it has to be pursued.

SERPUKHOV
Future Soviet h.e.p. facilities

The particle physics community in the Soviet Union is evolving plans for the construction of a major complex of higher energy machines at the Institute for High Energy Physics (IHEP), Serpukhov. The first stage of this complex is seen as a 2000 GeV (2 TeV) proton synchrotron and a 20 GeV electron synchrotron with the ability to collide the proton and electron beams. As a second stage proton-proton colliding beams with energies up to 2 TeV are envisaged. The whole complex is known under the name of UNK.

The 2 TeV proton machine would have superconducting magnets with fields up to 4.5 to 5 T. They would use niobium-titanium superconductor and the later application of superconductor such as niobium-tin is seen as the route to higher energies (up to 5 TeV). The existing 76 GeV synchrotron at IHEP would be the proton injector and a 1.5 GeV fast cycling (20 Hz) booster is being added to the 76 GeV machine so as to increase the beam intensity to 5×10^{13} protons per pulse. The booster is scheduled for operation in 1978-79.

The 2 TeV synchrotron, which would probably be housed in a tunnel 18 km in circumference, would take ten 70 GeV pulses in multiturn injection during 54 s. The subsequent acceleration time to 2 TeV would be 15 s (lessening the superconducting magnet problems which accompany fast risetimes) and 5×10^{14} protons would then be available for ejection, using fast or slow ejection systems, during a flat-top as long as 30 s. Adding the time for the magnet fields to return to injection level, gives a total cycle time of 114 s.

Another version of the accelerator complex to reach 2 TeV foresees acceleration in a smaller synchrotron ring to 400 GeV with a 6 cm magnet aperture using conventional magnets and further acceleration to 2 TeV in a second ring with a 4 cm magnet aperture, using superconducting magnets. This version could double the average intensity by allowing faster cycle times and could also make proton-proton colliding beams possible. The magnet fields in the first of the new rings would be capable of holding protons of up to 800 GeV with magnet fields of 1.8 T when operated as a storage ring so that protons of 800 GeV could be collided with protons of up to 2 TeV. Superperiods of the two rings would be interlaced in the vertical plane giving intersection regions at the straight sections. A maximum luminosity of 10^{33} per cm^2 per s is considered feasible with some beam shaping in the intersections.

Both new rings would be built in a tunnel some tens of metres below ground. Two ejected beam lines to bring particles to large experimental halls on the surface and four colliding beam experimental halls at tunnel level would be built. The tunnel would also have room for a 20 GeV electron synchrotron (against its outer wall so that the proton rings would not be in the synchrotron radiation zone). The electron beam intensity is seen as 5×10^{13} particles per pulse with injection at 2 GeV and a total acceleration time of 3 s.

Design of the 'conventional' parts of UNK including the 400 GeV conventional magnet stage of the proton accelerator, is receiving detailed attention. The superconducting stage requires further input from research and development programmes before it is designed in detail and, in the meantime, some thought has been given to the possibility of doubling the role of the electron synchrotron to serve

A plan view of the Charged and Neutral Spectrometer (CNS) at the Argonne ZGS which has been used in a careful search for 'lost' mesons (particles predicted by the quark model but not yet found). The spark chambers which measure the direction of the negative pion beam are not shown. GHF, GHR are scintillator hodoscopes used for triggering on gammas.

(Photo Argonne)

as a proton storage ring. It seems that this would be feasible for a moderate additional cost. Various other energy variants for the conventional magnet stage remain under consideration.

ARGONNE
Spectrometer searches for lost mesons

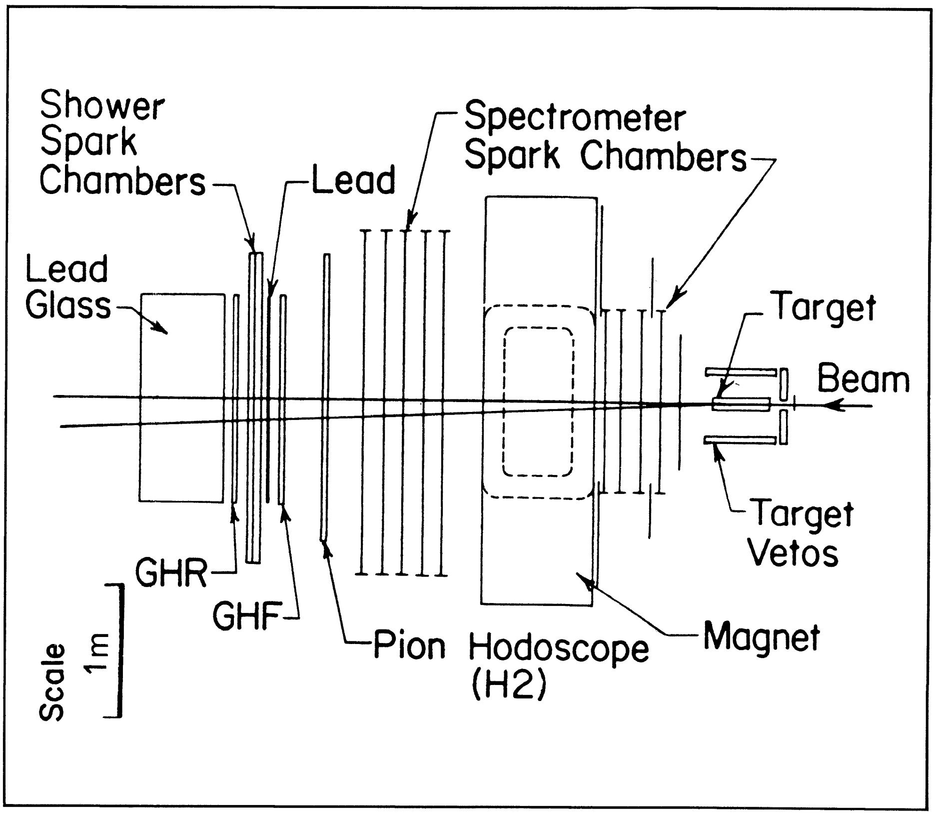
A powerful spectrometer at the ZGS has recently completed a first round of experiments. It is designed for meson spectroscopy studies and is called the Charged and Neutral Spectrometer (CNS) since it can measure both charged particles and gamma rays resulting from the decay of mesons. Reactions producing many neutral particles, some of which were not previously accessible to study in high statistics counter experiments, may be detected in this apparatus. The CNS was built by a USA/Canada collaboration involving groups from the Universities of Ohio State, Michigan State, Carleton and Toronto, who were subsequently joined by a group from McGill.

The recent discovery of massive new particles which are interpreted as bound states of heavy new quarks, has renewed interest in charmless meson spectroscopy as a proving ground for the quark model of elementary particles. The most recent experiment at the CNS was a search for lost mesons — those predicted by the model but not so far confirmed experimentally.

The prime quarry was the elusive neutral A_1 meson whose absence has been an embarrassment to the quark model for several years. If this particle does not exist, the model has some tortuous explaining to do. However, the A_1, like other predicted but as yet unseen mesons, is expected to show a preference for decaying into both charged and neutral pions (the A_1 is supposed to decay copiously into $\pi^+ \pi^- \pi^0$) which makes their detection difficult. Much of the existing data on these missing particles has come from limited statistics bubble chamber experiments which may not have been sensitive enough to see the lost mesons if their production cross sections are small. The CNS experiment is able to obtain data on such reactions as $\pi^- p \rightarrow \pi^+ \pi^- \pi^0 n$ and $\pi^- p \rightarrow \pi^+ \pi^- \eta n$ without the necessity of observing the recoil neutron.

The CNS is constructed around a large bending magnet with an aperture 1 m high, 2 m wide and 0.8 m along the beam direction. Large area magnetostrictive wire spark chambers are located on both sides of the magnet, to measure the momentum of charged particles produced in a hydrogen or deuterium target. Just downstream is a sheet of lead to convert gamma rays to electron-positron pairs, followed by several more wire spark chambers to locate the conversion points. Finally, a 56 element 1.5 m × 1.5 m array of lead glass Cherenkov counters measures the energies of the electromagnetic showers. Events with gamma ray multiplicities as high as four have proved to be quite easy to analyse. Scintillation counter hodoscopes before and after the lead converter allow the system to be triggered on events with the desired charged particle and shower multiplicities. Scintillator-lead sandwich counter arrays surrounding the target can be used to reject most events with recoil particles other than a single neutron. An on-line computer records the data and reconstructs about 30 % of the events between beam pulses. Typical beam intensity is 10^5 negative pions at 8.5 GeV/c.

A preliminary $\pi^+ \pi^- \pi^0$ mass spectrum from the lost meson experiment (based



on 45 % of the data analysed to date) contains an average of 900 events per 10 MeV/c^2 mass bin, already an order of magnitude improvement over previous experiments. The known resonances η, ω, A_2°, and ω (1675) are clearly seen but there is no evidence for the A_1. A final limit on its presence will not be certain until a more sophisticated three-pion phase shift analysis is performed on the full data sample. The mass spectrum of the $\pi^+ \pi^- \eta$ system (where the η is observed via its decay to two gammas) shows clear peaks for the η' (960) and D (1285) mesons, but no evidence for the E (1420). The decay D (1285) $\rightarrow$ δ (980) π is clearly seen. Finally, examination of the final states $\pi^+ \pi^-$ 3 γ and $\pi^+ \pi^-$ 4 γ shows clear evidence for the radiative decays $\omega \rightarrow \eta \gamma$ and η' (960) $\rightarrow \omega \gamma$, as well as for the neutral B meson via its decay $B^\circ \rightarrow \omega \pi^\circ$.

Earlier experiments with the CNS include a high statistics study of eta and omega production and of omega-rho interference in $\pi^\pm N \rightarrow \pi^+ \pi^- \pi^\circ N$. Some of this data has already been published. Future plans include improving the gamma detection efficiency to provide higher sensitivity for such multigamma final states as $\eta \pi^\circ$, $\eta \eta$ and η' (960) π° as well as those already mentioned. Also planned are searches for charged mesons in $\pi^- p \rightarrow \pi^+ \pi^- \pi^- (n \gamma) p$, where the meson decays are in such channels as $\omega \pi^-$, η' (960) π^-, and $A_2^\circ \pi^-$.

Construction of superconducting accelerator

Construction is beginning at Argonne of a linac which will increase the energy of heavy ions which have gone through a first acceleration stage in a tandem Van de Graaff. The linac will use superconducting 'split-ring' resonators which will reduce the capital cost by about 30 % and the necessary operating power to one tenth.

The idea for the superconducting split-ring type resonators was promoted by Ken Shepard and his colleagues at Cal. Tech. in 1974 who started with leadplated copper versions. Shepard moved to the Argonne Physics Division and worked on the superconducting linac with Lowell Bollinger (who now leads the linac project). The resonators are now made of niobium and conclusive tests were carried out at the end of April of this year. Accelerating gradients of 3 MV/m were achieved with the resonators at 4.2 K and operating at 97 MHz.

$ 2 million have been assigned to the linac project which involves both the Chemistry and Physics Divisions at Argonne. The linac will be 10 m long housing 18 resonators each of which will consume about 1 W of power. It will receive heavy ions at about 60 MeV from the tandem (10 MV terminal voltage) and accelerate them to about 400 MeV before sending them to a new target area (which has been under construction for several months) for nuclear physics experiments. The linac is scheduled for completion in the first half of 1978.

Lowell Bollinger (left) and Ken Shepard nurse a superconducting split-ring resonator such as will be used in a linac to accelerate heavy ions at Argonne. The resonators have been successfully tested at accelerating gradients of 3 MV/m.

(Photo Argonne)

BROOKHAVEN
Protons in medicine

The Brookhaven Medical Proton Facility has been prepared for commissioning now that the AGS is back in action since the end of August. The project brings physics and medicine together in a joint effort of the Medical, Applied Science and Accelerator Departments to develop proton radiation therapy.

