CERN COURIER

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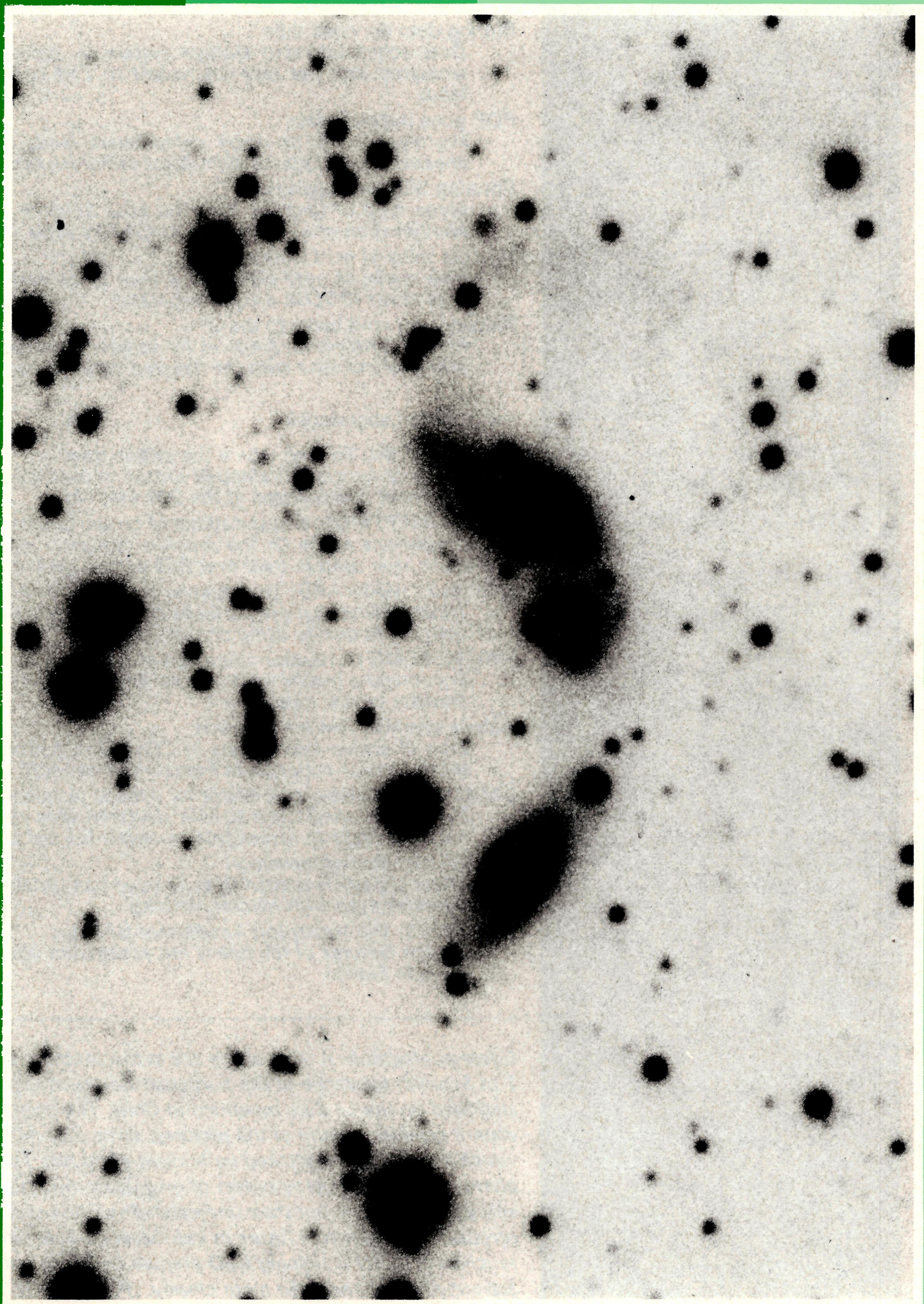

CERN, the European Organization for Nuclear Research, was established in 1954 to '... provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto'. It acts as a European centre and co-ordinator of research, 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: A view of the sky in the southern hemisphere as seen by the 1 m Schmidt telescope of the European Southern Observatory, ESO, stationed on the La Silla mountain in Chile. The photograph reveals three distant galaxies (centre of the picture), some 300 million light years away, which seem to be interlinked by bridges of matter. The scale of these phenomena is very many orders of magnitude from those studied at high energy accelerators but their understanding often seems to invoke the same physical processes that figure in individual particle interactions. It is a nice touch that CERN is helping ESO prepare its 3.6 m optical telescope to study astrophysical phenomena more closely. (Photo ESO)

Physics Nobel Prize 1975

O. Kofoed-Hansen

Before 1949 every physicist knew that the atomic nucleus does not rotate. The reasoning behind this erroneous belief came from the following arguments. A quantum-mechanical rotator with the moment of inertia J can take up various energy levels with rotational energies equal to $h^2(I+1)I/8\pi^2J$, where h is Planck's constant and I is the spin. As an example, I may have values 0, 2, 4, . . . etc. If the nucleus is considered as a rigid body, then the moment of inertia J is very large and the rotational energies become correspondingly very small. Consequently states of high spin and low excitation energy would exist and isomers would thus decay rapidly via these states. Since isomers do in fact exist, it seemed that the nucleus does not rotate.

In 1950, J. Rainwater pointed out that the observed large nuclear quadrupole moments could be accounted for by unifying the Mayer-Jensen nuclear shell model and the Niels Bohr liquid drop model into a picture which has since been elaborated considerably by A. Bohr and B. Mottelson. Using these ideas, large quadrupole moments can be combined with small effective moments of inertia and both low lying isomer states and higher lying rotational states can occur.

In the terms of A. Bohr, one has a deformation that travels as a surface wave. This point nowadays sounds trivial but at the time it was first mooted, it was a major breakthrough in thinking about the nucleus and opened a whole new field of research in nuclear physics. This work has for years been guided by the inspiration of Bohr and Mottelson.

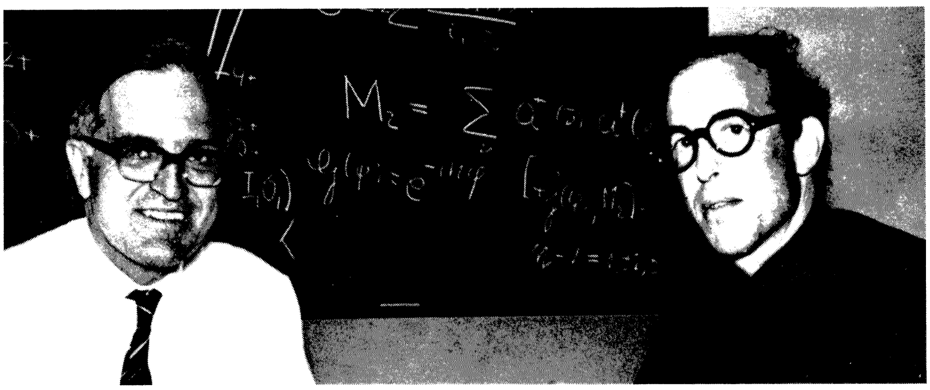
An entire industry of nuclear research thus began with Rainwater's brief contribution to Physical Review in 1950 entitled 'Nuclear energy level argument for a spheroidal nuclear model'. Today a fair-sized library is needed in order to contain all the papers written on deformed nuclei and on the related experimental results. Some of the major results concern rotational states, Coulomb excitation, intensity rules in decay branches, the nuclear physics equivalent of superconductivity, vibrational states, the Nilsson model, models of fission, etc.

Bohr, Mottelson and Rainwater received the 1975 Nobel prize in physics for this work. All three remain active in physics and have repeatedly opened new doors. Bohr and Mottelson have stayed mainly in nuclear physics while Rainwater has moved to higher energies. Needless to say, they are all three highly respected members of the scientific community.

Aage Bohr was born in Denmark in 1922. At the time when he would normally have been concentrating on his studies, life in Copenhagen had its difficulties and he and his father, Niels Bohr (Nobel Laureat 1922), escaped to join a British research team from 1943-45. From December 1943 he was actually in the USA. Back in Denmark after the war, he obtained his Ph. D. in 1954 for work on rotational states in atomic nuclei. His thesis was thus based on the work for which he has now been recognized at the very highest level. He is Professor at the Niels Bohr Institute of the University of Copenhagen and a member of the CERN Scientific Policy Committee.

Ben Mottelson was born in the USA in 1926 and has, for many years, been a naturalized Dane. I know little about his education and pre-Danish background. He seems studiously to avoid filling in the forms which the innumerable 'Who's Who' compendiums have sent to him. The subsequent write-ups are all very laconic and most frequently list him simply as a Professor at NORDITA without further comment.

James Rainwater was born in the USA in 1921. He studied at the California Institute of Technology and later at Columbia University, New York (Ph. D. in 1946) where he has felt at home ever since. He has major research achievements in many other fields. He invented and applied (together with W. Havens) the time of flight method for neutron spectroscopy, he is the constructor of the Nevis synchro-cyclotron, he introduced the field of mesic atoms and has a long list of experiments to his name.



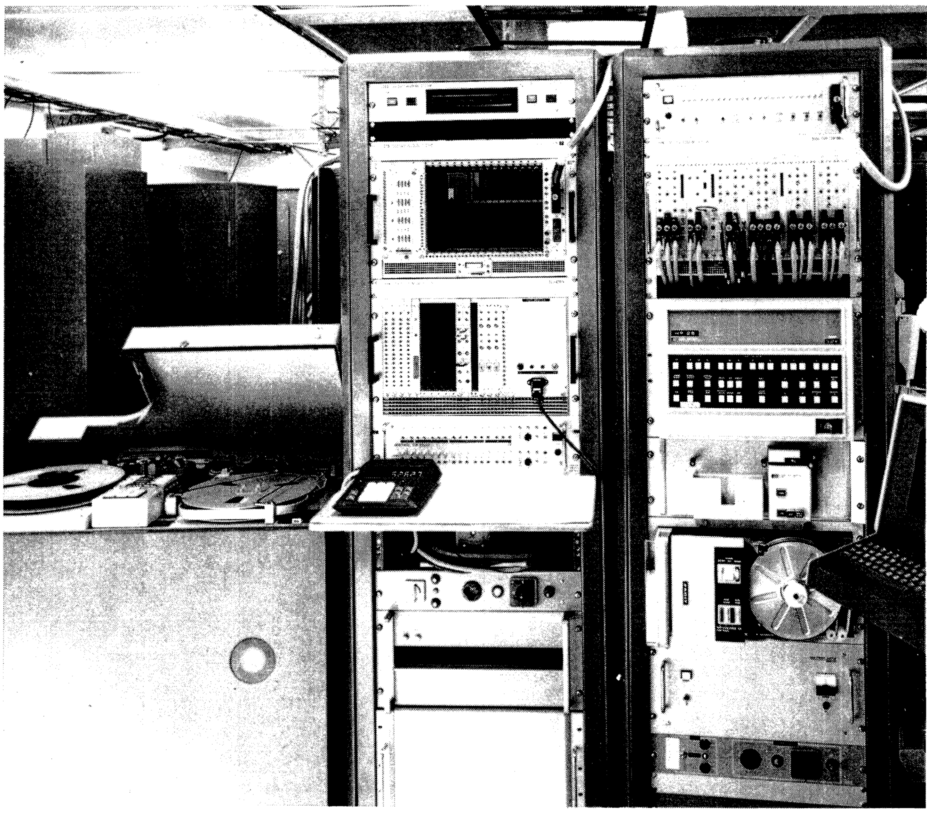
Nobel prize winners, left to right, A. Bohr, B. Mottelson and J. Rainwater.

(Photos Keystone Press, Photopress)

CERN News

The video tape data recording system which has recently come into use for an experiment at the Intersecting Storage Rings. The IVC tape unit is on the left and alongside is the controller the minicomputer and CAMAC electronics. The system can pack data on tape so that one reel holds as much information as 250 or more conventional magnetic tapes.

Below: A closer look at the video tape deck. The crucial element appears in the centre of the picture where the tape winds in a helix around the cylinder carrying the recording heads. Data is written at an angle across the width of the tape as the cylinder revolves at high speed.



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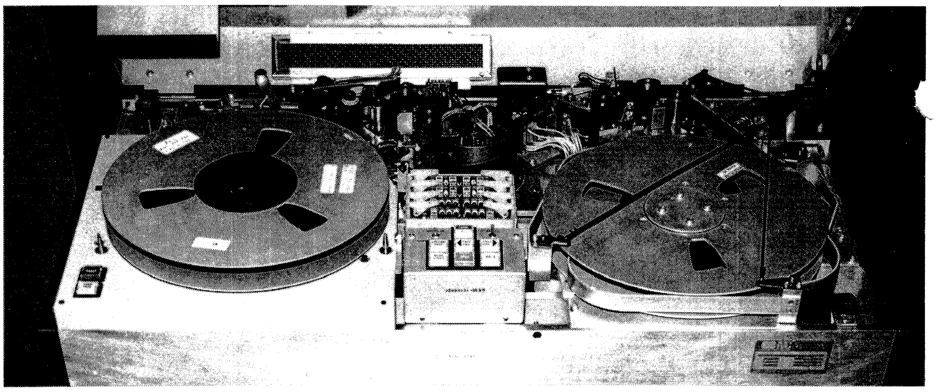

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Storing data on video tape

One of the present problems in doing high energy physics experiments is the handling and storage of the large volume of data which may need to be collected. Many detection systems, particularly those using multiwire proportional chambers and drift chambers, are able to accumulate information at very high rates when recording multi-particle events. It is not unusual for an experiment to need a thousand magnetic tapes to store the data pouring out of the detectors. As a result CERN's bank of data tapes stands at over 60 000 reels and is being added to at a growing rate (10 000 in 1974).

