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*Cover photograph: A Soviet Ilyushin-76 heavy freight aircraft arriving at Geneva's Cointrin airport with a cargo of equipment for CERN. On board were fifty wire proportional counters and associated electronics, together weighing ten tons, supplied by the Joint Institute for Nuclear Research, Dubna, USSR for the CERN / Dubna / Munich / Saclay collaboration's muon physics experiment now being installed in the North Area of the CERN SPS. (Photo CERN 371.2.78)*

# Not quite impossible

## A look over the history of the neutrino

It is continually puzzling to 'outsiders' that elementary particle physics — the study of the smallest components of matter — requires some of the largest machines and equipment ever built.

Nowhere is this paradox more striking than in the study of the neutrino, one of the lightest (perhaps massless?) and most bizarre of all the particles discovered so far. In the words of Bruno Pontecorvo, a physicist who has spent many years studying the behaviour of this curious particle, 'it reminds me of the man who went to the zoo and saw a giraffe for the first time. 'That's impossible' he murmured.'

The neutrino was discovered on paper by Wolfgang Pauli, who found that the emission of small amounts of energy carrying spin one-half were needed to explain the observed behaviour in nuclear beta decay. This discovery was developed subsequently by Enrico Fermi, who first coined the name neutrino ('little neutral one' — since they carried no electric charge) for the emitted particles.

Although the postulate of the neutrino explained beta decay, to observe such a particle directly was another matter. With no other handle than its spin, the neutrino is simply a burst of energy with no rest mass hurtling through space at the speed of light and interacting only through the weak interaction. A low energy neutrino could travel through a block of lead light-years thick and still emerge unscathed.

How could such ridiculously elusive particles ever leave sufficient observable traces for us to study them ? The only hope was that if enough of them could be found concentrated together and a large amount of detecting material put in their way, the tiny fraction which interacts might give observable effects. It is a tribute to the ingenuity of physicists that this hope has been realized to such an extent that not only have neutrinos been detected, but they have also now become a commonplace experimental tool !

This work began in 1953 when, undeterred by the awe-inspiring aloofness of the neutrino, F. Reines and C.L. Cowan installed tanks containing tons of cadmium solution alongside the Savannah River nuclear reactor, where $10^{13}$ antineutrinos per square centimetre per second emerged from the beta decay of nuclear fission products. Large scintillation counters above and below the tanks saw the correlated gamma rays coming from the absorption of the neutrino reaction products in the tons of solution. For this feat of detection Pauli was forced to provide the case of champagne which, twenty years before, he had wagered against anybody ever seeing neutrinos.

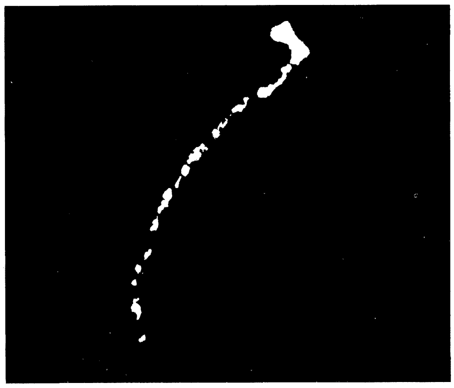
Several years later, Bruno Pontecorvo in the USSR and Mel Schwartz in the US pointed out that it should be possible to use high energy neutrinos to study the weak interactions, and interest in neutrino experiments began to revive. It was realized that the new generation of proton synchrotrons then being built (particularly the 33 GeV Brookhaven AGS and the 28 GeV CERN PS) would be sources of high energy neutrinos which would interact with matter about a million times more readily than those from nuclear reactors. Even so, neutrino catching was still a difficult challenge.

What could these high energy neutrino experiments at accelerators show? Simply to detect neutrinos would contribute little, as there was ample proof of their existence. But could neutrinos be used as a probe to investigate yet unseen aspects of particle structure? In principle this was possible, but the logistics of separating neutrinos from all other particles, of providing enough target material for them to interact, and then of detecting the products of these interactions, seemed an insuperable obstacle.

### *Theoretical interlude*

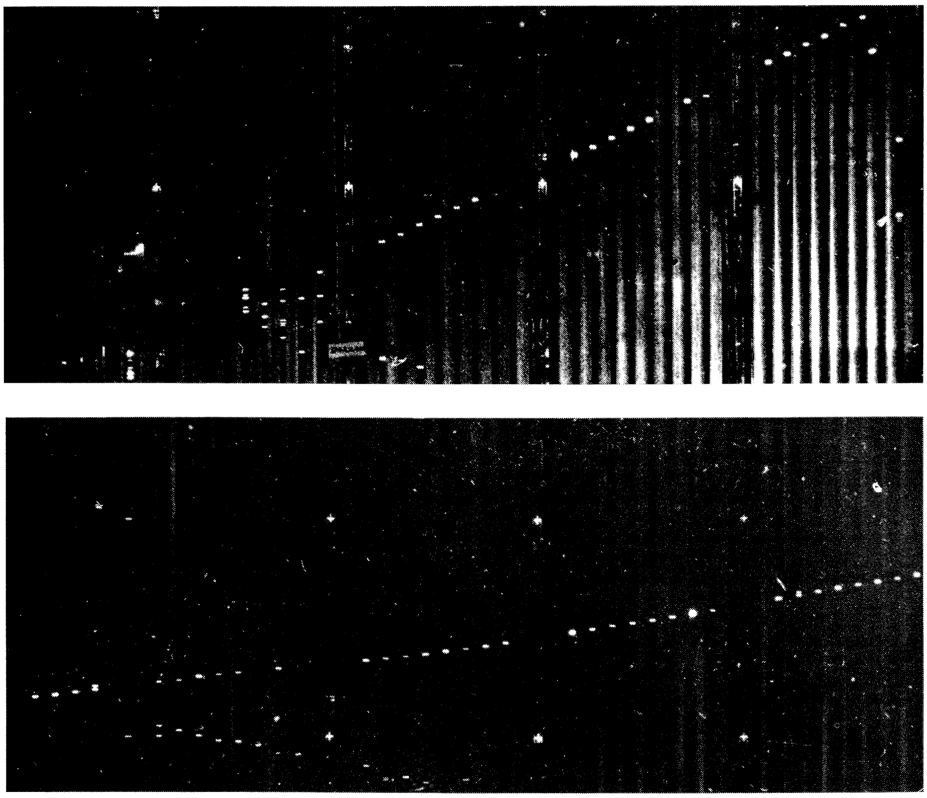
In the 1950s, the study of spin and polarization effects in nuclear beta decay led to the discovery of another peculiar neutrino habit. The electrons coming from the beta decay of spin-polarized nuclei were found to show definite asymmetry effects. This implied that the long cherished notion of parity conservation (which says that Nature does not distinguish between right and left) is not valid in beta decay. We cannot transform a radioactive decay into its mirror image (so that, for example, a nucleus spinning clockwise would instead turn anticlockwise) and hope to leave the features of the decay unchanged.

This was a puzzling discovery because until then Nature had seemed to show a universal left-right symmetry which meant that every reaction had a 'mirror image' which behaved in the same way. Now it seemed that, in beta decay, there is some fundamental mechanism which differentiates left from right, clockwise from counterclockwise. These directional concepts are fixed in the weak interactions and



*Direct evidence for the existence of neutrinos in nuclear beta decay as reported in Soviet Physics, JETP, in 1959. A cloud chamber experiment carried out at the Nuclear Physics Institute, Debrecen, Hungary, showed this example of the beta decay of helium-6. The long track of the escaping electron and the short track of the recoil nucleus can clearly be seen. A third (invisible) particle — the neutrino — must obviously also have emerged from the decay in order to conserve momentum.*

*Some of the first evidence of the interaction of high energy neutrinos with matter revealed that neutrinos exist in two types. In 1962, a Columbia University team working at Brookhaven produced a beam of 'artificial' neutrinos from the decay of pions and kaons. The neutrinos interacted to produce muons, which easily traversed the spark chamber plates, as seen in these photographs. The fact that muons, rather than electrons, were produced showed that these neutrinos from meson decay were inherently different from the neutrinos produced along with electrons in nuclear beta decay.*



are not some whim of human choice.

The ability of the weak interactions to distinguish left from right was quickly attributed to the neutrino. A theory was developed in which the observed beta decay asymmetries could be explained if the neutrino spin direction were restricted so that neutrinos could only exist in a polarized 'left-handed' form with their spin vectors pointing back along the way they had come, and antineutrinos only in a right-handed form with their spin vectors pointing forwards.

These 'helicities' of the neutrinos are immutable and contradict the old idea that the mechanism of a particle reaction can be reflected in a mirror without affecting the observable result. In fact the mirror image of the neutrino looks like an antineutrino, so contradicting another long cherished idea — the particle-antiparticle symmetry of charge conjugation invariance.

It is an entertaining anecdote in retrospect that a theory describing a zero mass, spin one-half particle had been developed by Herman Weyl several years before the neutrino was first postulated. When Pauli predicted the neutrino, he found no use for the Weyl formalism as it violated parity conservation!

Neutrinos were postulated and discovered as a result of nuclear beta decay, a process which produces electrons, but they play a similar role in the weak decays of the pion and the kaon, a process which produces muons. The muon itself, although unstable, was not seen to decay into an electron and a photon, as might be naively expected from ideas of the muon as some sort of heavy electron.

It was as though the weak interactions distinguished between muons and electrons, as well as between left from right. If this were the case, then the neutrinos coming from beta decay should be somehow different to those coming from pion decay. This was something which could only be checked in experiments at accelerators.

### *The first accelerator neutrinos*

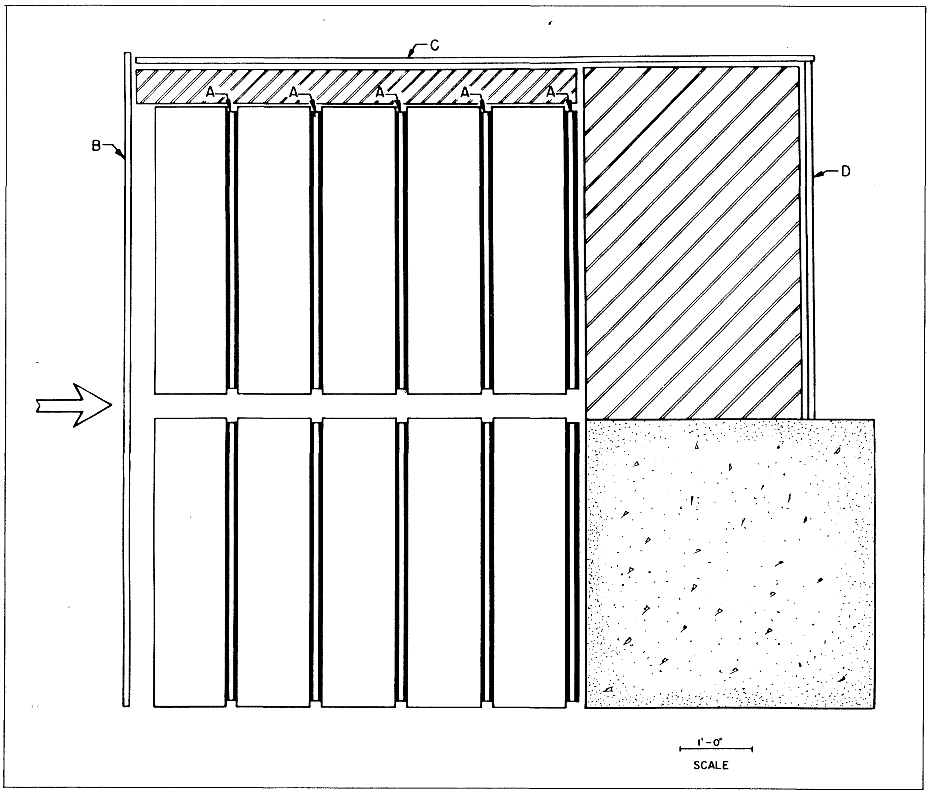
To do neutrino experiments, three things are necessary — a lot of neutrinos, a lot of shielding to isolate them, and a lot of target and detecting apparatus. Only by paying careful attention to each of these requirements had Reines and Cowan been able to see the interactions of neutrinos from beta decay. Now the problem had to be solved again for experiments at accelerators.