As at several other accelerator centres, the goal is to use charged particles (pions, protons or heavy ions) for destroying cancer cells. When such particles are stopped in body tissue, they deposit the bulk of their energy in a small volume at the end of their range and can thus attack a cancerous region with less harm to surrounding healthy cells. Comparing 200 MeV protons from the Brookhaven linac with gamma radiation from a cobalt-60 source showed that the dose received by healthy cells was reduced by a factor between 2 and 5.

To deliver the dose to the cancerous region requires accurate knowledge of the tissue (particularly its density) traversed by the beam. A technique under development at Brookhaven is to monitor radionuclides produced in the tissue by protons and to set the beam penetration depth having measured this induced activity. Oxygen-15 and carbon-11 are produced in measurable quantities using doses which are small compared to the therapeutic dose needed in the same volume. Monitoring ^{15}O and ^{11}C during a low level irradiation could be used to set the conditions for the therapeutic irradiation by introducing a shaped plastic absorber in the path of the incoming beam.

The radioactive oxygen (half life 2 minutes) and carbon (half life 20 minutes) emit positrons which combine with electrons to give a pair of gammas emerging in opposite directions with an energy of 511 keV. With a well defined beam into the irradiated volume and detectors on each side, the location of the positron annihilations can be found. The aim is a spatial resolution of 1 cm with a dose of less than 50 rads.

The Brookhaven linac can deliver 10^6 rads per pulse ten times per second while only about 2 rads per pulse are needed for the localization measurements. Collimators in the beam transport system cut the intensity by a factor of 250 and scattering and collimation separated by a 30 m drift space complete the reduction giving a well defined, highly uniform beam. Experiments so far have satisfactorily checked the effect on the resolution of such parameters as dose, energy spread and scattering. Beam control techniques and the magnitude of competing background reactions have also been studied.

A phenomenon which could confuse the results is that the radionuclides can move from the position where they are produced by the incoming protons before they give off their positron. This biological transport was investigated by irradiating rats and it was found that about 30 % of the radionuclides were quite mobile. This was identified with the extracellular fluid which needs only travel some 50 μm to a capillary and then enter the circulatory system.

Fortunately, with such a short diffusion path, the phenomenon does not mask the desired measurements other than to add a near uniform background of magnitude about 2 %. Most of the observed radiation is identified with the intracellular fluid which is almost immobile. The technique is complementary to that of injecting radioactive substances into the body (where initially the radioactivity is extracellular) and could give new insights into molecular transport in biological systems.

LOS ALAMOS Optimizing clinical accelerators

The Machine Physics Division at the Los Alamos Scientific Laboratory has recently been awarded a three year grant from the National Cancer Institute (NCI), Division of Cancer Resources and Centers, to study linear accelerator optimization for pion generators to be used in cancer therapy in hospitals.

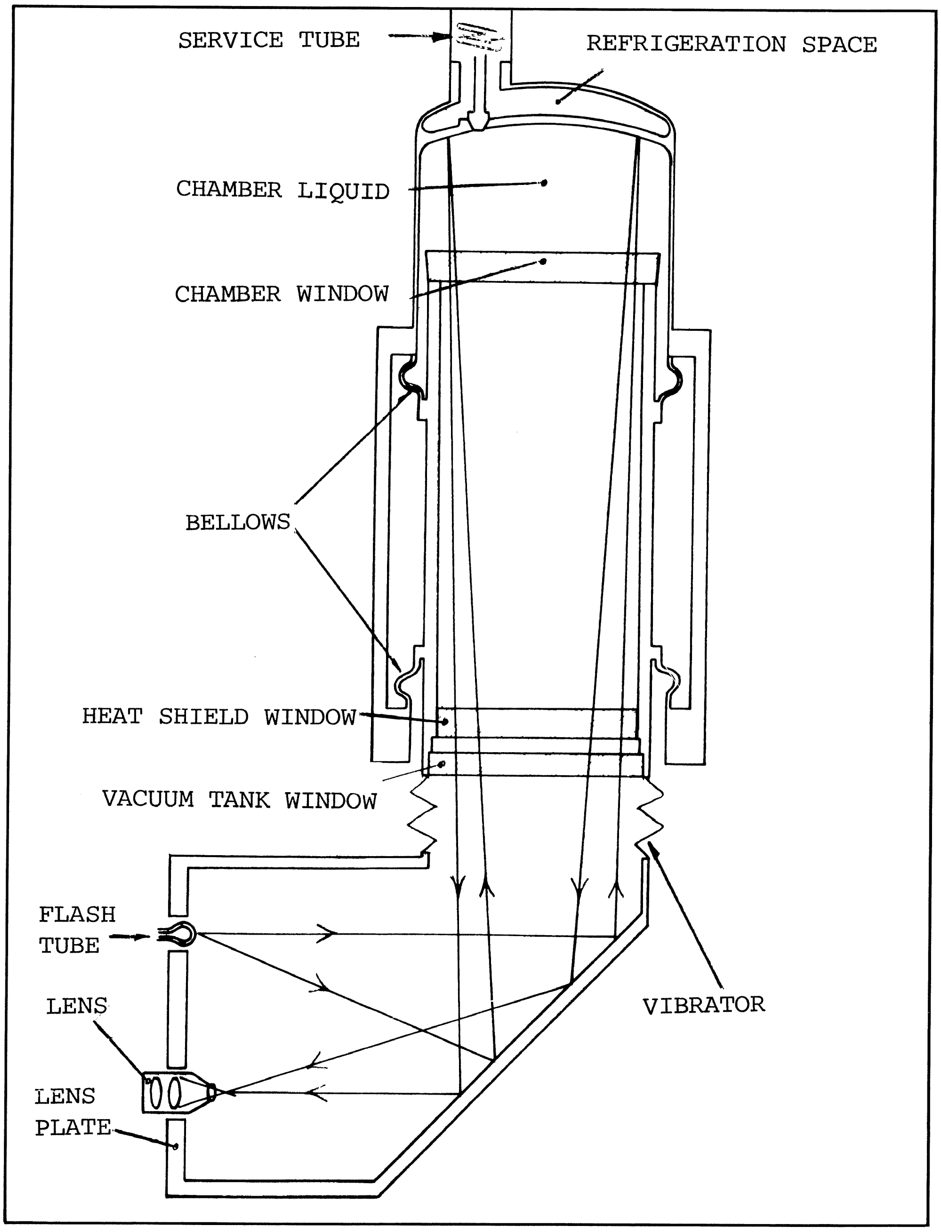
Los Alamos is heavily involved in a programme to investigate the use of pions in cancer therapy — the 800 MeV proton linear accelerator, LAMPF, has a dedicated pion channel and clinical facility. This facility was built by a collaboration between ERDA and NCI who continue to support its experimental programme. The experience gained in this work and the accelerator experience at Los Alamos will be combined to produce prototype accelerator sections whose properties are optimized for use in the special circumstances expected in a hospital environment. Edward Knapp is the principal investigator with Donald Swenson as deputy.

Several accelerator parameters will be significantly different in a clinically based facility compared to a physics facility. In the design of LAMPF, duty factor played a central role but in a clinical facility it is a minor importance. Overall length on the other hand is a major consideration when thinking of siting it at hospitals. Reliability and cost are also of major importance and it has to be remembered that in a hospital the maintenance and operating staff would probably be smaller and less technically sophisticated than at a large physics Laboratory.

The Los Alamos programme will tackle the design of proton linacs to generate pions with the following goals in mind — (1) to raise the frequency of the drift tube linac from the standard 200 MHz to 450 MHz; (2) to achieve the use of permanent magnet focusing in drift tube linacs; (3) to extend the radial focusing properties of alternating phase systems so as to reduce the injection voltage into the machine substantially; (4) to devise a manifolding system which will simplify accelerator tuning and adjust-

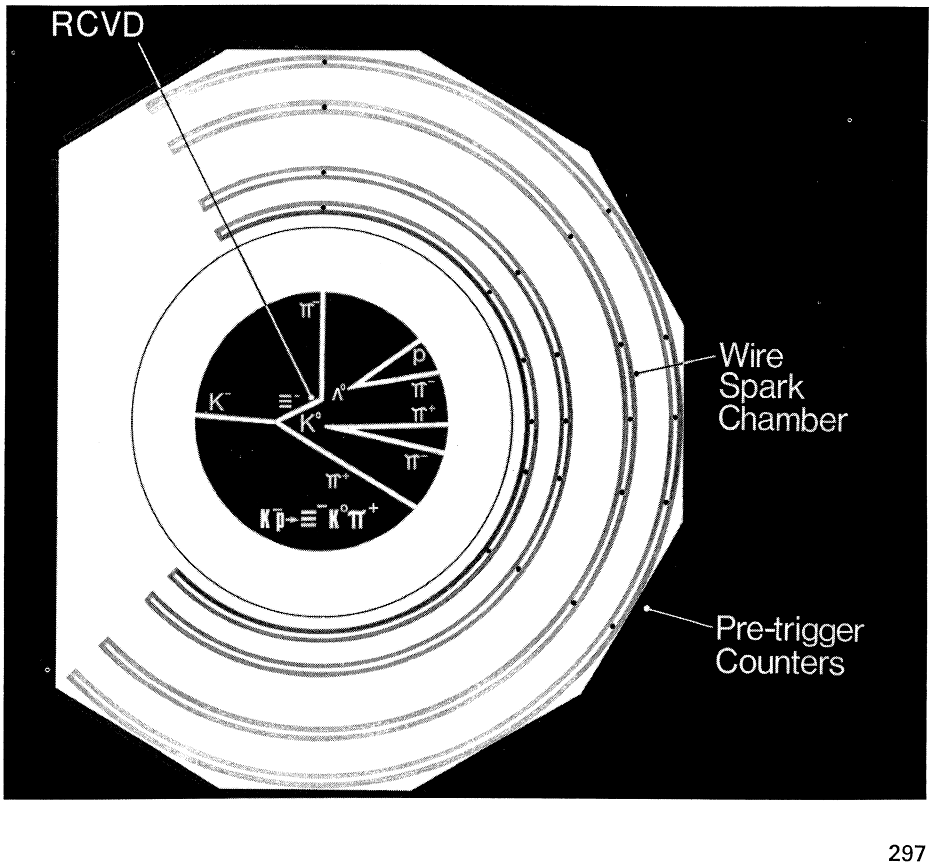
Diagram of the RCVD, Rapid Cycling Vertex Detector, which has had its first tests at the Rutherford Laboratory. The bubble chamber is 30 cm in diameter and 20 cm high and will operate at up to 60 expansions per second. The expansion system and optical system (for which light paths are drawn in) are located below the chamber.

The RCVD will be used initially in conjunction with four cylindrical spark chambers and the picture shows how such a hybrid system will record multiparticle events, firing the RCVD flash when five or more particles are detected. The interaction vertex can then be examined in detail on the bubble chamber photographs.



ment and allow klystron failure without machine shutdown; (5) to increase the maximum gradient achievable in drift tube linac structures and in side-coupled structures by proper surface preparation.

At the present time a short section of drift tube linac is being fabricated and a 450 MHz klystron system is being assembled. Model tanks for bead perturbation measurements of the field distributions in the alternating periodic system are planned this fall and prototype permanent magnet quadrupoles have been assembled and tested. By the end of the three year period of the grant, a low energy (about 10 MeV) prototype will be completed and extensive beam tests will have been accomplished.



RUTHERFORD RCVD coming into action

The Rutherford Laboratory's Rapid Cycling Vertex Detector (RCVD) was sensitive for the first time on 18 July. The RCVD is a small rapid cycling bubble chamber designed specifically to operate with external counter systems in a hybrid mode. The hybrid philosophy, which retains the merits of the bubble chamber at the interaction vertex in combination with the merits of counter techniques to analyse the particles leaving the chamber, has already been used very successfully at Stanford with 15 inch and the 40 inch bubble chambers. It is also the basis for the European Hybrid Spectrometer proposed for the North Area of the 400 GeV SPS at CERN and its counterpart using the 30 inch chamber at Fermilab.