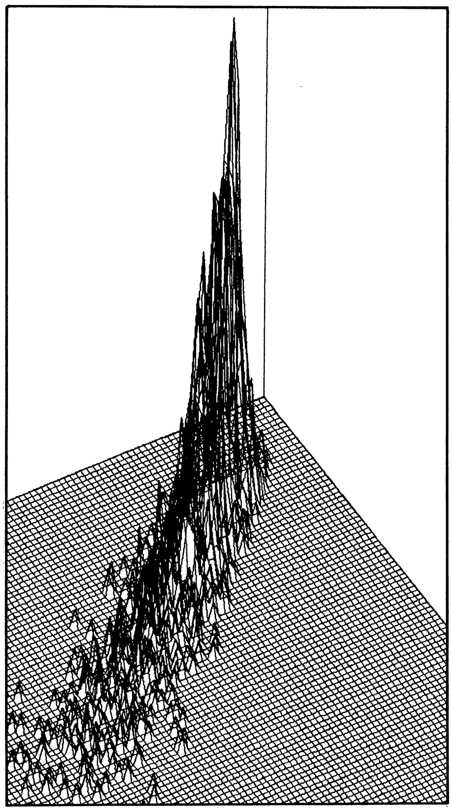
In addition, some experimenters advocate an 'open' philosophy towards data collection. Rather than rigidly triggering their detection system so that only information on well defined types of interaction is collected, they aim for a 'loose' or 'combined' trigger which will store a lot of data on several types of event. The tapes holding the data can then be scoured repeatedly to gather information on different features each time. The tapes become like a stack of bubble chamber pictures which can be rescanned many times looking for additional information. This philosophy obviously also implies much more stored data.

We discussed some techniques for data storage in the March issue 1972. Since then, 'conventional' magnetic tapes have been considerably improved. Those normally used at CERN can now hold 1600 bits per inch, and tape units are now being marketed which use improved techniques for writing and reading data to achieve 6250 bits per inch. Such high density tapes are in successful use for example at Stanford.

It was realized some years ago that a much more radical improvement is possible if video-tape technology can be adapted for use in digital data collection. This is because video recorders make more efficient use of the available tape surface area, and avoid the problems of tape skew and head contact and wear at high transport speeds. A project to develop such a system for CERN use was initiated by C. Rubbia in 1972 and has resulted this summer in the implementation of a data handling system incorporating an IVC MMR-1 video recorder for an experiment located at intersection I-6 of the Intersecting Storage Rings. The experiment is a charmed particle search by a CERN/Harvard/Munich/Riverside/Northwestern collaboration, and A. Staude has taken the project responsibility for the group. The video-tape software was written by S. Cittolin, and the engineering development of the system has been the responsibility of B.G. Taylor.

Representation of some of the results emerging from the R 605 experiment where the video data storage system is used. The experiment, located at intersection I-6 of the Intersecting Storage Rings is a search for charmed particles by a CERN/Harvard/Munich/Riverside/Northwestern collaboration. They catch electrons and then look at the related particles to see whether they correspond to the special conditions which are expected to prevail when a charmed particle has been produced.

The horizontal axes in the figures plot the energy of the particle (as measured in a lead glass counter system) against the momentum of the particle (as measured in a magnet spectrometer system), the vertical axis being the number of events. Figure 1 is data for electrons lying around the 45° line since for relativistic electrons energy and momentum are proportional. Figure 2 opens the trigger to pions also. For them energy and momentum are not proportional and they cluster along a particular quite low energy value at the lead glass counters while their momenta are picked up by the spectrometer.



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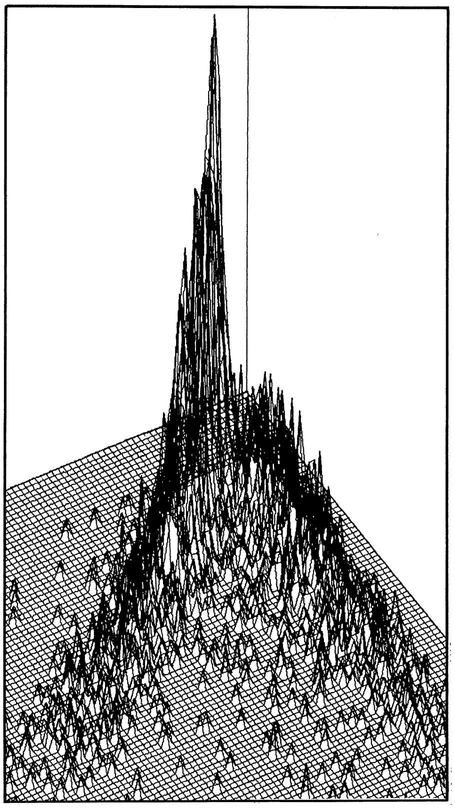


2.

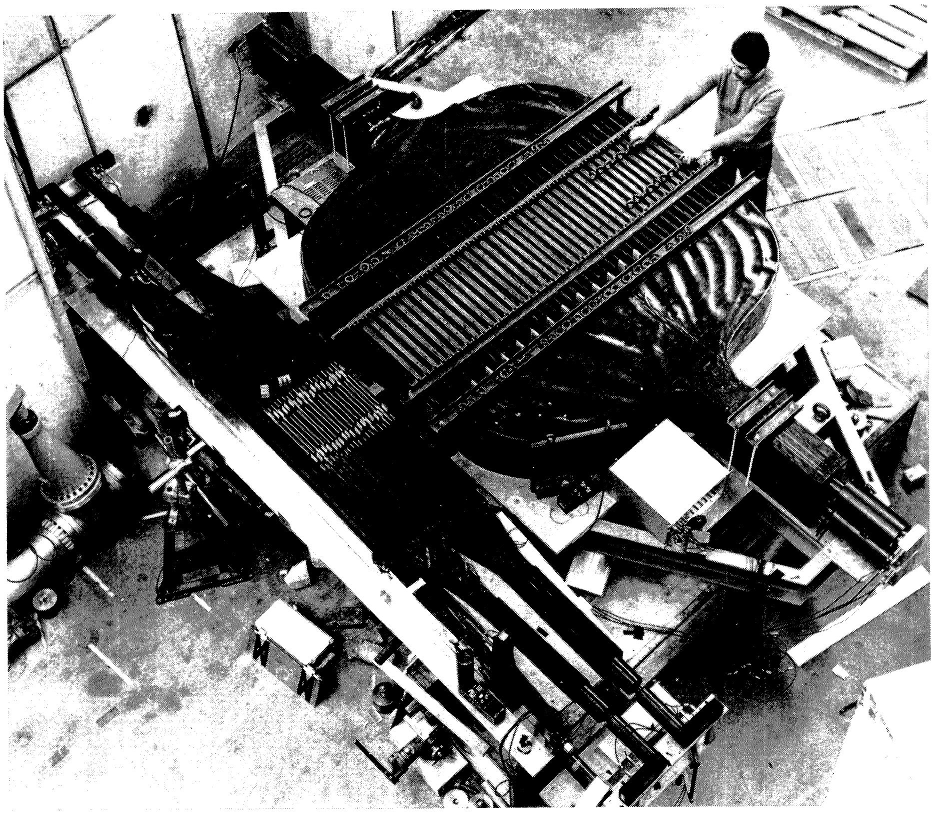
The MMR-1 recorder is linked to the experiment via a controller, a small HP 2100 A computer and CAMAC. The small computer is also linked to an IBM 360/44, giving enough computer capacity to do sample analysis of the data during recording, and most of the off-line analysis on playback. The small computer runs foreground monitoring tasks, while background programs simultaneously control the data acquisition system, the video-tape unit and the data link.

Data are written on the 1 inch wide tape with a density of 10^6 bits per square inch, allowing 9 Gigabytes of information to be stored on a single reel. The tape loops in a helix around a cylindrical scanner containing the recording heads, and it is this helical scanning technique which enables data to be packed so much more closely than in conventional longitudinal recording. While the tape moves past at only 6.9 inches per second, the heads rotate at high speed, recording information in scan-lines across the width of the tape at an angle of 5° to the direction of motion.

The way in which the system is organized is for the buffer store of the HP 2100 A to collect data until it has enough to fill a scanline on the tape. This information is then written, and a 'write status' track is updated with the run number to indicate that the corresponding address has been filled. The tape continues to wind on until another line's worth of information is ready to be written. When a file equivalent in length to a few conventional magnetic tapes has passed the scanner, the tape rewinds at high speed and the process continues with empty lines being filled in with fresh information. This technique eliminates the requirement for a staging disc and a large capacity high-speed data buffer. The data are interleaved along the tape, which is normally filled up to over 95 %. On closing each file, the system automatically performs a read check and generates a performance report. During the playback of data for analysis, the tape winds to the desired file at the 'search speed' of 400 inches per second. A 'quick-look' facility provides the operator with a status directory to the file, and 'read status' information is recorded as each scanline is processed so that selected runs can be read and re-read at will.

The video-tapes used are not certified for digital recording and exhibit error rates of 1 in 10^7 to 10^8 bits. The errors are detected by the read electronics and any event containing a data error is rejected, which results in the loss of typically one event in ten thousand. It is anticipated that a point-finding hardware processor (see April 1974 page 116) will soon be in use to increase the analysis rate, with a track-reconstruction processor possibly to follow.

There were many problems to be solved in developing the system to a satisfactory state, including major modifications to the video recorder during 1974. Also the associated software to make maximum use of the data storage potential took time to perfect. The system is now in regular production operation, amassing data with a compactness which makes one video tape equivalent to 250 conventional 1600 bits per inch tapes or to 400 of the 800 bpi tapes. Besides its contribution to data storage, the system proves convenient during the running of an experiment since the need for tape changing is very infrequent (once every few days) and one-experimenter shifts are practical. Other features are its ability to work at high data rates of up to 1 Mbyte/s (which matches well the maximum rates of CAMAC electronics) and the



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Prototype calorimeters being developed to be part of a vast collection of detectors which will be used to study high momentum transfer particles in the North Area of the 400 GeV proton synchrotron. The calorimeters are to take energy measurements on hadrons (prototype on the right) and leptons (prototype on the left). They use a new type of plastic scintillator called 'plexipop'.

lower tape costs (a factor of more than ten down on the conventional equivalent).

The video-tape data handling system has now run for over 2500 hours and is performing well. It is a pioneering project in that no other high energy physics laboratory has yet attacked the on-line data storage problem in this way. Video tapes can at least dent the problem considerably and could be the most appropriate and economical technique in many applications.

POP goes the plexiglass

One of the experiments scheduled for the North Area of the 400 GeV proton synchrotron is a study of high transverse momentum leptons and hadrons emerging from hadron collisions. It will be carried out by a CERN/Ecole Polytechnique/Collège de France/Orsay/Saclay collaboration and will involve a vast array of detectors — including many multiwire proportional chambers, multi-cell Cherenkovs, large aperture superconducting magnet, lepton and hadron calorimeters.

'Calorimeters' are detectors which measure the total energy of a particle. They have moved higher on the popularity list of detectors in recent years and examples can be found at the CERN PS and ISR, at the Stanford SPEAR storage ring, at Fermilab, etc. They are usually some sandwich arrangement of converter and scintillator enabling an estimate of the energy to be made by measuring the total light output generated by the shower of secondary particles initiated by the incoming high energy particle.

When moving to Fermilab or SPS energies, the volume of a calorimeter to contain the secondary particle shower becomes large. Therefore before launching into the production of the calorimeters for the North Area some prototype work is under way during the course of which a cheaper scintillator has been developed.

Prototypes of a hadron calorimeter and an electron calorimeter were built in the West Workshop and have recently been successfully tested in the PS South Hall using electrons and hadrons in the energy range 5 to 20 GeV. The hadron variety has 40 scintillator plates, 1 m wide, interleaved with 40 iron plates 25 mm thick. The electron variety has 24 scintillator plates interleaved with 24 lead plates 5 mm thick. These are babies compared to what will be needed at the SPS. The hadron calorimeter will then be an interleaved assembly 5 m wide by 5 m high by 2.5 m deep with 36 modules. The electron calorimeter will have 240 modules. The total weight will be around 250 tons and will include about 1000 m² of plastic scintillator plate.

With such a large surface area of scintillator it was worth taking a fresh look at the production of scintillator material to see if costs could be brought down while still retaining adequate properties. This has been done by CERN/Ecole Polytechnique and Saclay members of the collaboration and reported in NP 75-12 ('Scintillator developments at CERN'). They worked in collaboration with Rohm (Federal Republic of Germany), Perlite (France) and Polivar (Italy).