Big water filled detectors like those used at the Savannah River reactor were no good, because physicists wanted to look at the behaviour of the neutrinos, not just to record them. As well as providing enough bulk to stop some of the elusive neutrinos as they flew through the beam lines, any detector would probably have to distinguish muons, which are also notorious for their reluctance to interact with matter.

New types of large detectors were required, and people conjured with proposals such as embedding thousands of counters in a mass of lead. The detector problem was handily solved by the development of large-scale spark chamber techniques, which allowed big enough counters to be made. At about the same time, the techniques of large bubble chambers filled with heavy liquid were sufficiently mastered to provide another means of detection.

At Brookhaven, the stage was set for the first experiments using 'synthetic' neutrinos. A substantial neutrino flux was obtainable from the AGS proton synchrotron without first having to focus the neutrinos' parent particles (pions and kaons) into a concentrated beam. An ample supply of iron

*A plan of the apparatus used by the Columbia team at Brookhaven to study high energy neutrino interactions. Other particles in the incoming beam were first removed by 13.5 m of iron shielding before neutrinos entered the detector, made up of ten one-ton spark chambers, each containing nine aluminium plates. Sheets of scintillator (A) between these chambers acted as triggers, while anticoincidence counters (B, C, D) surrounding the detector eliminated the cosmic ray background.*



shielding had been procured from naval scrapyards, and large spark chambers were ready and waiting.

In 1962, a ten ton aluminium spark chamber used by the Columbia group (including Mel Schwartz, Leon Lederman and Jack Steinberger) caught about fifty examples of the elusive neutrino interactions. In these photographs, it was seen that the synthetic neutrinos coming from pion decay interacted with nucleons to give muons rather than electrons, and were therefore different to the neutrinos found naturally in nuclear beta decay. This showed that neutrinos come in two forms, electron-like and muon-like, both equally elusive !

At CERN, techniques using 'magnetic horns' had been developed to concentrate the neutrino parent particles into a narrow beam and so boost the flux of neutrinos. As well as confirming the Brookhaven sighting of the muon neutrino, CERN experiments using spark chambers and the freon-filled heavy liquid bubble chamber were able to use the neutrino beams as a nucleon probe, and deduced that the distribution of electric and magnetic charge in nucleons viewed by neutrinos was the same as that seen in other experiments using electron projectiles.

## *The reluctant W boson*

At the same time as the identification of the two kinds of neutrinos was achieved, physicists were also looking for another type of particle. They were convinced that weak interactions, including those of neutrinos, came about through the exchange of 'intermediate vector bosons' (vector bosons being spin one particles) in the same way that electromagnetic interactions had been so successfully explained in quantum electrodynamics by the exchange of photons (also spin one particles).

Unlike the photon, the intermediate vector boson, usually codenamed 'W', would have mass. The heavier it was, the more difficult it would be to produce it as a 'free' particle, living long enough to leave its signature in an experiment. It was the hope of the first generation of neutrino experiments that this W-particle would turn up, but this hope was not realized. All that could be done was to demonstrate that its mass was much higher than that accessible to the experiments and to plan for the day when higher energy accelerators would be available.

However, as theoreticians were quick to point out, the discovery of the W would not have opened the door to any new understanding at that stage — it would simply have confirmed a belief of some thirty years standing in its existence. While its mass is steadily pushed up as higher and higher energy experiments fail to reveal it, sooner or later something should show up. Even if it is not as simple as a single particle, there seems certain to be some mechanism in weak interactions which mimics boson exchange. The reluctant W-boson continues to tantalize physicists and offers a tempting prize for future experiments.

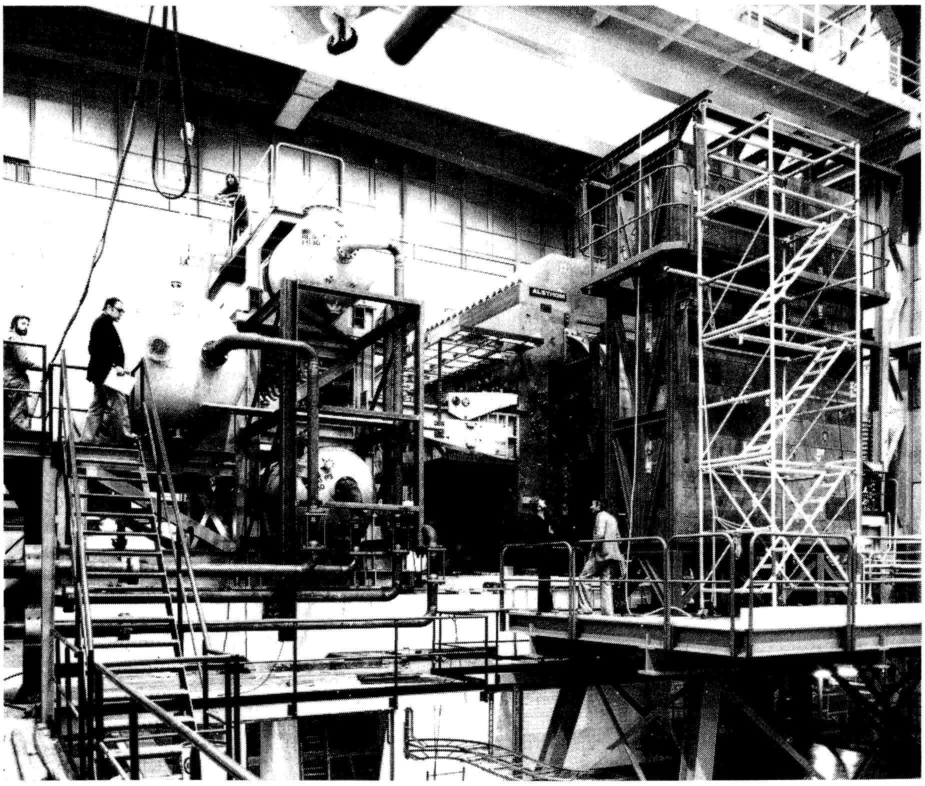
## *Giants, new and old*

The next major discovery in neutrino physics was less expected (though some theoreticians had predicted it) and did open up a new area of uncharted physics. But first a detector of appropriate scale had to be built.

While the first generation neutrino experiments were under way at Brookhaven and CERN, an agreement was signed between the French Atomic Energy Authority (CEA) and CERN for the construction of a giant heavy liquid bubble chamber, weighing 25 tons and some 5 metres long, to contain some 18 tons of freon. This provided a many-fold increase in effective target size over the heavy

*The heavy liquid bubble chamber Gargamelle — scene of the discovery of the weak neutral current at CERN using beams from the PS. The 25 ton chamber is seen here being installed in its new position at the SPS, where it could add further chapters to the already eventful history of neutrino physics.*

*(Photo CERN 29.11.76)*



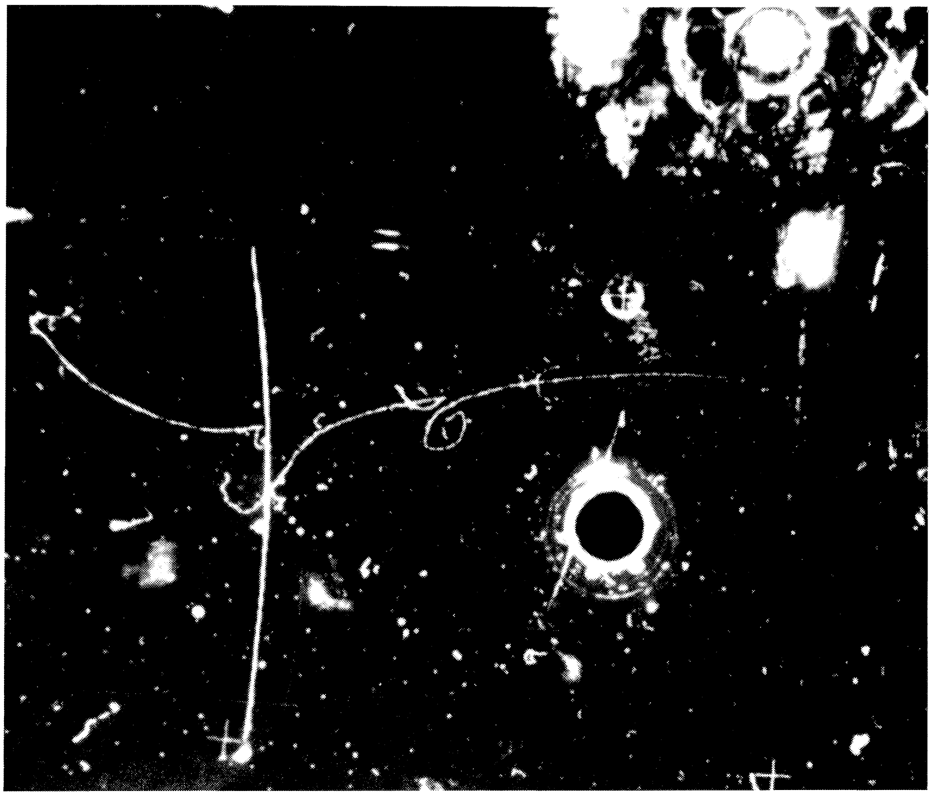
liquid chambers used up to then. Even by neutrino standards, here was a target to be reckoned with.

The new chamber was named Gargamelle, after the mother of the gluttonous giant Gargantua in the classic book by Rabelais. According to the story, she gave birth to her monster child through her ear after consuming sixteen quarters, two bushels and six pecks of tripe, followed by a potion which paralysed her sphincter. At CERN, the new Gargamelle was also to be the scene of some startling events !

## *The neutral weak current*

Until Gargamelle began work, neutrino interactions were always seen to result in a shuffling around of electric charges. Typically, an incoming neutrino (of the muonic kind, coming from the decay of a pion or a kaon) would strike a neutron in the target material, producing a negative muon and a proton. Whatever was responsible for the interaction (the W-boson ?) had carried a unit of negative charge away from the target nucleon — it was a 'charged current'. Unlike the electrically-neutral photon, the mediator of the weak interaction always seemed to carry electric charge.