The RCVD bubble chamber is cylindrical (30 cm diameter, 20 cm deep) with the beam direction across a diameter. To draw maximum advantage from the fast data taking abilities of the associated counters, the chamber should be able to take pictures many times per second. It is designed to cycle at 60 Hz — hence the words 'rapid cycling' in its title. Another essential feature is that particles should have a high probability of escaping from the chamber and to achieve this both the optics and the electromagnetic expansion system are positioned at the base of the chamber which has a wall thickness of only 3 mm of aluminium (chamber body and vacuum tank). The main window also serves as a piston and the illumination is bright field retrodirective using a concave mirror as the top of the chamber.

During the test period of about one week before NIMROD was shut down for its Summer break, the chamber was cycled in bursts of up to 0.5 s synchronised with the NIMROD flat top. At frequencies up to 20 Hz (ten expansions in 0.5 s) the chamber operated well and good tracks were still obtained on the 9th and 10th expansions during the burst. For these tests NIMROD was adjusted to give a series of fast spills on demand from the bubble chamber. Operation at 40 Hz was attempted during the last few hours of machine time and there were difficulties. The higher frequencies have yet to be properly explored because of necessary adjustments to the refrigeration and expansion systems. The chamber construction team feels very encouraged by this first operation and expects to achieve the full design performance fairly soon.

The RCVD physics programme at NIMROD is to make a high statistics study of the S = –2 baryon states (Ξ^* s). The chamber flash will be triggered when the counters register a multiplicity of secondary particles emerging from the interaction. It is hoped to have a sensitivity of 400 to 500 events per microbarn for the wanted events. The S = –2 states are typically multivertex events, topologically well suited to investigation using the bubble chamber technique, with cross sections of a few microbarns for the interesting resonance states.

When the charged decay modes of the strange particles occur, they generally lead to a multiplicity of six emerging particles of which at least five must be detected by the counters to give a flash trigger. The incoming beam will be negative kaons of momentum 2.8 GeV/c giving sensitivity to Ξ^* states with mass over about 2.0 GeV/c^2. Four cylindrical capacity read out spark chambers, concentric with the bubble chamber, are read out during the bubble growth time of 1 to 2 ms. These spark chambers are themselves triggered by the pretrigger scintillators using a looser logic (a particle multiplicity of three or over).

The experiment will be carried out by a collaboration involving physicists from Saclay, Collège de France, University of Rome, University of Oxford and the Rutherford Laboratory. The experience gained with the RCVD will be extremely valuable in the design and construction of the larger rapid cycling chamber to be built by the Rutherford team in collaboration with CERN for the European Hybrid Spectrometer.

Polarised deuteron target

A new target designed to produce polarised deuterons using helium-3 continuous cycle refrigeration has recently been completed at Rutherford. In one of the initial runs, polarisations of more than 28 per cent were reached. The target will soon be used in a two year data taking programme in kaon beams on NIMROD.

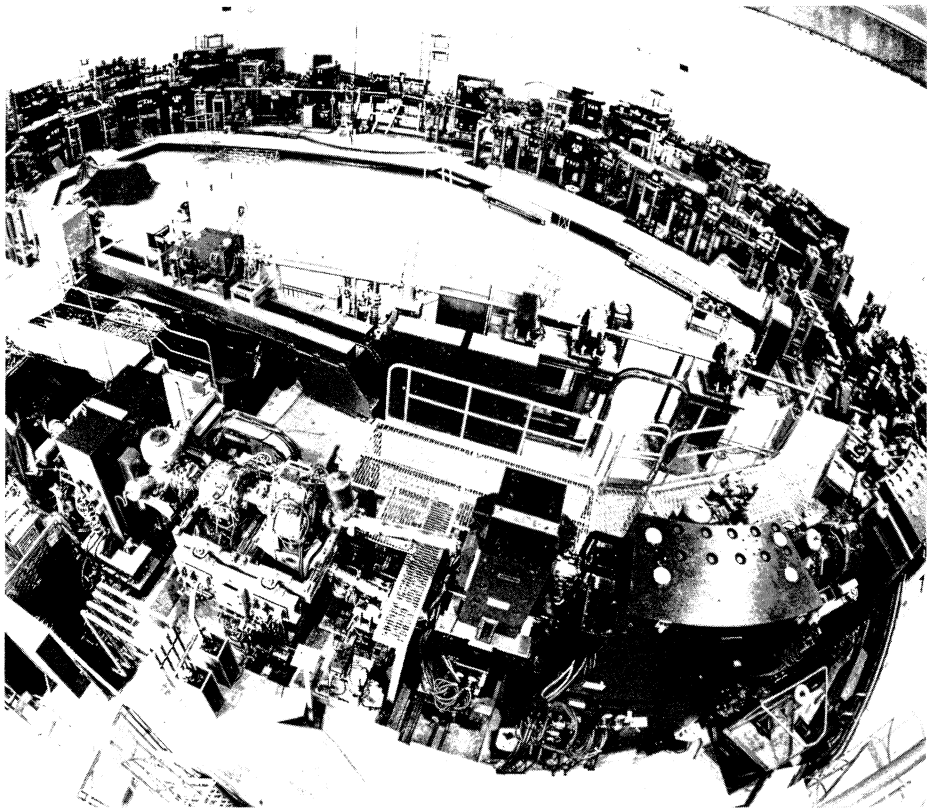
Using 50 cc of deuterated propanediol beads as target material, the target will be used to study asymmetries in K^+ n and K^- n two-body processes in the resonance region. It is therefore the neutrons aligned within the polarised deuterons which are of interest. As is often the case, a major problem is to deal with background events, in this case arising from the neutrons in the carbon and oxygen nuclei in propanediol and in the nuclei within the material of the cryostat. Arrays of proportional and spark chambers, as well as neutron counters, surround the target to give precise information to help in the task of separating out the good events. A lot of time will be spent in studying this background using ordinary propanediol as target material. Here the deuterons are replaced by protons so that the difference shows the neutron contribution.

The expensive target material therefore has to be changed rather frequently and much effort has concentrated on making this operation go smoothly. The target itself is removed from the cryostat along a set of rails into a glove box in which the cavity containing the target material can be easily exchanged without all the usual problems of frosting, etc.

Because the target has quite a large volume, it is important to have a good estimate of the way the polarisation is distributed since this enters into the final measured asymmetry. Four small coils are mounted in the propanediol beads to measure the polarisation of the few remaining free protons in the deuterated material, while one larger coil measures the deuteron polarisation over the bulk of the target. The magnet providing a uniform field for the target is iron cored and has already been used for several polarised target experiments over the past ten years, the last one being an experiment on the CERN proton synchrotron. For each new experiment the magnet has

View of the electron-positron storage rings, DCI, at Orsay. One of the two rings is now in operation for high energy physics and synchrotron radiation experiments. The second ring will be commissioned at the end of this year.

(Photo Baranger)



been modified and for its present application a hole has been made in the vertical return yoke to allow beam to enter the target while leaving maximum aperture available for detectors.

Baryon Conference

The first international conference devoted to baryon spectroscopy since the Purdue Conference three years ago was held at St Catherine's College, Oxford, from 5-9 July. The 'Topical Conference on Baryon Resonances', organised by the Rutherford Laboratory, enabled over a hundred physicists from fifteen countries to discuss new data, analyses and theories.

As well as being encouraged by the physics, participants enjoyed the gracious hospitality of St Catherine's College, especially the excellence of the wine which lubricated the Conference Dinner. Many people — particularly the UK delegates — were surprised by the subtropical weather which prevailed throughout the week prompting one commentator to suggest renaming the event as the 'Tropical Conference on Baryon Resonances'.

High precision data were presented on $\pi^{\pm}$ p elastic differential cross sections at 51 momenta between 0.4 and 2.15 GeV/c by the Bristol/Southampton/Rutherford collaboration and on polarisation and differential cross section measurements for the reaction $\pi^- p \rightarrow \pi^0 n$ at 22 momenta (0.62 to 2.73 GeV/c) by a Rutherford group. New πN partial wave analyses were presented by E.U. Pietarinen (Helsinki), A. Hendry (Indiana) and the Carnegie-Mellon/LBL group. All of these analyses use theoretical input from dispersion relations to limit the high energy behaviour so that even M and N waves were presented. (This raised a point of convention concerning labelling of partial waves, and a reference to the bible of Atomic Spectroscopists, Condon and Shortley (1935), established that the symbol J is to be omitted from the partial-wave sequence SPDFGHIKLMNOQRTU...).

Barrelet zero critiques of partial wave analysis were presented by D.M. Chew (LBL) and E. Barrelet (Ecole Polytechnique) and an animated discussion on the merits of the various techniques ensued. The continuum ambiguity was discussed by D. Atkinson (Groningen). Experimentalists were relieved to see that the continuum of solutions cannot erase the more prominent features of Argand diagrams, though small resonance loops are often in grave doubt.

Many results and analyses were presented on hyperon resonances. In addition to conventional high statistics K^-p data from the Rutherford/Imperial College collaboration, there were new pure I-spin data from K^-d (CERN/Heidelberg / Munich, Birmingham and CERN/Caen) and K^0_L p (Bologna/Edinburgh / Glasgow / Pisa / Rutherford and Birmingham/Paris) experiments. These data constrain partial wave analyses, and much discussion was provoked by a significant disagreement in the $\bar{K}N \rightarrow \Sigma\pi$ (I = 1) cross section obtained by the two techniques. The Yale/BNL total cross section measurement reported several narrow structures in the I-spin separated $\bar{K}N$ cross sections between 1530 and 1830 MeV. New data bearing on the Σ (1660) resonances and dramatically increasing the world supply of Ξ^* and Ω^- events were presented by the Amsterdam / CERN / Nijmegen / Oxford K^-p 4.2 GeV/c experiment. Hopes of building an Ω^- beam were dealt a heavy blow by their lifetime measurement; they reported a value of (0.75 ± 0.15) 10^{-10} s based on 32 events compared to the previous world average which was almost double that value.

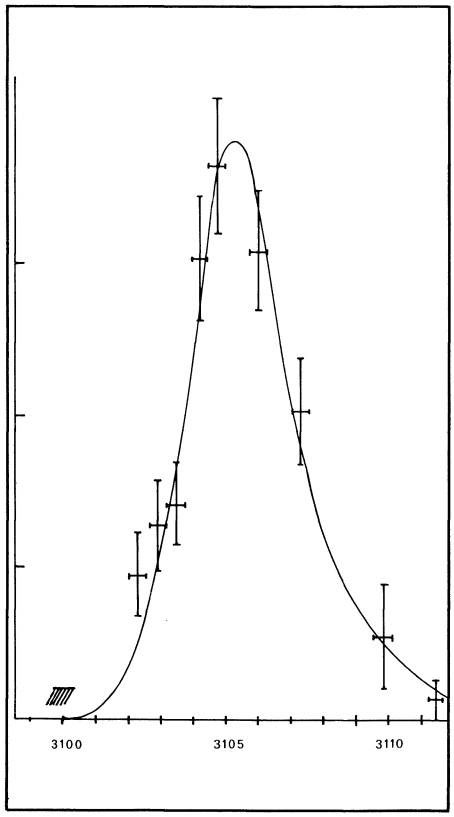
Finally there were several talks on models to explain the observed baryon spectrum (and predict new states!). Perhaps the least familiar of these is the Bag Model presented with enthusiasm and clarity by R. Jaffe (MIT).

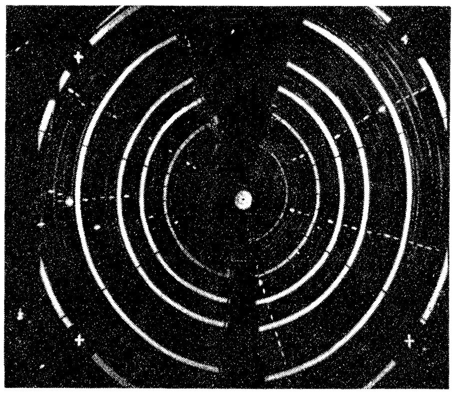
In his summary of the Conference, R. Tripp of Berkeley pointed out the progress that had been made in the past four years in the systematic study of one of the most fundamental interactions of physics and urged that efforts be continued and renewed to provide both better and more varied data in the resonance energy region.