They tried doping the cheap plastic called plexiglass with a variety of known scintillating agents and wavelength shifting substances. They emerged with a three component dope (naphthalene, PBD and POPOP) which can be introduced into plexiglass to give adequate light production, light transmission and speed of response for use in the calorimeter. The plastic scintillator thus produced has been blessed with the name 'plexipop'.

Spotting 3000 new galaxies

The 1 m Schmidt telescope of the European Southern Observatory, ESO, stationed on the La Silla mountain in Chile has photographed an impressive number of new objects in the Southern sky. The analysis of 150 photographic plates carried out in collaboration with the Uppsala Observatory, has revealed more than 4000 interesting galaxies including some 3000, giving off very little light, which have never been observed before.

Since August, the ESO astronomers have been making a spectroscopic study of these objects with the 1.5 m telescope at La Silla. Of the first thirty objects observed, seven galaxies exhibit fairly strong emission lines in

In view of the restrictions that the Member States have found it necessary to impose on personnel, CERN is having to resort to desperate measures. Here the Director General of Laboratory II is seen brazing bus-bars in the SPS tunnel. J.B. Adams was actually closing the magnet bus-bar circuit in the ring on 24 October, two and a half months ahead of schedule. He needed no briefing to perform his ceremonial task because he became expert in copper brazing when coping with the tricky component manufacturing problems of the early days of radar.

Comet West, discovered on 5 November at the Sky Atlas Laboratory at CERN in the examination of film from the Schmidt telescope of the European Southern Observatory at La Silla in Chile. The comet is named after R.M. West and is the second that he has found this year.

(Photo ESO)

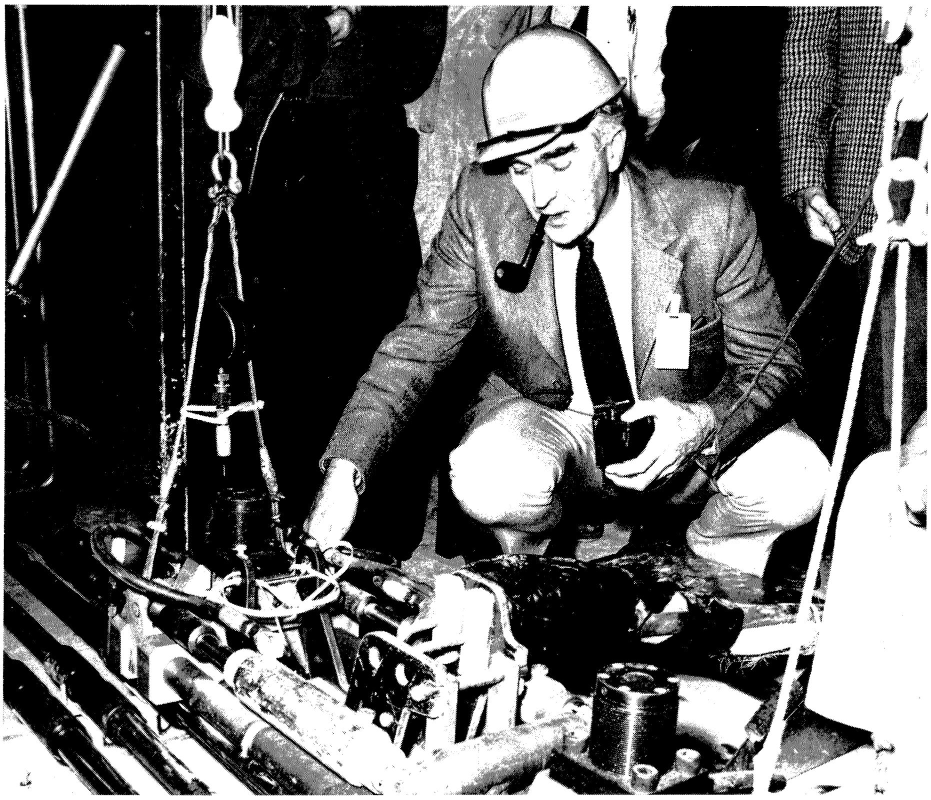
their spectrum, and the recession velocities, which can thus be calculated attain 48 000 km/s for some of them. According to Hubble's empirical law, this corresponds to distances of three thousand million light-years.

Galaxies with emission lines in their spectra are rare and astrophysicists seize upon them like doctors n a pathological case. The 'nucleus' in such galaxies must be subject to some mechanism resulting in very high energy emission. Of the seven investigated in detail so far, two (judging by the width of the emission lines) exhibit a movement of the nuclei with speeds of 1000 km/s. This corresponding to a very considerable momentum and they seem to be galaxies of the Seyfert type.

These first spectroscopic observations in the ESO-Uppsala programme whet the appetite for the use of the ESO 3.6 m telescope which is now being built in collaboration with CERN. This large optical telescope could give a much better idea of the physical processes which are taking place within the nuclei of these newly observed galaxies.

Later news: On 5 November a new comet was discovered at the ESO Sky Atlas Laboratory at CERN. The comet was recorded on three photos taken with the Schmidt telescope at La Silla when compiling the Atlas of the Southern sky.

The comet has been named Comet West after its discoverer, R.M. West, who already has another comet to his credit this year. West communicated the comet positions on the three photographs to B. Marsden at the Smithsonian Observatory, Cambridge, USA who calculated the orbit. It is anticipated that the comet will pass within 30 million kilometers of the sun on 26 February 1976. It is at present a very faint object in the southern constellation of Sagittarius but it may be visible to the naked eye next year.



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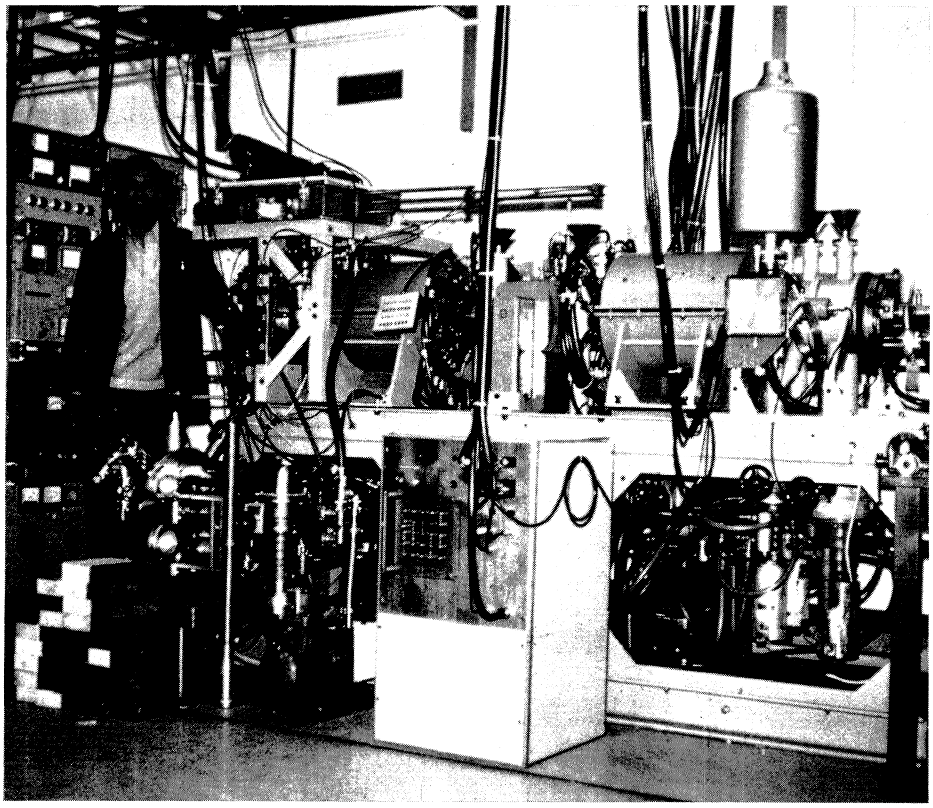
Nuclear spins of gold isotopes

At the ISOLDE on-line isotope separator a Göteborg/Uppsala team (C. Ekström, I. Lindgren, S. Ingelman, M. Olsmats, G. Wannberg) has measured the nuclear spins of five gold isotopes for the first time.

The spins were measured using the atomic beam magnetic resonance method which has been known since the work of I. Rabi in the 1930s. The method is based on the fact that the effective magnetic moment of an atom as a whole depends on the magnetic field in which it finds itself. The total magnetic moment comes from the movement of the electrons and from the fact that the nucleus also has a spin which influences the possible energy states of the electrons (hyperfine structure). Generally, the contribution of the electrons is well understood and it is in seeing the hyperfine effects that it is possible to calculate back to obtain the spin of the nucleus which caused them.

Equipment to study these effects has been built at Uppsala and used for several years mainly with samples from the synchro-cyclotron of the Gustaf Werner Institute. It has been used to measure about one third of the known nuclear spins of radioactive isotopes. The move to ISOLDE at the CERN 600 MeV synchro-cyclotron aims to extend the measurements to shorter lived isotopes and to benefit from higher beam intensities. It is only by using the high intensity extracted proton beam from the improved SC that it has been possible to produce enough gold atoms far from stability to measure their nuclear spins.

The experiment on gold atoms proceeds as follows. The proton beam impinging on the ISOLDE lead target yields mercury isotopes. These are filtered out by mass separation and a particular isotope is collected on a platinum foil. (For later experiments on shorter lived isotopes it will be possible to go direct into the oven system of the atomic beam apparatus but since the gold isotopes are moderately long-lived, over 5 minutes, the foil collection technique can be used.)



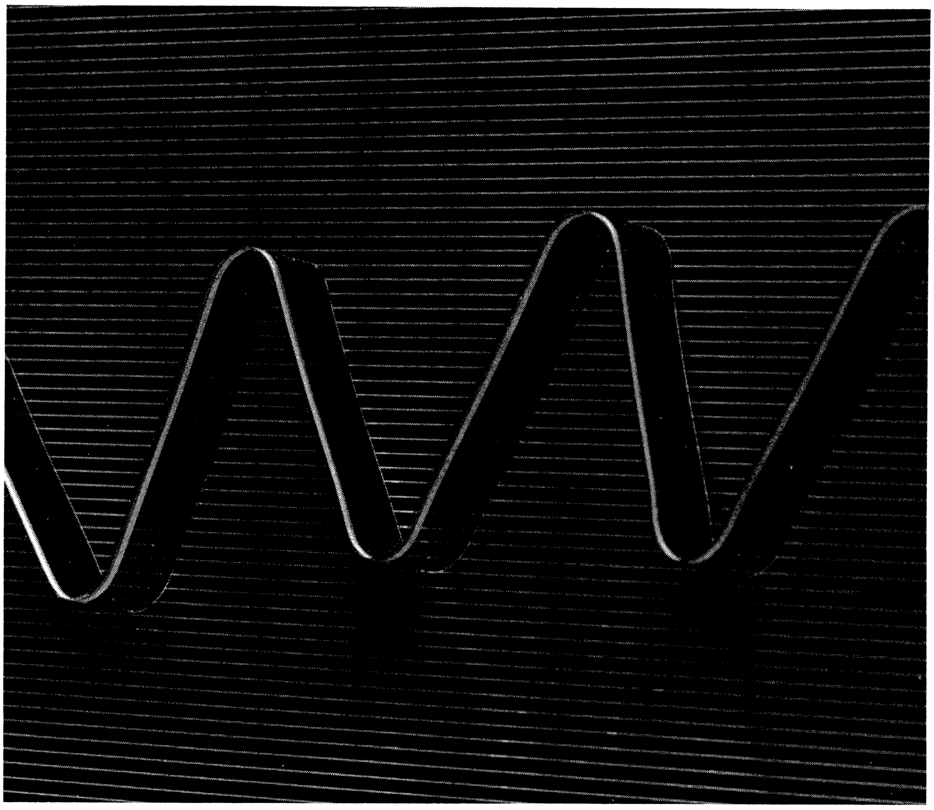
Atomic beam resonance equipment of the Göteborg/Uppsala team working at the ISOLDE on-line separator. It has been used to measure five new nuclear spins of gold isotopes and has a big programme of spin determinations to do. An atomic beam starts from the right in the picture and passes through a sextupole, dipole (where the spin flipping r.f. field is applied) and, finally, quadrupole en route to the detector.

The foil is then introduced into an oven and heated to 1500°C. Gold isotopes evaporate off and enter the inhomogeneous field of the first magnet, a sextupole, which polarizes the atomic beam according to the sign of the effective magnetic moment of the atoms (negative in this case). The atoms then enter a weak homogeneous field where a r.f. field is applied. A particular quantum of energy from the r.f. can flip the atoms from the energy level associated with negative effective moment to one with positive moment. The atoms pass into the inhomogeneous field of a third magnet, a quadrupole, and only those atoms which have changed from negative to positive effective moments are able to pass through t a collector.

