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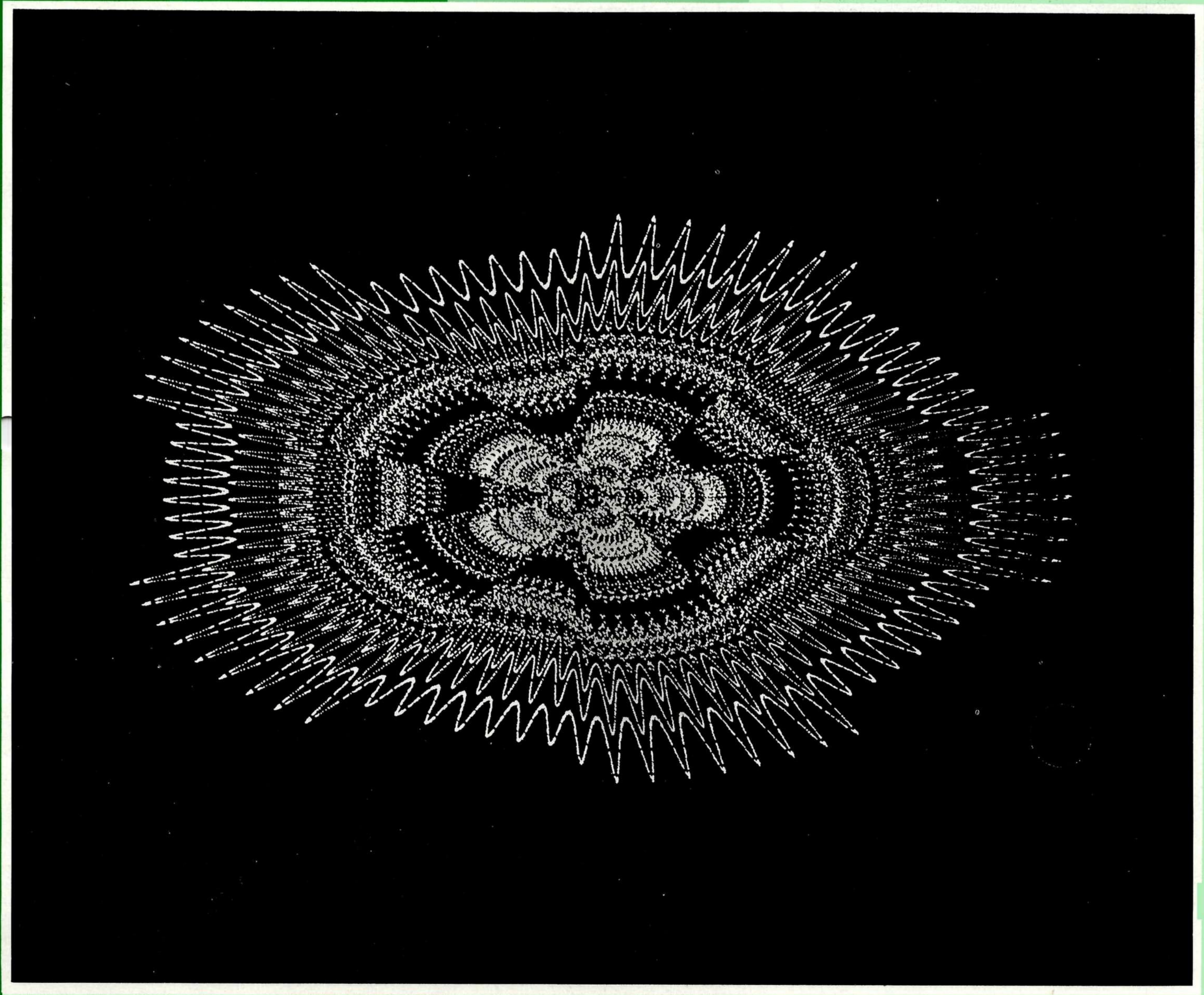

CERN, the European Organization for Nuclear Research, was established in 1954 to '... provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto'. It acts as a European centre and co-ordinator of research, theoretical and experimental, in the field of sub-nuclear physics. This branch of science is concerned with the fundamental questions of the basic laws governing the structure of matter. The Organization has its seat at Meyrin near Geneva in Switzerland. There are two adjoining Laboratories known as CERN Laboratory I and CERN Laboratory II.

CERN Laboratory I has existed since 1954. Its experimental programme is based on the use of two proton accelerators — a 600 MeV synchro-cyclotron (SC) and a 28 GeV synchrotron (PS). Large intersecting storage rings (ISR), are fed with protons from the PS for experiments with colliding beams. Scientists from many European Universities as well as from CERN itself take part in the experiments and it is estimated that some 1500 physicists draw research material from CERN.

The CERN Laboratory I site covers about 80 hectares almost equally divided on either side of the frontier between France and Switzerland. The staff totals about 3200 people and, in addition, there are about 1000 Fellows and Scientific Associates. Twelve European countries contribute, in proportion to their net national income, to the CERN Laboratory I budget, which totals 410 million Swiss francs in 1975.

CERN Laboratory II came into being in 1971. It is supported by eleven countries. A 'super proton synchrotron' (SPS), capable of a peak energy of 400 GeV, is being constructed. CERN Laboratory II also spans the Franco-Swiss frontier with 412 hectares in France and 68 hectares in Switzerland. Its budget for 1975 is 237.9 million Swiss francs and the staff totals about 450.

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Cover photograph: 'God is a mathematician' even when manifest in artistic form. This Persian carpet design emerged from studies of dynamic systems (such as proton beams under external and self-generated forces). The mathematical equations involved are also relevant to astronomy and control theory and, in addition, yield fascinating patterns when handled with varying parameters by a computer. Some of these patterns were shown in May at an exhibition in Rio de Janeiro. They come from work by I. Gumowski of CERN and C. Mira of the Laboratoire d'Automatique et d'Analyse de Systèmes, Toulouse.

New games with old detectors Old games with new detectors

Under this title, Georges Charpak spoke on 15 May about the recent work in his group at CERN on particle detection techniques. This article is based on the talk and will attempt to convey the ideas, the achievements and the potential of the detectors now under development.

The Charpak group has been doing pioneering work in this field for many years and achieved in 1968 the great breakthrough which led to multiwire proportional chambers and drift chambers. To appreciate what is happening now, we should back-track a little and simply pull out the essential operating principles of these detectors which Charpak puts under the heading 'old'.

The proportional counter has a distinguished history as a detector stretching back to the golden era of atomic physics. It usually consists of a thin anode wire along the axis of a cylindrical cathode. A charged particle can be recorded when it causes ionization within the cylinder. The liberated electrons initiate a pulse on the anode. The important features lying behind the new developments are that an electron first 'drifts' towards the anode under the influence of the electric field. Only in very close proximity to the wire are the field gradients high enough to initiate 'amplification' as the electron gains sufficient energy to liberate further electrons. In a few tens of microns an amplification of 10^5 is possible. It is the positive ions left in the wake of the electron avalanche which induce the bigger part of the pulse as they move away from the anode wire traversing a large potential difference.

Multiwire proportional chambers

The idea of having planes of wires operating like a series of independent proportional counters had been avoided since it was thought that capacitative coupling between the wires would make it virtually impossible to distinguish the wire which received the electron avalanche. The important CERN contribution was simply to demonstrate that the wire receiving the electrons records a negative pulse (from the electrons and more so from the induced pulse as the positive ions move away) while the neighbouring wires record a positive pulse due to the ions. Localising the wire nearest to the initiating charged particle was thus a comparatively easy task and the multiwire proportional chamber (MWPC) was born.

By now, MWPCs are in widespread use in high energy physics experiments. The Split Field Magnet detection system at the CERN Intersecting Storage Rings is perhaps their most spectacular application with arrays involving 70 000 wires surrounding the proton collision region. The picture on page 157 of the May issue illustrates their bubble-chamber-like abilities for recording many emerging charged particles with the added advantage of being triggered to pick out events of interest from the 100 000 events occurring per second.

MWPCs can detect particle positions to an accuracy of about 1 mm (spatial resolution) and detect their time of arrival to about 25 ns (time resolution). They are virtually continuously sensitive so that detection rates of millions per second are possible. In addition, there are techniques for obtaining both spatial co-ordinates from one chamber — one co-ordinate is obviously picked out by the anode wire recording the negative pulse, the other can be picked out by measuring the 'centre of gravity' of the positive pulses induced by the ions on a plane of cathode wires stretched at right angles to the anode wires. (Ingenious ways of achieving this second co-ordinate have come, for example, from the V. Perez-Mendez group at Berkeley and C.J. Borkonski and M.K. Kopp at Oak Ridge.)

These properties were a considerable advance on those of the previous generation of spark chambers. They were not achieved for free — the cost of electronics per wire makes MWPC a fairly expensive detection technique. Now drift chambers are surpassing some of their abilities by considerable factors.

Drift chambers

In the same 1968 paper that opened the floodgates for MWPCs, it was pointed out that even greater precisions would be possible by measuring the time taken for an electron to drift from the position where it is liberated to the anode wire. The drift chamber revolution has been a little longer in coming.

Whereas in the MWPC the spacing of the anode and cathode is kept small, it is increased in the drift chamber so as to measure the time taken from the arrival of the particle in the chamber (clocked by a scintillation counter to better than 1 ns) and the appearance of the pulse on the anode wire.

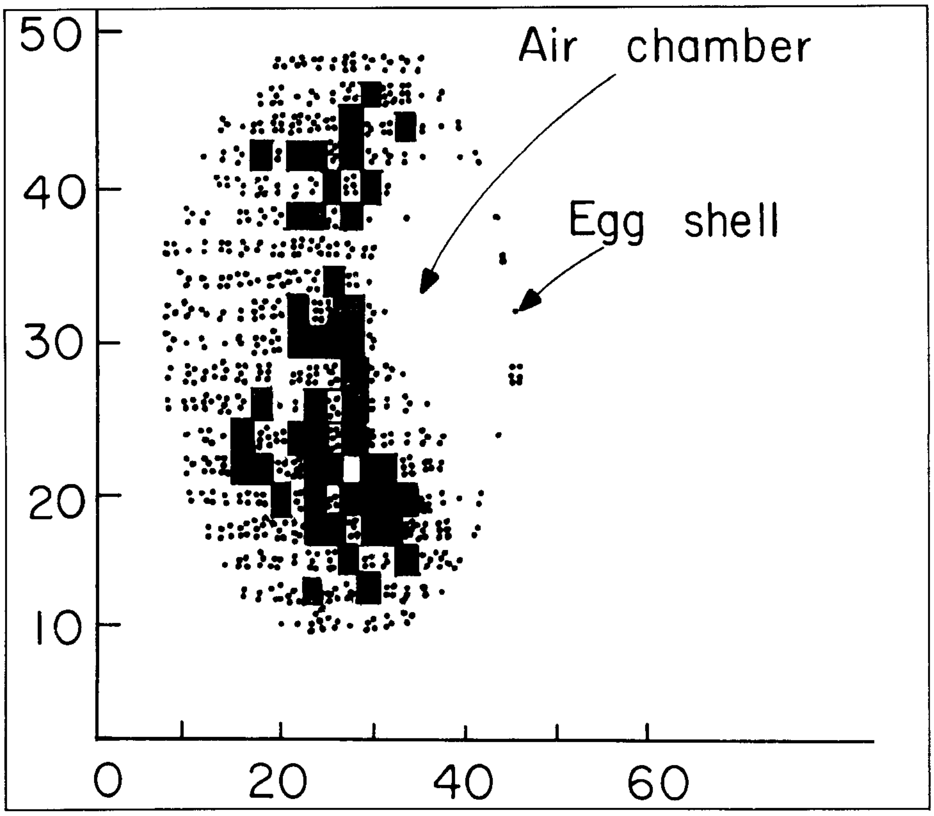
Unfortunately, without special tricks, the measured time is not directly proportional to the distance the electron travels. The electric field is inhomogeneous and the time is a complicated function of the position where the electron is liberated. The favourite way of overcoming this is to tailor the electric field so that the electrons see a constant field gradient along their drift path. Special gas mixtures are also used to reduce problems due to electron scattering. The measured time is then directly proportional to the distance travelled by the electron. The problems connected with field inhomogeneity can also be partly cured by selecting an appropriate gas. A Heidelberg group has taken this route and has produced chambers of very simple construction.

Huge 3.7 m × 3.7 m chambers now sit in a neutrino experiment at Brookhaven. Chambers with 50 cm drift distances are incorporated in a nuclear physics spectrometer at Saclay. Chambers 2.2 m × 1.5 m are being developed under F. Sauli at CERN for installation in the Omega spectrometer when it is used in conjunction with the 400 GeV synchrotron. The Omega chambers are aiming for a spatial resolution of 150 μm and a time resolution of 10 ns. We should spell that out. . . the chambers will tell us where a charged particle passed with an accuracy of nearly a tenth of a mm and tell us when a charged particle passed with an accuracy of a hundredth of a millionth of a second. Still better performances have been obtained in laboratory prototypes of smaller size.

We now move to recent developments beginning with some of the novel applications of the abilities of the 'old' detectors and concluding with a 'new' detector — a further advance in the drift chamber technique which promises to open the third generation of detectors stemming from the 1968 work.

Drift chambers in radioscopy

X-radiation has, for several generations, been the standard method to observe the internal structure of bodies. R.R. Wilson, now Director of the FermiLab, suggested as long ago as 1946 that accelerated protons could do the same job. It is only quite recently however that experiments on the use of protons have begun. At Argonne, prompted by R. Martin, an absorption technique more sensitive than X-radiation has been tested (see September issue 1974) and similar work is under way at Berkeley under K. Crowe. The shadowing effects of multiple small angle proton scattering has been investigated at Harwell under D. West and at Berkeley under C. Tobias.

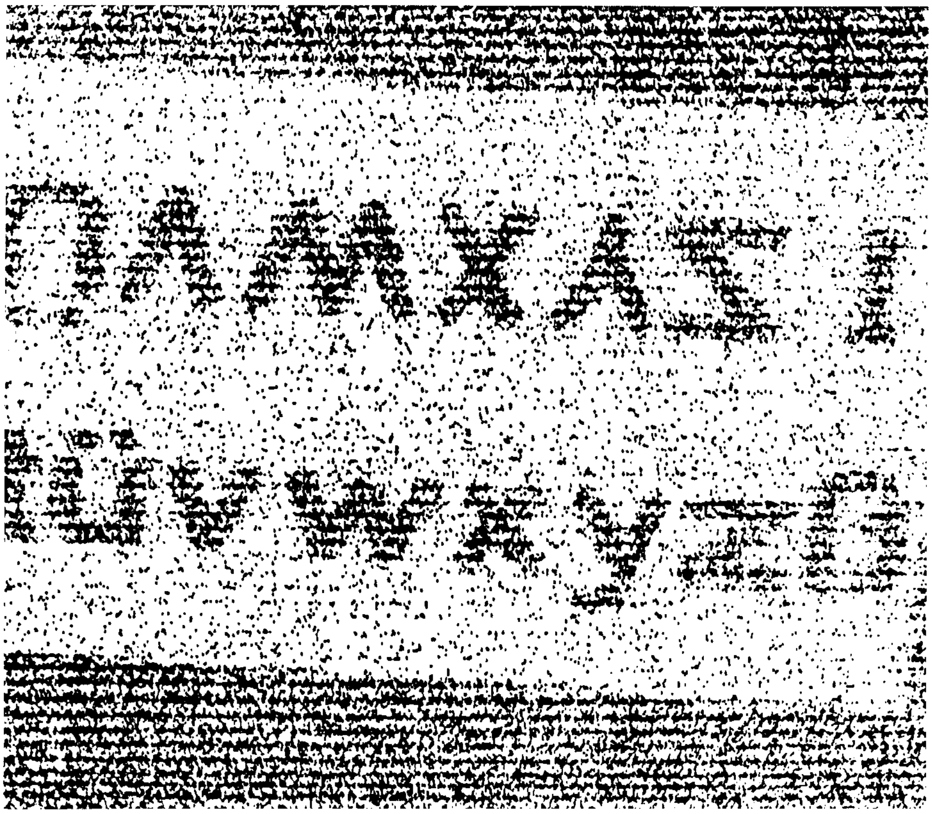


Proton radioscopy lays an egg. This is a computer reconstruction of the data on the density distribution in an egg (measurements in millimetres) which was detected by drift chambers. The egg was looked at during preliminary studies on the use of nuclear scattering in radioscopy.