ORSAY
Progress at DCI — J/Psi also observed

The July/August 1975 COURIER (page 228) reported the injection of a first electron beam in DCI. Since then, the main aim has been the commissioning

The J/psi particle spotted with the detector on DCI used in the M3N experiment. The curve shows the rise in cross section as the colliding electron and positron energies total the particle mass of just over 3.1 GeV. The photograph shows the tracks left in the detector.





of the first of the two e^+ e^- rings, for high energy physics and for the use of synchrotron radiation by LURE (Laboratoire pour l'Utilisation du Rayonnement Synchrotron). The construction of the second ring is meanwhile being continued. The second beam transport system became operational at the end of December 1975, and the linear accelerator is now regularly providing a 1 GeV positron beam of 5×10^8 particles per pulse, 20 ns wide, and a tenfold more intense electron beam. The pulsed units operating at 12.5 Hz make it possible to inject positron beams at an average rate of 1 A/hour (maximum 1.8 A/hour). It should be possible to double this figure with injection at 1.2 GeV, which can be done with the existing system.

The r.f. accelerating cavity supplied by a 100 kW power supply operates at 325 kV and has made it possible to give the beams a power of 15 kW with a power loss in the cavity itself of 20 kW. These values are provisional since so far no limit has been observed in practice. The main problem encountered here has been caused by a parasitic mode of the cavity, which, outside a narrow regulation range, induces phase oscillations in the stored beams. The vacuum pressure continues to improve with the progressive outgassing of the walls by the synchrotron radiation. During storage tests in a single beam and a single bunch, the intensity reached 185 mA of positrons and 250 mA of electrons, once the horizontal and vertical chromaticities of the machine had been made positive.

The maximum energy of the beams with electrostatically separated orbits is 1.56 GeV which requires the exciting currents of the horizontal magnets and the ring quadrupoles to be highly accurately programmed. Finally, the orbital measurements made by twenty stations distributed along the machine gave a relative precision better than 0.1 mm. Work is now being done on optimizing the luminosity for various working energies: 0.8, 0.92, 1.0 and 1.56 GeV, and respective values of 0.7, 1.3, 1.9 and 1.1 $\times$ 10^{29} $cm^{-2}s^{-1}$ have been attained. The machine was adjusted at low energy so as to obtain the maximum beam cross section (ν_x = 3.72, ν_z = 1.72), while, at high energy, the luminosity obtained was produced only with flat beams.

High energy physics and synchrotron radiation

The M3N experiment installed in the experimental section of DCI is particularly suitable for detecting meson neutral modes. It consists of a number of wire proportional chambers and optical spark chambers separated by layers of scintillators and lead radiators (half a radiation wavelength thick) and an iron absorber making it possible to detect muons over a fraction of the solid angle.

After a highly selective detector triggering device had been regulated, an energy sweep between 3070 and 3130 MeV has started quite recently, with the energy calibration of DCI known a priori only to within 1 %. The sweep pitch was 4 MeV with a duration of ten minutes per energy. At 3106 MeV (the J/psi particle), a signal twice as strong as the background was measured. Visual observation of the spark chamber tracks immediately confirmed that every other exposure showed a multi-track event which differed considerably from the background noise photographs, in which there were hardly any sparks. A first excitation curve, obtained within less than two hours, gave a width of 3.3 MeV (FWHM), which agreed with the energy spread of the two beams in DCI.

The first LURE-DCI line was opened in May 1976. It uses synchrotron radiation with an energy above 3.5 keV and comprises five windows so that five experiments may be conducted simultaneously. Beams with an initial intensity of 90 mA were stored at an energy of 1.56 GeV for the first experiments. The total radiated power was then 15 kW and the life of the beams was four hours.

Two windows are fitted with a curved crystal monochromator focusing the monochromatized beam at 1

The superconducting post accelerator section installed in a beam line at the Heidelberg tandem. The superconducting section was built at Karlsruhe and has had a successful first series of tests.

(Photo Karlsruhe)

or 2 m and providing a choice of wavelength. A small-angle X-ray diffusion experiment is now being set up behind one of these monochromators. The second is followed by an X-ray diffraction apparatus intended for biological structure investigations. A first exposure obtained on a crystal of phycocyanine shows that, with a three times shorter exposure, the resolution is greater than that obtained behind a rotating anti-cathode tube.

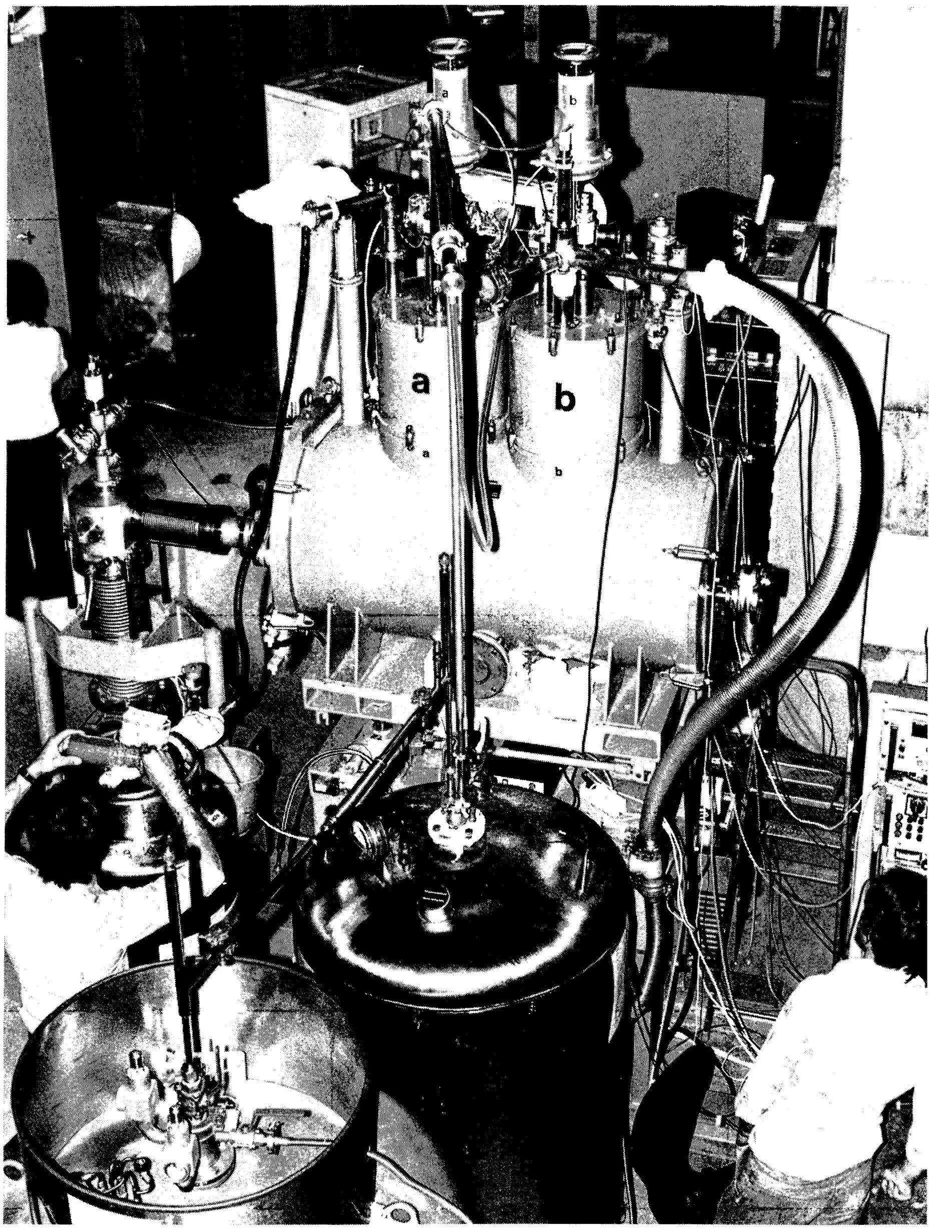
Two other windows are fitted with channel-cut monochromators with cut germanium or silicon crystals, isolating a pass band of about 1.5 eV into a quasi-parallel beam about 4 cm wide and a few millimetres high. The energy can be continuously swept, making it possible to perform experiments not feasible with ordinary photon sources. One of these monochromators is used for fine absorption structure measurements (EXAFS) in the field of solid state physics and biology. Initial measurements have already been made this July on the K threshold of chromium and titanium in TiO_2. The other monochromator is at present being used to measure X-ray fluorescence in atomic physics. The fifth channel uses white radiation for topographical experiments. Tests on the transmitted images obtained show that it is now possible to produce images of a quality comparable to those obtained with the usual topographical apparatus in times which are 100 to 1000 times shorter; the present beam dimensions and stability already give good resolution.

After a two-month shutdown during which the installed power at the laboratory will be increased to 14 MVA, the collection of data for the M3N experiment will begin again next October, together with further design studies on the beams and the use of the synchrotron radiation beams by LURE. It is intended to commission the second ring of DCI by the end of 1976.

KARLSRUHE
Post accelerator tested at Heidelberg

Following on the news about superconducting linear accelerator systems from Argonne is related news from Karlsruhe. On 26 June, tests were started at the 13 MV tandem accelerator of the Max Planck Institut für Kernphysik at Heidelberg on a superconducting heavy ion post accelerator section built at IEKP Karlsruhe. The short accelerator line consists of two helix resonators made from niobium together with the necessary cryogenic and r.f. control systems.

In the first run an accelerating voltage of 0.5 MV was achieved with both resonators phase synchronised



in c.w. operation. The measured energy gain for sulphur 14 ions at 120 MeV was 7.12 MeV. The design field levels of 2.3 MV/m axial field and 1 MV average field per resonator length are conservative values, for which good reliability and reproducibility over long periods of time are expected with present technology. Further tests confirmed that the usable velocity range of the short helix resonators was for particles with a ß (ratio of particle velocity to the velocity of light) between 0.06 and 0.1. Calculation shows that identical resonators of this type are suitable for any stage of a 10 MV post accelerator for ions within the range from carbon to bromine.

The corresponding r.f. power loss was less than 1 W per resonator and this power was supplied, together with the r.f. power required for frequency control, by a 100 W transistor amplifier. The total cooling power required, including cryostat and transfer losses, was 9 W at 4.2 K. It was provided by shipping about 1000 l of liquid helium per week from Karlsruhe to Heidelberg.

Considerable reductions in construction and operation costs with respect to earlier superconducting devices are achieved by three measures: (1) argon arc welding of niobium instead of electron beam welding; (2) forced flow cooling with 4.2 K helium instead of 1.8 K bath cooling (this cooling concept, first used for r.f. superconductivity, reaches a high cooling capacity for the helix and cuts the cost of the cooling system to a half); (3) an improved r.f. system with modular construction adapted to computer control.

Operation of the system with various ions during this autumn should yield information on reliability and ease of operation, on possible deterioration of the superconducting surfaces after exposure to various types of ions, and on long term averages of power and helium consumption. These points are of particular importance because they will permit a direct comparison with the normal spiral resonators already in operation at Heidelberg.

BERKELEY
ESCAR progress

The Lawrence Berkeley Laboratory is constructing a small proton synchrotron/storage ring (a few GeV peak energy) to check out the use of superconducting magnets in a true accelerator environment. It is a 'research and development' project, known as ESCAR (Experimental Super-Conducting Accelerator Ring), which will feed information into the large scale projects which incorporate superconducting magnets.