Knowing the field in the central magnet and the applied frequency which allowed atoms through to the detector makes it possible to calculate the nuclear spin. Values for five nuclei ^{186}Au, ^{187}Au, ^{188}Au, ^{189}Au, ^{189m}Au have been found (3, 1/2, 1, 1/2, 11/2 respectively). Information on dipole moments of the nuclei will also be looked for by seeing the effect of applying the r.f. in higher magnetic fields. The experiment has moved to studying rubidium isotopes and three resonances have been found so far. With ^{78}Rb the system clearly separated between two isomers; thus at the ISOLDE facility it is possible to filter elements, then masses and then isomers.

The longterm aim is to survey

At first sight this looks like some sinusoidal function being reproduced on an oscilloscope screen. In fact it is a self-supporting spacer used in large area multiwire proportional chambers. Chamber wires form the background to the picture. The spacer is a kapton strip 100 μm thick which has conducting silver paint on its edge (so that the efficiency of the chamber is not decreased over too big a region where the self-supporting spacer touches the wires). The spacer is positioned between the high voltage wire plane and the anode wires which receive the signals. It helps solve instability problems for the anode wires besides sustaining the gap between the large wire planes.



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nuclear spins over a wide range of isotopes bringing in the shorter lived isotopes by having on-line operation (beginning with cesium in December). Results from systematic spin measurements will determine trends over the whole nuclear chart and test nuclear models. Knowing spins is also vital information for spectroscopy studies and for interpreting other nuclear phenomena.

Preparing to send beam to the SPS

The PS has to supply a beam of 10^{13} protons per pulse with an energy of 10 GeV to be spread around the 7 km circumference of the 400 GeV synchrotron. This will involve 'shaving' the PS beam over several revolutions to send a long ribbon of protons towards the SPS (a process also known as 'continuous beam transfer').

In the PS, the protons orbit in twenty bunches whereas in the SPS they will be regrouped in 4620 bunches. It had been planned to debunch the beam in the PS and to impose on it the bunch structure of the SPS (200 MHz). However, serious difficulties were encountered in ensuring stable de-bunching in the PS, even with modest intensities, and it was decided to carry out this operation in the 400 GeV machine.

The first step will, however, be to reduce the r.f. voltage in the PS, which will lengthen the bunches, and some 200 MHz structure will then be imposed. The SPS monitoring stations can fasten on to such a structure right away so that they do not need to cope with a very wide range of frequencies. One of the latest decisions is that beam shaving will be effected not over 11 but over 10 PS revolutions so that, at injection, a gap is left in the ribbon of protons around the SPS circumference. In this way the voltage in the inflector can drop to zero before protons pass it again, and they will not have their orbit disturbed by the inflector field.

The ejection system in the PS consists of dipoles to deform the orbit of the beam, an electrostatic septum which serves as the knife to shave the beam and a septum magnet to complete extraction from the machine. Four dipoles will be used for deformation of the orbit — two for directing the beam close to the electrostatic septum, and two further on to cancel out the deformation for particles remaining in the machine. To ensure that the desired fraction of the beam crosses the electrostatic septum on each revolution, the magnet field in these dipoles must increase in steps in unison with the revolutions in the machine. In fact, one dipole will have a constant field while the second will receive increasing current pulses to increase its field at each revolution during the ejection. The main components for this system were installed at the end of October.

The electrostatic septum is 1.91 m long and consists of a 0.1 mm metal foil. With a cathode gap of about 18 mm, the deflection of the particles crossing the septum will be 1.06 mrad. In order to reduce particle losses at the septum, a set of two quadrupoles will expand the beam horizontally in the region of the septum. On completion of successful laboratory tests, the septum was also installed at the end of October and high intensity ejection tests started in November.

The extraction septum magnet is not yet in position, but has passed tests in the workshop; it has withstood more than 5 million pulses at 30 kA. The first beam ejection tests were carried out with old septa which had smaller length or aperture, but they showed the behaviour of the beam and the equipment to be as expected.

During the annual shutdown of the PS at the end of this year the remaining ejection equipment will be installed. Intensive tests will then take place for a month, so that the PS will be ready to serve as SPS injector. A high quality beam will be needed at the end of March to feed the 400 GeV accelerator using one out of every two PS machine cycles with a 1.2 s flat-top at 10 GeV. A second 2.4 s cycle will be used for the normal experimental programme and for filling the ISR.

Successful tests have already been carried out in the common beam transfer line used for filling the ISR and for carrying protons part of the way to the SPS. This line is pulsed in order to take, from one PS cycle to the next, either a 10 GeV beam for the SPS or a beam with an energy of up to 26 GeV for the ISR.

Around the Laboratories

BROOKHAVEN
Finding where the proton goes

The Brookhaven Laboratory has received a grant of $ 0.5 million to look at some problems in the use of accelerated particle beams in the treatment of cancer. The research will be done in collaboration with scientists from Stony Brook and the Nassau County Medical Center.

We have touched many times in recent years on these applications which are occupying such centres as Harvard (protons), Los Alamos (pions), Berkeley (heavy ions), Hammersmith (neutrons)... and some of the further information is given below.

The Brookhaven work will, initially, tackle the problem of knowing where the particles in a beam deposit their energy. This is obviously crucial in achieving successful irradiations of cancerous tissue while leaving healthy tissue virtually unharmed. If the map of the energy disposition could be accurately established, a compensating mask could be introduced in the beam in front of the patient. The mask could be shaped so as regulate the penetration of the beam into the patient in the desired way.

The method under investigation is to make use of radioisotopes created by the incoming particles. Since oxygen is so abundant in the body (about 65 %) an obvious candidate is the short-lived oxygen-15 isotope. A high energy particle can create oxygen-15 from the stable oxygen-16 and, with a half life of about two minutes, oxygen-15 will reveal its presence by the emission of a positron. The positron will rapidly annihilate with an electron of a nearby atom giving two gamma rays emerging in opposite directions. Gamma ray detectors surrounding the irradiated body could map where the beam has been depositing its energy and the absorber material to be used as a mask can then be tailored in consequence.

Preliminary calculations and experiments have been going on during the past three years with encouraging results. However before this technique of beam localization 'in vivo' can be applied in actual treatments, a thorough study of its feasibility is necessary. This will now be undertaken using 'spare' protons from the 200 MeV proton linac. The linac's main task is to feed the 33 GeV proton synchrotron but the synchrotron needs only one in ten of the pulses the linac can provide. Linac protons are already in use for the production of radioisotopes.

DUBNA/ITEP
Medical applications of proton beams

Since 1967 at the Joint Institute for Nuclear Research, Dubna, and 1968 at the Institute for Theoretical and Experimental Physics, Moscow, accelerated protons have been used in medical applications. Proton radiotherapy is carried out at both centres by staff from the Moscow Institute of Experimental and Clinical Oncology. The Dubna work is centred at the 680 MeV synchro-cyclotron; the ITEP work is centred at the 10 GeV proton synchrotron using 200 MeV minipulses between the main machine pulses. (Preparations are also under way for the use of protons from the 1 GeV synchro-cyclotron at the Gatchina Laboratory near Leningrad in medical applications).

At Dubna the protons are reduced in energy to 185 MeV by passing them through a liquid moderator and are then focused and collimated to an intensity of about 10^9 per s. The beam is in general rather large (5×10 cm^2) and small beams of adequate intensity, such as are needed in some applications, cannot yet be produced. Irradiations are made by shuttling the position of the Bragg peak (the range at which the stopping protons deposit most of their energy) backwards and forwards across the tumour area while rotating the patient. A remotely controlled (using a MINSK-22 computer) water column of variable length is used to move the Bragg peak as dictated by the signal from a tiny semiconductor introduced into the centre of the tumour. When this feedback system cannot be applied the isodose distribution is calculated, using a BESM-6 computer, prior to the irradiation.

Over 90 patients have been treated so far. The initial irradiations were for surface tumours and they have now advanced to include cancers of the larynx, bone, esophagus and lung. The reaction of patients to proton treatment has compared favourably with the reaction to treatment by the conventional X-ray method.

In 1977 it is hoped to rebuild the 680 MeV synchro-cyclotron as a four-sector AVF cyclotron. The design aims are to achieve an internal proton beam of 50 μA (compared with the present 2.3 μA) and to achieve extracted beam intensities a hundred times higher. The medical facilities will then include a better collimated proton beam, with two areas for proton treatment, and a negative pion beam which will also be used in therapy.

At ITEP, proton beams are drawn from the synchrotron at energies from 70 to 200 MeV and tailored to a pencil beam which enters the treatment room. Typical beam sizes are 6 to 7 mm diameter and broader beams, up to 100 mm diameter, can also be delivered. A tumour is irradiated while rotating the patient with great accuracy in position, 0.5 mm, so that beams approach from up to 25 directions.

Over 260 patients have been treated so far for cancers of the cervix, larynx and esophagus. The beam quality has made it possible to do small volume irradiations such as the pituitary gland. They intend to treat other lesions of the cranium soon, for example tumours at the bottom of the eye which have already been irradiated with success in tests with animals.

All the irradiations were carried out prior to the synchrotron shutdown for an improvement programme which started in 1972. The machine came into operation again in 1974, upgraded from 7 to 10 GeV, and medical work has not yet been taken up again due to running in and reliability problems. Treatments are expected to restart soon on an extensive scale. Better beam quality and better techniques for patient positioning are hoped for and a novel acoustical method of Bragg peak localization, in vivo, will be tried.

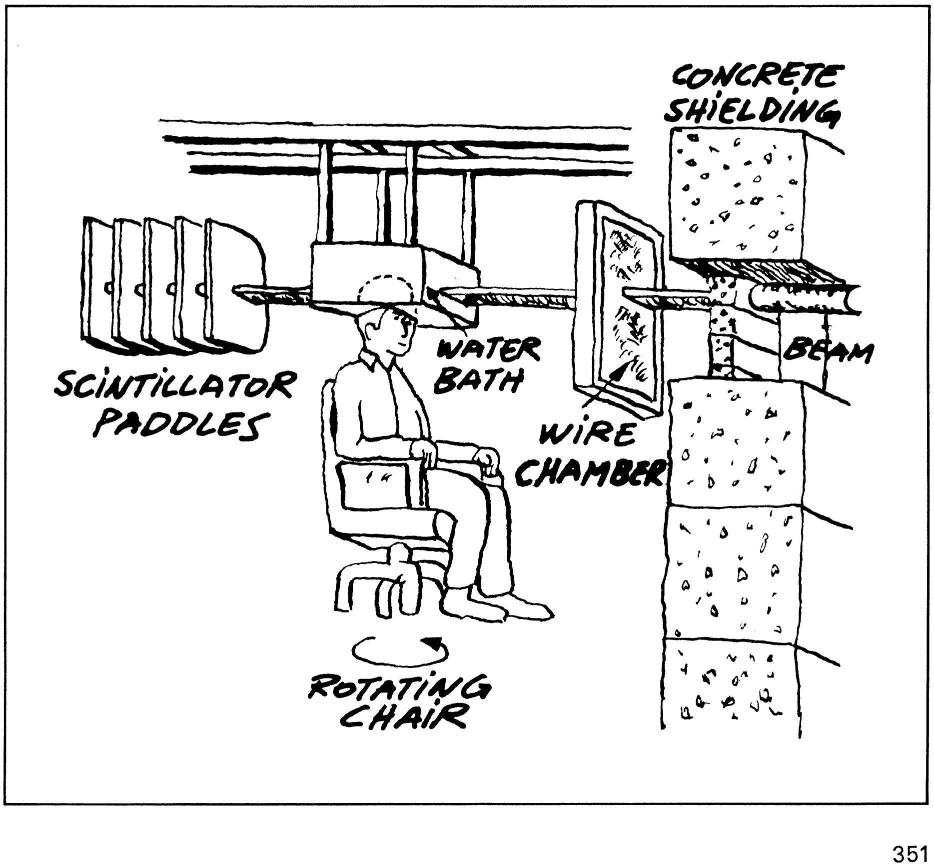
BERKELEY/HARVARD Tomography with alphas and protons

There has been a dramatic increase in the use of X rays to produce three dimensional density maps (or tomographs, since they are assembled from maps of a series of slices) of parts of the body. This has come particularly from the arrival on the market of the EMI scanner which is one of the great commercial successes in the medical world in recent years. It gives 'computerized axial tomographs' detecting density differences of the order of 1 % and locating the differences with an accuracy of millimetres.

Still greater density sensitivity and accuracy in location may be feasible

Inside the Alvarez section of the 800 MeV proton linear accelerator, LAMPF, at Los Alamos during cleaning operations which were carried out earlier this year in the 'great shutdown'. The machine is now back in action and has succeeded in accelerating a beam of 100 μA with less beam loss than was previously experienced accelerating a beam of 10 μA. While on the general subject of medical applications of accelerators – the use of negative pion beams for cancer therapy is being pioneered at LAMPF and a programme of further treatments of patients is lined up. Large amounts of radioisotopes for diagnostic purposes are also produced.
(Photo Los Alamos)

Drawing of the set-up at the Berkeley cyclotron used to investigate the use of alpha particles to produce accurate three dimensional density maps. They are known as tomographs since they are built up from a series of exposures seeing different slices of the body. The aim is to improve on the conventional X-ray tomographs while exposing the patient to a smaller radiation dose.



using heavy charged particles (protons, alphas, heavy ions) to take radiographs. These improvements could also be accompanied by the advantage of lower radiation dose to the patient. Two further investigations of these possibilities have been reported. At Berkeley, K.M. Crowe, T.F. Budinger, J.L. Cahoon, V.P. Elischer, R.H. Huesman and L.L. Kanstein used a 910 MeV beam of alpha particles from the 184 inch cyclotron. At Harvard, A.M. Cormack and A.M. Koehler used a 158 MeV beam of protons from the cyclotron.