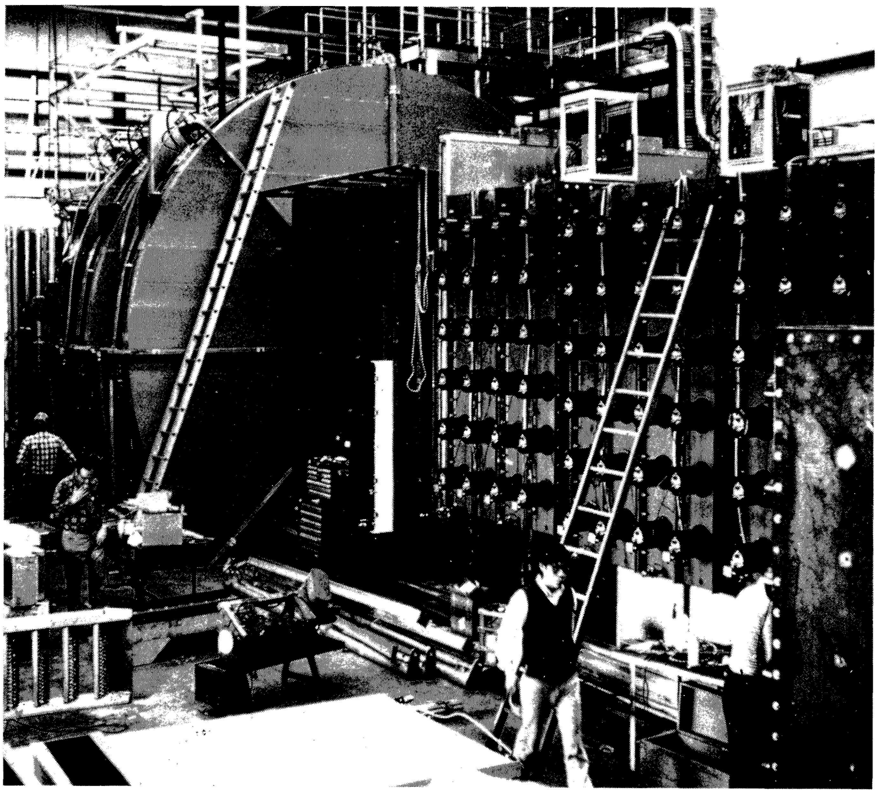
In the meantime, however, a host of theoreticians had been piecing together an ambitious model which incorporated the weak and electromagnetic interactions of both leptons and hadrons in the same breath. One by-product of this model



*The discovery of the neutral current in the Gargamelle bubble chamber at CERN in 1973. Previously, weak interactions had always been seen to involve a shuffling around of electric charges between the participating particles. In this example, the (invisible) neutrino coming in from the right has passed unaltered through the chamber but on its way has set an electron in motion. This discovery gave strong support to some theoretical predictions that weak and electromagnetic interactions could be unified and also paved the way for the identification of an additional type of quark — the charmed quark.*

*The study of the smallest particles requires the largest apparatus. This apparatus seen under construction at Fermilab at the end of 1976 is the second generation neutrino detection system of a Harvard/Wisconsin/Pennsylvania/ Fermilab / Rutgers collaboration. Their detectors found the emission from the neutrino interactions of two muons, explicable in terms of the existence of the charmed quark, and of three muons, which has no clear explanation yet.*

*(Photo Fermilab)*



was the prediction of a neutrino interaction mechanism which carried no electric charge — the so-called neutral weak current.

While conventional neutrino interactions are elusive enough, this neutral current would be even harder to see. The neutrino of course leaves no track in a bubble chamber, but the conventional charged current interactions produce charged muons which do leave tracks. In a neutral current interaction, the neutrino would fly undetected through the bubble chamber, but on its way it would interact and set other particles in motion.

An analysis of about 700000 bubble chamber pictures from Gargamelle revealed an event where a neutrino had flashed right through the chamber but on its way had nevertheless interacted with an electron leaving evidence of the interaction in its wake. Many other events were then found. As well as being startling in its own right, the new discovery confirmed the predictions of the theorists and paved the way for the discovery of the new particle property called charm — another prediction of the same model.

Neutrino experiments added to the charm story — they saw negative muons and positrons in association with strange particles and quantities of events producing two muons. Neither of these two types of event could be understood in terms of previously known processes, but fitted in with ideas of an additional type of quark — the charmed quark. These neutrino observations provided some of the first evidence for the existence of charmed particles.

## *The deep inelastic age*

After the discovery of the neutral current, attention turned to the use of the neutrino as a tool for probing the deep interior of nucleons. Experiments using high energy electron beams at Stanford had shown that in so-called 'deep inelastic scattering', the proton seemed to behave as though it were a composite particle made up of smaller objects, termed partons.

It was important to see if such behaviour also showed up in high energy neutrino experiments when the weak interaction rather than the electromagnetic interaction was at work, and if so, to investigate the relationship between these newly discovered partons and the familiar but unseen quarks, held to be responsible for the static properties of hadrons (see January/February issue, page 7, for a fuller account of the parton saga).

The behaviour seen in high energy electron experiments was indeed found to occur in neutrino experiments, showing that similar mechanisms are at work. In addition to this, a wealth of data gathered in Gargamelle on the apparent inner structure of nucleons enabled the older static quark ideas to be combined with newer dynamic parton concepts to produce a single but powerful new model for hadrons. Moreover, this basically simple quark/parton model has a lot of predictive power and any deviations from these predictions would be expected to show up sooner or later in neutrino or other experiments.

The behaviour which is now emerging over repeated observations in the neutrino programme now being carried out at Fermilab and CERN is broadly in line with the quark/parton model using a minimum number of quarks and with the standard theoretical formulation which predicted the existence of the neutral current.

Eyebrows are raised from time to time by odd happenings like events with the unexplained production of even more muons (the record now stands at four muons per event, seen at both CERN and Fermilab) but, apart from this, the high energy neutrino seems to be remarkably 'well behaved'.

*Surprises and no surprises*

Neutrino experiments have been a steady source of surprises. The prediction of such an unusual particle was itself a surprise, and subsequent discoveries such as parity violation, the existence of two kinds of neutrinos, the neutral weak current and the multimuon events have lived up to this initial reputation.

Neutrino physics continues to attract some of the ablest experimenters and command some of the most impressive configurations of apparatus. It seems to have entered a, possibly illusory, phase of respectability where little is happening that is not expected. But, with such a concentration of ability and resources, it would not be surprising if neutrino physics lived up to its reputation and continued to be surprising.

## Neutrinos: the Steinberger view...

*According to Jack Steinberger, spokesman of the CERN / Dortmund / Heidelberg / Saclay counter experiment studying neutrino interactions at the CERN SPS, neutrino physics seems to have become fashionable these days. A veteran at the neutrino game, having been a member of the team which first studied high energy neutrino interactions at Brookhaven back in 1962, Steinberger prefers instead to overlook transient trends and concentrate on what in his view is the central objective of neutrino physics — the study of the structure of the nucleon.*

*The neutrino, says Steinberger, provides the easiest way to get inside the nucleon, providing data which is 'cleaner' and more relevant than that obtained using other lepton beams. The mechanism of neutrino interactions, he points out, is not damped by 'propagator terms' due to the exchange of light quanta and is therefore able to probe deeper into the high momentum transfer region where we lack understanding. It is at these high momentum transfers that the deep interior of the nucleon is laid bare and where candidate theories of strong interactions, like quantum chromodynamics, have to prove their worth.*

*With logical developments of today's apparatus, Steinberger maintains, it should be possible to do still better neutrino experiments, ensuring good physics material for another five years or so, the aim being to build up comprehensive data on the deep inner structure of nucleons and to contribute towards the development of a theory of the strong interactions.*

*As regards potential new discoveries, he prefers to adopt a 'wait and see' attitude. The intermediate vector boson phenomena can perhaps be written off to await experiments with the high energy storage rings now being built, although a short-term programme of neutrino physics could uncover signs of new quarks.*

# Around the Laboratories

## DARESBURY
## Computer networking

During the past few years there have been changes in the functions of the UK Science Research Council (SRC) Laboratories which have had repercussions on the facilities which university scientists need for their computing. The Daresbury Laboratory has been helping users through the transitional years and bringing in new facilities for the future.

Most computing which arises from the research work supported by the SRC is handled either at the Rutherford Laboratory, which has two IBM 360/195s or at Daresbury, which has an IBM 370/165. About three years ago, both Laboratories developed star networks in which land lines radiated out from the central computers into university departments and other Laboratories (such as CERN). These lines were attached to small computers with card readers, line printers and time sharing terminals. Users could then submit jobs to the central machines, receive output and do other interactive work.

The requirements are fairly obvious; the computing systems at the two Laboratories need to be interconnected with the possibility for a user at any workstation to select his host computer. Previously he could communicate only with the computer to which his station was originally attached. To implement such a scheme was a substantial undertaking and much of the work has been done in collaboration with Rutherford. All the essential components are now installed and working but a continuing programme of improvements and developments can be expected to meet the changing requirements.

All the Daresbury workstations have access to the network through a gateway (small computer system) at the Laboratory which connects into the

370/165 and also into the land lines to Rutherford. Both Laboratories have implemented the Interactive Terminal Protocol (ITP) defined by the UK Post Office. This defines a standard format for messages between computers and terminal controllers and its adoption allows any terminal attached to the two centres to access either the file editing and job submission system (ELECTRIC) at Rutherford or the IBM Time Sharing Option (TSO) at Daresbury. The use of ITP will also enable these terminals to access facilities elsewhere on the Daresbury network, such as the data acquisition systems at the accelerators.

The Daresbury workstations operate in a packet switched mode. The data packets flowing to and from them contain information on their source and destination — they are in a form suitable for transmission through a network containing many sources and destinations. The lines to the workstations now operate 'fully duplex' — data can flow in both directions at the same time. Individual terminals can communicate independently with different host computers. Line printer output can be received from different hosts on the same printer. Each workstation can also act as a node or switch and can provide other attached computers or workstations with access to the network.

Most of the objectives, formulated two or three years ago, are now beginning to be met. New requirements have since emerged and the development programme is by no means complete. Nevertheless, a system has been built in which existing workstations and lines can be used more efficiently and the computing facilities available to the users have been greatly improved.

The vacuum system of the protosector was tried in January using

## CORNELL
## CESR injection tests

*A 'protosector' of the 8 GeV electron-positron storage ring, CESR, installed on the left in the tunnel at Cornell. The 12 GeV synchrotron is on the right. Positrons have been transferred from the synchrotron into the CESR section at energies of 5 and 8 GeV.*

*(Photo Cornell)*

Early in December 1977, positrons were accelerated up to 5 GeV in the Cornell synchrotron and transferred into a 'protosector' of the 8 GeV electron-positron storage ring, CESR, consisting of five half-cells of the storage ring lattice. The positron intensity from the protosector was observed in a quantameter and the transfer efficiency was measured to be about 85 %. The actual intensity of positrons in the sixty-bunch train was close to the design value.

The positron filling scheme for CESR has a fast kicker magnet to extract successive single positron bunches from the storage ring and send them back around the synchrotron for varying numbers of turns in order to compress them finally into one intense bunch (see April issue 1976). The kicker, consisting of three ferrite-loaded modules each 50 cm long, was installed in the protosector and tested. The required deflection of the positrons for filling at 8 GeV was successfully achieved. The detailed time structure of the pulse was studied and the rise time was adequate to pick out a single bunch (about 30 ns). However, the trailing edge would probably disturb the next bunch and it will be necessary to pick successive bunches from the end of the sixty bunch train. Injection studies were concluded by transferring an 8 GeV positron beam from the synchrotron into the protosector.