The present programme aims to have two quadrants of the ring ready for tests in the Summer of 1977. The quadrants will be virtually complete with magnets, refrigeration, vacuum and controls. These tests could dictate further changes in completing the ring. It is above all in providing experience of a total system that ESCAR hopes to make its contribution rather than in the perfection of the superconducting magnets themselves. In addition, the completed ring may find application in investigating accelerator techniques such as proton cooling.

The first production dipole is being tested and three of them have been wound. The last of their predecessor model magnets (1 m long) was powered in February of this year achieving 3.7 T central field on a 6 s pulse cycle. The field quality was very good and the heat losses as expected. The production magnets have extra turns to reach a peak field of 4.6 T. Winding of the first quadrupoles will start soon.

DESY
PETRA experimental programme discussions

During the last week of August, the international PETRA Research Committee discussed first proposals for PETRA experiments and the DESY Scientific Council, now extended to include scientists from other countries — J.C. Kendrew (EMBL), J. Manelli (Pisa), J. Perez-y-Jorba (Paris), E. Picasso (CERN), B. Richter (SLAC), and G.H. Stafford (Rutherford) — joined physicists from several countries to listen to the open presentations. PETRA is the large electron-positron storage ring being built on the DESY site in Hamburg.

Experimental setups have become larger and new techniques have been developed as small cross sections make it necessary to accept large solid angles. All experimental groups want to be ready with new detectors mid-1979 when electrons and positrons are expected to collide in PETRA. The international collaborations are therefore pressing for early decisions on the first generation of experiments.

At its first session in June, the PETRA Research Committee (PRC) fixed 31 July as the deadline for a first round of proposals which would be discussed during a study week from 30 August to 3 September. The importance which high energy physicists are giving to the coming PETRA facilities has already been demonstrated by the number of proposals reaching the PRC. Seven big detectors were presented during the first two days of the study week and, according to the speakers, each of them could be ready for the PETRA start up.

Surprisingly most of these detectors are based on a solenoid producing a magnetic field parallel to the beam

Professor Helwig Schopper, Director of DESY, addresses the meeting held at the end of August when the proposals for experiments at the PETRA electron-positron storage ring being built at DESY were discussed.

(Photo DESY)

line near the interaction point. The talks however showed that this is not due to lack of imagination but a result of careful thinking about all types of spectrometers. The solenoids varied from large radii, to give good time of flight resolution, and small ones with the possibility of good lepton identification. Both superconducting and normal coils for the magnets have been proposed. The detectors cover the full spectrum from well established to very new technologies (such as shower counters, high pressure jet, drift chambers, lead glass blocks, liquid argon calorimeters,...) and consequently a wide range of physics will be covered.

This rush of proposals and the fact that up to four interaction regions are to be available at the beginning of PETRA operation (two more will come into use at a later date) make it impossible to fulfill all wishes of the experimenters. One aim of the study week was therefore to bring together different collaborations with similar interests with the hope that they might join forces. Some success along these lines was reported to the PRC. Another possibility, to be discussed, is to place two detectors at the same experimental area so that the third possibility — to refuse one or more proposals — might be avoided.

Another meeting will take place on 28 September with an open session to present further proposals which arrived after the July deadline. The PRC is planning to take decisions at its meeting on 19, 20 October.

In the last three days of the study week, physicists took the opportunity to discuss technical details with DESY staff members and financial and co-operation problems with the DESY Directorate. The international character of PETRA experiments is demonstrated by the fact that contributions to proposals came from Great Britain, France, Italy, Netherlands, Israel, Japan and, last but not least, the United States.

DESY also calls in international experience on the storage rings themselves. A PETRA Machine Advisory Committee has been created under the chairmanship of David Gray of the Rutherford Laboratory. Its first meeting on 16, 17 August started with a status report of the PETRA group. Then the committee split up into six groups and discussed, together with members of DESY, special topics such as beam optics, magnets and tunnel installations, r.f. system, parasitic mode losses, vacuum system, injection and control system. The results of these discussions were presented in a plenary session and the meeting ended with summaries by David Gray and Gus Voss, leader of the PETRA project, both pointing out that these discussions were very important for the PETRA team which will make full use of the new input in the coming weeks.

Confidence in the starting date for experiments in 1979 is based on the fact that the PETRA construction is thus far on schedule. Design, ordering and delivery of all components are on time. The ring tunnel is three quarters complete; two experimental halls and the north r.f. hall are already roofed and three more experimental halls are under construction.

TRIUMF
Now ready for higher intensities

The TRIUMF Laboratory received authorization from the Canadian government in August to take their cyclotron intensity to 100 μA. A licence was necessary because of radiation regulations which had previously required the intensity to be held to 1 μA. No great problems are anticipated in sustaining an average current of 10 μA; brief tests had earlier realized 5 μA extracted from the machine and all the systems already look capable of handling much higher currents. In fact, there is confidence that in 1977, when the necessary money for extra shielding etc. is released, the design figure of 100 μA will be achieved.

During the past year the Laboratory has established itself on the nuclear physics scene in a very impressive way. The accelerator has been performing reliably and is providing several unique research possibilities in its energy range (polarized beams, continuously variable energy of the extracted beams over several hundred MeV, independent energy and intensity operation of two experimental areas). The physics programme has got into its stride using proton, polarized proton, pion and muon beams. For a four-University collaboration to have mastered the building and operation of such a complex machine — the first large cyclotron to use negative hydrogen ion acceleration — and to have mounted a lively experimental programme so quickly is a considerable achievement.

The accelerator settled down to reliable (85 %) operation in the Spring of this year with a schedule in two week cycles of 12 days on and 2 days maintenance. During the Winter, there had been trouble due to some mysterious local heating of the r.f. resonators which was powerful enough to melt the aluminium resonators. The effect set in above a threshold voltage of about 75 kV and possibly originated in trapped charge oscillating around equipotentials. The problem was eliminated by running below the threshold voltage and, during a June shutdown, some resonators were changed for copper versions of different shape. When operation began again there was no sign of the effect even at high voltages.

Beams are provided simultaneously to two experimental areas with the ratio of their intensities selected typically to give 10 nA of protons into the Proton Area for nucleon-nucleon experiments and 1 μA of protons into the Meson Area to produce pion and muon beams. The intensity ratios can be adjusted as high as 5000 to 1 (using a carbon wire of 25 μm diameter to give the low intensity beam) which is much higher than the design aim of 2000 to 1. Polarized beams of energy between 180 and 515 MeV are available reliably over long operating periods with polarization of the extracted beam around 70 %. The intensity of the polarized beam is 30 nA and 100 nA is probably attainable.

When higher intensity beams are available, a second meson target will be brought into operation and the beam dump (probably a water cooled lead-bismuth target) at the end of the beam line will be used as a source of thermal neutrons. The additional facilities will include four neutron lines, a high flux muon channel, and a channel for producing radio-isotopes (initially for a series of experiments rather than production of radiopharmaceuticals for use in hospitals).

We have already reported on some of the features of the experimental programme including the use of two large sodium iodide crystals by a British Columbia/Montreal team for studying interactions producing gammas from neutral pion decays. This spectrometer has already improved on previous measurements by almost a factor of ten.

Muon beams are being used by a Tokyo/British Columbia team to study spin rotation in solids. They have observed spin precession of positive muons in an iron crystal down to a temperature of 23 K, much lower than has been seen before. It gives new information on the detailed behaviour of the local magnetic fields within the lattice of the ferromagnetic. Other measurements have been carried out on gadolinium and cobalt. A British Columbia/Berkeley team are also using the muon beam for a programme of muonium chemistry. The first tests on a spectrometer system involving gas jets bombarded by the 500 MeV proton beam for nuclear spectroscopy experiments have been successful. Proton induced fission of uranium nuclei and spallation of iodine nuclei have been used to produce neutron rich and neutron deficient isotopes for study.

An elegant experiment on polarized proton scattering has confirmed predictions that the spin and orbit parameters of the target nucleon will affect the quasi-free knock-out cross section. An Alberta team used a 200 MeV polarized proton beam incident on oxygen nuclei and, by separating events according to the binding energy of a knocked-out proton, effectively selected the target protons with a particular orbital angular momentum. These target protons could then have their spins parallel or antiparallel to the orbital angular momentum and the scattering cross section could be expected to show asymmetries of opposite sign depending on whether the scattering took place from a nucleon with spin parallel or antiparallel. Such asymmetries were clearly seen.

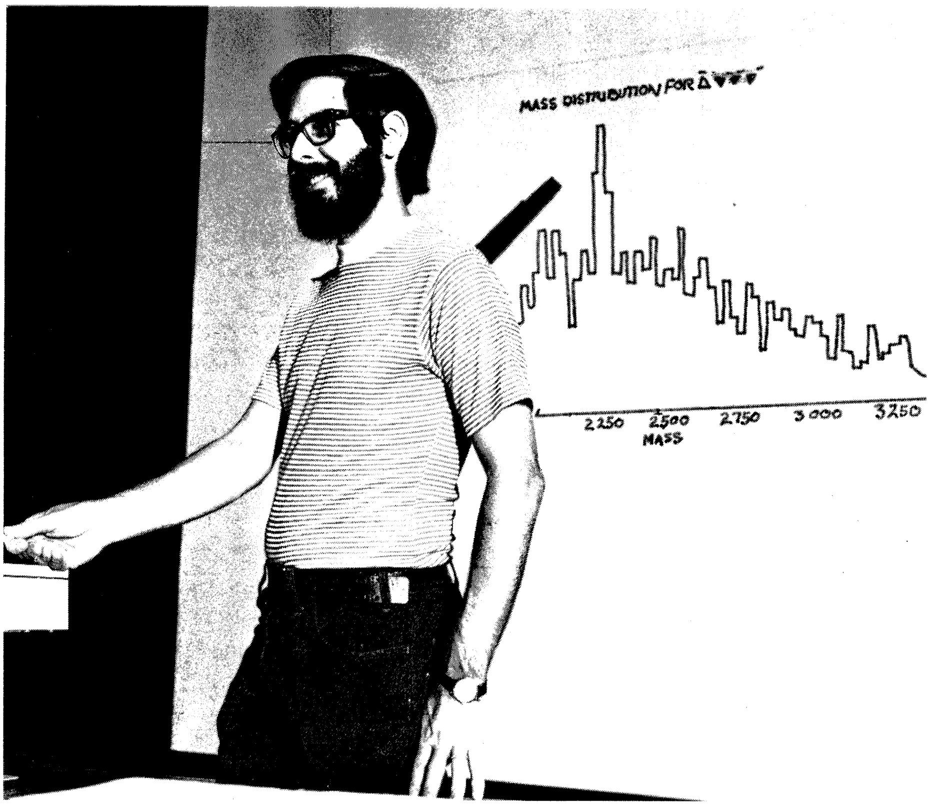
A very thorough study of the nucleon-nucleon interaction at intermediate energies is being carried out by the BASQUE collaboration (Bedford / AERE Harwell / Surrey / Queen Mary/Universities of B.C. and Victoria). Over a range of energies from 200 to 500 MeV they are measuring all the interaction parameters. Proton-proton data using the polarized proton beam is now being analysed at the Rutherford Laboratory and data collection on polarized neutron-proton scattering is now under way.

Some experiments where intensity is at a premium are at the TRIUMF medical facility where negative pion beams are to be used for radiotherapy. Known as the Batho Biomedical Facility (in memory of Harold Batho, the physicist from the British Columbia Cancer Institute who initiated the development of the facility before he died in 1974), it is supported by the British Columbia Cancer Foundation, the Health Resources Fund and the National Cancer Institute of Canada. Tests of the pion beam line began in June 1975 and in March of this year the first irradiation experiments (using a technique of suspending cells in gel which could then be sliced to examine cell survival at different depths) were carried out.

The beam line is kept very short (7.2 m) to minimise pion decay. It consists of a series of nine magnets computer controlled to transmit pions of up to 200 MeV/c (a range of 29 cm in water) with a momentum resolution of 1.5 %. The pions can be delivered over an area variable from 3 × 3 cm² to 10 × 10 cm² or to 4 × 15 cm². The excellent quality of the beam has already been exploited by a British Columbia team in a positive pion elastic scattering experiment on carbon at 29 MeV.