For the alpha radiographs, the changes in energy of the incoming alpha, caused by the density of matter they have traversed, is detected by a system consisting of multiwire proportional chambers and a range counter of scintillators. The detectors are linked to a PDP-15 computer for three dimensional reconstruction after taking multiple views of the subject rotated to different positions. Radiographs were taken of various 'phantoms' and it was demonstrated that density differences of less than 2 % can be detected with radiation doses one tenth of those necessary using X-rays. Only one of three wire chambers was installed and an improvement of a factor of three should be achieved with the full system in action. Approval for tests with patients has been given.

For the proton radiographs, a detection system of two sodium-iodide counters was used which was not considered as optimised. A lucite phantom had annular and cylindrical apertures which could be filled with substances of different densities (sugar solutions, polystyrene). The experiments showed that differences of 0.5 % can be seen clearly and sharply.

The use of heavy ions has been investigated also at Berkeley by C.A. Tobias and E.V. Benton using neon ions from the Bevalac. We may have more on this in a future issue.

HAMMERSMITH
Neutron treatment of tumours

Over a period of three years, clinical trials of fast neutron beams for the treatment of advanced tumours have been carried out at the cyclotron of the Hammersmith hospital in London. The results were reported this summer to the UK Medical Research Council by M. Catterall, I. Sutherland and D.K. Bewley.

About 50 patients were involved and their reaction to the treatment was compared with that of a similar number submitted to conventional X-ray or gamma ray exposures.

The neutron beam had a mean energy of 7.5 MeV and was applied some twelve times during four week periods to deliver a total dose of 1440 rads to the tumour. In 37 cases the local tumour regressed among the neutron patients and there were no recurrences. This compared to 16 regressions with 9 recurrences among the X-ray patients. Mortality rates were, however, not significantly different between the two groups. It is believed that the better reaction to neutron therapy is due to its more favourable biological effects.

Longer term studies are being undertaken in the next stage of these tests by treating patients at an earlier stage with smaller tumours. The Hammersmith team are already sufficiently confident in their results to maintain that the place of neutron beams in cancer therapy should be established as soon as possible.

Bubble chamber film in education

A pedagogic experiment on the use of bubble chamber film to transmit some basic concepts of physics is being carried out in several high schools in France on the initiative, particularly, of J. Duboc. Seven schools were involved in the 1974-75 school year and twelve schools in the present school year. The relevant age group is 16-17 years old.

Some 12 000 pictures of 2 GeV proton-proton interactions were taken in the CERN 2 m hydrogen bubble chamber and from them ten elastic and ten inelastic scattering events were selected. The criteria for selection were that the events be 'flat' (so as to avoid the necessity of reconstructing in three dimensions), clear (uncluttered by other particle interactions) and with their vertex near the centre plane of the picture giving 40 to 50 cm of track length for the measurements.

Each high school is then provided with four large pictures (100×70 cm), two elastic and two inelastic, of events and with a set of templates to measure track radii. If the exercise is to spread throughout the education system, it is important that costs be kept down. The initial cost was 350 Swiss francs per school; it will probably decrease by a factor of two this year.

Measurements of the track radii are made followed by computations of momentum, knowing the momentum of the incoming particle. Elementary ideas on relativity have already been taught. Momentum conservation tests first establish whether the event is elastic or inelastic. Energy conservation tests are carried out on the elastic events using non-relativistic and relativistic formulae. This demonstrates the necessity and validity of quantum mechanics.

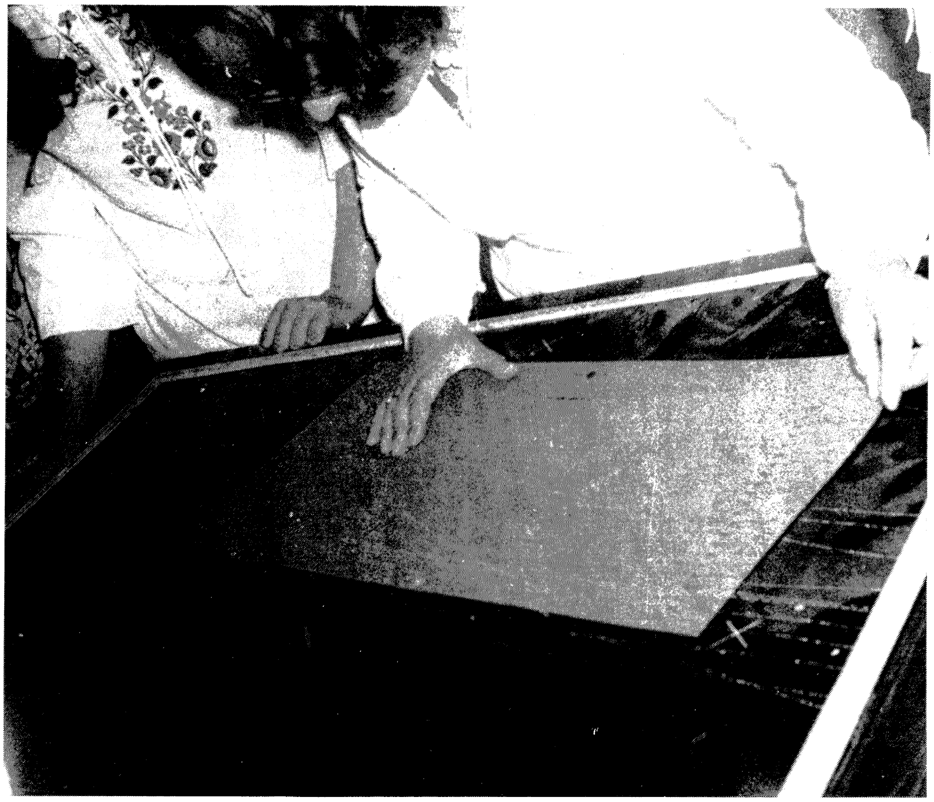
For the inelastic events, the 'missing momentum' is calculated and several hypotheses

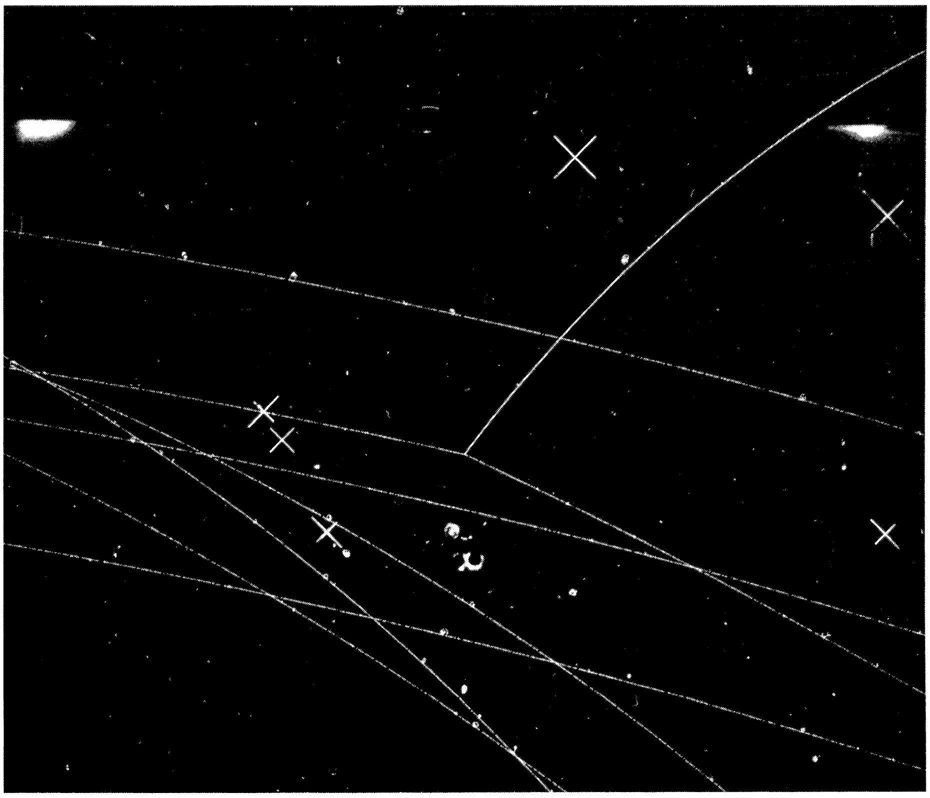
$$p + p \rightarrow pp\pi^0/p\pi^+n/\pi^+pn$$

are compared and checked by energy conservation. Only one of them fits the

Students in a French high school measuring film from the CERN 2 m bubble chamber. Pictures of proton-proton interactions are being used in the physics course in several schools to help communicate concepts of relativity, the mass-energy relationship and so on.

An example of a proton-proton event which is used in the high schools. A few pictures of elastic and inelastic scattering events were selected. They are 'flat' (to avoid reconstruction in three dimensions), clear (uncluttered by other interactions) and give long tracks for momentum measurements.





energy balance. This demonstrates particle creation and the energy-matter relationship.

No practical problems have been encountered during the experiment so far. The students seem to have no difficulty in establishing that the relativistic approach is more exact than the non-relativistic or in selecting from amongst the possible particle creation hypotheses.

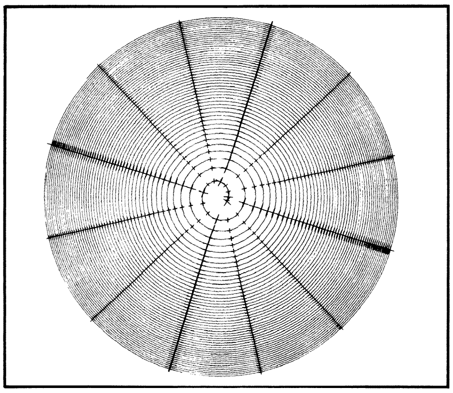
If the success of the experiment continues, it may be incorporated in the standard physics teaching programme. Although more sophisticated concepts are conveyed at University level using bubble chamber photographs (for example, in the physics course of the Open University in the UK) it is believed that the French experiments is the first extensive one to be carried out at high school level.

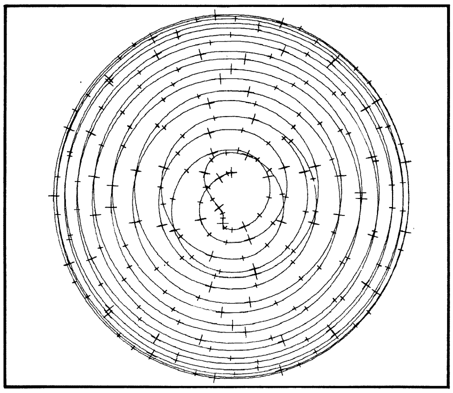
BROOKHAVEN New accelerator for applied research

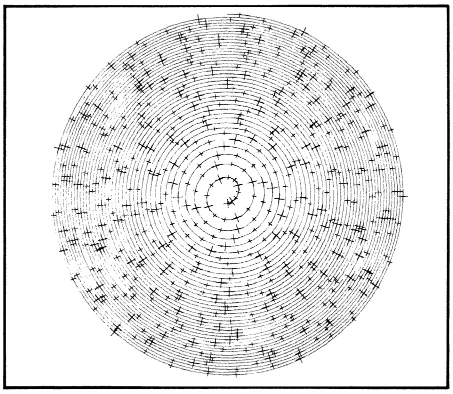
Brookhaven has recently requested funds from the ERDA Division of Controlled Thermonuclear Research to design and construct a linear accelerator to investigate radiation damage of materials for fusion reactors. We first mentioned this project in the November issue of last year; it aims to tackle some of the basic problems involved in mastering thermonuclear fusion.

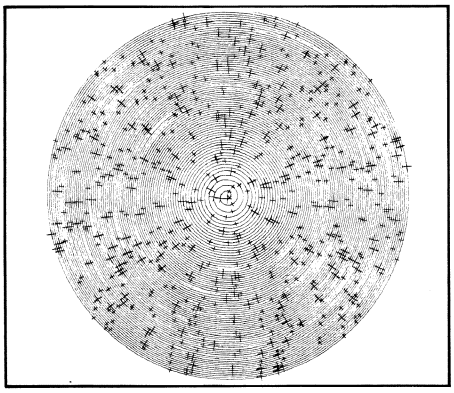
The development of materials for the so-called 'first wall' of a fusion reactor is one of the major hurdles to surmount before such a reactor becomes feasible. The plasma containment vessel will be subjected to very high 14 MeV neutron fluxes (over 10^{14}/s/cm^2) in addition to the lower energy neutrons which are common in fission reactors. At present, there is no 14 MeV neutron source which can

Still in the field of education, the series of spirals below emerge from an interactive computer program developed by S. Brandt (Siegen) and H. Schneider (Heidelberg) as an aid in University physics teaching. The computer plots proton trajectories in a constant homogeneous magnetic field such as is encountered in a cyclotron. The various figures emerge from changing the conditions applying to the proton by manoeuvring the computer program. Figure 1 is for a non-relativistic particle exposed to a normal cyclotron accelerating field, Figure 2 is for a relativistic particle in a normal cyclotron where the particle slips out of phase with the accelerating field. Figure 3 is for synchro-cyclotron conditions where the accelerating field frequency decreases in step with the revolution time. Figure 4 is a repeat of synchro-cyclotron conditions with a higher magnetic field. Using this interactive program gets across accelerator physics and computing techniques.









produce fluxes high enough to simulate the fusion reactor environment or to accumulate rapidly radiation exposures of the order of 10^{21} to 10^{22} neutrons/cm^2.