Both these techniques depend on the density of matter encountered along the path of the proton. Local variations are not necessarily recorded and irradiations from different directions are needed to yield a three dimensional picture. Recent CERN work has attempted to bring high energy physics methods even more directly into medicine. It involves radioscopy using nuclear scattering of protons with energies up to about 1 GeV.

A beam is directed at the object to be examined. Most protons pass almost straight through, suffering only small deviations due to multiple Coulomb scattering. Some, however, will experience strong interactions with the nuclei in their path and be deviated through wide angles. Detectors placed before and after the object will pinpoint the position of the interacting nucleus. The number of scattered protons emerging from particular small volumes in the object will be proportional to the density of nuclei in the volume. A three dimensional density distribution can thus be determined from the information provided by the detectors.

Another interesting piece of information can be unearthed using this proton radioscopy technique. If the scattered proton has been in collision with a 'free' proton, the nucleus of a hydrogen atom, it will emerge coplanar with the recoil proton and the incoming proton directions. If the scattered proton has been in collision with a bound proton or neutron, in the nuclei of oxygen, carbon or nitrogen atoms etc. . ., because of the Fermi motion of the bound particle within the nucleus, the emerging proton/recoil particle/incoming proton directions will not be coplanar. This gives a unique piece of chemical information in the radioscopy.



An example of the abilities of a multiwire proportional chamber (1 mm wire spacing) in the detection of X-rays. A thin plastic sheet with letters cut out of it was placed against the MWPC and the signals recorded by the detector were reconstructed as shown by a computer.

The tests at CERN have used proton beams from 540 MeV to 1 GeV (the precise energy does not introduce much difference over this range). Scintillators and drift chambers (capable of 0.3 mm accuracies and with small 'dead-times' of 0.5 μs) were used to track the proton directions looking at scattering angles from 19 to 40°. Compared with the detection systems which could be assembled, the set-up was comparatively primitive. Nevertheless three dimensional spatial resolutions of 10 mm^3 were rapidly achieved and, at the end of May, this was improved to 1 mm^3. Initially they had fun with boiled eggs and could identify the yoke, white, air chamber and shell from the data provided by the detectors. The dose rates involved are below human tolerance levels. The tests are moving onto rabbits and mice and encouraging results continue to be achieved.

The preliminary results are now being made known to the medical community and we should await their reactions before discussing any further the advantages and difficulties associated with making such proton radioscopy available on a widescale.

Drift chambers for X-ray, neutron and gamma detection

It was appreciated early in the history of MWPCs and drift chambers that they have special potential in the detection of neutral particles. Once a neutral particle initiates a charged particle by an interaction in the chamber volume, its position in two co-ordinates can be extracted to high accuracy. Obtaining two co-ordinates from a single detector is a great advantage with low energy particles which have often insufficient energy to emerge for further observation in a second detector. Medical applications with X-rays and gammas have received a lot of attention in several Laboratories including Berkeley, Brookhaven and Oak Ridge.

At CERN increased efficiency in X-ray detection was obtained by adding a drift region to a MWPC — the liberated electrons in the drift space move into the MWPC for detection. However, when the X-ray is not travelling parallel to the electric field in the drift region, it can liberate electrons at several positions along its path giving signals on several wires, thus blurring the information as to its true direction.

A neat way out of this has been to build a drift chamber region like a piece out of a sphere with the electric field lines radiating out from the point where the specimen being X-rayed is located. A scattered X-ray then travels along a field line and liberated electrons trigger the same wire. Accuracies of 0.5 mm are obtained with a 4 cm drift length and such chambers have many applications in X-ray crystallography, pin-hole imaging, etc. . .

For the detection of higher energy neutrals another type of drift chamber has been designed (initially prompted by A. Jeavons for a gamma detection experiment). It involves filling the drift region with high density matter in which the high energy neutrals will 'convert' to detectable charged particles.

A chamber has been built with the drift region filled with a series of lead-bismuth plates perforated with 1 mm square holes spaced 1.5 mm apart. The plates are insulated from one another and connected along a series resistance so that a drift field is set up within the holes. A MWPC is placed under the stack. Incoming gammas liberate electrons in the alloy and these pass into the holes causing ionization electrons which drift down the holes and are detected. For 0.66 MeV gammas, the detection efficiency

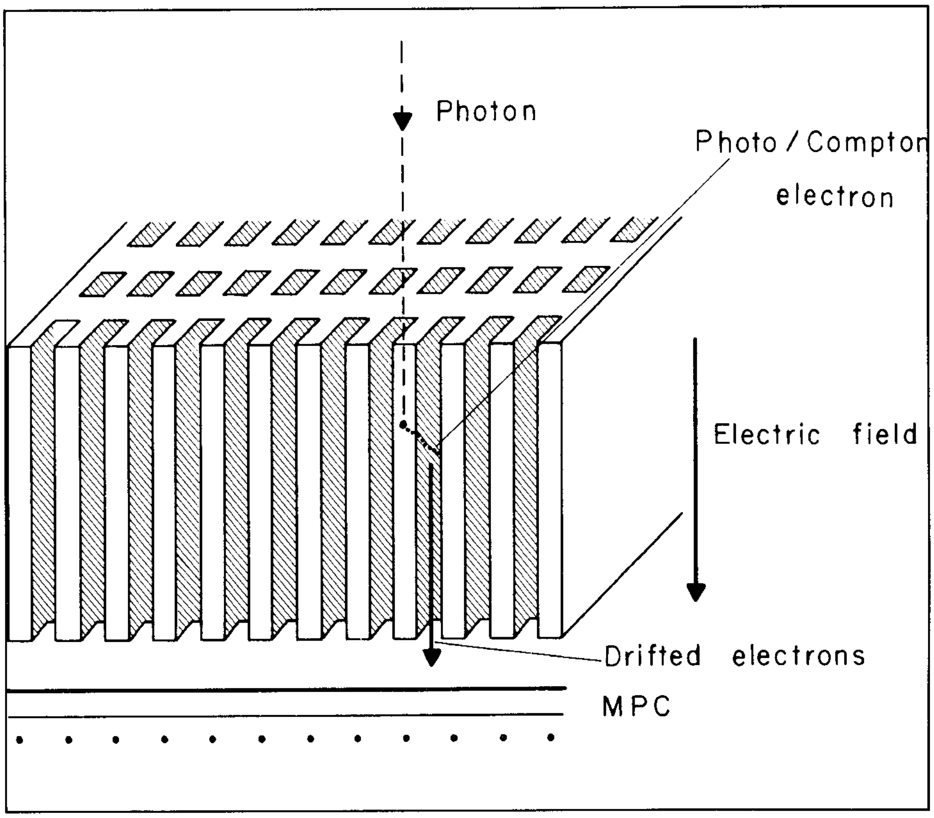


Diagram of the construction and operating principle of the 'high density drift chamber' which is under development for the detection of high energy neutral particles. The neutral converts in the high density material, the liberated electron emerges into slots where ionization electrons are caused. The drift chamber principle then takes over.

was 5 % (corresponding to the calculated fraction of electrons emerging from the plates into the holes) and the spatial resolution was 1.3 mm. The latest results from Jeavons at the end of May yielded 20 % efficiency for gamma detection at 0.5 MeV with slightly better spatial accuracy.

Large drift chambers based on these ideas might prove serious competitors to the huge calorimeters (such as the lead/liquid argon type) in very high energy neutral detection. For example, the electron shower from high energy gamma conversion could move along a drift field back in the direction of the incoming gamma. The first detected electrons would then give information on the point of conversion with good accuracy, the total number of detected electrons would give information on total energy and the 'centre of gravity' of the detected electrons would give information on the direction of the shower. Much work remains to be done, however, to convert these interesting possibilities into reality.

Drift chambers studying channelling and blocking in crystal lattices

Ten years ago, theoretical (J. Lindhard) and experimental work at the University of Aarhus in Denmark uncovered phenomena in crystals which had been accessible to investigation from the early days of atomic physics but had never previously been seen. They have become known as 'channelling' and 'blocking' – they concern the strong directional effects which are related to the structure of crystal lattices.

When an incoming particle is lined up with a crystal axis (or plane) to within a small angle, its transmission through the crystal is influenced by the string of atoms it encounters along the axis. It is as if the particle skids across the plane of atoms. Quite dramatic changes in transmission are seen by simply turning a crystal in front of a particle beam and the effect is different for positive and negative particles. For non-relativistic (low energy) particles, the angles are of the order of degrees and the effects are easy to measure. Many Laboratories have studied them during the past ten years and numerous applications, especially in semiconductor physics, have been explored.

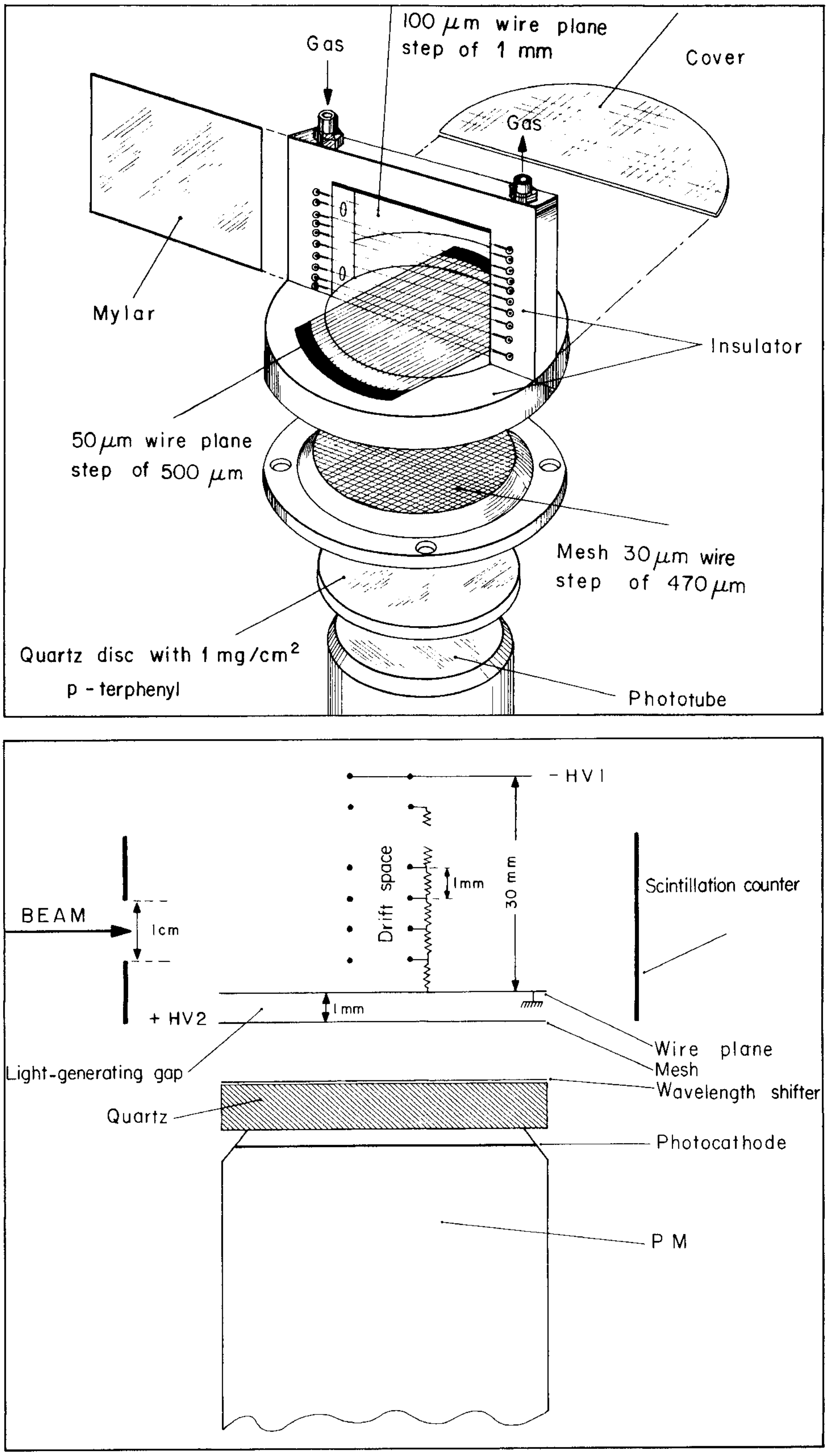
The initial classical theory developed to explain channelling has been extended to take in quantum mechanics. Higher energy, relativistic, particles are needed to check this more refined version but, until recently, there had only been some higher energy experiments with electrons and positrons. Great accuracies are needed in the angular measurements, which are now in the milliradian range, in order to extract the required information with scattered high energy particles. The use of drift chambers to achieve these accuracies was suggested a year ago and an Aarhus/CERN experiment began recently on a 1.1 GeV/c beam at the CERN proton synchrotron.

Proton and pion beams were transmitted through a germanium crystal 1 mm thick. The drift chambers were able to give positions to 150 μm bu scattering on windows and wires reduced overall angular resolution to about 1 mrad. Nevertheless, this was sufficient for the scattered beam to give clear information. A computer print-out of the angular distribution of the scattered particles identified the effects caused by the main crystal axis and planes for both negative and positive particles. More refined measurements are being taken and the effects on energy loss are now also being investigated.

It might prove possible to use these effects in detectors. For example, it could be feasible to determine the sign of charged particles and to obtain accurate information on their directions. Another possibility is the location, by means of the blocking technique, of particles coming to rest in a crystal lattice.

The 'blocking effect' concerns particles blocked from travelling along the main axis or planes with, again, a characteristic pattern for each crystal type. It has been used in nuclear physics for several years to determine lifetimes of nuclei decaying in the lattice (knowing distance and velocity information) down to lifetimes in the 10^{-18} s region.

There is speculation as to whether the technique could be applied to particle lifetimes. The Aarhus/CERN team, in their experiment at the synchrotron, have recently seen blocking using a high energy pion beam and the possibilities can now be investigated more thoroughly.



Diagrams of the prototype scintillating drift chamber which has been built at CERN. Electrons liberated by the passage of a charged particle are drifted to a small gap where the field is sufficiently strong to cause photons to be produced but not to cause an electron avalanche. Detection of the photons gives a signal without having a cloud of positive ions which takes time to disperse. The rate at which particles can be detected goes up by a factor of a hundred compared with the 'conventional' drift chamber.

The scintillating drift chamber

We now come to a new type of detector which carries even further some of the remarkable properties of drift chambers. It is based on the observation of light quanta, which are produced by electrons in the wake of a charged particle, rather than on the collection of an electric signal from an electron avalanche.

An electron liberated by a charged particle can excite atoms in the surrounding gas without causing further ionization (and the start of an electron avalanche). The excited atoms will return to their lower energy state giving off a light quantum or photon. The effect has been studied by many researchers for about twenty-five years but it was only in 1972 that a thorough series of investigations (testing a variety of gas mixtures and wavelength shifters) by a small group in Portugal demonstrated that it could be used as a technique for particle detection. The group was led by A.J.P.L. Policarpo and included M.A.F. Alves, M.C.M. dos Santos and M.J.T. Carvalho. Their crucial paper in Nuclear Instruments and Methods in 1972 went unnoticed by many 'old hands' in the field of detectors.

When the ionization electrons move under the influence of an electric field they can excite many atoms and thus initiate many photons. In general, the light is in the ultra-violet wavelength region and 'wavelength shifters' are needed so that the light will trigger standard photomultiplier tubes.

The most important gain compared with the 'conventional' drift chamber is in the rate at which data can be collected. The scintillating drift chamber is operated with a low electric field gradient so that the electrons do not cause further ionization. At the end of a drift space, they move into a gap between grids where the field is sufficiently high to cause photons to be produced. There is no avalanche and thus no cloud of positive ions which needs to clear before the passage of the next charged particle can be recorded. The event rate that can be handled goes up by about a factor of a hundred.

A scintillating drift chamber has been built at CERN. Various gases have been tried — the best light emitting properties being achieved with xenon, though the much cheaper mixture of 90 % argon, 10 % nitrogen worked well also. Experiments were carried out with alpha particles, X-rays and minimum ionizing particles. Despite the fact that many features of the chamber were a long way from being optimised, very good results were obtained. Positional accuracies were a few hundred microns, depending on drift distances.

The parameter of most interest was the event rate. For the 'conventional' drift chamber performance begins to deteriorate beyond about 10^4 counts per mm^2 per s. The prototype scintillating drift chamber was exposed to an X-ray beam of 1 mm^2 cross-section. A count rate of 5×10^5 per s with a 20 % duty cycle (so that the instantaneous count rate is over 10^6 per s) was achieved with no sign of falling efficiency.