The higher intensities which are becoming available with the increase of the cyclotron current to 10 μA will allow animal irradiations to begin. Treatment of patients, from a cancer hospital about 10 km away which serves a population of some 2 million people, is likely to begin within two years when the cyclotron current is at its design value of 100 μA and after considerable experience with the animal irradiations.

The Biomedical Facility is being given considerable priority in the experimental programme at TRIUMF. It is intended to establish one of the finest such facilities in the world.



Irwin Gaines presenting the results of the Columbia/Fermilab/Hawaii/Illinois experiment at the Fermilab which has strong evidence for the existence of a charmed baryon at a mass of 2.26 GeV.

(Photo Fermilab)

FERMILAB
And now a charmed baryon

Month by month we seem to be chalking up fresh pieces of evidence supporting the hypothesis that a fourth type of quark, the charm quark, exists. The latest pro-charm news comes from a Columbia/Fermilab/Hawaii/Illinois experiment at Fermilab which seems to have identified a charmed baryon.

With our three familiar quarks we can build our familiar particles (protons, neutrons, pions, kaons, etc...). If there is another quark then we should have many more particles by building them exactly as we have done before but this time substituting the charm quark for one of the others.

The newly discovered J/ψ, of mass 3.1 GeV, and its surrounding family of particles, fit the hypothesis of a

Charming people on the West coast had long discussions on the new particles during the 1976 SLAC Summer Institute on Particle Physics. Left to right, Wonyong Lee (Columbia), Sheldon Glashow (Harvard) and Gerson Goldhaber (Berkeley) in consultation during the meeting. Theoretician Glashow was kept busy checking his predictions each time experimental evidence for new charmed particle states was presented.

(Photo J. Faust)

charm quark - charm antiquark combination in various energy states. This family has 'hidden charm' since the quark-antiquark combination cancels out the charm and peculiar properties related to its presence are not apparent. Earlier this year examples were found of charmed mesons (two quark combinations like the pion where only one quark has charm) — data from the SPEAR storage ring at Stanford pinned down a neutral particle of mass 1.86 GeV and, later, two charged particles of mass 2.02 and 2.12 GeV. These particles violate a rule, which works for our familiar particles, in exactly the way that charmed particles are expected to do. (They also decayed to give strange particles which is another characteristic expected of charmed particles.)

The rule in question says that when a hadron (a strongly interacting particle) decays, its product hadrons will have a change of strangeness quantum number equal to the change in total charge ($\Delta S = \Delta Q$ rule). The charm picture suggests that when charmed hadrons decay then a $\Delta S = -\Delta Q$ rule would apply.

The data from the Fermilab experiment gives the first detailed information on a possible charmed baryon (a three quark combination like the proton where one of the quarks has charm). The new particle violates the rule just as the charmed mesons do.

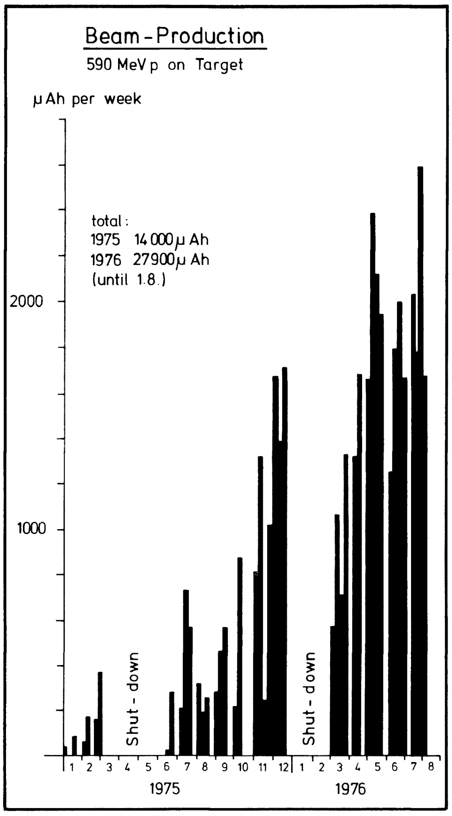
The Fermilab team hit a beryllium target with a beam of photons filtered through 30 m of liquid deuterium. From an accumulation of fifteen million events, their detection system saw over fifty examples of an event in which five particles emerged. Three pions (one positive, two negative) came from the target and the remaining two (antiproton, positive pion) came from the decay of an antilambda particle which had travelled about a metre before breaking up.

In this interaction a strange particle, the antilambda, is produced as expected from a charmed particle decay and also the production of the antilambda means a change in strangeness of + 1, while the total charge changes by — 1 (i.e. $\Delta S = -\Delta Q$). These two signatures of a charmed particle look convincing. The production of an antilambda which is a three quark combination implies that the charmed particle was a baryon. A single event spotted over a year ago in a picture from the Brookhaven 7 foot bubble chamber also had charmed baryon characteristics and was in the same mass region. The Fermilab result has the data of fifty events behind it.

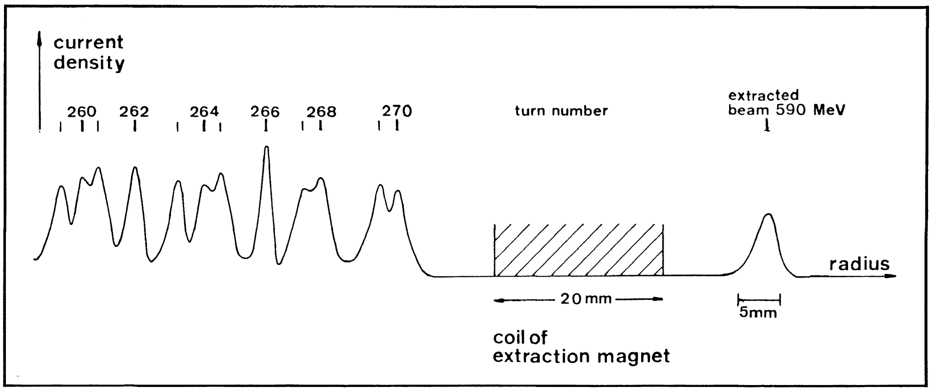
The experimental team was B. Knapp, Wonyong Lee — experiment spokesperson, P.S.P. Leung, S.D. Smith and A. Wijangco (Columbia), M.E. Binkley, I. Gaines, M.F. Gormley and J. Peoples (Fermilab), J.P. Knauer, D.E. Yount (Hawaii), J. Bronstein, R. Coleman, G.E. Gladding, M.C. Goodman, T. O'Halloran and A. Wattenberg (Illinois).

SIN
Precision experiments

The higher particle fluxes obtainable at the new 'meson factories' were expected to yield more precise measurements of some particle properties than was possible before. Some of the experiments on the floor at the SIN 590 MeV cyclotron are confirming this — providing preliminary data comparable with, or better than, achieved so far. An example is the experiment of the ETHZ/Mainz/Zurich group (M. Camani, F.N. Gygax, E. Klempt, P.D. Patterson, W. Rëgg, A. Schenck and R. Schulze), to determine the magnetic moment of the positive muon by means of a stroboscopic method to an accuracy better than one part per million.



A graphical presentation of the improvement in performance at the SIN cyclotrons during the past two years. The histogram records the beam production rate, with 590 MeV protons onto a target, measured in μAh each week.



Representation of the last few turns in the ring cyclotron showing the current recorded on a secondary emission probe located in front of the extraction magnet. Inducing a small coherent amplitude at injection causes the last two turns to cluster together and increases the separation at the extraction septum (giving a dip in the current density). This technique has given extraction efficiencies over 99 % with 30 μA currents.

A preliminary result, after only a few days running in July with the superconducting muon channel and a liquid bromine target, is μ_μ/μ_p = 3.1833545 (112) which is an accuracy of 3.5 ppm. The quoted uncertainty includes the statistical uncertainty (1.8 ppm), systematic uncertainties, the precision in determining the proton resonance frequency and an uncertainty for chemical shift effects (0.7 ppm). The value itself contains a correction of —0.7 ppm for chemical effects.

The result agrees with, and is of similar precision to, the best direct measurement from Berkeley (2.6 ppm) but is in significant disagreement with the most precise value determined indirectly by the Hugues group (Yale 1975) from the muonium hyperfine splitting frequency, involving QED corrections. The group at SIN will now continue to improve their measurements and increase their precision to (hopefully) below the 1 ppm level during the autumn.

Another precision experiment is the measurement of the muon momentum in stopped pion decay by the SIN group (M. Daum, G.H. Eaton, R. Frosch, J. McCulloch, R.C. Minehart, E. Steiner). Positive pions from the πE1 high intensity channel are stopped in a small scintillator inside a magnet which is used to analyse the momentum of the decay muons (detected in a surface barrier detector). A preliminary value of the muon momentum is 29.7889 ± 0.0021 MeV/c where the statistical uncertainty is 0.0017 MeV/c and the total systematic uncertainty is 0.0013 MeV/c. This is nearly an order of magnitude more precise than previously available.

Assuming the positive pion mass is equal to the negative pion mass, as determined from pionic X rays, the result gives a value of the squared muon neutrino mass of (—0.10 ± 0.19) MeV^2/c^4. Alternatively, assuming from cosmological arguments, that all neutral lepton masses are small (less than about 10 eV/c^2), the positive pion mass can be derived as 139.5673 ± 0.0028 MeV/c^2, which is in good agreement with, and of similar precision to, the best negative pion mass measurements from pionic atom studies.

A further experiment achieving high precision is by the ETHZ/Fribourg bent crystal spectrometer group (B. Aas, W. Beer, I. Beltrami, J.C.L. Dousse, P. Ebersold, R. Eichler, J. Kern, T. von Ledebur, H.J. Leisi, W. Sapp and W. Schwitz), studying muonic X rays with internal targets mounted in the superconducting muon channel. The group have carried out multiple measurements of the $^3d_{5/2}$ — $^2p_{3/2}$ transitions in ^{28}Si, ^{24}Mg and ^{31}P. Measurements were continued after the shutdown to improve the statistical precision. (The group also measures the 4f-3d transitions in order to reduce certain systematic uncertainties.) An appreciable fraction of the data for silicon has now been analyzed, and the experimental group have obtained the value 16.18339 ± 0.00050 pm.

Accelerator operation

After the shutdown until 1 March, the accelerator has been operated on a new schedule — four weeks of high energy operation followed by one or two weeks of low (variable) energy beam production. There has been a substantial increase in efficiency and in the number of μAh delivered to the pion production targets each week. Extracted proton beam intensities are mainly in the range 20-25 μA with several up to 30-40 μA. The emphasis has been more on stable beam than on high intensities.

A proton beam for pion production was provided for 1500 hours up to 1 August out of 1765 scheduled hours. In this 1500 hours an integrated current of 28 000 μAh was delivered to the external targets. Also, the injector cyclotron provided low energy beam for 420 hours (from 497 scheduled) for the nuclear research programme, mainly with alpha particles, polarized and unpolarized protons, and deuterons. The regular weekly isotope production programme (of ^{123}I by the Swiss Federal Reactor Institute), using 3-4 hours of 72 MeV protons from the injector, has con-

People and things

tinued with increasing efficiency and over 1000 mCi/per week are produced.

Up to 1 August, the failure rate of about 15 % of scheduled beam time has been lower by almost a factor of two compared with the average for 1975. The main problems were repairs of the extraction system of the injector (insulator and cooling) and drop-outs of the ring cavity voltages.

A significant improvement can be seen in the ratio of integrated beam current brought to the pion production target compared with the integrated beam loss at the most sensitive location — the septum of the injector. Presently, this ratio is about 4.5-5, which is a factor of 2 better than in 1975. The improvements and modifications to the injector r.f. and centre region during the shutdown, plus the improved interlock system and steady improvements of beam transmission are paying off.