The idea, put forward at Brookhaven in 1973, is to build a linear accelerator to take a high intensity deuteron beam to about 30 MeV. Firing such a beam on to a lithium target results in deuteron break-up and the production of a forward neutron beam with an energy spectrum peaked at about 14 MeV. To achieve a flux of 10^{14} neutron/s/cm^2 within a reasonable experimental volume (about a litre) requires a 100 mA continuous deuteron beam. The total yield of such a system is expected to be over 10^{16} neutrons/s.

The proposed 30 MeV accelerator consists of eight r.f. accelerating cavities in a single vacuum tank, each cavity being powered by its own amplifier operating at 50 MHz. The cavities contain 66 drift tubes including strong magnetic focusing. The vacuum tank dimensions are about 4 m diameter and 40 m long. With a continuous beam of 100 mA the beam power is 3 MW; the necessary power, including r.f. losses in the accelerating cavities, is then 4.5 MW.

The injectors are two 500 kV d.c. accelerators, one to supply D^+ ions and the other D^- ions. They can be used simultaneously, since the ions of different sign can be accelerated in the different halves of the accelerating cycle, or one can serve as a spare in case of breakdown or maintenance of the other.

The target system is separated from the accelerator by about 60 m so that the bunched beam from the cavities can debunch and become a virtually continuous beam. The separation also serves to isolate the high radiation levels in the experimental area from the accelerator. The target area has four target caves and a beam dump. With D^+D^- operation, two targets can be operated simultaneously, using a magnet to divide the ion beams, while experiments are being set up in the other two caves. A typical target consists of a liquid lithium jet, 1.5 cm thick and 12 cm wide, crossing the beam with a velocity of about 10 m/s. Analysis of heat deposition in such a jet indicates that the 3 MW of beam energy in the target receiving D^+ ions can be dissipated.

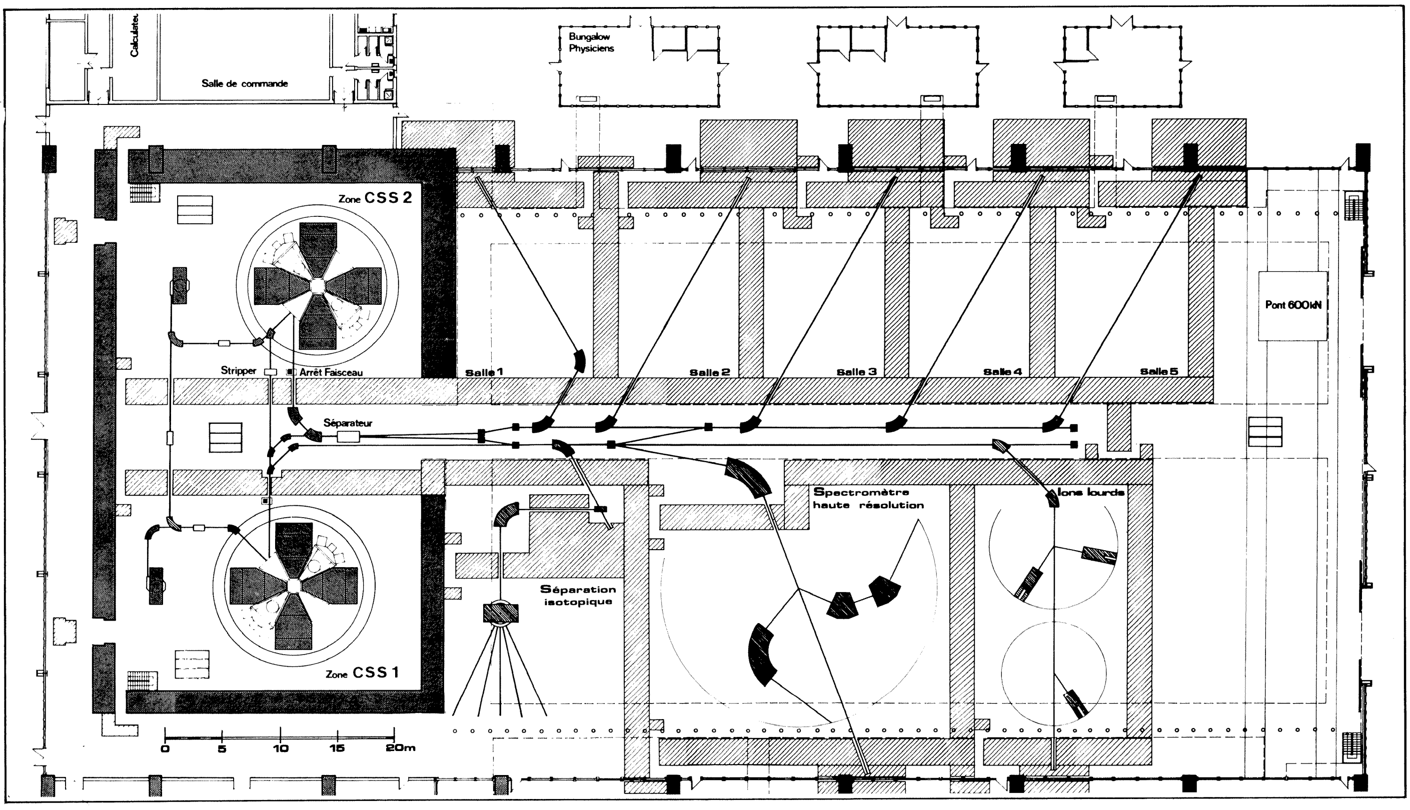
The accelerator has been designed to be very versatile, providing adjustable neutron fluxes, variable neutron energies, simultaneous acceleration of two independent deuteron beams, operation of two independent target facilities and flexibility in neutron delivery from short pulses (such as would be produced in Theta-Pinch type fusion reactors) to d.c. fluxes (such as would be produced in steady-state Tokamac type fusion reactors).

It is hoped that the project will be funded in 1978. The interest in this type of facility is now so great that three other Laboratories in the USA are also preparing proposals using the same concept.

MICHIGAN
Scatter focusing

In the September issue, we reported work at Harwell and Los Alamos on proton scattering radiography. The technique can pick out the edges of objects very cleanly because Coulomb scattering enhances the flux of particles just beyond an edge (where direct and scattered particles arrive) while depleting the flux just inside the geometrical shadow (where a lower number of scattered particles arrive).

L.W. Jones looked at this pheno-



Proposed layout of the heavy ion accelerator, GANIL, which is to be built at Caen in France. On the left are the two sector-focused cyclotrons (CSS1 and CSS2) with their injectors. To the right is a layout of beams to feed many experimental areas.

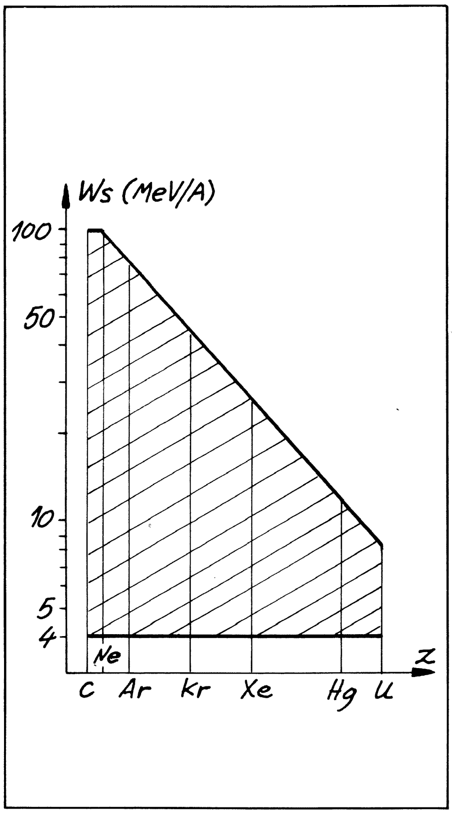
menon in 1963 while working on the external beams of the Brookhaven 3 GeV Cosmotron. He has recently, together with D.G. Koch at the University of Michigan, explored the possibility of using this scattering to focus particles. The seeming paradox of scattering in order to focus can work provided a lot of the particles can be thrown away while achieving a concentration of the remaining particles. A particular interest is that 'scatter focusing' can also be applied to neutral beams which are impossible to get hold of by the usual electromagnetic methods.

The application to charged particle beams is likely to be attractive only in very special circumstances. A beam passing through a block of matter shaped as a lens, for example with a plane face to the beam and a concave face downstream, will have a scatter focus but the local enhancement in flux will only be by a factor of typically about 3. This compares with factors of several hundreds which can be achieved using magnetic lenses and also involves producing a higher radiation environment due to the many scattered particles not retained in the beam. The advantages are that the scatter lens, once introduced into the beam could sit there doing its job without attention and without need for electrical power.

The application to neutral beams is more interesting. Several scatter lens configurations (rings with a central aperture, coaxial cylinders of different materials, etc.) have been considered. The flux gains for multi-GeV neutron beams or for neutral hadron beams are less than 50 % but chromatic aberration in the lenses can concentrate the neutrals around a desired momentum. This concentration in momentum can be further improved by going to a two-stage lens system but then there is a considerable loss in flux.

CEA/IN2P3
The Heavy Ion Accelerator GANIL

In the September issue (page 278) we reported the French government's decision to construct the heavy ion accelerator known as GANIL. It is a joint project between the Commissariat à l'Energie Atomique (CEA) and the Institut de Physique Nucléaire et de Physique des Particules (IN2P3). In this article we shall describe the main characteristics of this machine which, from 1980 onwards, will make possible more thorough studies of many nuclear reactions, thanks to beam characteristics not achievable elsewhere. GANIL will meet the requirements of experimental nuclear physics with ion beam energies, intensities and inherent qualities (energy resolution, emittance and duty cycle) which will be exceptional.



A diagram illustrating the energy potential of GANIL. The y-axis gives the energy plotted against the mass of the accelerated ion.

The maximum value of the energy is a strong function of the mass of the accelerated ion — from 100 MeV per nucleon for light ions (carbon, neon...) up to 8 MeV per nucleon for heavy ions (uranium). For a beam of optimum quality, the intensity will vary from 10^{12} particles per second in the case of light ions to 10^{11} pps for heavy ions. For a beam that is 'not so good' the intensity may be ten times higher.

The intrinsic quality of the beam is determined by the energy resolution, emittance and duty factor. For the 'good' beam, the aim is to achieve a) an energy resolution better than 4×10^{-4} for the light ions (atomic number less than 60) and 10^{-3} for the heavy ions (over 60), b) maximum horizontal and vertical emittances at an energy of 10 MeV per nucleon of 50 mm.mrad for light ions and 100 mm.mrad for heavy ions, c) a duty cycle of the order of 100 %. For the 'not so good' beam, an energy resolution of 10^{-3} will be accepted for the light ions with an emittance of 100 mm.rad, whilst the duty cycle remains unchanged.

It is also important that adjustments to the machine are straightforward, rapid and stable, that the output energy is variable in very small steps and that the overall reliability is high. To achieve these requirements with an accelerator which is to be partly operative in 1980, it is necessary to use techniques which, if not fully proven, are at least reliable extrapolations of existing systems.

In view of the above considerations, and bearing in mind economic considerations, the CEA/IN2P3 working group has decided to build a system around two identical separated-sector cyclotrons (CSS1 and CSS2) used in sequence with further ion stripping between the two. Injection is by means of a compact cyclotron (CO). For reasons of reliability, two injectors will be provided (CO1 and CO2) capable of alternate operation. The combinations CO1 + CSS1, CO2 + CSS2 will also make it possible to use each CSS independently.

The cyclotron injector

Each injector is a compact cyclotron with a conventional PIG source at its centre. This type of source defines the highest charge states with intensities that can be used by GANIL (1 to 40 mA peak per charge state). A Lyon/Grenoble team is at present studying the possibilities of this source (intensity, emittance of beam, possibility of extending the range of ions hitherto used...). The ions are then accelerated in the cyclotron and ejected towards CSS1.

An experimental study of the central region of the cyclotron (which will have four geometries, one for each operating harmonic) is at present being carried out in the CERN Synchro-cyclotron Division by a joint SC/GANIL team. It will also be possible to use a 1 MV electrostatic platform as an injector for the heaviest ions, the advantage being that this type of installation can easily be adapted to new types of source which may be developed in the coming years.