Applications which readily come to mind are legion. At nuclear physics energies and for heavy ion research where there is high ionization in the chamber gas, the drift chamber can operate well 'self-triggered', without the need for scintillation counters. Self-triggered operation would be excellent for detecting neutral particles such as X-rays and neutrons. They would be ideal detectors for installation at the focal plane of nuclear physics spectrometers and at Van de Graaff machines to cope with high event rates. Detectors with special geometries (for example, cylindrical or spherical chambers) should be much easier to build. Obtaining two positional co-ordinates from a single chamber should be possible using techniques such as the centre of gravity method.

A great deal of research remains to be done to extract the full abilities of the scintillating drift chamber but the prototype results are already impressive.

It has obviously not been possible in this general account to enter into much technical detail on the various techniques we have described. Enthusiasts might like to consult the following series of papers:

'Recent observations and measurements with high accuracy drift chambers' M. Atkinson, A. Breskin, G. Charpak, C. Schultz, F. Sauli Nuclear Instruments and Methods

'Nuclear scattering applied to radioscopy' G. Charpak, J. Saudinos, F. Sauli, D. Townsend, J. Vinciarelli Physics in Medicine and Biology

'Channelling of 1.1 GeV/c protons and pions' G. Charpak, O. Fich, J.A. Golovchenko, K.O. Nielson, F. Sauli, E. Uggerhoj Physics Letters

'The spherical drift chamber for X-ray imaging applications' G. Charpak, Z. Hajduk, A.P. Jeavons, R. Kahn, R.J. Stubbs Nuclear Instruments and Methods

'The high density multiwire drift chamber' A.P. Jeavons, G. Charpak, R.J. Stubbs Nuclear Instruments and Methods

'The scintillating drift chamber: a new tool for high accuracy very high rate particle localization' G. Charpak, S. Majewski, F. Sauli Nuclear Instruments and Methods

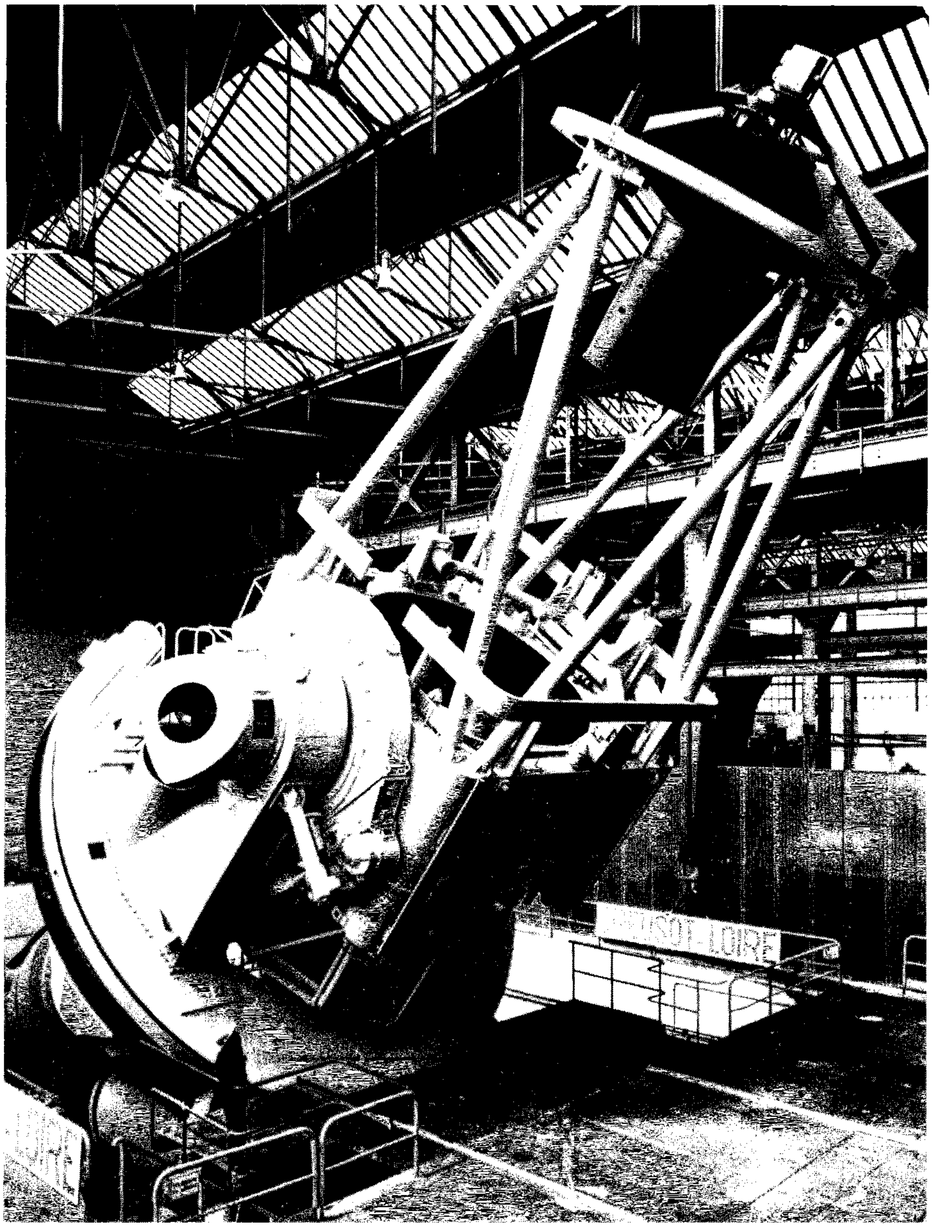
First results emerge from SC2

The first paper to emerge from experiments at the revamped 600 MeV synchro-cyclotron is being published in Physics Letters. It concerns the observation of decays of unstable cesium nuclei with the emission of a continuous spectrum of alpha particles. The data was collected at the beginning of this year at the on-line isotope separator, ISOLDE, which has also benefited from a programme of improvements while the synchro-cyclotron was out of action (see February 1973, page 38).

ISOLDE is used to produce nuclei which are 'far from stability' — their balance of protons and neutrons is abnormal. Studying these abnormal nuclei can give a lot of information on nuclear properties. For example, one of the most fruitful approaches is to find out how the nuclei break up to reach a more stable configuration. This break up, or decay, can take several routes and observing which routes are taken, and with what frequency, reveals how particles were grouped in the abnormal parent nuclei, what energy states they were in and so on.

The classical routes of decay to lower energy states and more stable nuclei are via the emission of gammas, electrons or positrons (beta decay) or alpha particles (two proton-two neutron clusters). In recent years information has been gathered, mainly from ISOLDE plus experiments at Berkeley and Dubna, on decay with emission of a proton from an excited nuclear state populated by beta decay. A closely related phenomenon is that of 'beta-delayed alpha emission' which, outside of the light nuclei, occurs in only two special cases identified forty years ago by Rutherford. Here beta decay occurs from an unstable nucleus

The mechanical structure of the huge 3.6 m telescope of the European Southern Observatory (in whose design and construction CERN is participating) was 'on show' to the Press at the Creusot-Loire factory on 21 May. The structure is now under test before being transported to the Observatory in Chile. The building to receive it is completed and its 30 m diameter dome is being erected ready for the telescope which is scheduled for operation next year.



and the new nucleus thus produced, survives a short time before finding a route towards stability via the emission of an alpha-particle. It is predicted that for extremely neutron-deficient nuclei the emission of delayed particles should be observable throughout the nuclear chart. A new field is therefore expected to open up, where the combined study of alpha and proton spectra originating in regions of high level density will give information on nuclear structure in the region of 4 to 10 MeV excitation energy.

Before the synchro-cyclotron shutdown a new beta delayed alpha emitter, a mercury isotope 181 Hg, had been spotted at ISOLDE but with meagre data (ten events). In the tranquillity of the shutdown it dawned that rather lighter elements are more favourable candidates for this effect (they have lower level densities and the Coulomb barrier is less difficult to overcome). The recent experiments concentrated on cesium nuclei, in particular 118 Cs and 120 Cs, which are very deficient in neutrons compared with the stable isotope 133 Cs. They were produced in a molten lanthanum target bombarded by the SC's 600 MeV protons and subsequently ionized, accelerated and magnetically separated.

The 118 Cs isotope first decays to a highly excited xenon nucleus, 118 Xe, by emitting a positron. The xenon nucleus can then approach stability by gamma emission to less excited energy states, by proton emission to an iodine nucleus 117 I, or by alpha emission to a tellurium nucleus 114 Te.

A large number of alpha events were recorded, confirming the theoretical calculation that lighter elements would show the phenomenon more often. The rate of alpha events was, in fact, surprisingly high, about 1:16 compared with the proton events. This is fresh information relevant to a topic which is intriguing a number of nuclear specialists at present.

The topic is concerned with 'fluctuations' in the delayed particle spectra. Fine structure is seen in these spectra which relates back to the energy levels from which the delayed particles came and to the intensity with which these levels were populated. The fine structure is reproducible for a particular nucleus but varies in a seemingly random way from nucleus to nucleus. Theoretical work has tackled this as a sort of 'nuclear noise' with mathematical techniques rather similar to those used in treating noise in electrical circuits. In this model, Nature has done its own selection from all the possibilities. The statistical effects can entail important modifications to the alpha/proton emission ratios. It is a challenge to future experiments to determine the fine structure and to account for these ratios.

Accelerating other particles in the PS

Way back in 1964, the possibility of accelerating polarized protons and particles heavier than the proton in the CERN synchrotron was first considered. The linac had at that time already squeezed through a 7 mA beam of deuterons. However, the proton programme was so rich that these possibilities were put aside. In a few years time, the situation could be different. The burden on the PS for filling the 400 GeV synchrotron and the Intersecting Storage Rings will not take up all the pulses that the machine can handle and the commissioning of the new linac will leave the present linac free to handle other particles.

Other particles at PS energies would already be a considerable addition to the research possibilities and there is also the prospect of subsequent injection in the storage rings where unique energy conditions would be achieved. A two year study has therefore been launched to see whether, in addition to its primary task of feeding the SPS, ISR and the normal PS programme, the PS could provide polarized protons and light ions.

The machine could accelerate fully stripped ions up to argon to an energy of 12 GeV per nucleon. If an ion source capable of providing fully stripped ions in sufficient intensities is developed, the present linac is usable almost without modification using a different acceleration mode to take account of the different charge to mass ratios. With this mode, the particle capture rate is lower and beam intensities would, in turn, be lower. If, however, only partially stripped ions are available, a new first cavity would be needed followed by a stripper to remove all the electrons from the accelerated ions before continuing the acceleration to higher energies.

Acceleration of the ions in the PS would require some gymnastics with the r.f. system. They would be injected with 1/6 (rather than 1/3 for protons) of their final velocity and the accelerating cavities would have to cope with a much broader swing in frequency. It would be necessary to capture the ions on the second harmonic (giving 40 bunches) and at an appropriate stage stop acceleration while they are 'debunched' prior to rebunching for further acceleration at the normal harmonic (20 bunches).

The deuteron is the simplest of the additional particles to confront and a test of deuteron acceleration in the PS will take place during a machine development run early in 1976. Proposals for deuteron experiments in the ISR have been discussed by the ISR Committee.

Polarized protons are likely to be more tricky. Work at Argonne, where the Zero Gradient Synchrotron has been accelerating polarized protons since 1973 (see July 1973, page 227) and at CERN with polarized targets, has revealed some mysterious effects related to spin direction. Since an intensity of at least 10^{10} particles per pulse is needed for reasonable experiments in the storage rings, one of the concerns is to demonstrate that these intensities can be achieved beginning with a 100 μA source of polarized protons or deuterons.

Further development of the source which is already giving such beams at Argonne is under way in collaboration with H.F. Glavish who conceived this type of source. Argonne is also collaborating in the study of depolarizing resonances which have to be crossed during the acceleration cycle. Theory indicates that these are likely to be more serious in a strong focusing machine like the PS than in a weak focusing machine like the ZGS. The first simulation tests at the ZGS took place in April.

A small group of physicists are examining the experimental possibilities in more detail. It is difficult to predict the decisions on other particle acceleration which are likely to be taken at the end of 1976. They will depend on the predictions emerging from the continuing machine studies, on the interest expressed by the experimental community and on the general policy of CERN at that time.

Performance of the PS Booster

The 800 MeV Booster was designed to enable the CERN proton synchrotron to reach an intensity of 10^{13} protons per pulse with a 100 mA beam from the linac. The Booster has, in fact, to strain itself beyond these design figures. The linac beam yields only 80 to 90 mA and in 1976 a beam of 1.3×10^{13} ppp will be needed in the Booster in order to reach an intensity of 10^{13} in the 400 GeV proton synchrotron after the inevitable losses during the beam transfers.

The efficiency of all the machines involved, especially the Booster, has to be improved. In addition, the Booster has to satisfy the various requirements in the Intersecting Storage Rings and in the experimental halls making direct use of the PS beams. It will be necessary to change properties of the beam, particularly its intensity, from one pulse to the next.

During the latest annual shutdown there were modifications and new equipment installation for these purposes (see January issue, page 7). The subsequent start-up of the machine was unusually smooth and was followed by a period of operation for physics experiments which was the longest and most successful yet. It lasted 836 hours with a breakdown rate below 2 %. Some time was then available for Booster machine studies as the physics programme did not require the high intensities for which the Booster must be used. There were twenty study sessions with the linac beam at 80 mA, which contributed a great deal to the success of the work.

Multiturn injection

The horizontal emittance and the injection efficiency were studied in relation to parameters such as the density of the linac beam, the angle of injection . . . and a special method of improving the injection efficiency was examined. It consists of injecting on a coupling resonance between horizontal and vertical betatron oscillations. During multiturn injection (over thirteen turns), the closed orbit is initially shifted locally to the interior of the injection septum magnet, and then gradually brought back towards the centre of the vacuum chamber.

The betatron amplitudes of the protons injected in each turn are thus increased, which raises the horizontal emittance of the beam.

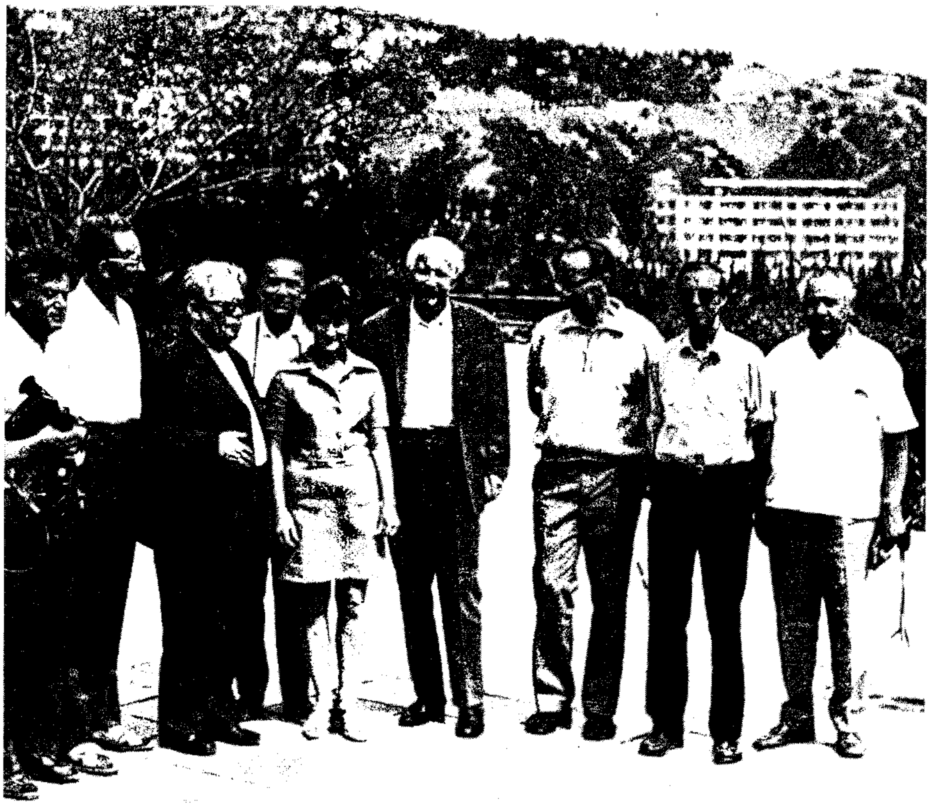
A compromise has to be struck between limiting the emittance (in order to obtain a dense beam) and obtaining high injection efficiency. The aim is to limit the horizontal emittance to that which will be accepted by the PS ($130\pi\ 10^{-6}$ rad m beginning with a linac emittance of $30\pi\ 10^{-6}$ rad m). This is attained by decreasing the orbital deformation relatively slowly but more than half the injected particles are then lost on the inside of the injection septum. With 4.2 betatron oscillations per turn ($Q_H = 4.2$), this loss mainly occurs five turns after injection. The horizontal amplitude is made to drop at that moment while the vertical amplitude is increased so that there is no loss of protons.