On the beam development side efforts have concentrated on improving beam quality and reducing losses, rather than on increasing intensity. In the injector cyclotron vertical collimators were installed in the centre, which boosted the extraction efficiency from 75 % to 85 % but restricted the extracted currents to 50-60 μA. The average intensity for experiments was thus increased while keeping the radiation level as before. There will be no attempt to raise the record of 62 μA on target until spare elements for all extraction devices in the injector are available.

The improved beam quality from the injector was also appreciated by the ring cyclotron. Even at the extraction radius of the ring, the turns are almost separated, and by using some small coherent radial oscillations in the injection process, the current density at the extraction septum can be kept very low. Extraction efficiencies of over 99 % have been observed with 97-98 % as routine values.

Changes in CERN Experiments Committees

The Experiments Committees at CERN review the research programmes at the accelerators and make recommendations on proposals for experiments to the Research Board (which is chaired by Research Director General, Leon Van Hove). The Committees are always chaired by physicists from outside CERN. In July two of them, the Electronic Experiments Committee and the Track Chamber Committee, which covered the programme at the 28 GeV proton synchrotron were amalgamated to form the Proton Synchrotron Committee under the Chairmanship of Alan Astbury from Rutherford. In September the Chairmanship of two others changed hands — J. Perez-y-Jorba from Orsay succeeded Helwig Schopper from DESY in the Intersecting Storage Rings Committee and Ian Butterworth from Imperial College London succeeded Eric Lohrmann from DESY in the Super Proton Synchrotron Committee. One Committee emerges unscathed — the Synchro-cyclotron Committee under the Chairmanship of V. Soergel from Heidelberg.

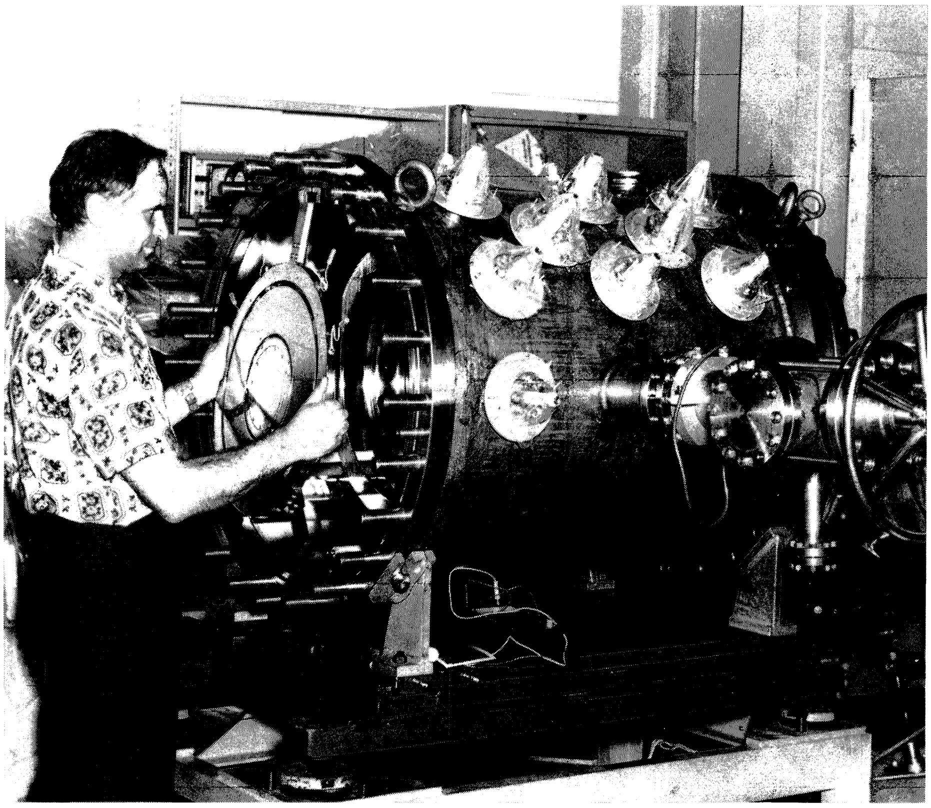
What value science education?

The Careers Organisation Bulletin in the UK recently carried an advertisement for a 'man to work on nuclear fissionable isotope molecular reactive counters and three phase cyclotronic uranium photosynthesisers. No experience necessary'.

On 8 September the CERN Scientific Policy Committee toured the Intersecting Storage Rings. The Chairman, Professor Paul (back to camera), said a few words of tribute to Werner Heisenberg (1901–1976) in the Control Room where a commemorative plaque has recently been installed. Professor Heisenberg inaugurated the ISR on 16 October 1971.

CERN 59.9.76

G.A. Korolev from the Leningrad Nuclear Physics Institute at Gatchina assembling the ionization chamber which has arrived at CERN from Leningrad for a high precision study of elastic scattering by a CERN/Clermont-Ferrand/Leningrad/Lyon/Uppsala collaboration. The novel type of detector will be used at the higher energies available at the 400 GeV SPS after performing well at the 76 GeV accelerator in Serpukhov. About eight visitors from the Soviet Union will participate in the experiment.



CERN 6.8.75

On people

Marcel Anthonioz, Deputy Mayor of Divonne and Vice-President of the French National Assembly died on 31 August. He had done much to promote CERN's interests in the surrounding region of France. He became involved in CERN affairs particularly from the time of the extension of the site for the construction of the Intersecting Storage Rings and played a major role in the negotiations concerning the installation of the 400 GeV project mainly in France.

Among the recipients of the 1976 University of Chicago awards for Distinguished Performance are Tat Khoe, Everette Parker and Lazarus Ratner from the Argonne Accelerator Research Facilities Division for their role in achieving high energy polarized proton beams from the ZGS. Their's was a joint award with Ron Martin, the Director of the Division who was also cited for 'his many outstanding contributions to the development of the ZGS'.

Ernest Courant, the well known accelerator physicist from Brookhaven who was a co-discoverer of the alternating gradient focusing principle used in synchrotrons, has been elected to the USA National Academy of Sciences. The Academy is dedicated to the furtherance of science and its use for general welfare. Election to its ranks is one of the highest honours in USA science.

Argonne Universities Association has selected Malcolm Macfarlane, from the Physics Division at Argonne, and Alfred Schild, from the University of Texas as 'Distinguished Appointees' for 1976. Dr. Macfarlane is spending a year doing nuclear physics experiments at the new 200 MeV machine at Indiana University and Dr. Schild is spending a year in the Argonne High Energy Physics Division working on relativity theory.

Moved across the Atlantic from Rutherford is accelerator physicist Martin Donald, who has joined the PEP storage ring project in California. Multi-disciplinary Bob Sheldon, ex-Rutherford/Fermilab/CERN has joined the TFTR (Tokomak Fusion Test Reactor) project led by Paul Reardon at Princeton.

Dennis Theriot became head of the Neutrino Department at Fermilab on 1 September in succession to Dick Lundy. He arrived at Fermilab from LAMPF in 1969 and since then he has worked in the Radiation Physics Group and was in charge of the Neutrino Mechanical Support Group.

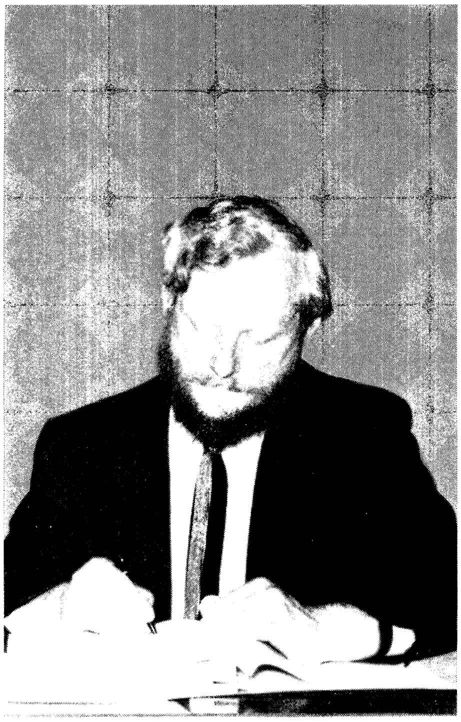
'Adventures' covers new particles

Anyone who would like to relive that wonderful time at the end of 1974, when the J/psi particle was found and the whole world of high energy physics burst into flame, should get their hands on the latest issue (volume 5) of 'Adventures in Experimental Physics'. Sam Ting, Gerson Goldhaber and Burt Richter give their personal accounts of the discovery. The same issue also carries Bogdan Maglich's story of the discovery of the first neutral vector meson. 'Adventures' continues to be a very readable and very human approach to the fascinations of physics.

We all do research in a yellow submarine

From 6-19 September a Workshop was held at Honolulu, Hawaii under

John Mulvey, seen here in action at the June Council Meeting, returned in September to his post as Professor at Oxford University after several years in senior positions at CERN. He had particular responsibilities for the experimental programmes and computer facilities and brought to them an enormous appetite for work and a thoroughness of approach which were a very valuable help in the recent years of retrenchment.



CERN 323.6.76

the title 'DUMAND — Deep Underwater Muon and Neutrino Detection'. It considered the physics interest and technical feasibility of particle detection systems some kilometres below sea level. At this depth cosmic ray events would be almost entirely filtered out leaving the penetrating neutrinos and muons. As an example, M. Blood and collaborators at Fermilab have considered looking at the intense neutrino bursts (perhaps 10^{57} neutrinos emitted in milliseconds) from the collapse and vibrations of neutron stars. Antineutrinos from such events could interact with protons in seawater and the light from the resulting positrons could be spotted by photomultipliers. The bursts could give 10^5 antineutrinos at the earth surface and to spot just ten of them would probably require thousands of detector modules each enclosing 20 m^3 of water.

Network extensions

The computer network centred on the Daresbury Laboratory's large IBM 370/165 has, for some time, included links (using Post Office telephone lines) to work stations at Universities, at CERN and at the Institute of Oceanographic Studies at Bidston. A special link using packet switching technology has recently been commissioned to the Rutherford Laboratory which itself has a similar network centred on an IBM 360/95. A CAMAC-based switching node computer acts as a gateway enabling work stations to access either of the IBM machines. The ultimate aim is to enable any work station to reach any destination on the networks.

From a noticeboard in Berkeley

THE SIX PROJECT STAGES
Wild enthusiasm
Total confusion
Disillusionment
Search for the guilty
Punishment of the innocent
Promotion of the non-participants

Meetings

A 'Workshop on Future ISR Physics' has been organized at CERN for 4-15 October 1976 to review the physics programme which can be foreseen for the ISR from about 1980 after the present generation of experiments is concluded. A second session will be held in 1977. B.G. Pope is Secretary of the Organizing Committee.

The 'Ninth Annual Synchrotron Radiation Users Group Meeting' will be held at the Physical Sciences Laboratory Wisconsin on 25-27 October 1976. It will be immediately followed (28-30 October) by the 'Stanford Synchrotron Radiation Project Users Group Meeting' which will be held at Stanford University.

The '2nd International Conference on the Nucleon-Nucleon Interaction' will be held at the University of British Columbia, Vancouver, Canada from 27-30 June 1977. Nuclear and particle physics aspects will be included. Further information from D.F. Measday, Physics Department, University of British Columbia, Vancouver, B.C. Canada V6T 1W5.

The '7th International Conference on High Energy and Nuclear Structure' will be held at Zurich from 29 August–2 September 1977. Further information from Mrs E. Huber, SIN, CH-5234 Villigen, Switzerland.

ISABELLE magnet high

The MkII superconducting pulsed dipole built as a model for the magnets of the ISABELLE 200 GeV proton storage ring project at Brookhaven has climbed to a peak field of 4.9 T. The magnet trained to this level when the temperature was taken down to 4.1 K. The magnet is using forced cooling with high pressure gaseous helium.