The separated sector cyclotrons

The separated sector cyclotrons have a great number of advantages over the compact cyclotrons. The most important are: stronger focusing, higher energy gain per turn (hence shorter spirals and a better separation between the turns at the extraction septum), better beam accessibility and the possibility of inserting numerous devices for beam diagnosis. However, one CSS alone is not sufficient to achieve the final energies required. In order to optimize the technical and economic characteristics of the two CSS machines, it was decided to make them identical. This simplifies the design of the magnetic sectors and r.f. accelerating cavities.

The beam supplied to the experiments must also have good energy resolution. This considerably restricts the phase acceptance of the CSS (and therefore the final intensity), if use is made only of the usual r.f. cavities. To increase the intensity it is necessary to flatten the top of the sinusoidal r.f. wave, which can be done by adding additional cavities, known as 'flat-topping' cavities, increasing the phase acceptance from around 2° to as high as 15°.

The main characteristics of the magnets are set out in the table. An anti-saturing pole profile enables a field of 0.5 T to 1.6 T to be obtained. A solution with superconducting coils is at present under study in conjunc-

Parameters of GANIL

Energy ranges	CO + CSSI + CSS2		4-100 MeV/A
	CO + CSS		4-50 MeV/A
Peak intensity	(particles per second)		10^{13}
CO	ejection radius		0.375 m
	magnet gap		20 cm
	peak field		1.91 T
	weight of iron		54 t
	weight of copper		4 t
	number of Dee electrodes		2
	peak voltage		110 kV
	frequency range		5.5-14 MHz
CSS	ejection radius		3 m
	magnet gap		10 cm
	peak field		1.6 T
	weight of iron		1600 t
	weight of copper		16 t
	number of Dee electrodes		2
	peak voltage		250 kV
	frequency range		5.5-14 MHz

tion with a conventional coil solution. A 1/4 scale model of the sectors has been ordered and magnetic measurements will take place about mid-1976. Similar measurements were made this year at Oak Ridge on a four sector model (with a scale of 1/6). The measurements proved to be very valuable to magnet designers and theoreticians.

The conventional r.f. cavities are Dee-type co-axial resonators, split in the horizontal plane to allow the passage of the beam. Unlike the arrangement in a compact cyclotron, the cavities are not located inside the magnet gap. This enables the self-capacitance of the Dee to be kept at the upper end of the frequency spectrum, which reduces the r.f. power required.

A study of ion dynamics showed that it was not necessary to insert the flat-topping Dees inside the main Dees. It is even possible to use only one cavity, with a limitation being imposed on its radial extension in order to simplify construction. Studies are now under way on this type of cavity.

The ion transmission will be as high as 80 % in each CSS with a vacuum of 5×10^{-8} torr in CSS1 and 3×10^{-7} in CSS2. A combination of pumps (cryogenic, titanium sublimation and turbomolecular pumps etc.) will provide the necessary pumping speed (150 000 to 200 000 l/s).

Beam injection and ejection will take place in the same straight section using a series of magnets together with magnetic and electrostatic septa. In certain cases, these will not be easy to make because of the space limitations at the centre of the cyclotron where the available room in the magnet gap is less than 6 cm.

The charge states of the ions emerging from the PIG source are not sufficient for a single CSS to be able to give the required maximum energy, and it is therefore necessary to strip the ion beam further. The final charge state increases more or less rapidly with energy of injection into the stripper depending on the nature of the ion. A beam stripper is therefore located between CSS1 and CSS2 in order to obtain a fourfold gain (except in the case of light ions where such a gain is not possible). It is this factor of four which dictates the ratio of four between the ejection radius of CSS1 and the injection radius of CSS2.

This stripper may be of the gas type for light ions. In the case of medium and heavy ions it must be solid (carbon foil) and its 'thickness' will be of the order of 10 μg/cm^2. Crossing this target involves an energy loss (which has to be compensated), an energy spread and an increase in transverse emittance, besides causing a progressive deterioration of the target foil.

An experimental study of all these effects is now being made by a combined Strasbourg/GANIL team using the beam of a tandem accelerator. Initial results show that the life of the targets is very satisfactory (several hours for about 1 μA of gold ions) but that the energy spread is greater than that predicted.

The control system will have a modular and centralized data system incorporating a MITRA 125 computer. There will be two machine operating modes. In the manual mode during normal exploitation the machine will be controlled from the main console in the control room and during maintenance periods from local consoles near the actual equipment. In the automatic mode, the machine will be controlled by computer programms or respond to the requests of an operator.

The main functions of the MITRA 125 will be:

— systematic acquisition of a large number of machine parameters in order to track down rapidly the causes of failure, indicate operating conditions, keep a record of operation and acquire a better knowledge of the beam dynamics;
— occasional acquisition of certain beam parameters which cannot be measured without destroying the beam;
— automatic setting at pre-determined values of the machine and beam transport lines which will considerably facilitate changes in operating conditions (particularly in energy).

Construction programme, staffing and cost

After publication of a preliminary report (July 1973) prepared by a combined CEA/IN2P3 group of physicists and engineers which recommended the construction of the accelerator broadly as described above, a project group was formed to carry out feasibility studies. A second report, published in July 1975, confirmed the initial options as correct. Following the decision in August 1975 to build GANIL at Caen and the release of money (25 MF) to get the project under way, it was possible to make a quick start on construction. It is planned to obtain a beam from CSS1 in 1980 and one from CSS2 in 1981. From 1979 onwards, a staff of 120 will be required to meet these target dates. The predicted cost (January 1975) of construction is 175 MF (excluding taxes and salaries, and with only the first construction phase of the machine hall).

With GANIL it will be possible to explore a new area of nuclear physics. In a coming issue we shall examine the experiments that can be carried out with this facility which will be the only one of its type in the world.

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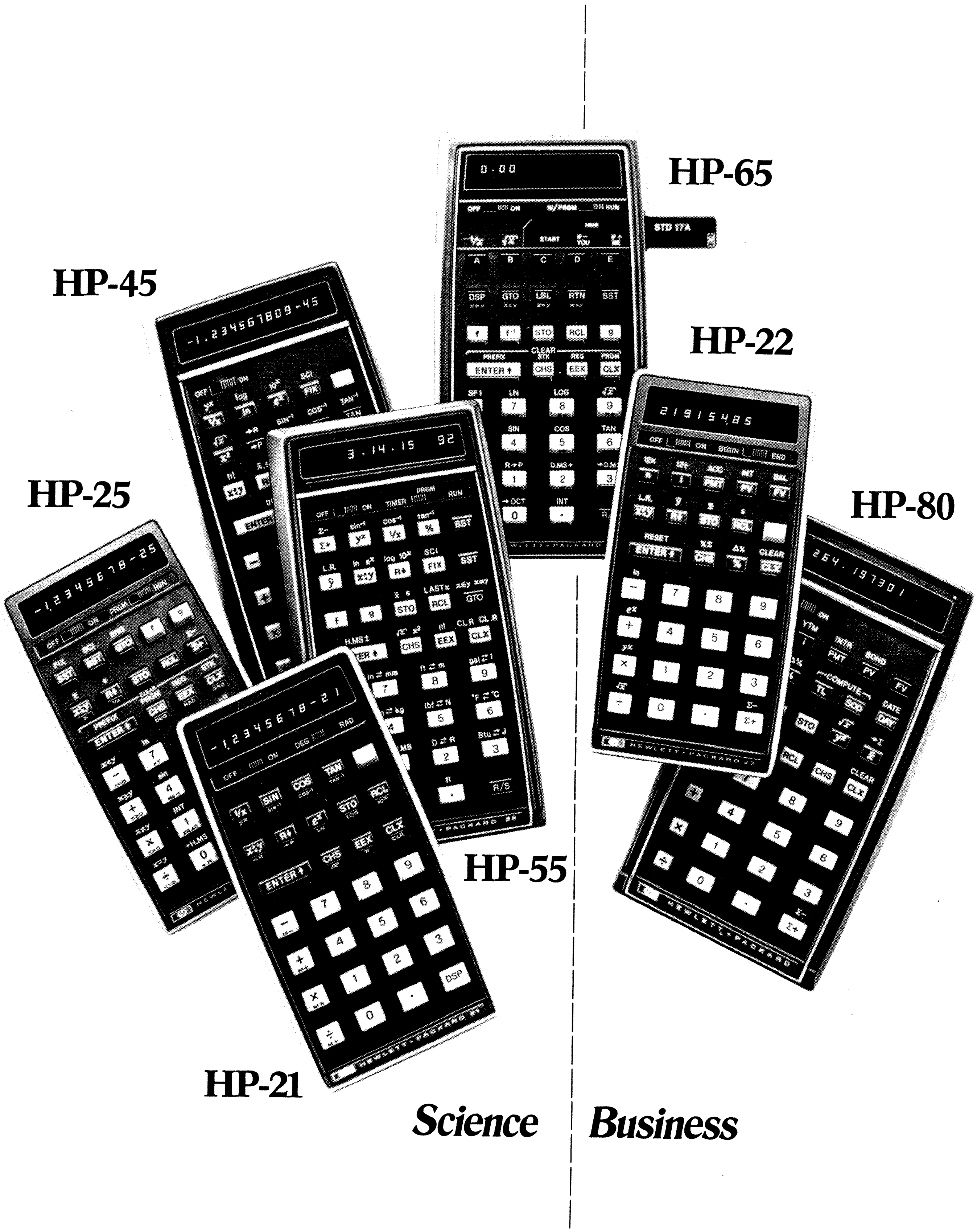

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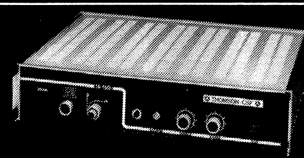
Possible applications for the Super-Nocticon range from photon counting to surveillance on particulary dark nights.



Low-light-level TV applications often require particular functions. To meet this need, THOMSON-CSF has also designed a series of video-storage units, among which the TH 7501, which includes an image-freeze feature, Electronic Zoom®, and enables image integration for up to several seconds.
Controlling the Nocticon photocathode by short pulses gives the possibility of capturing fast phenomena. The image, stored in the TH 7501, can then be observed at leisure on the screen of a conventional TV monitor.

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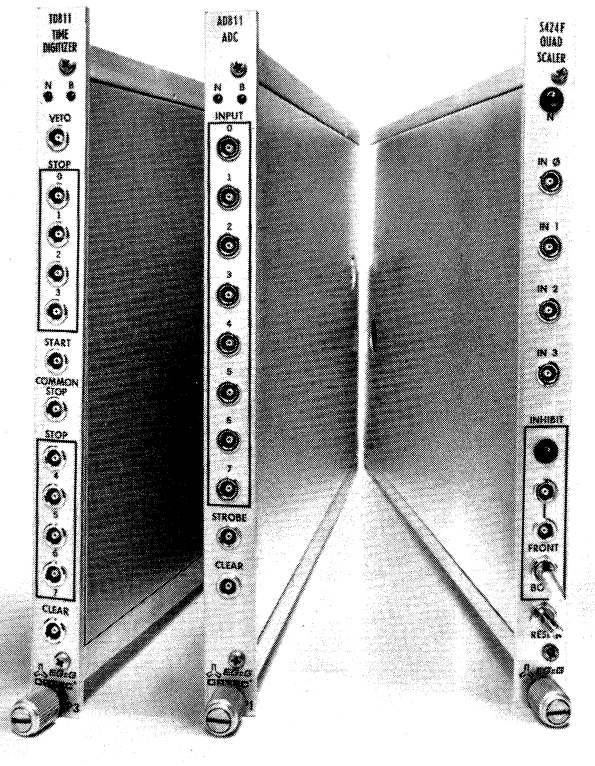

For complete information on these and other CAMAC modules by EG&G/Ortec, contact your nearby EG&G/Ortec representative or EG&G/Ortec Incorporated, 110 Midland Road, Oak Ridge, Tenn. 37830. Phone (615) 482-4411. Telex 055-7450. 74 offices in 49 countries providing sales and service around the world.