Injection was studied at the resonance $Q_H - Q_V = -1$ (excited by quadrupoles with a suitable harmonic distribution), which is close to the present operating point of the Booster. It proved possible to increase the injection efficiency from 35 to 41 % by carefully adjusting these quadrupoles, and thus to inject up to 4.5×10^{12} ppp (per ring) within the emittance of $130\pi\ 10^{-6}$ rad m. This was achieved at the cost of increasing the vertical emittance (from 52 to $62\pi\ 10^{-6}$ rad m still at 50 MeV) but the transverse density is hardly reduced.

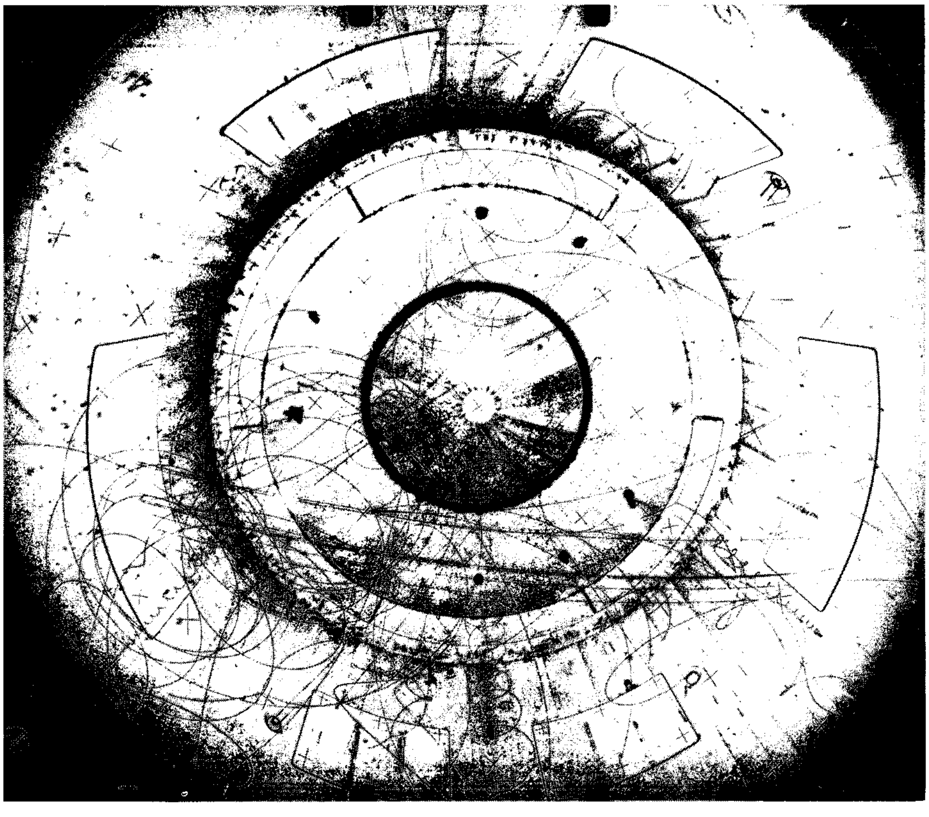
Optimising the operating point

As the Booster has a separated function magnet system, it is easy to change the 'operating point' — the Q_H and Q_V values which were initially intended to be between 4 and 5. It was found that values of Q_H less than 4.5 and of Q_V greater than 5 give lower vertical emittances and transversely stable beams (see December

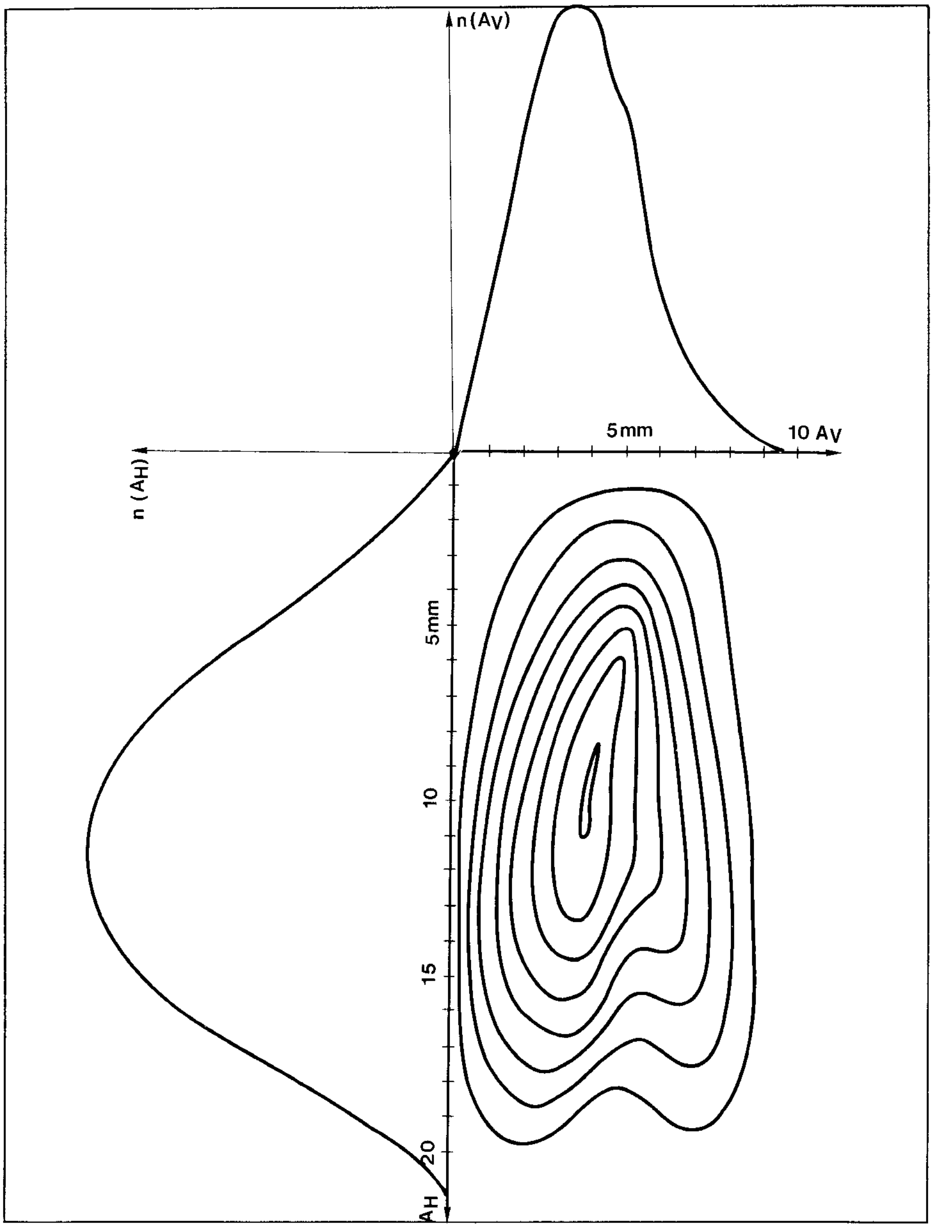
The fourth Joint JINR-CERN School of Physics took place at Alushta in the Crimea, USSR, from 14 to 28 May 1975. It was attended by about 60 students from Dubna and its Member States and 35 from CERN and its Member States. Lecturers from Western Europe were C. Michael from the University of Liverpool, L. Montanet and W. Jentschke from CERN, and B. Wiik from DESY.
The picture below shows N.N. Bogolubov, Director of Dubna (third from left) together with W. Jentschke (sixth from left) and L.D. Soloviev, Director of IHEP Serpukhov (second from left). This was generally regarded as the most successful joint School yet organized.



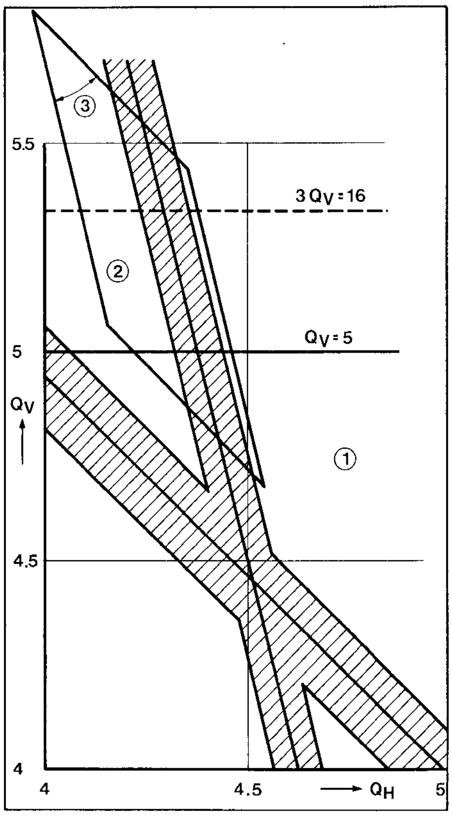
Picture from the recent run with the 3.7 m European bubble chamber, BEBC. The chamber has performed very well after its reassembly. Over 650 000 expansions have been clocked up without trouble. Pictures have been taken with negative pions at 22 GeV and antiprotons at 12 GeV (a charm particle search). The pulse rate was one every 5 s which is the 400 GeV synchrotron rhythm. The magnetic field was operated at its design value of 3.5 T.



The amplitudes of the betatron oscillations as measured in the PS Booster in both the vertical (A_V, above) and horizontal (A_H, left) planes. The two dimensional diagram (bottom right) shows lines of 'iso-intensity' with the outer boundary corresponding to a particle loss of 10 %.



The Q_H-Q_V diagram for the Booster. The hatched zones correspond to machine tune conditions which could not be achieved until recently. This was no problem when operating the machine tuned into zone 1 (as has been the case in the past) but did limit performance when operating in zone 2 (as at present). New control circuits have cleared this problem. The parallelogram 3 indicates a zone which can be used at 50 MeV injection with a 30 A current in these circuits.



1974, page 423). However, the minimum current threshold of the auxiliary power supplies for the quadrupoles prevented certain regions from being reached and, also, there was no means of controlling each ring individually.

A correction winding on each pole can be used to overcome these drawbacks by providing individual circuits for betatron tuning. It is now possible, using computer control to adjust the eight individual values (four rings, two planes) accurately and quickly. The interesting result is that the vertical density of the beam has been shown to be primarily limited by a drop in the value of Q due to space charge bringing particles into the resonance $Q_V = 5$. At present, 5 to 10 % of the protons are lost. Further correction lenses will be installed later in the year.

Betatron amplitudes and instabilities

Detailed knowledge of the betatron amplitudes is useful so as to be able to adjust multiturn injection, for stop band compensation, to study transverse instability, etc. Studies have been conducted by 'beam shaving' — a target is placed beside the beam, which is then gradually shaved by a locally induced orbit deformation. Protons with the highest betatron amplitudes are shaved first and the progress of this shaving process is monitored via a current transformer, whose readings are used to calculate the amplitude distribution.

There are several practical problems to be solved to achieve the desired measurement accuracy. (Beam acceleration must be kept constant during the beam shaving and the orbit deformation must be precisely known). Up to now measurements have been made by a rough-and-ready system and the correlation between the horizontal and vertical betatron distributions has been measured. To do this, a vertical target is put in position be-

Around the Laboratories

fore each horizontal distribution measurement and the measurement is repeated with different positions of the target. This gives a two dimensional projection of the beam with a set of 'iso-intensity' layers, corresponding to the area containing a given percentage of the intensity.

Transverse instabilities are at present countered by Landau damping set up by octupole lenses. These octupoles also produce undesirable effects, especially because of the widening of certain stop bands and a feedback damping circuit is being examined. The signal generated in a position measuring electrode by the unstable protons is amplified and applied with the correct phase to an electrode, setting up a bipolar electric field. The desired effect was obtained immediately during the first tests on a 50 MeV flat-top but the circuit cannot be used during acceleration and further development is needed.

Encouraging progress has also been made in damping longitudinal instabilities (see December 1974, page 251) but success has still not been achieved in all the conditions of interest and not without beam losses.

Knowledge and mastery of the protons in the four-ring Booster is thus advancing steadily and, though there is still much that can be learned, appropriate quality beams should be available when they are required by the rest of the CERN machines.

LOS ALAMOS
First patient irradiations

The use of particle beams for cancer therapy has been under study at accelerator centres for ten years. The ultimate subjects of these experiments are human beings and the approach has therefore to be exceptionally thorough before embarking on clinical treatment. This explains why so many years have gone by since the potential of energetic particles was first realised. Now, on 10 May, the preliminary results of the first ever patient irradiations have been reported at a meeting in San Juan, Puerto Rico.

The irradiations began at the Los Alamos 800 MeV proton linear accelerator, LAMPF, on 21 October 1974. They were conducted by the Cancer Research and Treatment Center of the University of New Mexico in collaboration with the LAMPF team and were stimulated particularly by M. Kligerman, the Los Alamos Assistant Director for Radiation Therapy.

Negative pion beams were used. They have the particular advantage that their energy is deposited in a small volume at the end of their range and they can thus attack tumours while causing much less damage to surrounding healthy cells than the conventional radiations used in therapy, such as X-rays. Two patients exhibiting tumour nodules in the skin received a series of irradiations through to 19 December. Some nodules were exposed to low doses of pions and others to low doses of X-rays.

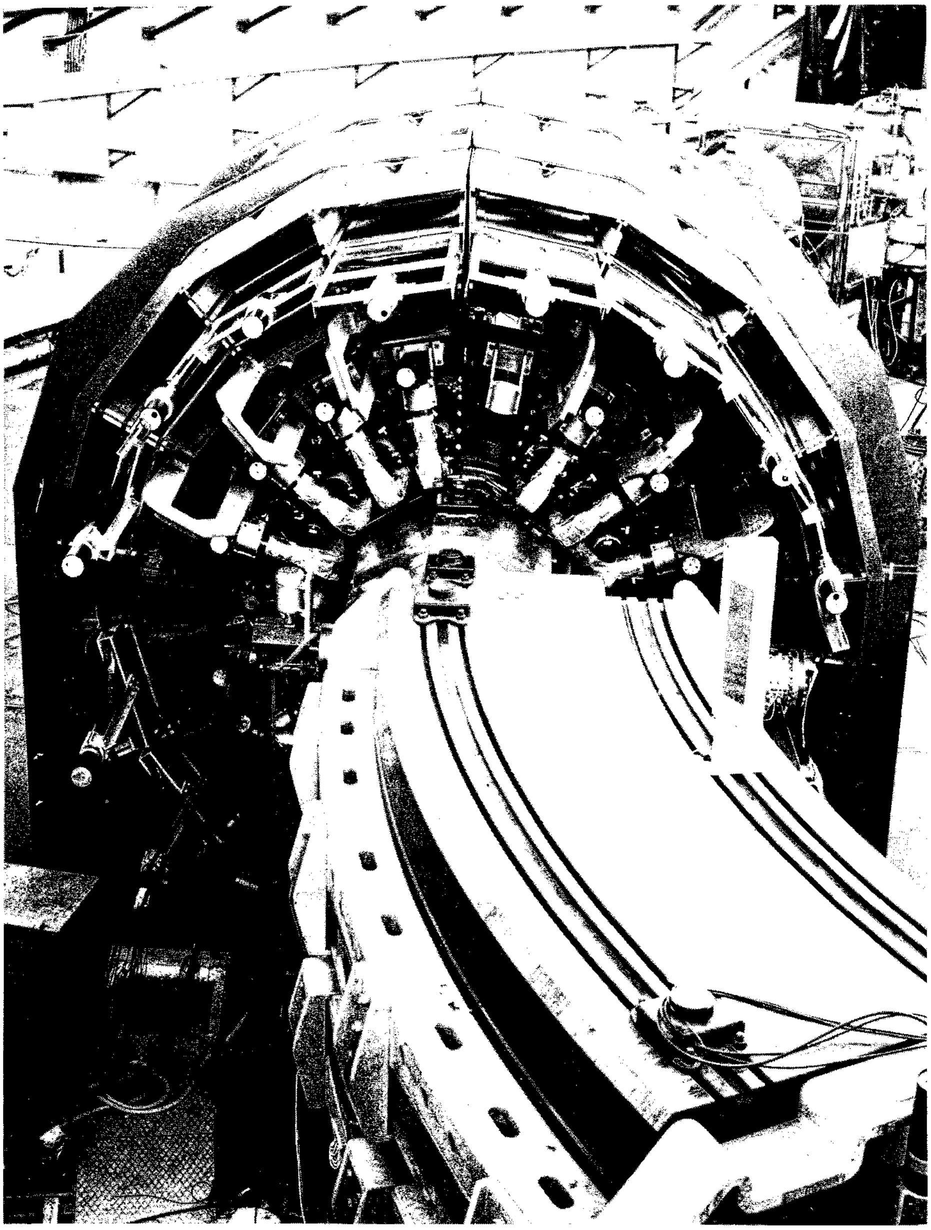
The paper to the American Radium Society in May reported that no unusual reactions had been observed from the pion treatment. It seems that pions can achieve an equivalent effect on tumour tissue with about half the dose needed if X-rays are employed. Also the pions seem to have less damaging effect than X-rays on normal skin included in the irradiated areas.