SPS slow ejection

First tests of the slow ejection system at the CERN 400 GeV proton synchrotron took place on 2 September. Spills of about 650 ms were achieved and though precise measurements on efficiency were not possible it already, without optimization, looks good with acceptable losses. With the r.f. off the ejection system performs exactly as predicted.

CERN ACADEMIC TRAINING PROGRAMME
(1976-1977)

This Programme of lecture series is organized each year by the Academic Training Committee.

Ist Term:

September 16, 17, 21 and 23	The quark bag model of hadrons, by J. Kuti (Central Research Institute for Physics, Budapest)
October 21 and 22	Relationship between the structure of materials and their properties, by M.B. Waldron (University of Surrey)
October 28 and 29	Reinforcement of brittle matrices (Composite materials), by A. Kelly (University of Surrey)
November 2, 3, 4 and 5	Statistical analysis and representation of counted data, by J.H. Friedman (University of Stanford & CERN)
November 16, 17, 18 and 19	Comparison of deep inelastic scattering of μ, e and ν's, by E. Gabathuler (Rutherford Laboratory & CERN)
November 30, December 1, 2, and 3	Structure of the hadrons, by J. Weyers (University of Louvain)
December 7, 8, and 9	New particle physics in a gauge theory for strong interactions, by R. Barbieri (University of Pisa & CERN)

The lectures are given at 11 h. 00.

The programmes for the 2nd and 3rd Terms will be published in the December and March issues of the CERN COURIER.

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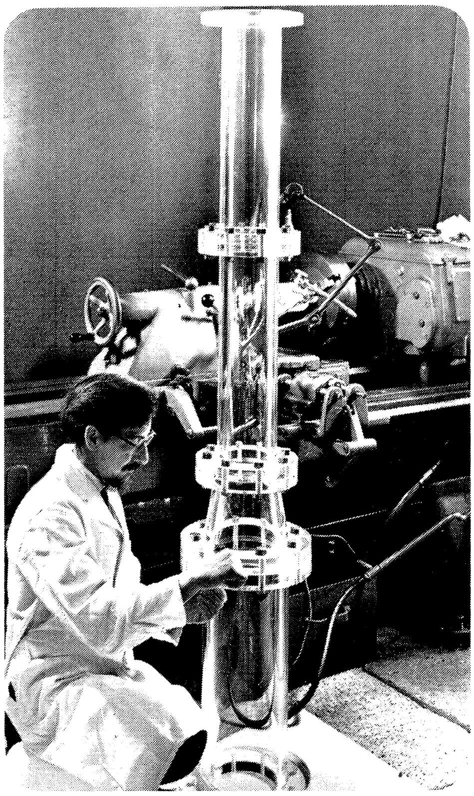

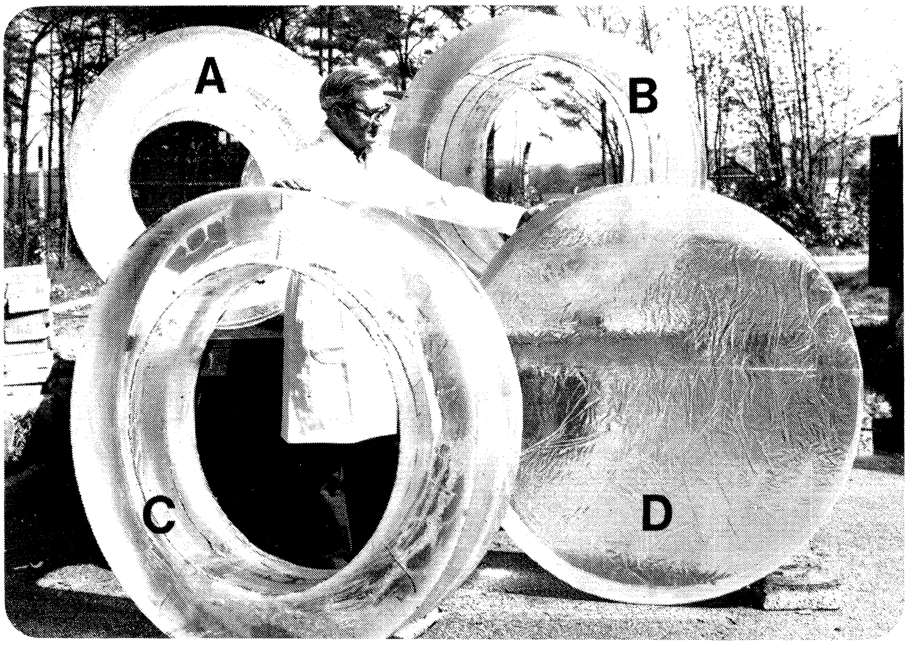

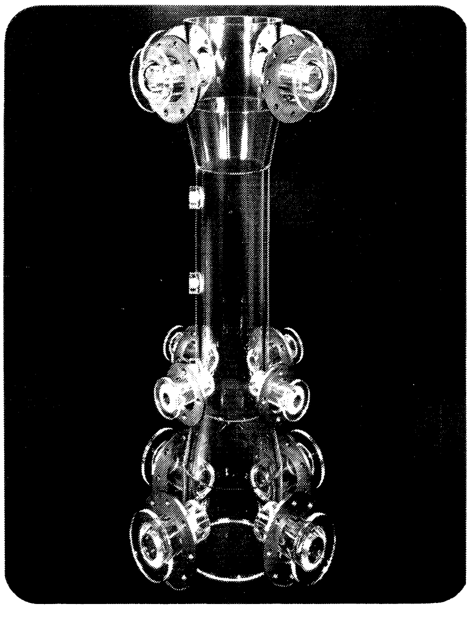

Above: Massive castings prior to machining. A – 914mm OD X 508mm ID X 762mm thick. Weight 453 kg. B – 1016mm OD X 762mm ID X 660mm thick. Weight 317 kg. C – 1270mm OD X 914mm ID X 381mm thick. Weight 317 kg. D – 1371mm dia. X 508mm thick. Weight 1134 kg.

Top left: Seamless flanged pipe assembly 304mm OD X 254mm ID with tapering section leading to 203mm OD X 152mm ID. For use as visibility section in pipe line. Working pressure 800 kg/sq.m.

Left: 2133mm high manifold manufactured from 355mm dia. X 25mm wall seamless tube with 152mm OD X 25mm thick exit ports. Tolerance ± .50mm.

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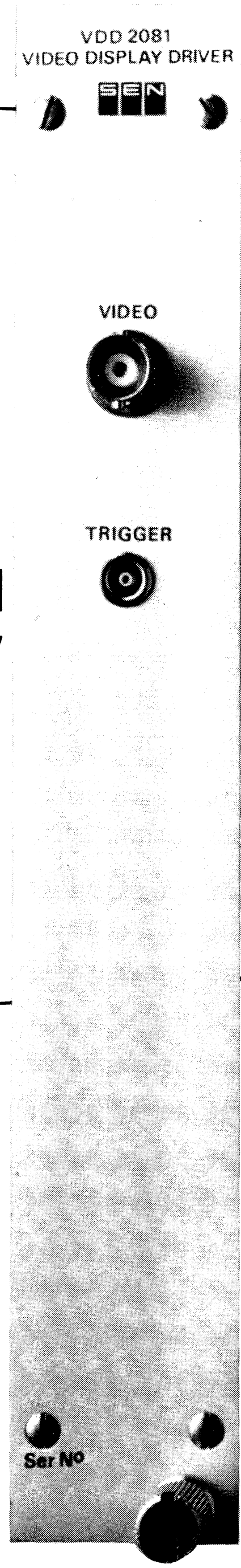

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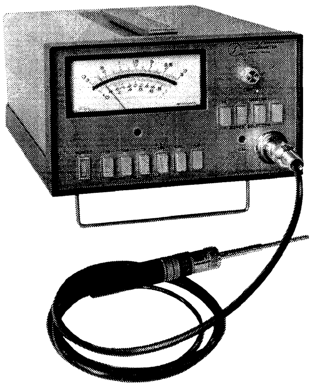

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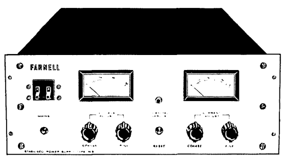

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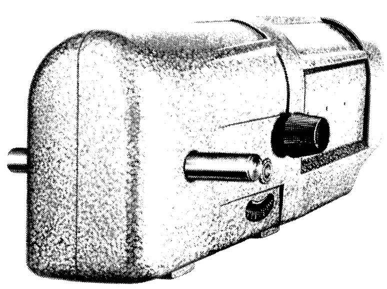

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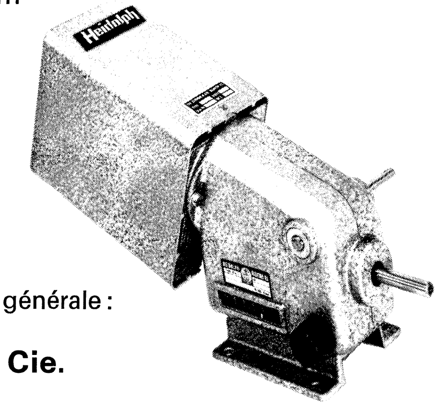

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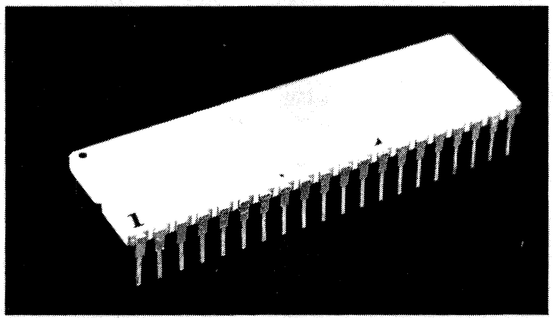

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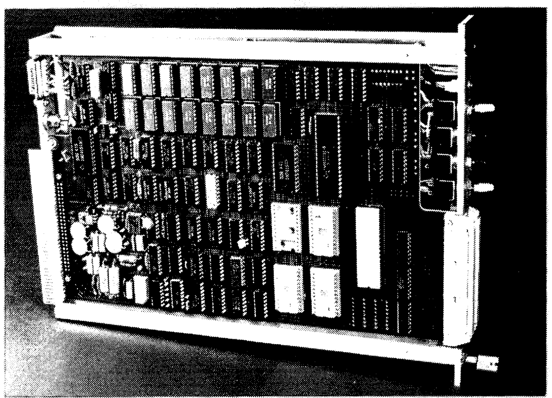

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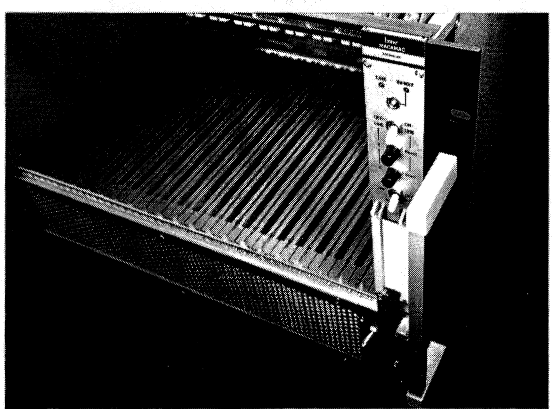

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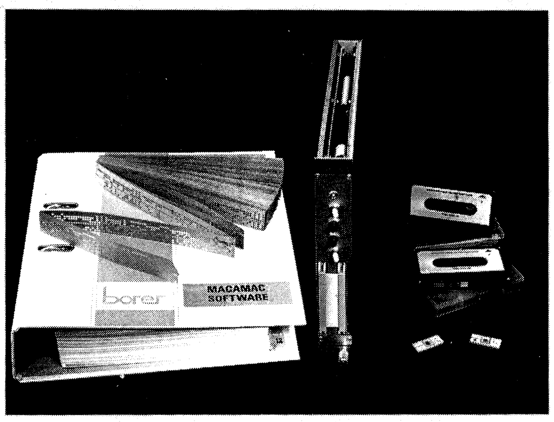

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