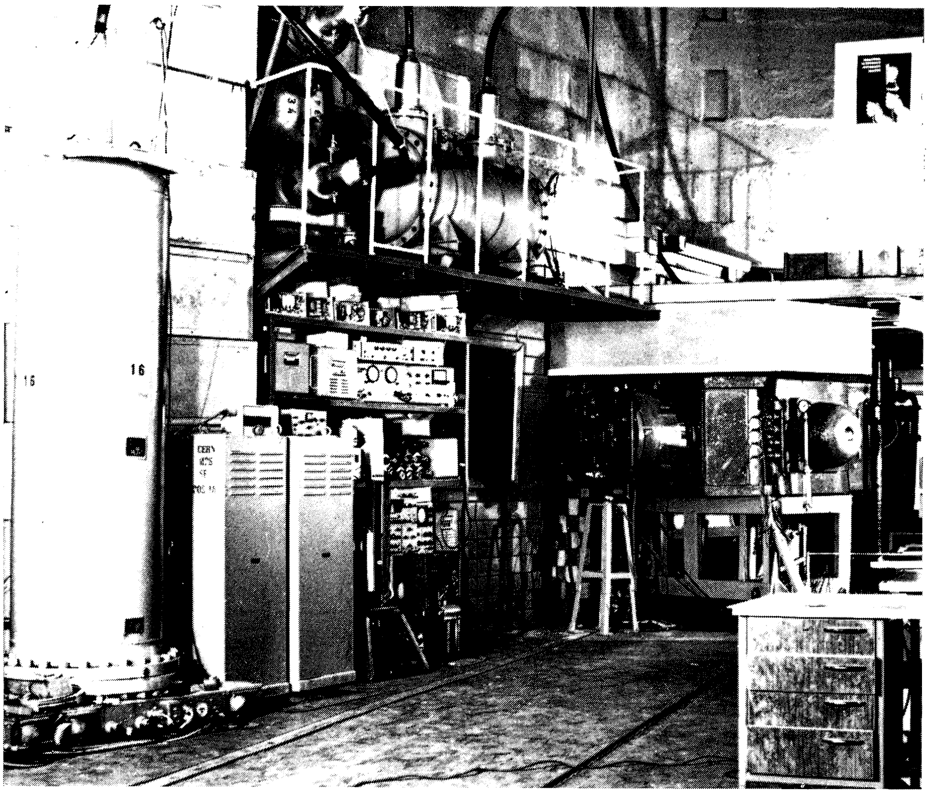
The vacuum system of the protosector was tried in January using the distributed ion pumps built into the chambers and 'lumped' ion pumps in alternate straight sections. After a mild bakeout at about 100° C, the pressure stabilized at about $10^{-9}$ torr.

Meanwhile, since the beginning of 1978, a horde of people has been at work in the experimental halls tearing out all the experiments and beam lines and even parts of the synchrotron, so that the building contractors could start in March to dig out the experimental pits and enlarge a part of the tunnel. The pits should be completed by 15 July and the auxiliary work by 1 October.

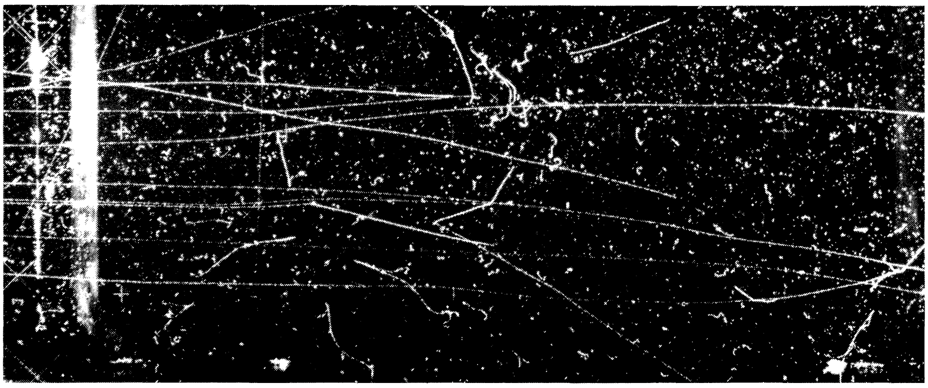
An effort is being made to speed up the completion schedule for CESR so that first operation of the storage ring, at beam energies of up to 5.5 GeV, can be projected for early summer of 1979.

## ITEP/PADOVA
## Neutral kaons in xenon

In 1977 a team of physicists from the Institute for Theoretical and Experimental Physics (Moscow) and the Istituto di Fisica dell'Università (Padova) began an experiment to study some rare modes of neutral kaon decay using the ITEP xenon bubble chamber at the ITEP proton synchrotron. This investigation is carried



The xenon bubble chamber in the experimental hall at the ITEP proton synchrotron. The chamber and part of the radiation shield are seen in the centre. On the left is the CERN high voltage equipment for the separated positive kaon beam.



A photograph of a neutral kaon decay, detected in the xenon bubble chamber, which gives three neutral pions converting to six gammas each yielding an electron-positron pair.

out under the terms of the agreement between CERN and State Committee for the Utilization of Atomic Energy (USSR).

The main aim is to study the time distribution of $\pi^0\pi^0\pi^0$ and $\pi^+\pi^-\pi^0$ decays of neutral kaons in order to obtain new and more reliable estimates for the CP violating parameters and also a new upper limit on the $K_s$ decay into two gammas.

In previous experiments studying the time distributions of neutral kaon decays the statistics were several hundred $\pi^+\pi^-\pi^0$ decays and only 22 of the $\pi^0\pi^0\pi^0$ decays. It is planned to collect about two thousand decays for each mode in the experiment, which will improve the knowledge of CP violation in kaon decays. The attainable limits for the CP violating parameters are about $10^{-2}$ whereas, from previous experiments, the limits are much higher. Another very important reason for improving the accuracy of the measurements is that their confidence limits must be known in order to check CPT invariance more precisely through the Bell-Steinberger unitary relation.

Experiments to investigate the decay into three neutral pions are difficult to perform since all six gammas from the pions have to be detected and their energy measured. These difficulties can be overcome with a xenon bubble chamber because the radiation length in liquid xenon is very short (3.8 cm). The ITEP chamber has a sensitive volume of 104 × 40 × 43 $cm^3$ and provides a 95% gamma detection efficiency.

It is exposed to a 0.85 GeV/c separated positive kaon beam equipped with a CERN/ITEP separation system. This momentum gives a momentum range in the effective volume of the chamber of 0.56-0.81 GeV/c where the charge exchange cross-section for reaction $K^+ + d \rightarrow p + p + K^0$ is at a maximum and the background from the reaction $K^+ + n \rightarrow K^0 + \pi^0 + p$ is negligible. This makes it possible to analyse small neutral kaon times of flight, which is the most sensitive of the parameters under study because of interference effects.

At the beginning of 1977 the tests of electrostatic separators, built in ITEP with the help of CERN, were completed and the tuning of the beam with two-stage separation was performed. By June the first exposures had been carried out and 600000 pictures were obtained. In January 1978 an additional 300000 pictures were taken and are now being scanned and measured in ITEP and Padova. In ITEP, besides the conventional image plane digitizers, there are also stereoreprojectors with computer on-line which make it possible to do a complete geometrical analysis of the events to obtain the results on a display screen during the measurement. This is essential for events with a complex configuration like the six gamma decays.

The preliminary results show that the average number of positive kaons per photo is eight, giving 0.4 interactions per photo where a neutral kaon is produced. The planned numbers of decays will be obtained by taking 1.5 million pictures which will be completed within this year.

## TRIUMF
## Pion production by polarized protons

Two surprising results have come from the experimental programme at the TRIUMF cyclotron using a variable energy polarized proton beam to study pion production in two body final states. Firstly, in the $pp \rightarrow d\pi^+$ reaction, significant d-wave effects have been found close to threshold. Secondly, *A general view of one of the stereoreprojectors used at ITEP for the treatment of the neutral kaon film.*

*(Photos ITEP)*

for positive pion production from beryllium-9 and carbon-12, the polarization analysing power has remarkably similar angular distributions, independent of the excited state of the residual nucleus. The distributions are like those for $pp \rightarrow d\pi^+$, suggesting a reaction mechanism quite different from that assumed in previous theoretical work.

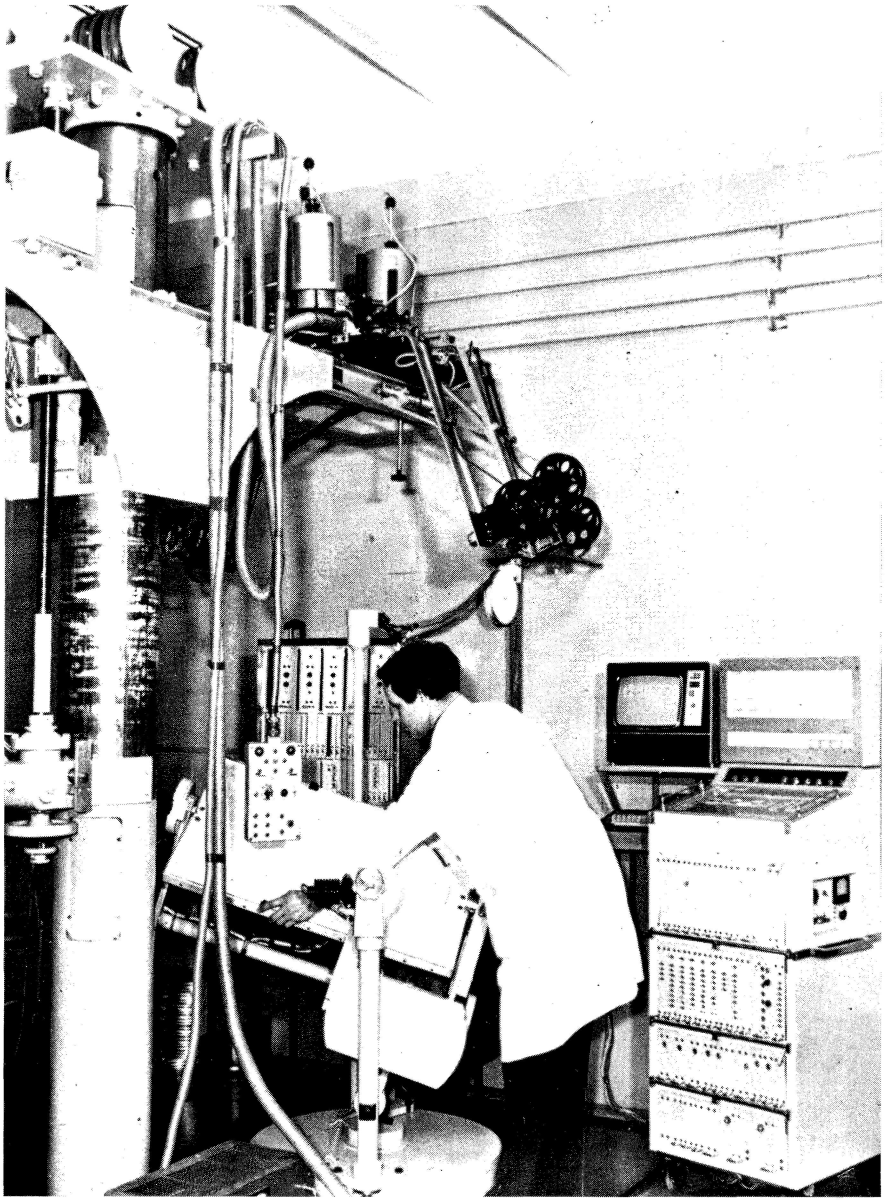
The experiments were mounted by a University of British Columbia group (led by Garth Jones and Ed Auld) on a beam line which provides high current proton beams to the meson production targets during unpolarized running. The apparatus consisted essentially of a 50 cm Browne-Buechner magnetic spectrograph, inherited from the now-defunct 3 MeV Van de Graaff at the University of British Columbia. The spectrograph was instrumented by installing a 24 element scintillation counter hodoscope along the focal plane together with a number of transmission counters to provide logic pulses, energy loss and time-of-flight information. The current and polarization were measured by a downstream polarimeter which analysed the protons elastically scattered in a polyethylene target.