Obviously, these first results have to be interpreted with care. Continued observation is needed to check for long-term effects and more irradiations are necessary to test effects on other types of body tissue. When LAMPF comes back into action during the summer after 'the great shutdown' (see October 1974), the research will be extended to lymph nodes in the neck and in the lungs, and then to larger tumours in other sites in the body. The first results give every encouragement to pursue this medical application of particle beams.

FRASCATI
Adone and the new particles

As we have reported before (December 1974), when the news of the discovery of the particle at 3.1 GeV reached the physicists working at Adone, the electron-positron storage ring at Frascati, an intense programme was started to push the energies of the beams to this value, which is a little above the nominal top energy (1.5 GeV per beam) of the storage ring. At that moment, a new set of detection systems with high acceptance was starting to investigate the unexpectedly large multihadron production which had been seen at Adone during the first generation experiments. The programme was aiming, on the suggestion of the Frascati and Rome theory group, to search for narrow resonances in the energy range 1.8 to 3.0 GeV in steps of 1 MeV.

The discovery of the new particle swung the programme onto the study of the new phenomena and, thanks to the joint efforts of the machine



The detection system of the 'baryon-antibaryon' group which has recently been completed at the Adone storage ring at Frascati. The system incorporates lead glass counters, which have been set up by the Stony Brook component of the collaboration, to be used in studying the energy distribution of the gammas emerging from the decay of the newly discovered particle at 3.1 GeV.

(Photo Frascati)

group and of the experimental teams, a clear signal of the new particle was observed within a few days in all three working detection systems. This result was reached in spite of the fact that, due to saturation of the magnetic field in the Adone dipoles which were working in a current region never used before, the nominal machine energy was a few MeV different from the true energy.

The simultaneous measurements of the total and of the leptonic cross-sections at 3.1 GeV give information on the intrinsic width of the particle (which is linked to the particle stability). From the data obtained in the first studies, the Frascati group have published a value of the ratio of the width in the e^+e^- channel compared to the total width indicating that the total width is less than 100 keV.

The subsequent work was partially devoted to the study of the production of muon pairs and of the electron-positron angular distributions at 3.1 GeV. Radiative decays have also been studied and upper limits for the partial decay rates into a neutral pion and a gamma (less than 0.5%) and eta and a gamma (less than 1.6%) have been measured. Special attention has been devoted to the measurement of the neutral component of the decays into many pions (multiplicity, angular distribution, etc.). At present an extensive search is in progress for narrow resonances in the mass range 1.90 to 3.15 GeV.

ARGONNE
ZING goes 56 million

Another application of accelerated beams in a different field of research has been investigated at Argonne. In the course of development of a booster to increase the injection energy into the 12.5 GeV Zero Gradient Synchrotron, ZGS, they have been ploughing pulses of 200 MeV protons into heavy element targets surrounded by a moderator. The result is intense pulsed fluxes of thermal neutrons (four or more times the input proton intensities) which are very healthy for research in neutron scattering and neutron radiation damage.

The initial proposal was to build ZING (ZGS Intense Neutron Generator) in association with the 500 MeV ZGS booster providing 5×10^{12} protons per pulse at 60 Hz. This was estimated to yield 1.5×10^{15} neutrons per cm^2 per second. Sights have now been raised and a more extensive project, IPNS (Intense Pulsed Neutron Source), is under study by a team led by J.M. Carpenter. The aim is to have the project approved for Fiscal Year 1977 at an estimated cost of around $56 million.

IPNS would start with ZING as its first phase but would later have its own high intensity proton accelerator providing 5×10^{13} protons per pulse at 600 MeV or over. Neutron fluxes would then climb a factor of ten. The two accelerators could operate simultaneously — one feeding a uranium target for scattering experiments, the other feeding a tungsten target for radiation damage experiments — or could be switched independently from target to target.

Copious fluxes of neutrons with energies up to 1 GeV would be available for the first time from IPNS extending the research beyond the capabilities of present research reactors.

DARESBURY
SRS authorized

Authorization for the construction of the Synchrotron Radiation Source, proposed at the Daresbury Laboratory, was announced on 19 May. The project was described in some detail in the issue of November 1973.

The SRS is a 2 GeV electron storage ring which will eventually be capable of holding 1 A. It will provide usable fluxes of radiation in the wavelegnth range from about 0.5 angströms out to radio-wavelengths. The incorporation of superconducting 'wigglers' could later take the lower limit down to 0.1 angströms or below. The initial cost estimates have included money for three beam-lines but this number could be taken as high as ten as the demand for use of the SRS grows.

The cost is set at £3 million (1974 prices) and the construction will be completed in 1979. Teams from Universities throughout the UK will have access to the machine and many scientific disciplines will be represented. From among the machines which are presently booked for research with synchrotron radiation, the SRS will be the finest in the world.

DESY

Performance of DORIS storage rings

Since the discovery of the new particles in November of last year, the electron-positron storage rings, DORIS, at DESY have been running almost without interruption for experiments investigating the particles and their decay modes.

There is a great deal of information to be reaped and with the double arm spectrometer, DASP (see December issue 1974, page 427), the teams at DESY have probably the world's finest system for particle identification in observing the decays. They may have fresh information, beyond that mentioned in the April issue (page 119) to present at the Palermo Conference at the end of June.

During this period, the reliability of machine operation has greatly improved and the integrated luminosity is up to 3 × 10^{34} per cm^2 per day. The beam life is 10 to 20 hours and the filling procedure takes about half an hour (20 s for electrons, 5 min for positrons and about 25 min for readjusting synchrotron ejection and storage ring injection). The number of breakdowns due to component failure is down to about one per day. The operating schedule corresponds to 5500 running hours per year of which two thirds are available for experiments and one third for machine studies.

Machine studies were interrupted for several months in the enthusiasm for looking at the new particles and have only recently been taken up again. They confirmed that the dimensions of the bunches orbiting the storage rings can be made as small as theoretically calculated but the luminosity has not reached the design values because the total currents that can be stored in the rings are much less than expected. This is the problem that is now being investigated again.

The luminosity is not only limited by the number of particles per bunch but also by the total current stored around a ring. In a storage ring operating with very few bunches (typically 1 to 3), the space charge in a bunch is the main limitation of luminosity and therefore of the number of events which can be observed at the beam intersection regions. DORIS was designed to overcome this by using several hundred bunches circulating the rings, thus involving much higher total currents. Experience has shown that such currents are difficult to achieve because of a host of beam instabilities stemming from interaction between the beam and the r.f. accelerating cavities. The cavities oscillate not only at the fundamental mode which is used for particle acceleration but also at higher order modes which excite longitudinal or transverse coherent bunch oscillations, blowing up the beam cross-section and leading to particle loss once the current is increased beyond a certain threshold.

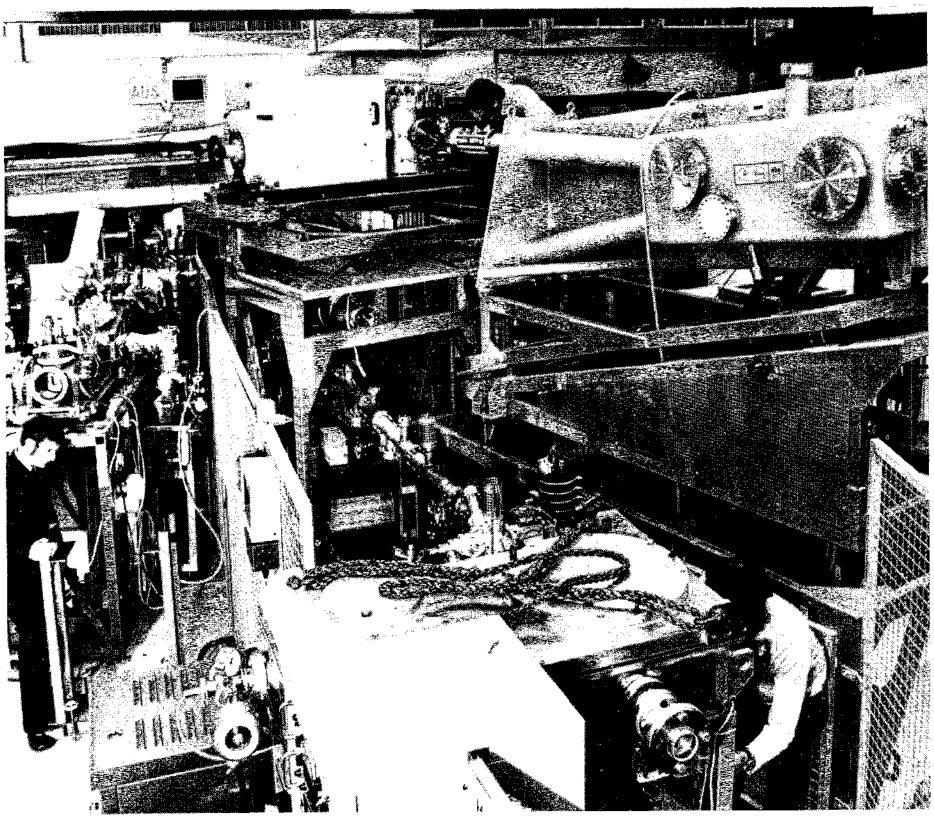
Damping antennas installed in the cavities and ferrite absorbers in the adjacent vacuum chambers have been partially successful in damping some of these higher modes in DORIS and the stability limit has increased by a factor of ten. However, with a partial fill of the ring and a correspondingly larger bunch current, the ferrites caused vacuum breakdown when getting too hot; they will be replaced by another absorbing material.

A mechanism conteracting these coherent bunch oscillations which blow up the beam size is the 'Landau damping' caused by the frequency spread of the particles within the bunch. A very interesting correlation between this damping and the current in a bunch has been observed at DORIS — it goes down with increasing current. Up to 0.5 mA per bunch, the damping effect decreases and the damping time rises from 2 to 9 ms. The 9 ms correspond to damping purely due to synchrotron radiation and is constant up to currents higher than 1.5 mA per bunch; the Landau damping fails to help any longer. For our machine specialists we will launch into the reasons which the DORIS team believe to be at the root of these phenomena.

They may be caused by interaction between the bunches and the vacuum chamber walls, due to the bunch inducing a potential proportional to the current it contains. This potential must be added to the accelerating voltage in the cavities to get the total voltage seen by a particle as it orbits the ring. If the bunch changes synchronous phase during a coherent synchrotron oscillation, it sees a vary-

The synchrotron radiation laboratory which uses the light from the electron beam at the DORIS storage rings. At present, three photon beam-lines are installed, with the configuration indicated on the opposite page, and a fourth is soon to be added. A contract was recently signed to add a second laboratory at DORIS for use in molecular biology research.

(Photo DESY)



ing accelerating voltage in the cavities while the potential from the vacuum chamber walls stays constant.

The oscillation frequency of the bunch as a whole is given by the r.f. voltage only but a single particle in the bunch sees a deformed piece of the sine curve and thus has a different frequency. Normally, such differences in frequency change coherent oscillations into incoherent oscillations — Landau damping. If, however, the frequency of the whole bunch is too far from that of a single particle, this damping vanishes leaving only the weaker synchrotron radiation damping with its correspondingly lower stability threshold.

These problems are not likely to be solved overnight. To get at the oscillations in time would need very fast feedback systems (a few hundred MHz bandwidth) which are still somewhat beyond the state of the art! The most promising route to the higher luminosity at present, seems to be to achieve the same total current in a smaller number of bunches. This is not unwelcome to the high energy physicists because the background events picked up by their detection systems are reduced in this way.

Further developments at DORIS will include a reconstruction, during a shutdown in August, of the injection systems to the two rings in order to speed up injections at higher energies by saving time needed for energy ramping. It will then be possible to transfer electrons and positrons from the synchrotron to the storage rings at energies up to 4.3 GeV.

Meanwhile the idea of proton injection into DORIS has not been forgotten (see September issue 1972, page 281), this will enable possible beam-beam interaction effects between orbiting protons and electrons to be studied in readiness for higher energy electron-proton storage rings which have a lot of physics attraction. The Van de Graaff for proton injection into the DESY synchrotron is ready for shipment from the USA and the special r.f. cavity (ex Princeton-Pennsylvania Accelerator) for proton acceleration in the synchrotron will probably be installed during the August shutdown.

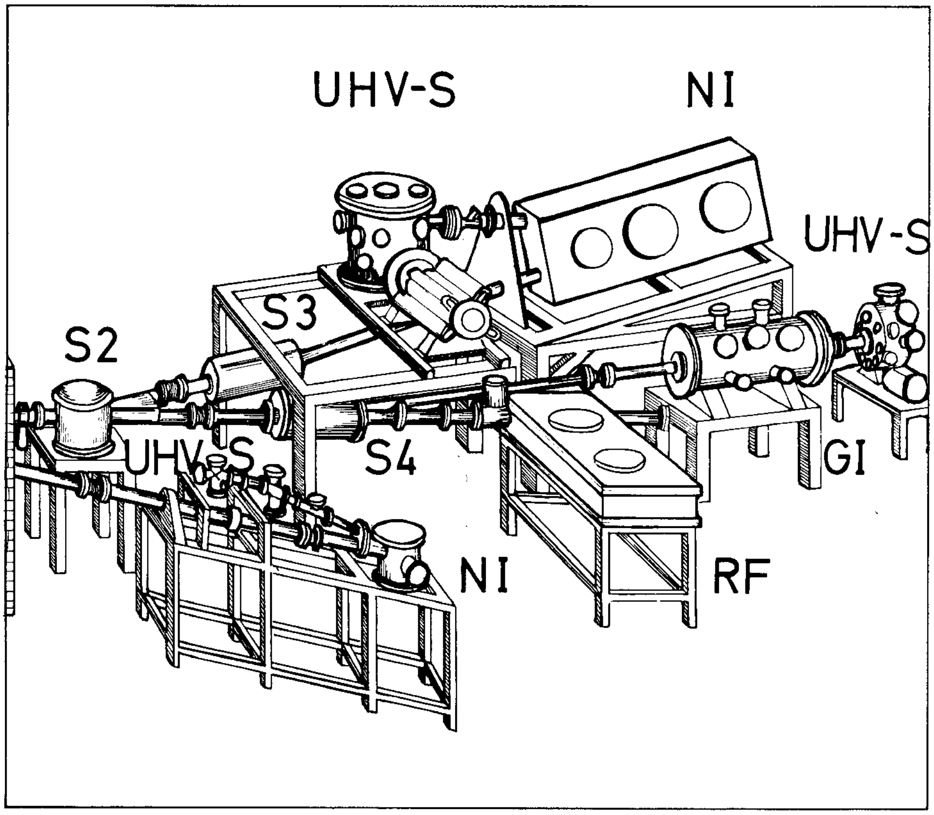
Longer term machine thoughts remain, of course, concentrated on PETRA one of the two higher energy electron-positron colliding beam projects in Europe. The other is EPIC proposed by the Rutherford Laboratory. PETRA was described in some details in February, page 37; EPIC in January, page 12.

A panel has been appointed within the Federal Republic of Germany to examine relative priorities of a number of pure research projects including PETRA. Their report, which is expected by the end of July, is the next step en route to full authorization of construction. Meanwhile as many preparations as can reasonably be made in the present limbo are going ahead.

Rather detailed engineering drawings have been completed and submitted to the appropriate authorities for cost estimates to be checked. A series of test drillings on the site have revealed no unpleasant surprises. A prototype r.f. accelerating cavity (a five cell, drift tube type made of aluminium) is being built; it could find application also in taking DORIS to higher energies. Tenders are out for the prototype magnet (vertical aperture is now up to 7 cm to take care of high horizontal-vertical coupling which is a possible worry uncovered by work on the Berkeley-Stanford PEP storage ring proposal). The Cornell (M. Tigner) new injection idea has been studied and temporarily set aside in competition with the initially proposed scheme involving DORIS, particularly because of concern about multibunch instabilities (a topic on which, as described above, the DESY machine people are not particularly delighted to be the world's experts). All is being lined up for the start of construction next Spring if authorization is forthcoming.