TD811 11-bit octal TDC
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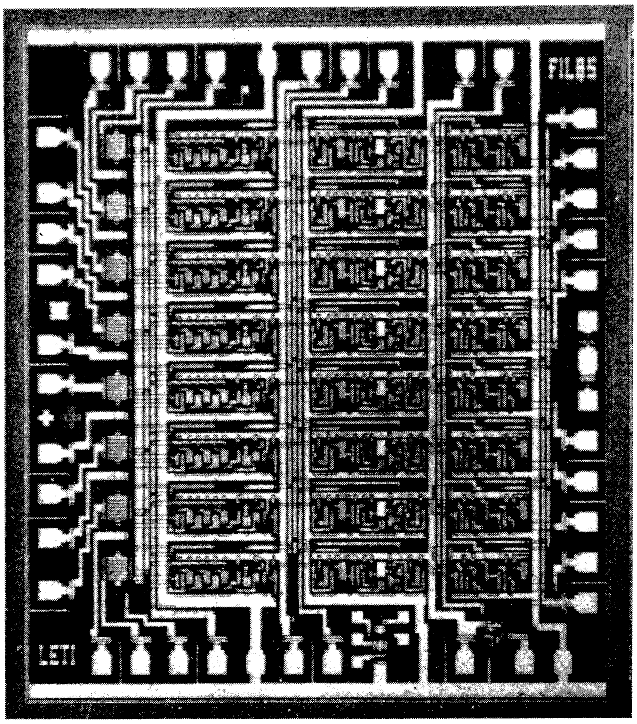

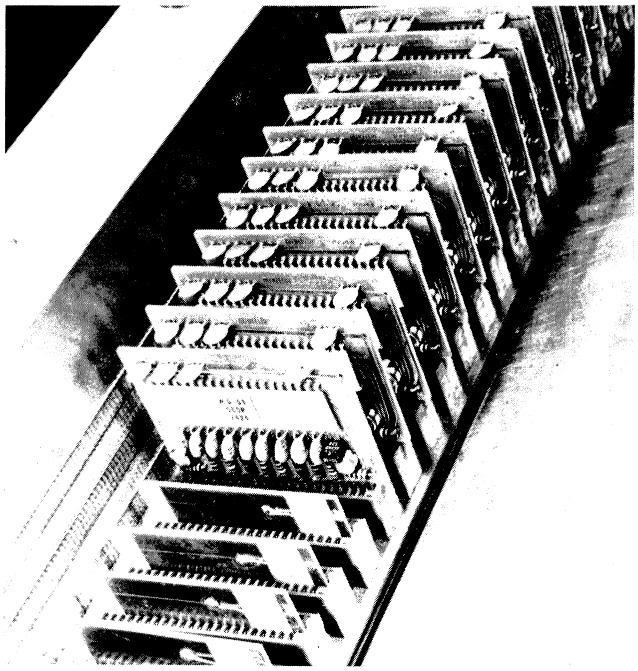

MBB coil for the SPS
at CERN (PHOTO CERN)

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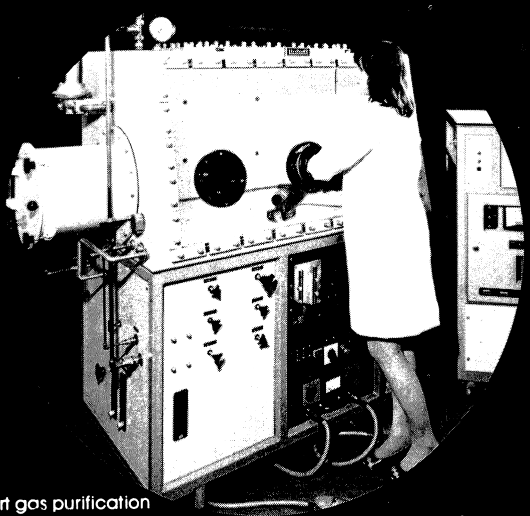

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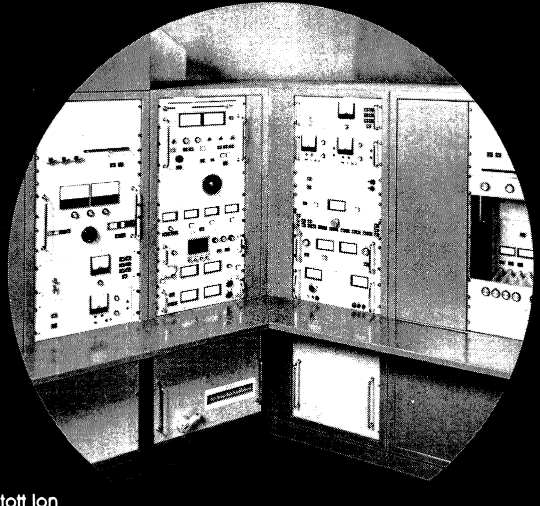

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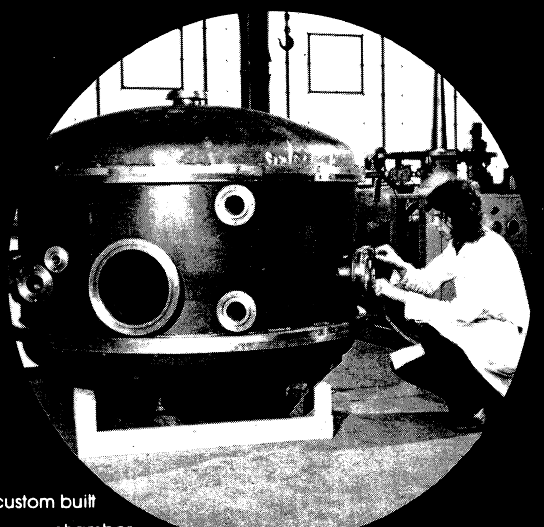

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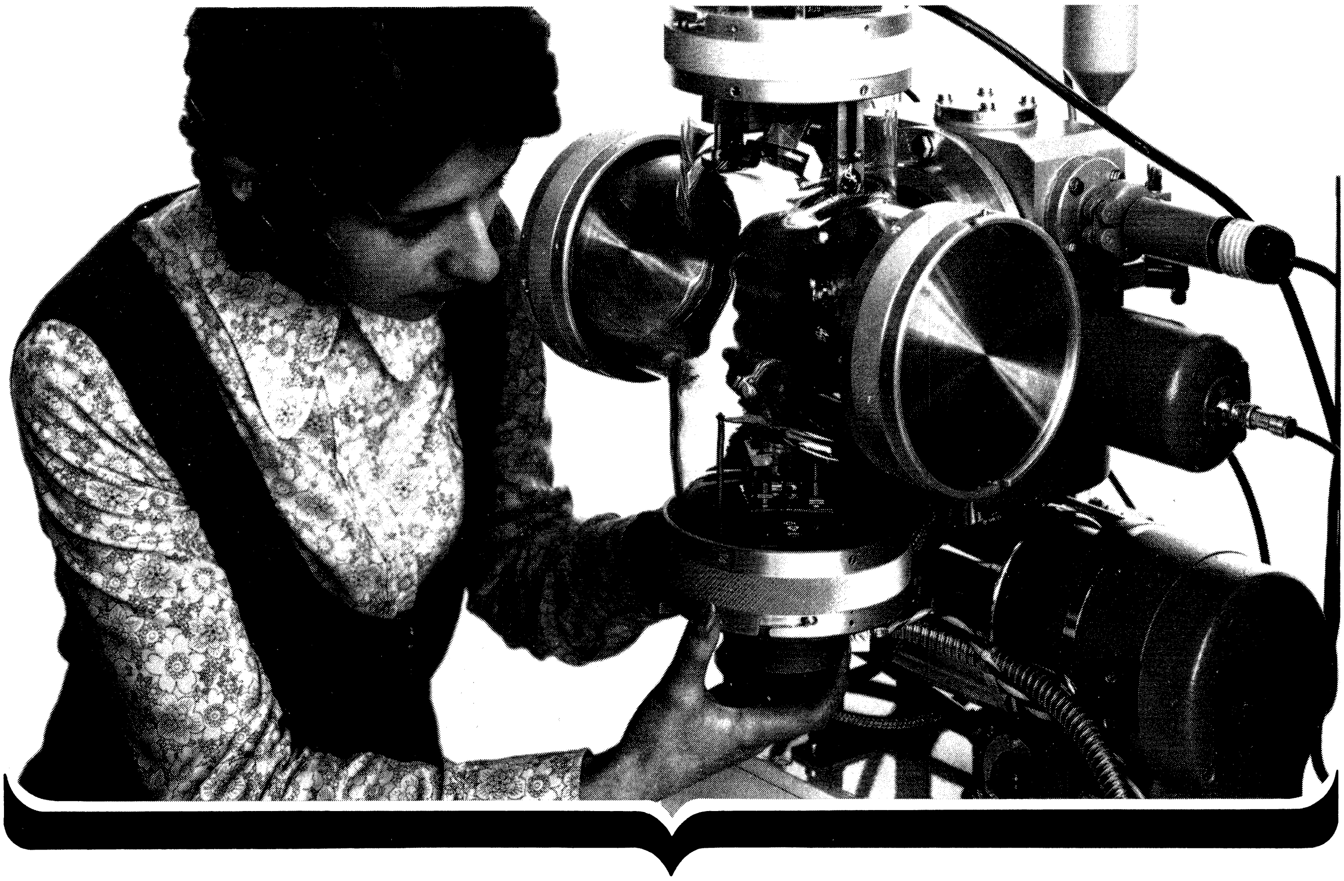
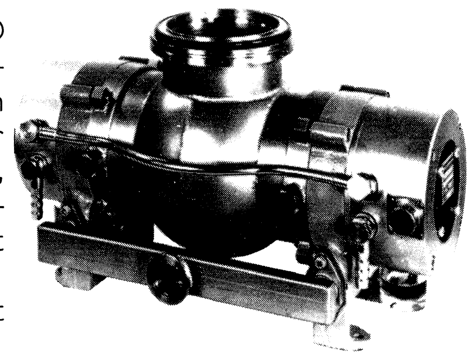
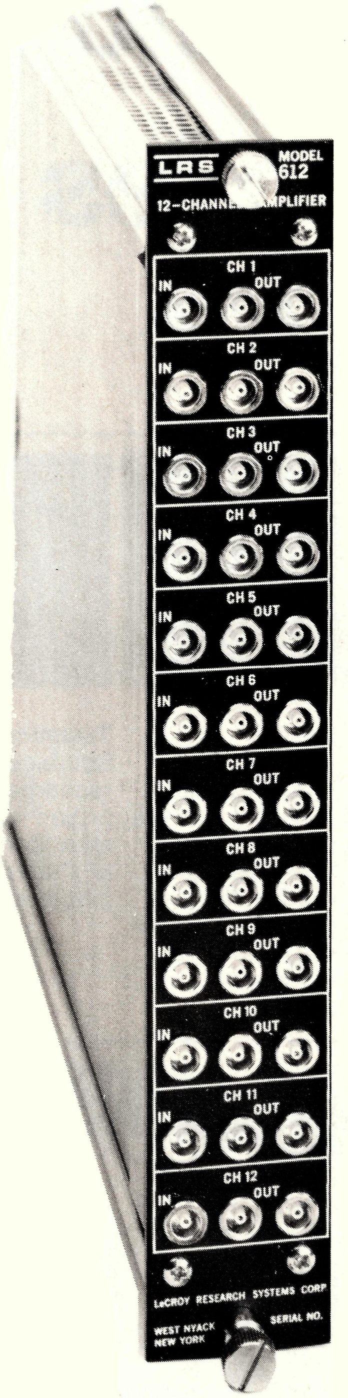
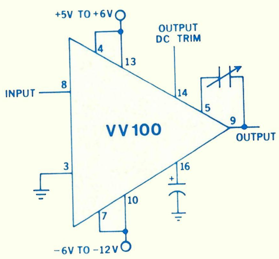






Increase the performance of your photomultipliers with uncompromising gain from LeCroy's new wideband, direct-coupled 10x amplifier



THE VV-100 . . . IN MODULAR OR INTEGRATED CIRCUIT FORM

By substituting highly stable, external amplification for that extra gain typically squeezed out of a photomultiplier by raising the high voltage, it is now possible to prolong the life of the tube and improve the linearity and signal-to-noise ratio at an extremely low cost. Consider these revolutionary features of the new VV-100 . . .

FLEXIBLE PACKAGING Either a standard 16-pin DIP hybrid circuit (VV-100), or a 12-channel NIM module (Model 612). In its hybrid form the VV-100 may be designed directly into your phototube base, or incorporated as a component in a subsequent circuit. It's ideal for applications constrained by a lack of space. In its modular form, the VV-100 is packaged 12-fold in a standard NIM module for convenient, general-purpose laboratory use.

WIDE GAIN-BANDWIDTH Offering a gain of 10, the VV-100 has a characteristic risetime of less than 2 nsec, yielding undistorted amplification at high pulse input rates. VV-100's (or individual channels of the Model 612) may be cascaded without appreciable signal degradation for gains up to 1000x.

TWO OUTPUTS PER CHANNEL . . . permit the user requiring photomultiplier outputs for both energy measurements and coincidence or counting applications to take advantage of the additional gain of the anode stage for both uses. This feature also eliminates the need for two cables (one each from anode and dynode) when the electronics are distant from the phototube.

TREMENDOUS LINEAR RANGE Integral non-linearity of less than 0.1% extends to -5 volts, permitting use of the VV-100 in applications demanding analysis over a wide dynamic range.

EXCELLENT DC AND GAIN STABILITY Negligible variation of output DC level with either supply voltage or temperature changes assures less than 1 mV long or short-term output drift under typical operating conditions. At last, a direct coupled amplifier suitable for ADC work!

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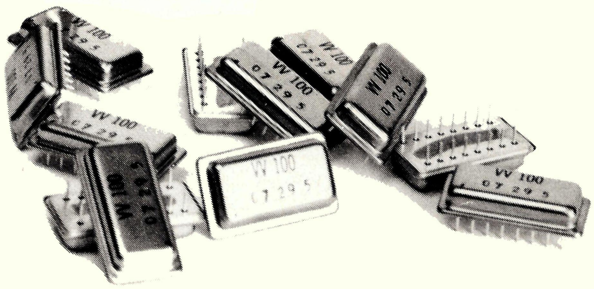
For further information, contact the LeCroy Particle Physics Division in West Nyack, New York, or your local sales office.



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