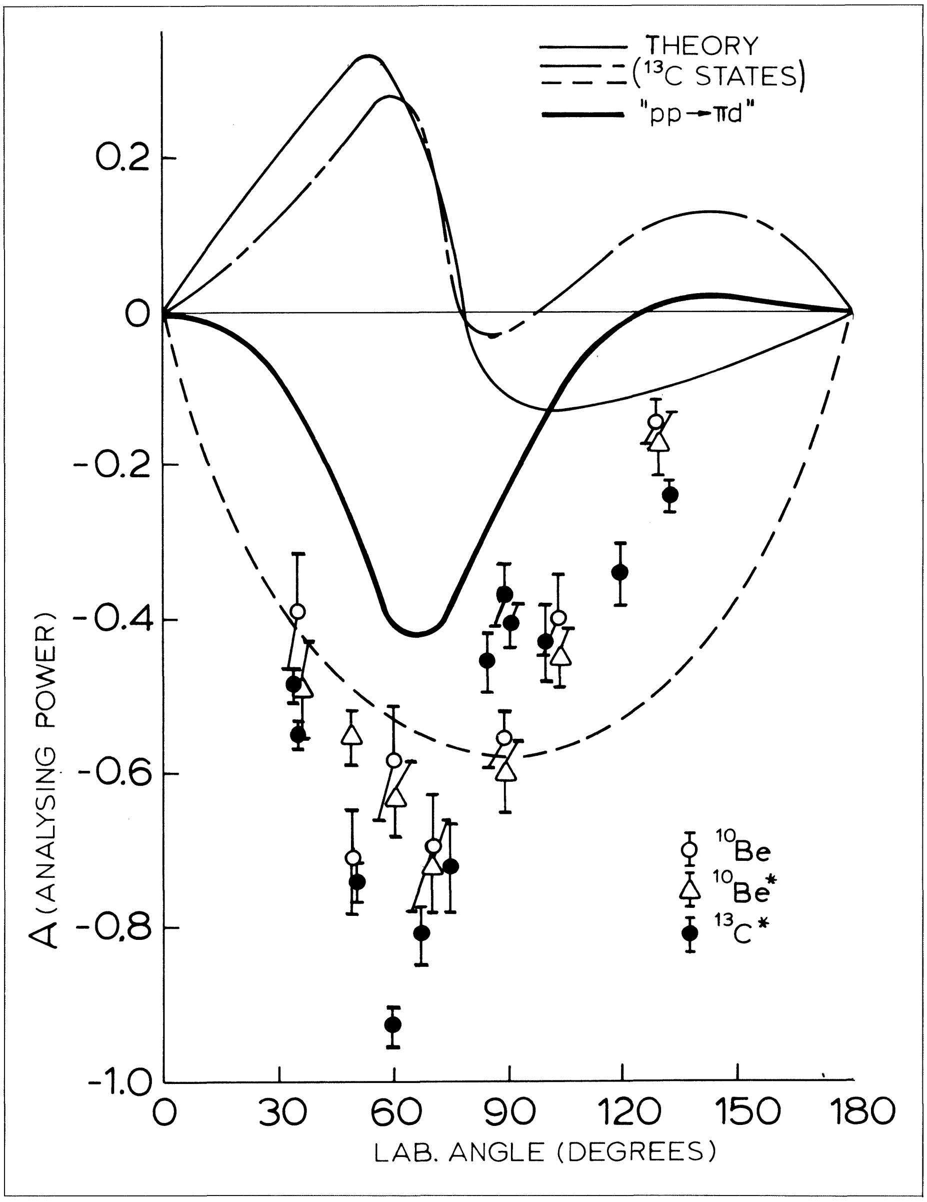
The first reaction studied was $pp \rightarrow d\pi^+$ (threshold 288 MeV). Other than an isolated measurement at 315 MeV about 20 years ago, the polarization analysing power for this reaction was unknown below 425 MeV. This energy region is often referred to as 'near threshold' where s- and p-wave pion production were thought to be sufficient to explain the shape of the pion angular distribution. The variable energy feature of TRIUMF allowed this reaction to be measured in detail between 305 and 425 MeV.

The two-body reaction gave a pion peak in the single arm detector which stood out clearly from the pion continuum from the $pp \rightarrow pn\pi^+$ reaction. By this technique the differential cross section and analysing power were measured for pions between 15 and 100 MeV over the angular range 35° to 145°. The raw energy spread of the TRIUMF extracted proton beam (typically about 1.5 MeV) allowed an overall energy resolution of about 2 MeV.

The results show the angular distributions of analysing power to be asymmetric about 90° in the centre of mass over most of the energy range, providing clear evidence for a significant d-wave contribution. This is the first measurement of the extent of d-wave pion production from the proton-proton reaction so near threshold.

Pion production in a two-body final state was also measured for protons incident on deuterium, beryllium and carbon. This was a development of the experiments of the Oxford / Göteborg group at the CERN synchro-cyclotron ten years ago. The momentum limitations of the pion spectrograph required





*Polarization measurements in proton-proton collisions producing single pions, showing that the angular distribution of the polarization analysing power seems to be independent of the excitation of the residual nucleus. The data for the beryllium-10 ground state and lowest excitation states are shown together with data from the reaction producing excited states of carbon-13. They do not agree with theoretical calculations (lighter curves) using a 'stripping' model in which the incoming nucleon emits a pion before being absorbed by the target nucleus. The shape of the spectra seems to fit calculations based on the Ruderman model (heavy curve) in which the momentum transfer in the reaction is shared between the nucleons.*

measurements with incident proton energy below 240 MeV for the beryllium and carbon targets. To link with the vast amount of data collected by the Uppsala group at 185 MeV during the past decade, the TRIUMF experiments were done at 200 MeV — the lowest energy that could conveniently be extracted into the beam line when it was first operated.

On running with carbon the group was surprised to find that the angular distribution of the analysing power was virtually independent of the excitation of the residual carbon-13 nucleus. The same was true for beryllium with very similar data. Furthermore, the experimental variation bears little relation to theoretical predictions for two of the carbon-13 states using a stripping model in which the incoming nucleon emits a pion before being absorbed by the nucleus.

The analysing power results are strikingly similar in shape (though not in magnitude) with those of the elementary pp→dπ$^+$ reaction if the momentum transfer in the nuclear reaction is distributed between the nucleons involved in the manner of the Ruderman model.

In the envisaged mechanism, the incoming proton interacts with a single proton from the nucleus through the pp→dπ$^+$ reaction, the two nucleons then being absorbed by the nucleus. Clearly, the results are in favour of a multi-nucleon, Ruderman type mechanism for pion production in nuclei. It remains to be seen whether measurements on other nuclei support these conclusions.

In September 1977 the experiment moved to allow installation of a thin pion production target. Also the planned increases in beam intensity will make an unfavourable environment for experimenters at that location. The group is in the process of instrumenting a larger 65 cm Browne-Buechner spectrograph to go in the new 'Peanuts' line (so called because of its cost philosophy) planned for operation in the summer.

## RUTHERFORD
## Preparing JADE

The JADE magnetic detector is one of the experimental facilities approved for operation at the electron-positron storage ring PETRA which is nearing completion at the DESY Laboratory. The Japan / Deutschland / England collaboration consists of groups from Tokyo University, DESY and the Universities of Heidelberg and Hamburg, and the Universities of Lancaster, Manchester and the Rutherford Laboratory.

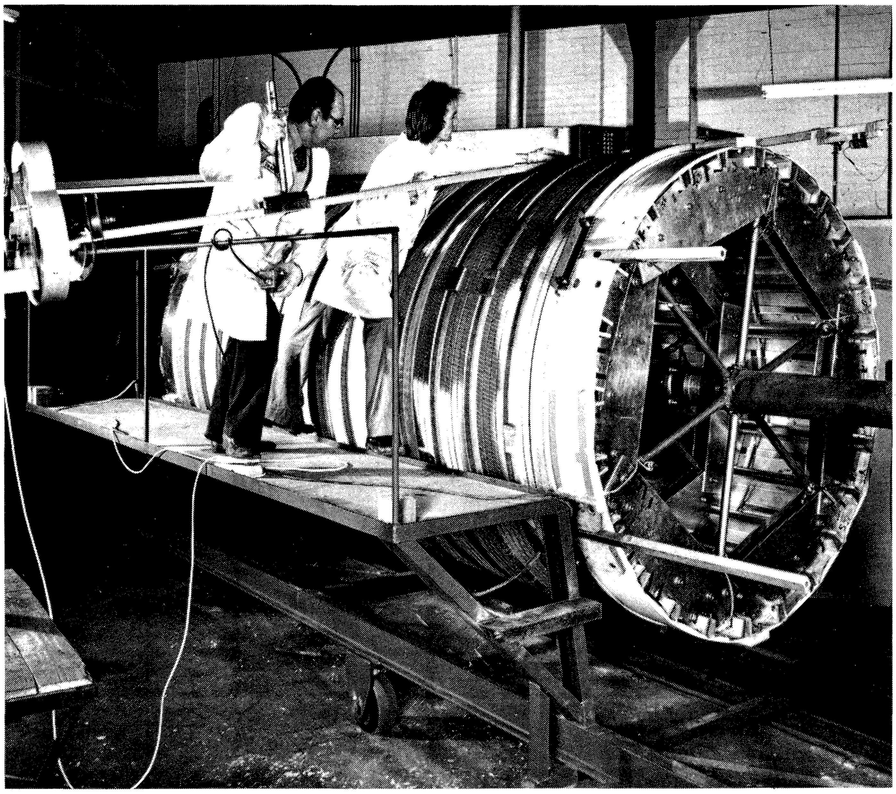
The extremely rapid construction of PETRA has put considerable pressure on the approved experiments to have their equipment ready by the end of 1978. In the case of the JADE detector, the solenoid coil, which was designed at Rutherford and is being built by Tesla Engineering Ltd. is ahead of schedule. Coil winding was completed on 13 January and, after curing the insulating resin, the electrical water flow tests started at the end of February.