Another strong topic in the DESY repertoire is research using synchrotron radiation from the orbiting electron beams. The Laboratory was the European pioneer of such research and two separate facilities are set up at the 7.5 GeV synchrotron — one of them on the initiative of the European Molecular Biology Organization, EMBO, for biological studies.

Now that DORIS is in action, the quality of the radiation that it can provide for experiments is in general very much better than at the synchrotron. The light intensity, for example, is up by a factor of a hundred and the light source is much more stable. For some experiments the bunch structure of the orbiting electron beam can also be put to use — the emerging pulses of light, as each 2.8 cm long bunch



passes the beam port, can initiate phenomena whose subsequent evolution can be followed before the next pulse arrives. Proposals for such experiments are under examination.

From a single beam port, three beam lines are fed at present and a fourth is soon to be installed. The degree of sophistication of the experiments is steadily increasing. They involve about 45 scientists from a wide variety of disciplines in a dozen groups.

Recently a contract was signed between DESY and the European Molecular Biology Laboratory, centred at Heidelberg, covering co-operation in the use of synchrotron radiation. The EMBL scientists will have a second facility on the storage rings to support a research programme for the use of the light from DORIS, including such novel studies as the observation of structure changes during muscle contraction.

KARLSRUHE
Towards a superconducting proton linac

Studies on the feasibility of a proton linear accelerator with superconducting accelerating elements have been going on for several years at the Institut für Experimentelle Kernphysik, Karlsruhe. They aim to reap the benefits of average currents of the order of several milliamps with duty cycles of 100 % which are not feasible with conventional linacs because of their high power consumption.

At present, two types of accelerating structures are under attack — superconducting helices for the lower energies and an Alvarez-type drift tube structure for the subsequent energy stage. Both types are being fabricated from niobium and are being installed for testing in a several stage linac at Karlsruhe.

Due to the high Q-value in both elements, it is most important to keep close control of frequency and phase. This is particularly tedious for helices which not only look like bed-springs, they behave like bed-springs — they are very sensitive to mechanical oscillations which change their frequency. Now, however, this problem seems to be mastered. In a recent experimental run at Karlsruhe, two helical accelerator sections were coupled at a given frequency with the required fixed phase relation. Stable operation was demonstrated by the acceleration of a bunched proton beam of roughly 200 μA to 1.28 MeV.

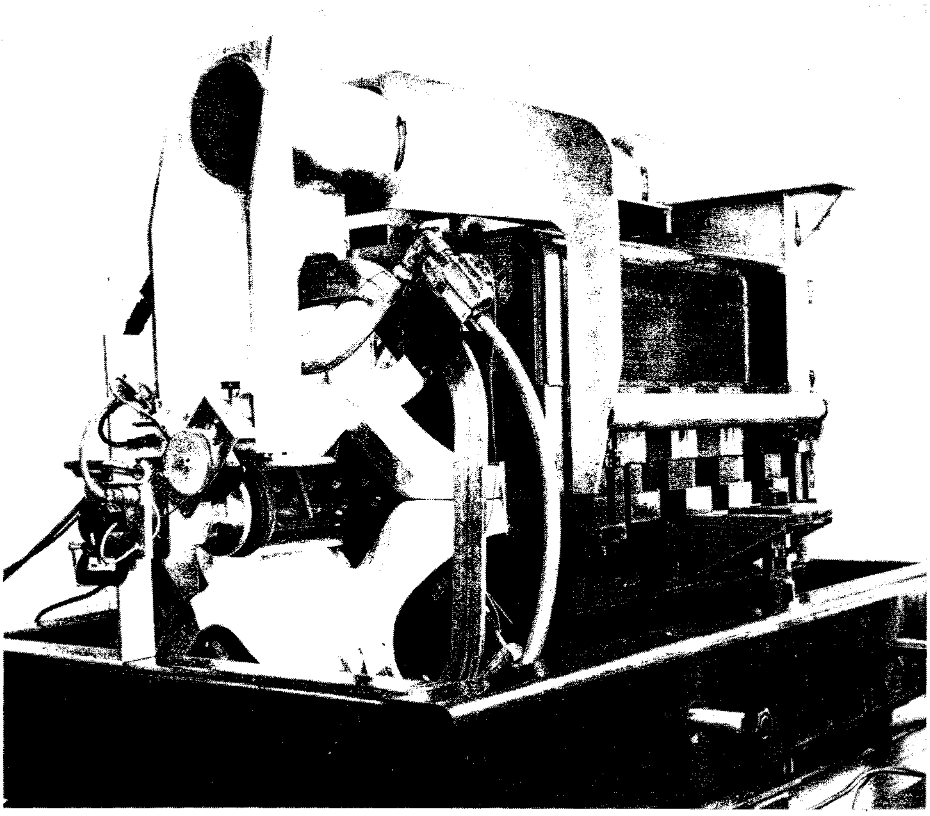
The experimental set-up consists of a conventional preaccelerator (injection energy of 750 keV), a bunching system and a 3 m long cryostat for operation at 1.8 K which is connected to the refrigerator through long cryogenic transfer lines. The cryostat contains the two helices and two superconducting quadrupoles for focusing. Each helix section is a 0.6 m long niobium tube of 0.2 m inner diameter into which several electrically coupled half wavelength helices are mounted.

Each helix section is fed from its own 90 MHz r.f. unit with a 1 kW amplifier and three control circuits, one of which ensures phase synchronization. It does this by means of a coaxial short circuit of variable length which is outside the croystat at room temperature with a special r.f. feed coupling it to the superconducting section. By moving the position of the short circuit along the coaxial line, the division of r.f. energy between the helix and the coaxial line is varied, leading to a stabilization of the helix phase relative to a given reference value in spite of frequency variations it is feeling due to mechanical oscillations. The control circuit, operating at 10 kHz has plenty of time to effect changes caused by mechanical oscillations which are in the 50 Hz range.

Stable phase synchronization of both helices was maintained at high accelerating fields for about a hundred hours. The energy gain of the beam in one or both helices was used to determine the key r.f. parameters of the set-up. The quality of superconducting surfaces in the helix sections proved to be better than was required, giving a peak surface field of 16 MV/m corresponding to accelerating fields of up to 1.4 MV/m for the low energy protons.

The encouraging results of this experiment and the reliable operation of the cryosystem in the refrigerator mode for almost 1000 hours means that additional sections of the helical structure will now be added to complete the accelerator by 1976. It will result in 6 MeV protons which will then be transferred into a drift tube test structure with accelerating fields of 2 to 3 MV/m. In laboratory experiments with an Alvarez resonator at

720 MHz, accelerating fields of 3 MV/m with sufficiently low r.f. losses have already been obtained.



A prototype focusing quadrupole (62.5 mm aperture diameter) for the proposed electron-positron storage ring, PEP, being tested at Stanford. The magnetic field measurement system consists of a long rotating coil linked to an on-line computer. Absolute calibration of the magnet and rapid determination of the strengths of the multipole fields are possible.

(Photo SLAC)

ECFA urges European e^+e^- ring

At a Plenary Meeting on 6 June, ECFA, the European Committee for Future Activities (European Committee for Future Accelerators that was), passed a resolution in support of the construction of a higher energy electron-positron storage ring in Europe. ECFA is representative of the full high energy physics community in Europe and reflects the concern of the community to have world class research facilities for electron physics, in addition to the research facilities for proton physics which are concentrated at CERN.

The statement reads —

'The European Committee for Future Activities, ECFA, considers that

i) electron-positron storage rings with centre of mass energy above 20 GeV would be an extremely valuable addition to the European high energy physics facilities, complementing existing proton accelerators and national electron-positron facilities at lower energies,

ii) it is of primary importance that such a project is realized with a minimum of delay,

iii) the exploitation of the storage rings should be open to the European scientific community,

iv) there should be no duplication of similar accelerators within Europe.

In view of these considerations ECFA will, if the Laboratories concerned agree, set up a working group to study and make recommendations about the international exploitation of an electron-positron storage ring facility.'

As mentioned above in reporting work at DESY, there are two projects PETRA and EPIC — under discussion in Europe. The concern for an early start on construction of one of these machines, reflected in the ECFA statement, is related to the existence of the equivalent project, PEP, at Berkeley/Stanford in the USA. The new particle discoveries, in particular, hold out the tantalising prospect that the first of these machines to come into operation could cream off some spectacular physics.

SERPUKHOV SKAT bubble chamber in action

The heavy liquid bubble chamber, SKAT, took its first pictures at the Institute for High Energy Physics, Serpukhov, on 27 May. Within a few days of operation with a neutrino beam from the 76 GeV proton synchrotron, over a hundred neutrino interactions were captured on photographs.

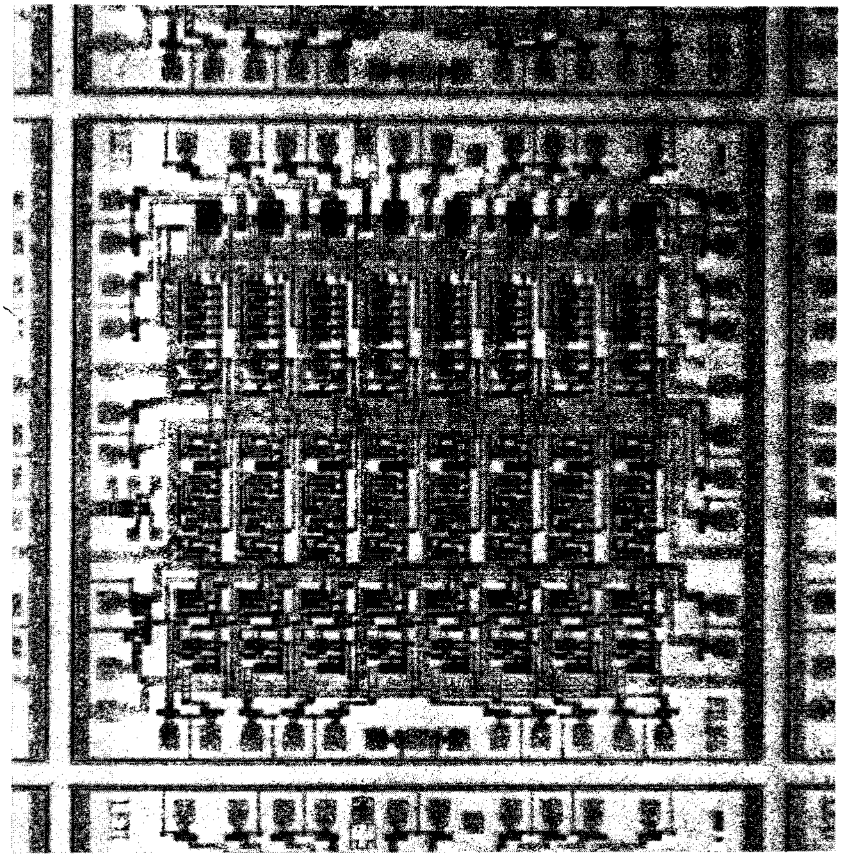
The chamber has a volume of 7 500 litres of which 6 200 litres are visible to the cameras. The height of the heavy liquid region is 1.3 m and its depth 1 m. A 2.5 T magnet achieves 5 % uniformity in the visible volume.

The most interesting technological feature of SKAT is a huge window, of optical glass quality, 4.2 m long and 14 cm thick along one wall of the chamber. Cameras look through this window and record the whole chamber visible volume on single photographs (240 × 70 mm film). This is in contrast to other large chambers which divide the volume into regions recorded by separate cameras. SKAT is now launched on a programme of neutrino physics.

8 CHANNEL MONOLITHIC INTEGRATED CIRCUIT

(Amplification, Fast Or, Delay, Strobe, Memory, Memory Or, Read-out gate)

FOR MULTIWIRE PROPORTIONAL CHAMBERS



LSI / MOS TECHNOLOGY

☐ 40 Pin dual in line ceramic package.

PERFORMANCES

☐ Threshold voltage: 2 mV
☐ Write pulse length: 90 ns
☐ Power dissipation: 1.6 W
☐ Radiation proof up to: 2.10^{10} α (645 Mev)/cm^2 or 2.10^{13} p (1 Gev)/cm^2

☐ **Low cost: about $ 10/Channel** mounted on the chamber.
☐ Samples available from stock – few months delay in 1000 quantity.

REFERENCES

CEN / SACLAY: Used on large MWPC's electronic equipment.
CERN (Geneva): On test.

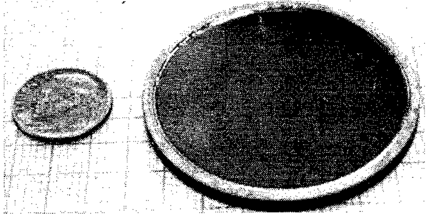
For data sheets, application reports, delay, prices or any information you may need for your particular application, write or call:

E.F.C.I.S. BP. 85, Centre de Tri 38041 GRENOBLE CEDEX (FRANCE)
Tel.: (76) 97 41 11 — Telex: ENERGAT GRENO 32 323

KEVEX Si (Li) DETECTORS

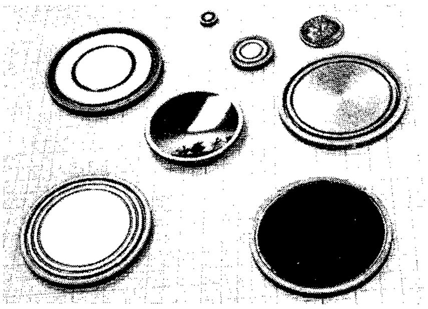
Charged Particle Analysis
● Uncooled Detectors ●

Kevex Si (Li) ultra high resolution detectors range in size from 10 mm^2 active area to 1,500 mm^2. A 750 mm^2 detector is specified at 16 keV FWHM for 624 keV conversion electrons (Cs-137).



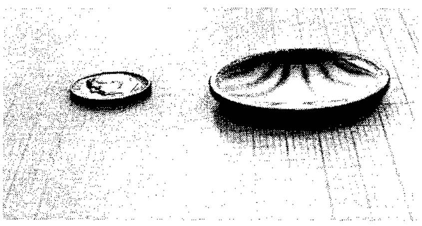
Size comparison: U.S. dime vs. 1500 mm^2 Si (Li) detector.

Two concentric Si (Li) detectors with negligible cross-talk are formed on a single silicon wafer. The outer detector may be operated in anti-coincidence with the central detector. A charged particle telescope consists of several such detectors assembled along a common axis.



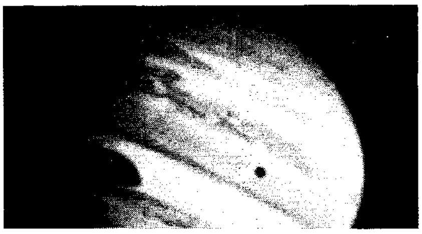
A sampling of the variety of Si (Li) detectors available to the physicist.

Grounded guard-ring concentric detectors (three rings) exhibit improved signal to noise ratios.



Size comparison: U.S. dime vs. spherical detector.

Spherical Si (Li) detectors with axial radii on the order of 50 – 100 mm offer uniform radial thickness for omnidirectional dE/dx measurements.

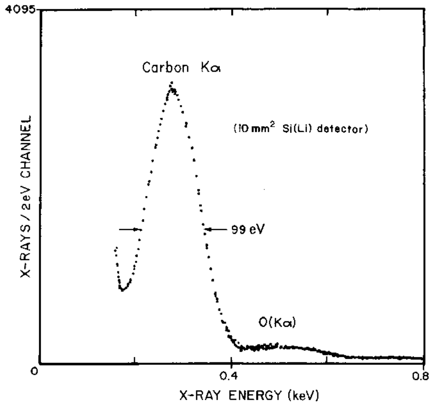


Detector reliability is vital on a 21 month mission.

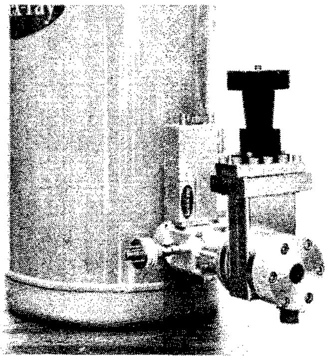
Sixteen Kevex Si (Li) detectors performed faultlessly in both PIONEER missions to Jupiter. As a result of this success, Kevex is the only detector manufacturer selected to supply Si (Li) detectors for the forthcoming MJS (Mars, Jupiter, Saturn) experiments.