The solenoid, which is 2 m in diameter and 3.5 m long, is the largest coil ever constructed by Tesla. To produce a uniform field of 0.5 T requires 200 turns of conductor, carrying a current of 8000 A. Substantial cooling is required to remove a thermal dissipation of 2.5 MW and protect the sensitive detectors which will be installed around the magnet. The solenoid will be shipped to Hamburg in May and assembled in the experimental area during the Summer. The detector elements will then be added in and around the magnet in the race against time to be ready for the first electron-positron collisions.

The JADE detector is designed using conventional elements but it is very compact and concentrates on lepton identification, which means the traditional electrons and muons, but if there are new heavy ones around, it should be possible to sort them out.

## CERN
## Primed to go off

The big superconducting Omega spectrometer in the West Area at CERN is soon to have a face-lift. Designed as a general-purpose electronic detector suitable for a wide range of physics and a correspondingly large number of user groups, it was first used with beams from the proton synchrotron back in 1972. Since then, Omega has been continuously upgraded to improve its capabilities. With detecting elements both inside the



*Work in progress at Tesla Engineering Ltd. winding the two layers of aluminium conductor for the solenoid coil which will be part of the JADE detector at PETRA.*

*(Photo Tesla Engineering Ltd.)*

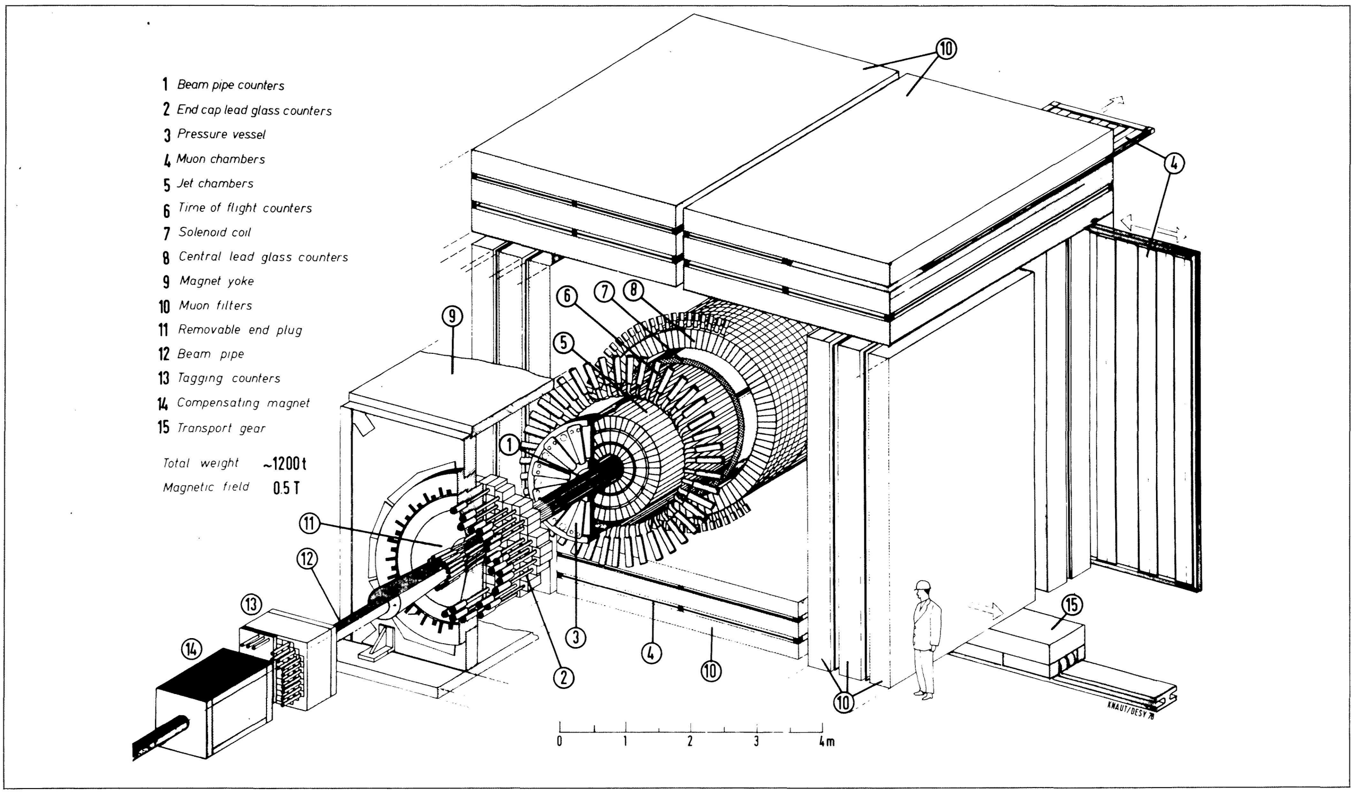
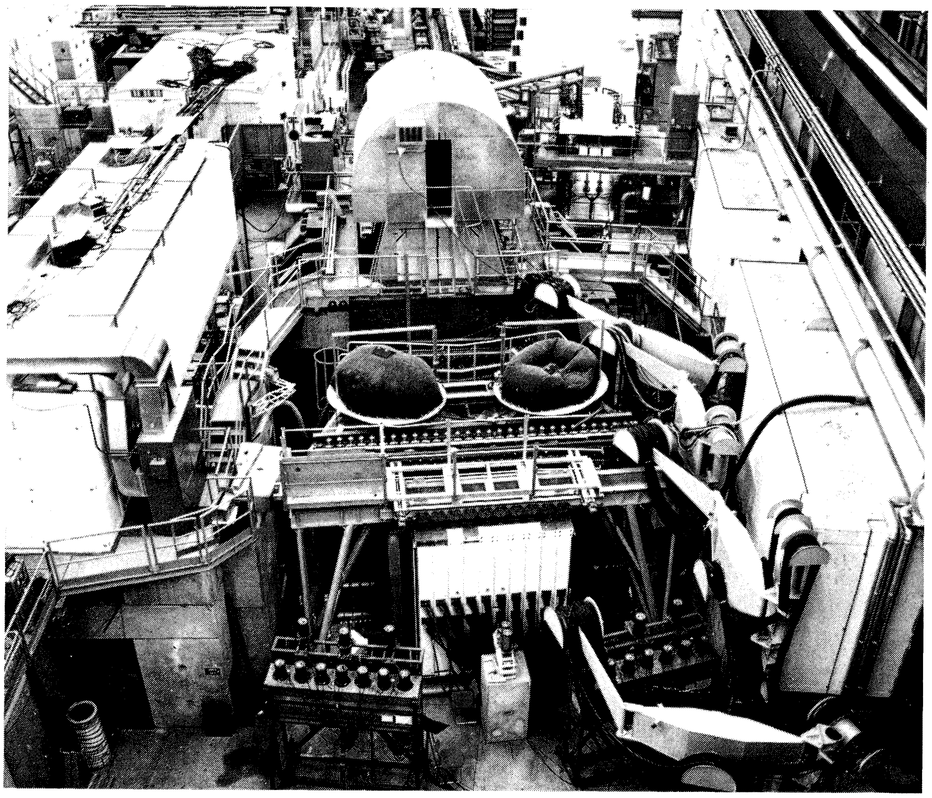


*Diagram of the JADE magnetic detector which is to be installed at the electron-positron storage ring PETRA at the DESY Laboratory during the Summer.*

*The large superconducting Omega spectrometer in the West Area at CERN. The interior of the magnet, equipped with optical spark chambers with TV readout, is soon to be replaced with an elaborate array of multiwire proportional chambers. This will extend its already considerable potential as a general-purpose detector for a wide range of user groups. The plan goes under the name of Omega Prime.*

*(Photo CERN 181.7.77)*



magnet and downstream, it provides by electronic detector standards an impressive means for analysing complicated events.

The physics work with this detector has already been outlined (see September 1977 edition, p. 282), notable recent achievements being the discovery of new baryonium states and the first completed experiment at the SPS.

Omega has benefitted from the continual addition of new features such as photon detectors, drift chambers, threshold Cherenkov counters, special trigger mechanisms for individual experiments, and a new computer system. However the interior of the detector, equipped with optical spark chambers with TV readout, has remained unaltered.

With the high energy beams from the SPS, and now with the availability of the new r.f. particle separator (see January/February issue, p. 13) the existing Omega central detector is stretched to its limit. The plan is to revamp substantially the installation by replacing the old spark chamber systems inside the magnet with an elaborate arrangement of multiwire proportional counters, a project which goes under the name of 'Omega Prime'.

The last physics run with the existing Omega configuration will be carried out this year, while the necessary wire chambers are assembled at CERN. These are scheduled to be installed during the Winter 1978/79 shutdown, so that the new Omega Prime will be ready for the first experimental period of 1979.

The multiwire proportional counters will give increased space resolution, enabling very close tracks to be distinguished from each other. This is sometimes difficult with the existing Omega set-up. Inherent distortions due to the TV cameras will be removed and the overall accuracy will be improved. The substantially reduced deadtime of the detecting elements will make for better time resolution, so cutting down background and enabling cross-sections to be measured about an order of magnitude smaller than with the existing equipment.

The detecting elements inside the magnet will be mobile so that the experimental configuration can be changed without having to shift all the heavy downstream equipment, which is the case with the existing set-up.

With its new all-electronic interior, Omega Prime will have distinct advantages over its predecessor, and will be better suited to its role as a general purpose, multi-user detector working with high intensity, high energy beams. Particularly for precision measurements of multiparticle production by photons, as yet a relatively unexplored field, for baryonium studies and for detailed investigation of kaon and antiproton reactions using the high particle fluxes available from the new r.f. separator, Omega Prime will open up important new research.

The first letters of intent for experiments using Omega Prime have already been prepared, largely by traditional Omega user groups capitalizing on their experience with the present detector. However the new set-up offers considerable scope for new user groups to try their hand with this versatile detector. With its wide user base and experienced operating crew, Omega Prime would provide a means of doing up-to-date physics with a minimum of preparation and installation work.

A typical interaction studied with Omega Prime will show several secondary tracks with a large range of momenta spread over a wide angle. The complexity of some of the events will be comparable to those recorded in bubble chambers, and requires sophisticated pattern recognition techniques.

The Omega Prime electronic detectors record a few points along the particle tracks. While it would not be difficult for an observer to trace curved tracks through these recorded points, filling in occasional missing points and ignoring background effects, it is notoriously difficult for a computer to carry out such apparently straightforward pattern recognition tasks.

From the experience gained in dealing with these problems in Omega, a configuration of wire chamber planes has been designed which optimizes these pattern recognition problems. In order to contend with the short, highly curved trajectories of low energy secondary particles in the central magnetic field, the wire planes near the target area are to be packed together as closely as possible, the density of planes being limited by the associated electronics which has to be fitted in.

Downstream from the target area, most of the medium and high energy tracks will be seen, together with particle pairs coming from the decay of neutrals. The detector planes in this region will be less tightly-packed than in the target area.

The highest energy particles will also be recorded by 'lever arm' drift chambers at the downstream end of the detector. These chambers are already in use in the existing Omega configuration and significantly improve the precision of measurement.

As well as having vertical wires perpendicular to the beam direction, the detectors will have additional wires inclined at a small angle either side of the vertical. This small inclination angle has as its cosine the ratio 63/64, a 'magic number' which facilitates subsequent binary data processing. The three types of wires will be used to obtain 'projections' of the event structure, similar to the photographic projections used in bubble chamber work.

Pattern recognition would be handled off-line by a new program called TRIDENT (short for TRack IDENTification), carrying out similar operations to the existing ROMEO routines for the Omega spark chamber system. Modified versions of this new program are being used by other experiments using multiwire proportional counter detection techniques.

To exploit fully the power of this detecting system, special triggering techniques are to be used. Even using the largest computer available at CERN, the CDC 7600, Omega Prime data-taking time at the maximum event rate would roughly correspond, second for second, with the requirements for off-line data processing time. To avoid such a bottleneck, new types of fast decision logic are to be used to enrich the data sample recorded and reduce the subsequent off-line computing load.

These techniques use the ability of the wire chamber to 'remember' their status longer than spark chambers. This gives fast electronics the chance to carry out interim selection procedures so that only 'good' events are selected from the wire chamber readings and recorded.

Fast electronics, with operating speeds of the order of tens of nanoseconds, can carry out these selection procedures much faster than a microprocessor or a software-driven computer and provides a significant improvement in triggering power over 'classical' coincidence methods. Patterns can be compared with standard types and a fast decision made so that only meaningful events are written to tape. Such triggering procedures have become possible with the use of the latest developments in emitter-coupled logic and, for example, of 'hash code' selection techniques which enable long lists of options to be scanned very quickly. Only in this way can the full potential of the detector be realized without making undue demands for off-line computing. This could mean that physicists will have to get used to thinking of triggering in a new light and providing physics tasks well suited to these novel methods.

With such a broad range of applications and depth of technique, Omega Prime should offer physicists both a challenging and a satisfying research too which fully lives up to its design aims as a general-purpose detector.

## New high spin meson

A high statistics, low background experiment, carried out at the CERN PS by a team from the University of Geneva, has uncovered evidence for a new spin four, positive parity, isospin one meson at 1900 MeV. This state could provide the charge triplet for the ($SU_3$ and spin) multiplet which so far has only contained the neutral h meson, seen at Serpukhov by the CERN / Karlsruhe / Pisa / Serpukhov collaboration. These are the highest meson spin states so far observed.

Using a double arm spectrometer to measure both the produced particles and the recoil protons, the Geneva team obtained 75 million triggers from an unseparated 10 GeV/c hadron beam. Of these, 40000 events produced by negative pions were identified as having final states containing a short lived neutral kaon and a negatively charged kaon, the neutral kaons being identified by their decay into charged pion pairs shortly after entering the spectrometer.

The $K^-K^0$ production channel is particularly selective since it is open only to even spin states of odd G-parity, such as the well known spin two $A_2$ meson, and to odd spin states of even G-parity, such as the spin three g meson. This channel gives clearer signals than the more complex isospin behaviour of the $K^+K^-$ channel.

The quantum numbers of the new state were deduced from a detailed analysis of the angular distribution of the produced negative kaon, while confirmation comes from an independent analysis of the same data using different techniques and involving physicists from Durham. The mass of the new particle is measured as 1903 ± 10 MeV and its width as 166 ± 43 MeV.

The discovery of this new state enables another piece to be fitted into the jigsaw puzzle of mesons predicted by the SU3 model and adds even more weight to the already overwhelming evidence for this hadron classification scheme.

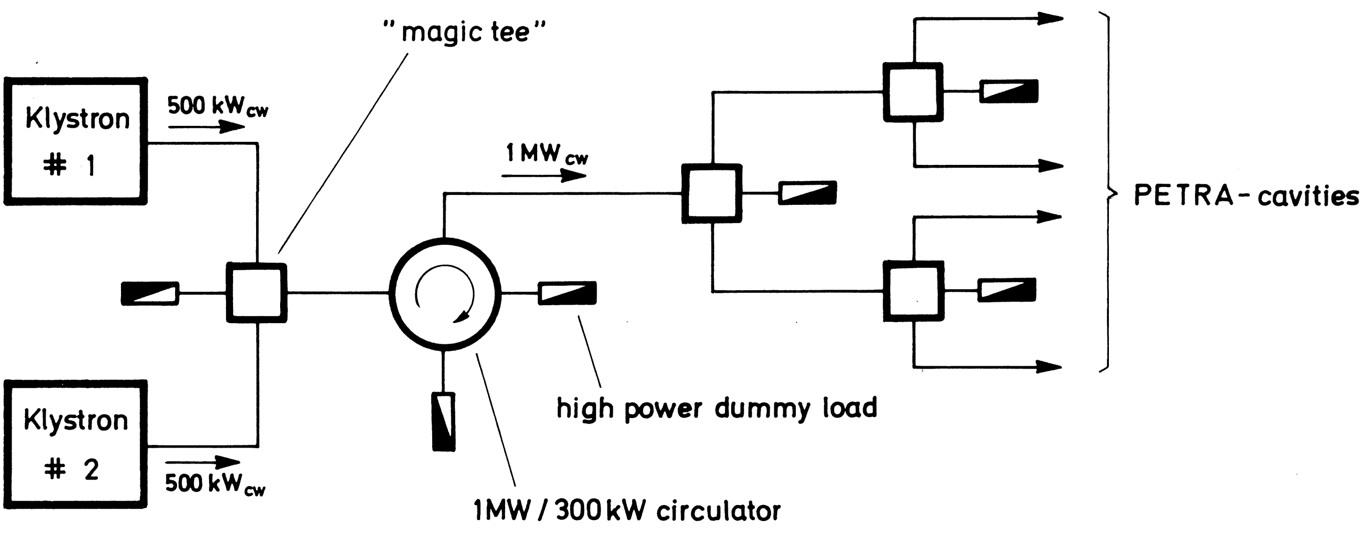
## The hunt for information

The CERN Library Accessions List gives details of the preprints and reports received at CERN in any one week and usually contains well over a hundred items. This continual accumulation of documentation means that the stock available for consultation at CERN is building up at the rate of over 6000 items each year, not counting papers published in journals and books!

To pick their way through such a maze of literature, scientists now have computer based systems using information retrieval techniques. As well as enabling a specific document to be located, these systems allow the user to search for material relevant to his work.

This can be achieved through a system of keywords which indicate for each publication the nature of the topics covered. For high energy physics, these keywords indicate the types of particles involved, their quantum numbers, the types of interaction, theoretical models used, experimental techniques, etc. The curious scientist submits his list of keywords to the system, which then produces a list of the available reports corresponding to his query — provided, of course, that someone has already supplied the appropriate keywords to the bibliographic record stored in the computer!

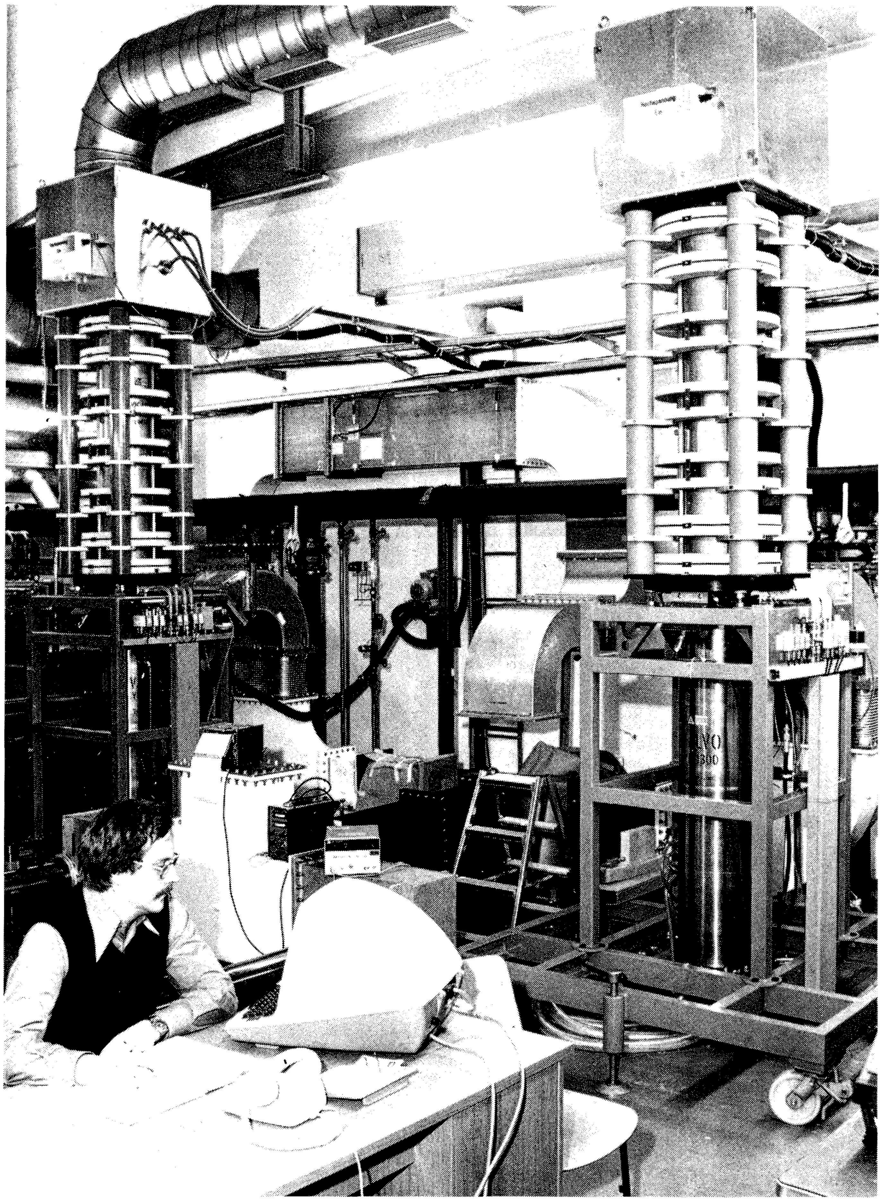
Besides issuing up-to-date author and report number indexes on microfiche each week, CERN provides the HEPPI (High Energy Physics Published Information) system on its central CDC 7600 computer as an integral part of the service of users. HEPPI can reference CERN's own store of reports and preprints (without keywords), as well as the database on high energy physics information maintained by DESY. A copy of the latter database is kept at CERN and is regularly updated using tapes supplied by DESY. As an example of the use of the system, a recent search of the DESY files for reports corresponding to the keyword 3MUON, or containing



*The layout of a 1 MW r.f. transmitter, eight of which are to be used in the PETRA storage rings at DESY. Each of the two klystrons will produce 500 kW at 500 MHz.*

the word 'trimuon' in the title, yielded 24 papers; not bad for a topic first reported only a year ago (see April 1977 issue, page 95)!

A separate database on computer science articles is also used at CERN. Called Castor, this system uses a database maintained by the Rutherford Laboratory.



*The first of four 1 MW r.f. transmitters for the PETRA storage ring at DESY. The pair of 500 kW klystrons supplying the power can be seen in the background, while the operator in the foreground controls the transmitter via a computer terminal. The unit operated for the first time in January.*

*(Photo DESY)*

# DESY
# PETRA r.f. transmitters

In January the first of four 1 MW r.f. transmitters for the PETRA electron-positron storage ring was successfully operated for the first time.