X-Ray Photon Spectroscopy
● Cooled Detectors ●

MICRO-X (windowless) Si (Li) detectors analyze K shell x-rays emitted by excited oxygen, nitrogen, carbon and — most recently — boron.

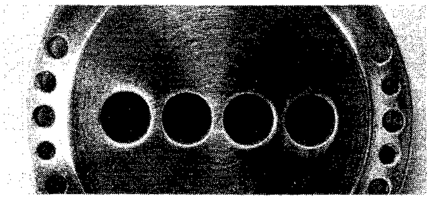


MICRO-X detectors feature minimum dead layer and high resolution.



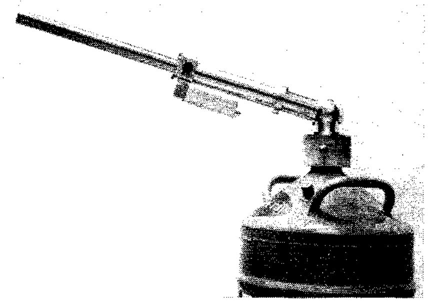
MICRO-X detectors can be tailor-made to your requirements.

Fusion experiments: Laser induced x-rays are analyzed by four Si (Li) Kevex detectors mounted on a single cryostat. Each detector is multiplexed to yield 4x the count-rate efficiency as compared with one detector.



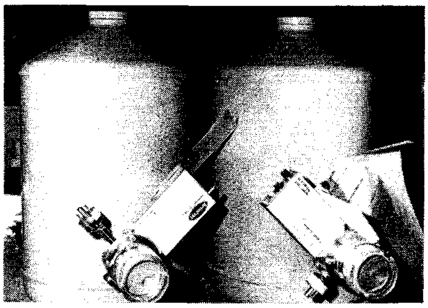
Fusion experimentors demand state-of-the-art Si (Li) detectors.

More than a score of laboratories use Kevex detectors for quantitative multi-element analysis using high energy particle bombardment. In a simple matrix, as little as 10^{-12} grams of an element can be detected.



Cryostat configurations are optimized for each application.

Kevex large area (500 mm^2) low background detectors yield specified resolution of 325 eV FWHM at 5.9 keV.



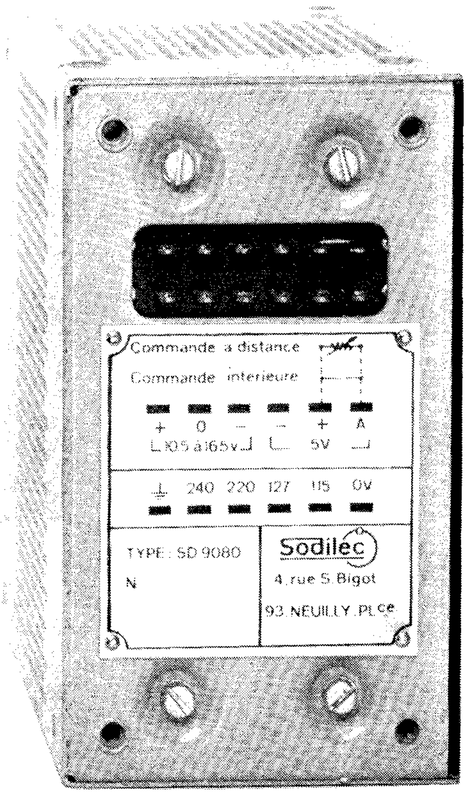
A matched pair of 500 mm^2 Si (Li) detectors.

Handbook—X-RAY ENERGY SPECTROMETRY — 160 pages by R. Woldseth, Ph.D. A practical guide on successful applications of x-ray photon spectroscopy. Useful tables, graphs, experimental data, etc. — a single reference source. $7.95 plus 50 cents shipping and handling (overseas — add $3.00 for air parcel post).

For complete details on Kevex Si (Li) detectors, contact:

kevex

KEVEX CORPORATION
Nuclear Physics Division
898 Mahler Road
Burlingame, California 94010, U.S.A.
Telephone (415) 697-6901
TWX 910-371-7249


Commande à distance
Commande intérieure
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L 0,5 à 16,5 v
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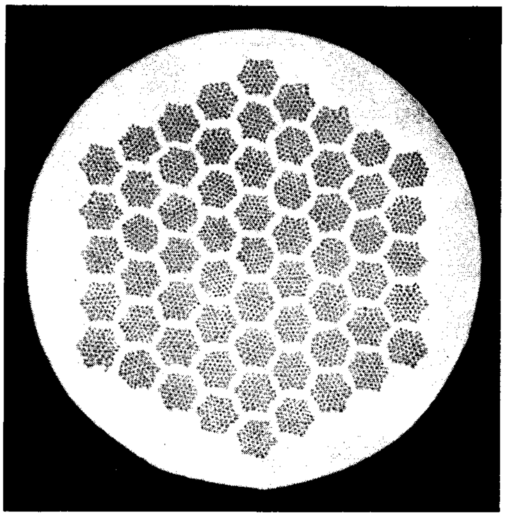
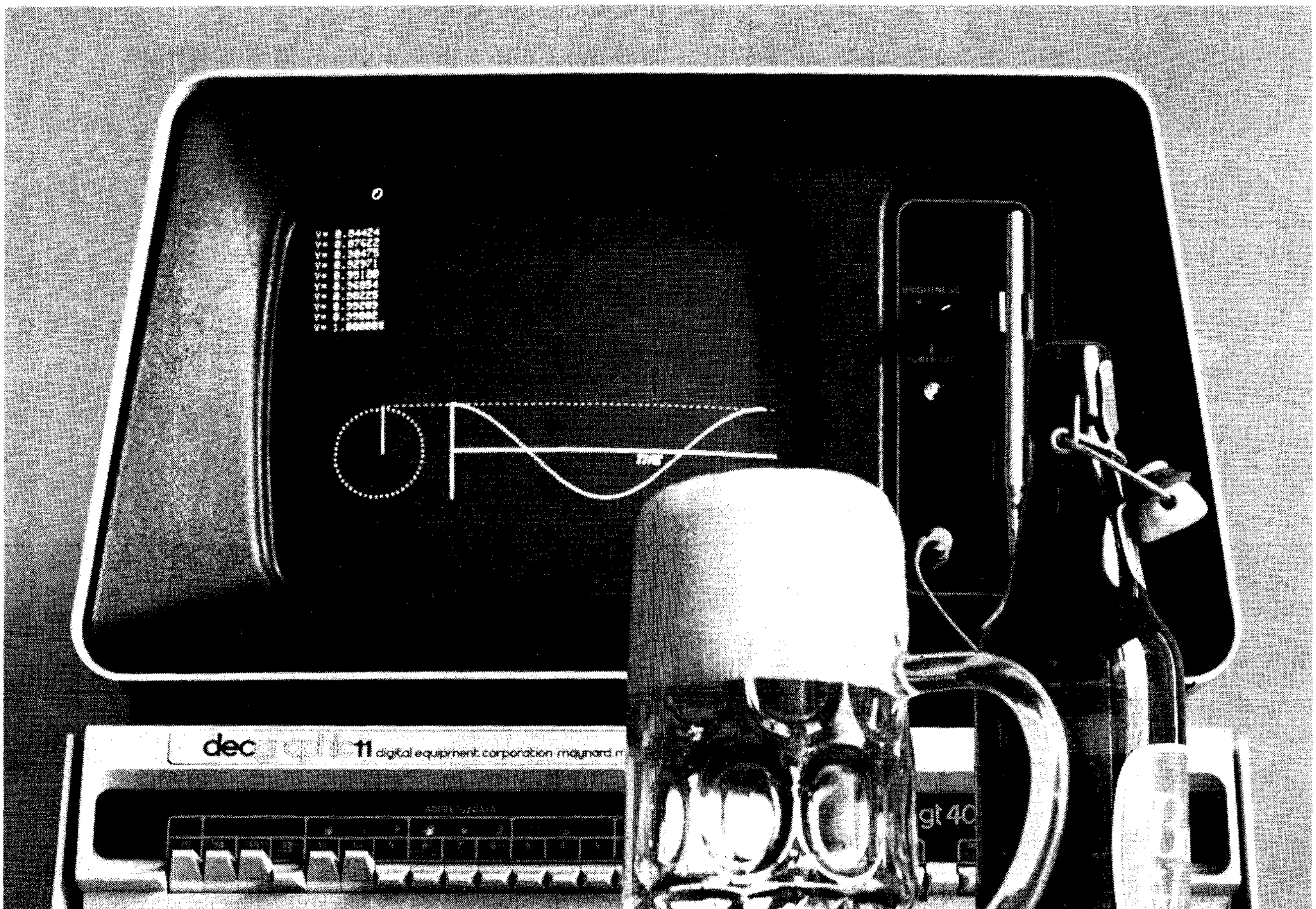


Graphics computing is no longer a rich man's tool.



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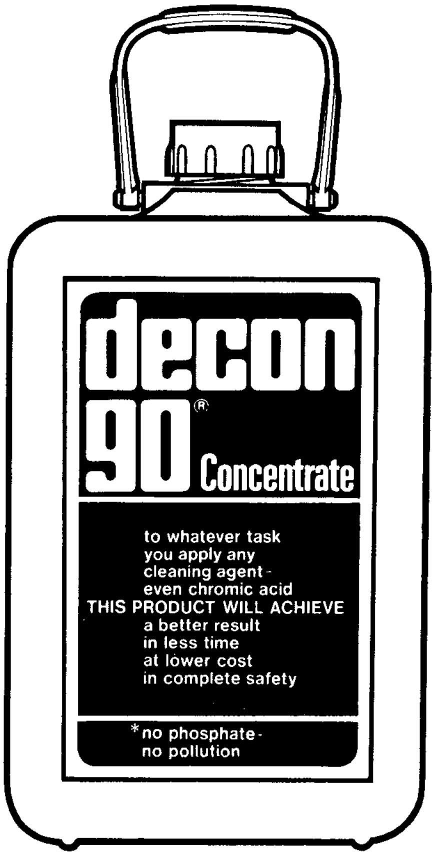

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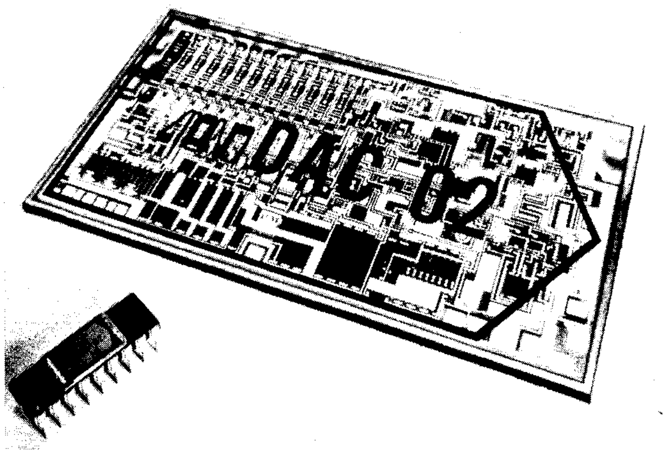
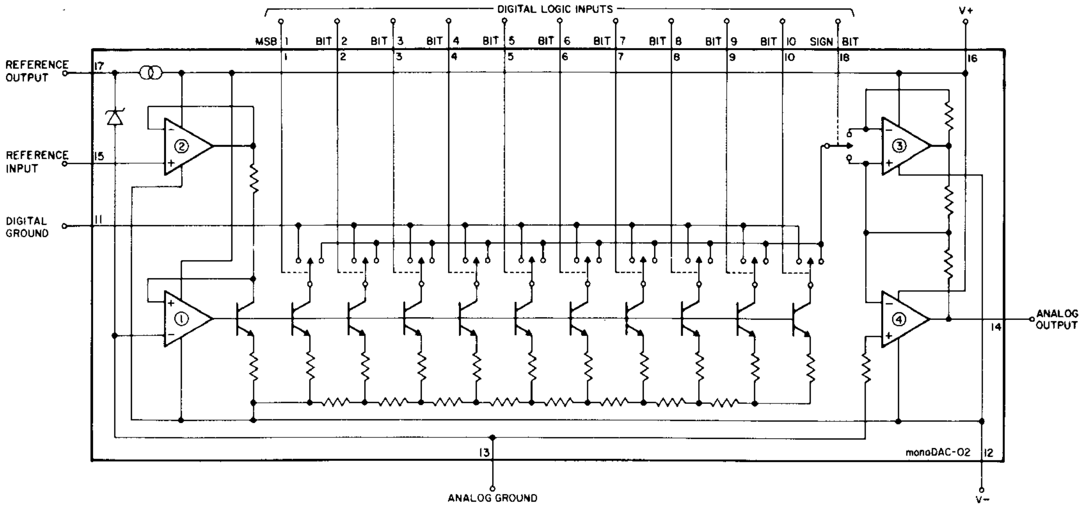


GENERAL DESCRIPTION

The monoDAC-02 is a complete 10 bit plus sign D/A converter on a single 82 x 148 mil monolithic chip. All elements of a complete sign/magnitude DAC are included – precision voltage reference, current steering logic, current sources, R-2R resistor network, logic controlled polarity switch and high speed internally compensated output op amp. Monotonicity guaranteed over the 0° to 70° C temperature range is achieved by the untrimmed diffused R-2R resistor ladder network. The buffered reference input is capable of tracking over a wide range of voltages, increasing application flexibility. The wide power supply range, low power consumption, choice of full scale output voltages and sign/magnitude coding assure utility in a wide range of applications including CRT displays, data acquisition systems, A/D converters, servo positioning controls, and voice and music digitizing and reconstruction systems.

SIMPLIFIED SCHEMATIC AND PIN CONNECTION DIAGRAM



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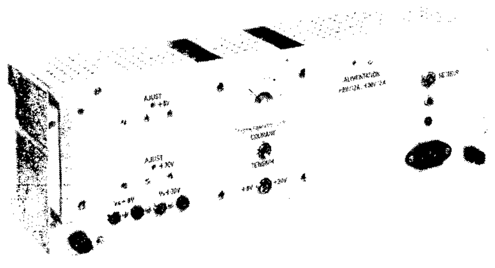

Version I: + 8V 12A
+ 30V 2A

Version II: + 8V 10A
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Protections: Etablissement, coupure ⩽ 1 ms
La chute de l'une quelconque des tensions entraîne la disparition de l'autre en un temps ⩽ 1 ms

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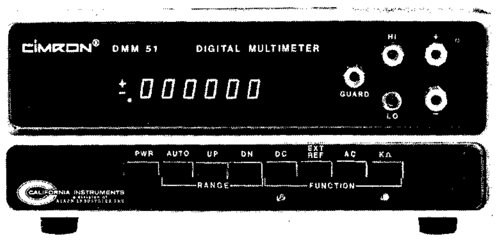

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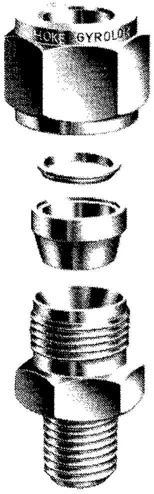
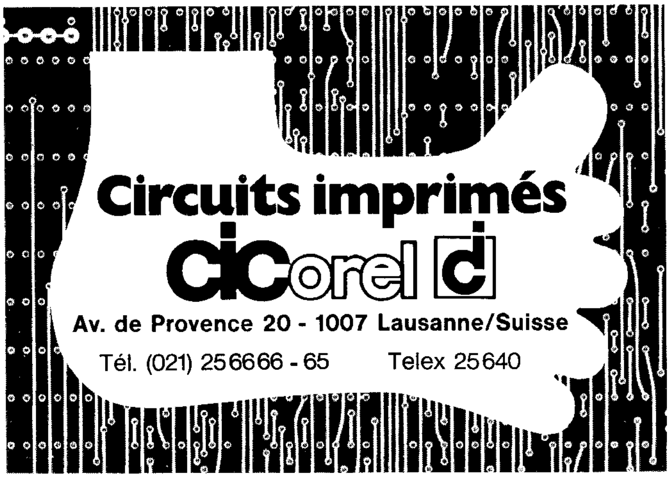
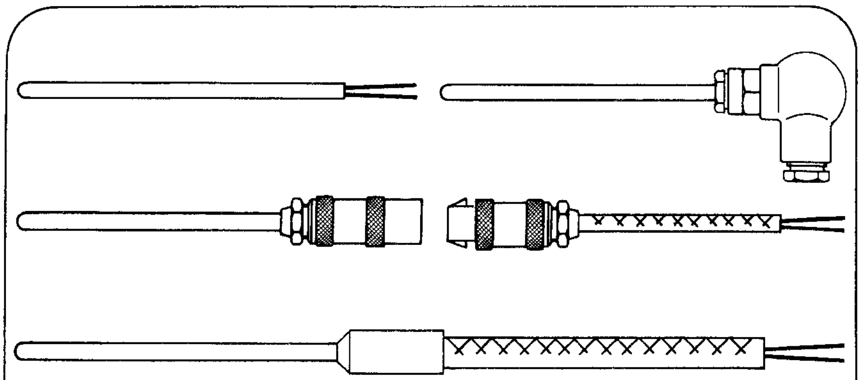

HOKE GYROLOK





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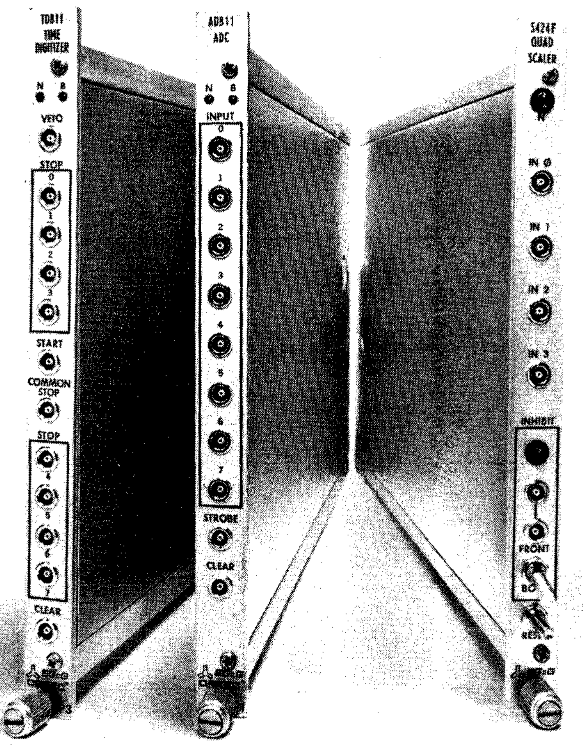

For complete information on these and other CAMAC modules by EG&G/Ortec, contact your nearby EG&G/Ortec representative or EG&G/Ortec Incorporated, 110 Midland Road, Oak Ridge, Tenn. 37830. Phone (615) 482-4411. Telex 055-7450. 74 offices in 49 countries providing sales and service around the world.

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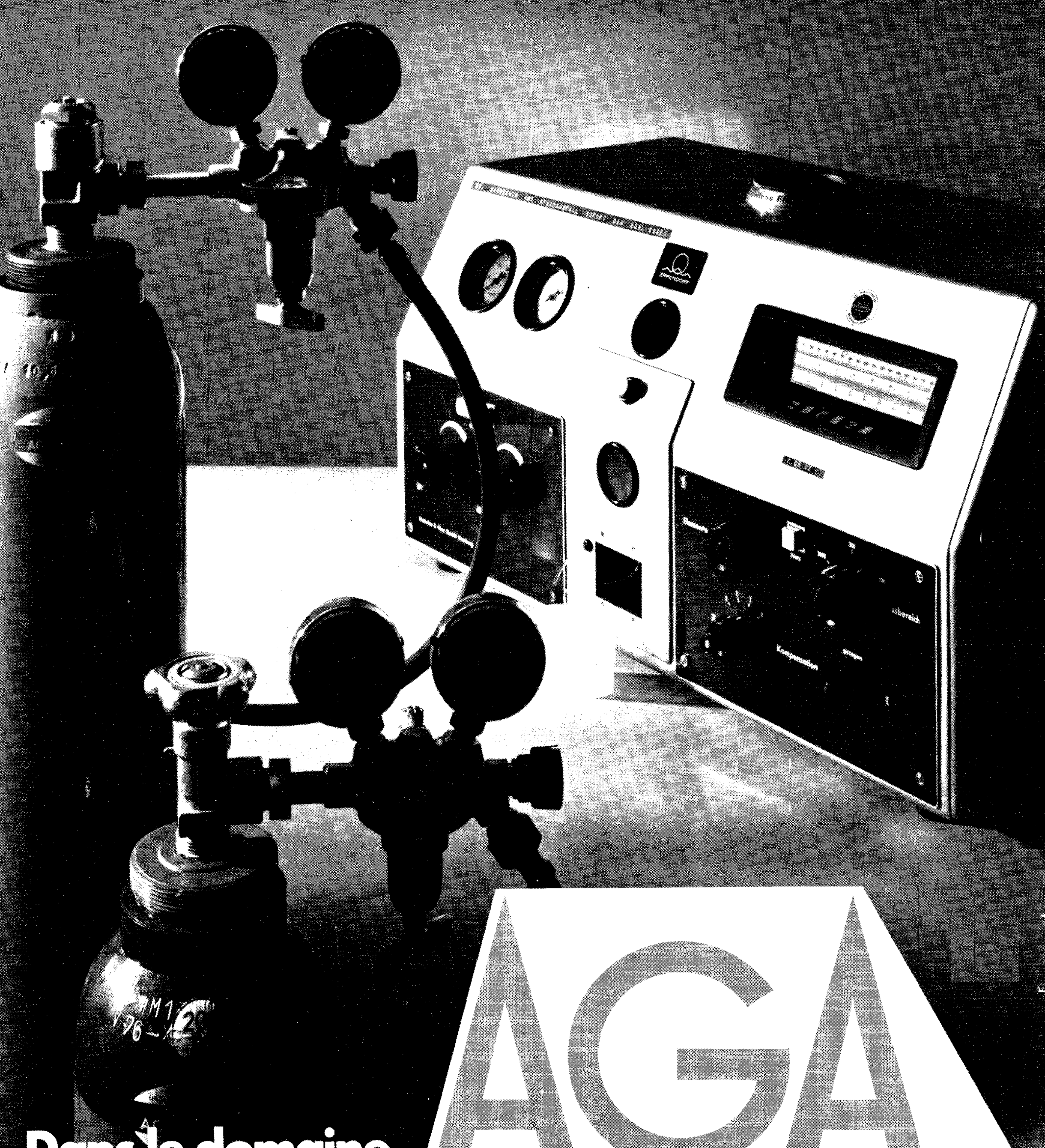

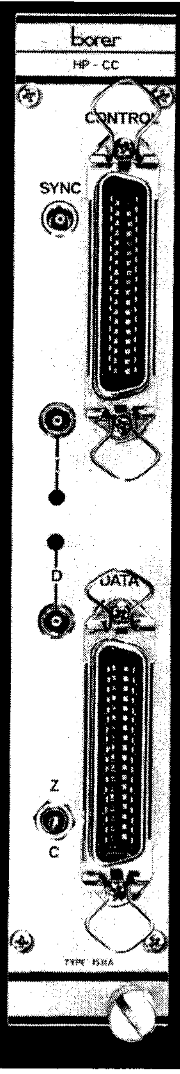
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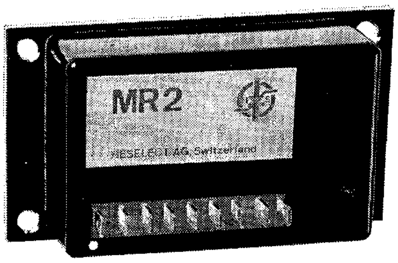
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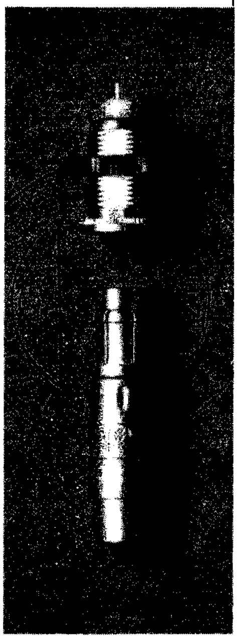
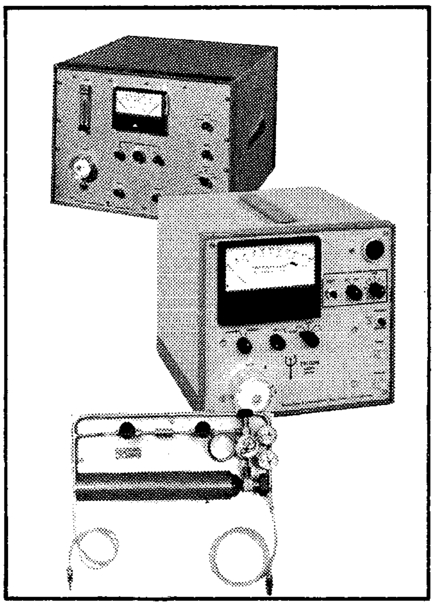


Count on Johnston for accurate, dependable radioactive gas monitoring.



Beta Gas Monitors
TRITON systems monitor tritium, argon-41, carbon-14, chlorine-36, fluorine-18, krypton-85, radon-222, sulfur-35, xenon-133, xenon-135, and gamma radiation. Features: 0.5 micron absolute filters, electrostatic precipitators, positive displacement pumps, gamma compensation to 5mR/hour.

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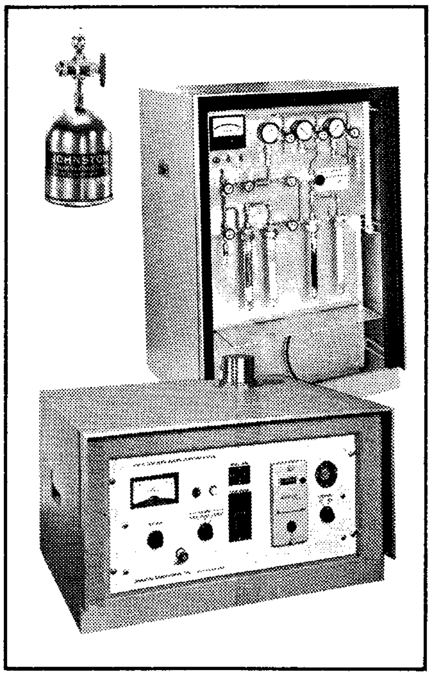
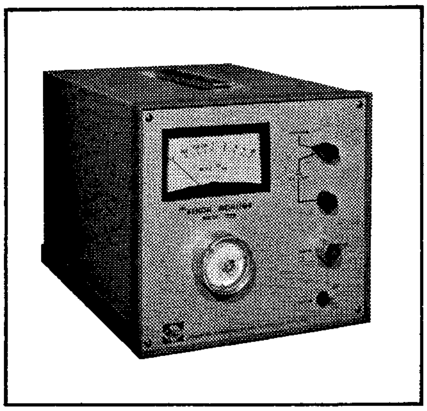


Radon Analyzer System
RADON SYSTEM for low-level analysis of radon samples from human respiration, mine, or water supply effluents, air. Includes Radon Concentrator (RCTS-2) which purifies, concentrates, and transfers samples to Radon Counter (LAC-2). Its scintillations produced by Radon gas are counted by photo-multiplier in Radon Analyzer (LLRC-2).



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Radiation hazards may result if multi-dose ^{133}Xe source containers are used or if expired air and ^{133}Xe from a patient will leak into the laboratory air.
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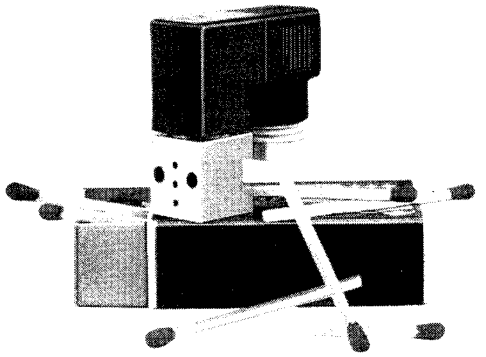

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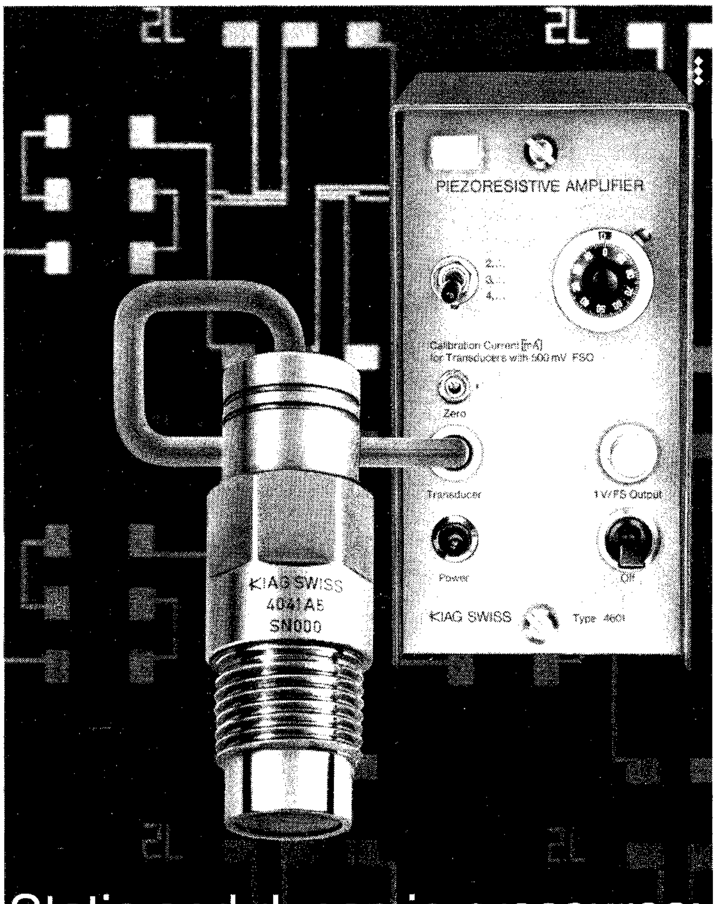
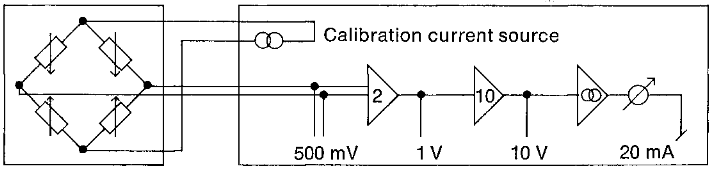


Static and dynamic pressures: measure them with piezoresistive instruments

Measure without maths

a feature of the new piezoresistive system too. The "calibration current", which standardizes the transducer full scale output, simplifies measurements to:
● dial calibration current ● measure



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Piezoresistive pressure transducers of novel design have outstanding characteristics:
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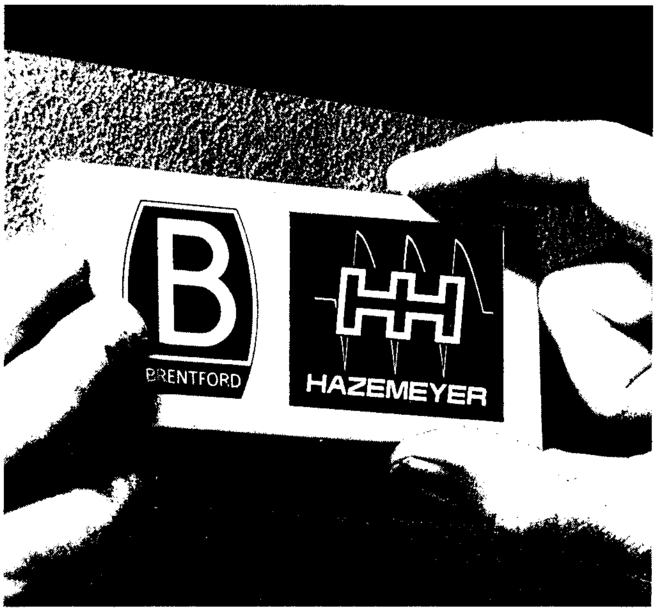

Powerful partnership...

Now, Hazemeyer of Holland and Brentford of England bring you a vast pooled experience in higly stabilized DC power supplies

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Examples:

- Highly stabilized DC power supplies for currents up to 20 kA and voltages up to 2 kV are powering amongst others bending - and focussing magnets for particle accelerators in Geneva (CERN), Hamburg (DESY), Harwell (Rutherford Laboratory), Daresbury (NINA).
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Brentford

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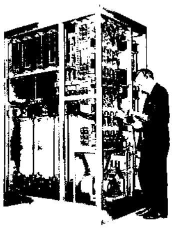

Hazemeyer

Hazemeyer B.V. RT - department
P.O. Box 23, Hengelo,
Holland,
Teleph. 05400 - 62723
Telex 44892

The power section of a 185 volt 1100 ampere Brentford/Hazemeyer highly stabilized DC power supply.