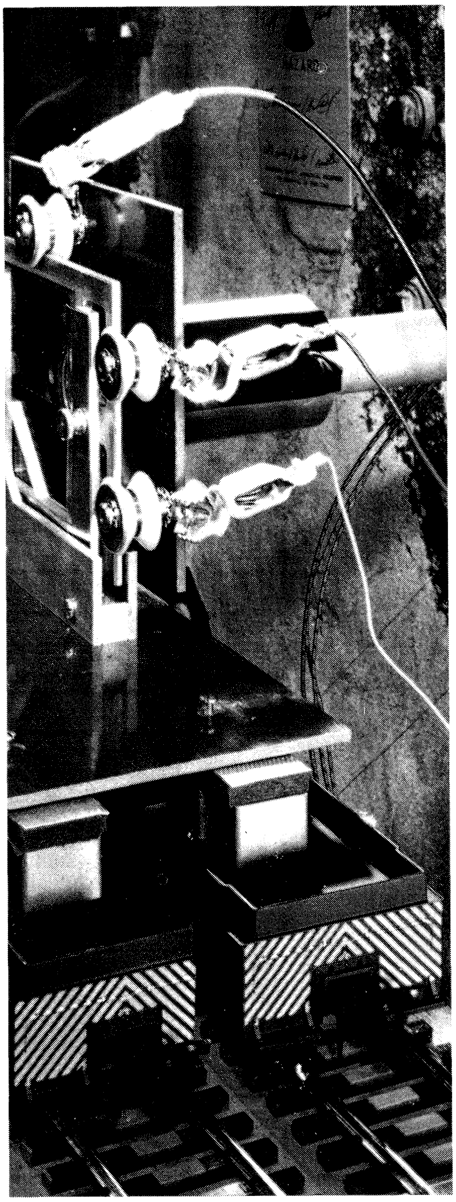
For the maximum PETRA energy of 2 x 19 GeV or a maximum luminosity of some $10^{32}$ cm$^{-2}$ s$^{-1}$ per interaction point at 2 x 15 GeV, about 4 MW of cw r.f. power are required in an accelerating system consisting of 64 five-cell cavities.

The r.f. power will be generated by a total of eight 500 MHz klystrons with a nominal power output of 500 kW each, with the four transmitters composed of pairs of those klystrons. Apart from essential technical details such as gun, resonators and output window, the PETRA klystron also features unique advantages for transmitter operation. The output power is controlled by means of a modulating anode. Since this anode is non-interceptive, it does not take power, and simple high voltage modulators consisting of a relatively small hard tube and a resistor are used as in the DESY synchrotron and DORIS storage ring. Operation is also facilitated by limiting the beam voltage to the 57-60 kV range, so that gun and modulator do not have to be insulated by immersion in oil.

According to its specification, the PETRA klystron should operate at 500 kWcw at 500 MHz with an efficiency of 60 % at 58 kV beam voltage and a micro-perveance of about unity. These requirements were nearly met by the first two tubes as delivered from the manufacturer (Valvo of Hamburg) in November 1977 and January 1978. The tubes were incorporated in the first of PETRA's four double transmitters and were first tested individually, the output power being absorbed in coaxial water loads. With beam voltages up to 60 kV, 540 kW and 60 % efficiency were achieved. Then the complete double transmitter with its final components was tested and operated for the first time. Computer control, crowbar and security systems, and phase amplitude feedback loops worked satisfactorily.

The maximum output power of the transmitter so far has been 910 kW. Since there are no high power dummy loads capable of absorbing so much power, the PETRA waveguides and a system of eight cavities had to be used as a load for these tests. For many components, including waveguide bends, magic tees, a 1.2 MW circulator, dummy loads and last, but not least, the PETRA cavity system with its control circuits, this was the first time they had been operated under high power conditions.

Some components will have to be slightly modified, but nevertheless it was possible to operate the entire system for many hours under high power conditions. It is expected that the first transmitter will be finally capable of delivering 1000-1100 kW r.f. power with efficiencies between 55 % and 60 %. A third klystron is under test at the factory. With some modifications from the design of the first two tubes, it delivers 500 kW at 58 kV beam voltage and 60 % efficiency; the maximum output power is expected to be around 570 kW. Installation for the second double transmitter is well under way. Like the first,



*The Argonne 'neutrino railroad'. To avoid experimenters being exposed to high radiation, foil samples for exposure to the primary beam were transported to and from the target area by this model train assembly.*

*(Photo Argonne)*

this transmitter is in the South Area at PETRA. Completion of the remaining two transmitters in the North Area is scheduled for Autumn 1978.

## ARGONNE 12-foot bubble chamber retires

On 13 February 1978, Argonne's 12-foot bubble chamber took its last physics picture and passed into retirement, marking also the end of ZGS synchrotron operation with unpolarized proton beams. Future ZGS operation will be exclusively with polarized protons or polarized deuterons until shutdown in October, 1979.

In its final four-month run the chamber took 1.3 million pictures of neutrinos in deuterium, with tantalum converting plates installed in the downstream end of the chamber to enhance detection of neutral pions. This second-generation neutrino experiment thus ended with a total of over 1.6 million pictures.

In the last weeks of its unpolarized beam career the ZGS outdid itself and achieved record beam intensities. On the final week-end of the run the circulating beam averaged over 7 x $10^{12}$ protons per pulse over long periods. Intensities of over 3 x $10^{12}$ protons per pulse were delivered to the neutrino target.

In the chamber's eight year lifetime many landmarks were achieved. These included the first observation of neutrino interactions with free protons, the first identification of an exclusive reaction occurring via weak neutral currents (one-pion production in $\nu n \rightarrow \nu p \pi^-$), and completion of a program of track-sensitive target (TST) experiments with a neon-hydrogen chamber filling. Although the chamber's useful lifetime is at an end, its superconducting magnet will be modified and used as part of the High Resolution Spectrometer (HRS) recently approved for operation at PEP. This new facility is expected to come into operation during 1980; work on conversion of the magnet will begin immediately at Argonne to meet this schedule.

In the final neutrino runs, frequent exposures of glass plates and gold foil at the pion production target were made to obtain information on the beam properties. Because of the length of the final run and the high intensities available, frequent entries into the target area could have produced unacceptable doses of radiation to the experimenters. The solution to this dilemma was provided by one of the ZGS engineers who is also a model train enthusiast. About 40 m of miniature track was laid through the tunnel labyrinth to the target region, where a device would pick up the foil or glass plate from a train car and lock it into position for the exposure. The train would then return the sample to the experimenters. This 'neutrino railroad' worked extremely well with only an occasional derailment during the entire four month run. As in so many other cases, this technique was pioneered by Enrico Fermi many years ago at the Chicago cyclotron.

## STANFORD State of SLAC

On 7 February Pief Panofsky, Director of the Stanford Linear Accelerator Center, gave his annual talk to the Laboratory staff about present progress and future plans. Some of the main points are reviewed here:

The money in the USA President's budget proposals for Fiscal Year 1979 to support the present Stanford experimental programme and for the construction of the Berkeley/Stanford electron-positron storage ring project, PEP, shows a small reduction for the next year (when corrected for inflation). The figures imply that the building of PEP will be partly at the expense of the existing programme of the Laboratory. Thus the encouragement of having the PEP and ISABELLE (proton-proton storage rings at Brookhaven) projects under way is tempered by continuing austerity in the use of the existing research facilities. Nevertheless Professor Panofsky emphasized that 'the overall picture of SLAC is that of a creative and expanding Laboratory'.

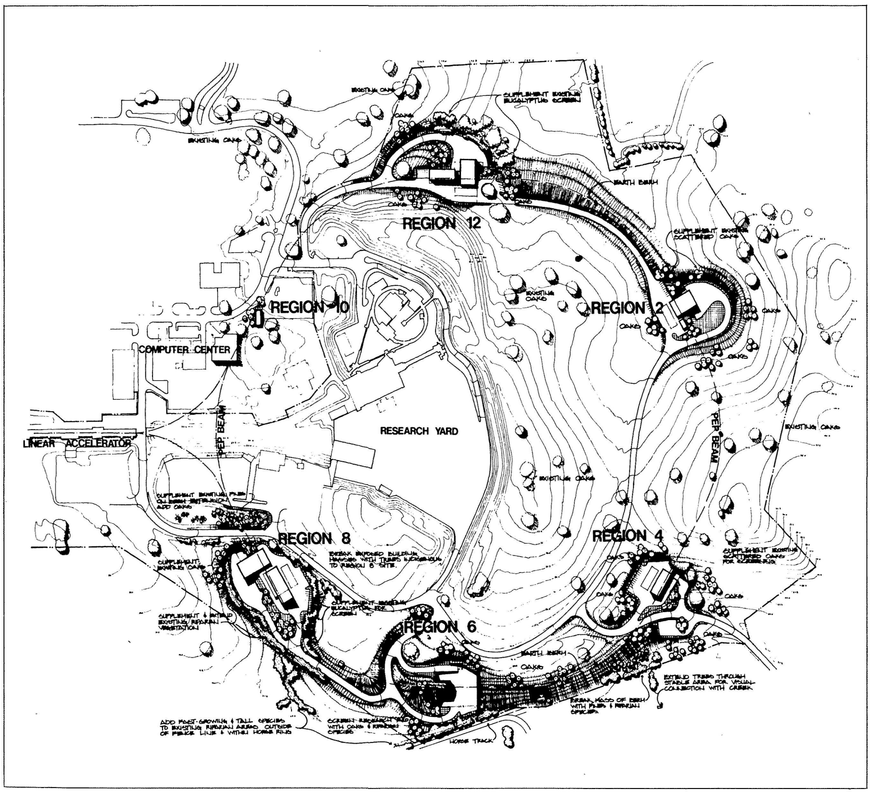
At PEP the beam injection tunnels were spliced into the linac complex last summer and the tunnel boring machines have started on their way around the ring. It is anticipated that the first section of the tunnel will become available for installation of machine components in late summer. Interaction Region No. 4 will be one of the first to be completed and will be ready to receive experimental equipment in October. The hope is that first collisions might be seen in PEP in October 1979. The Mark II detector and the MAC calorimeter (both systems accepted in the first round of experimental proposals — see May issue 1977, page 143) are expected to be ready for beam turn-on. The other two 'first round' experiments — the Time Projection Chamber and the Two Gamma facility should follow six months later.

A second round of proposals for PEP was studied in January and three experiments were accepted. One is a large scale spectrometer involving the use of the 1800 ton superconducting magnet of the Argonne 12 foot bubble chamber (an Argonne / Indiana / Michigan / Purdue collaboration). Two smaller ones will look for magnetic monopoles (a Berkeley / SLAC collaboration) and for quarks (a Berkeley / Northeastern / Stanford / Hawaii collaboration). The experiments have been chosen with an eye on the experimental programme at the twin machine, PETRA, at DESY so as to complement research which will begin there by the end of this year.

The long-term planning at SLAC has three main components in the experimental programme — fixed target experiments on the linac using the SLED system to take the energy above 40 GeV (see July issue 1974, page 259), colliding beam experiments at SPEAR and colliding beam experiments at PEP. PEP will have top priority; SPEAR will give 50% of its time to synchrotron radiation research; SLED operation is likely to be between 35 and 50% of maximum.

Upgrading of PEP is under consideration. Adding more r.f. could take the peak energy to 24 GeV per beam. Converting to superconducting r.f. could allow the energy to go as high as 30 GeV. Adding a proton ring could make possible electron-proton collisions with protons, in a ring in the

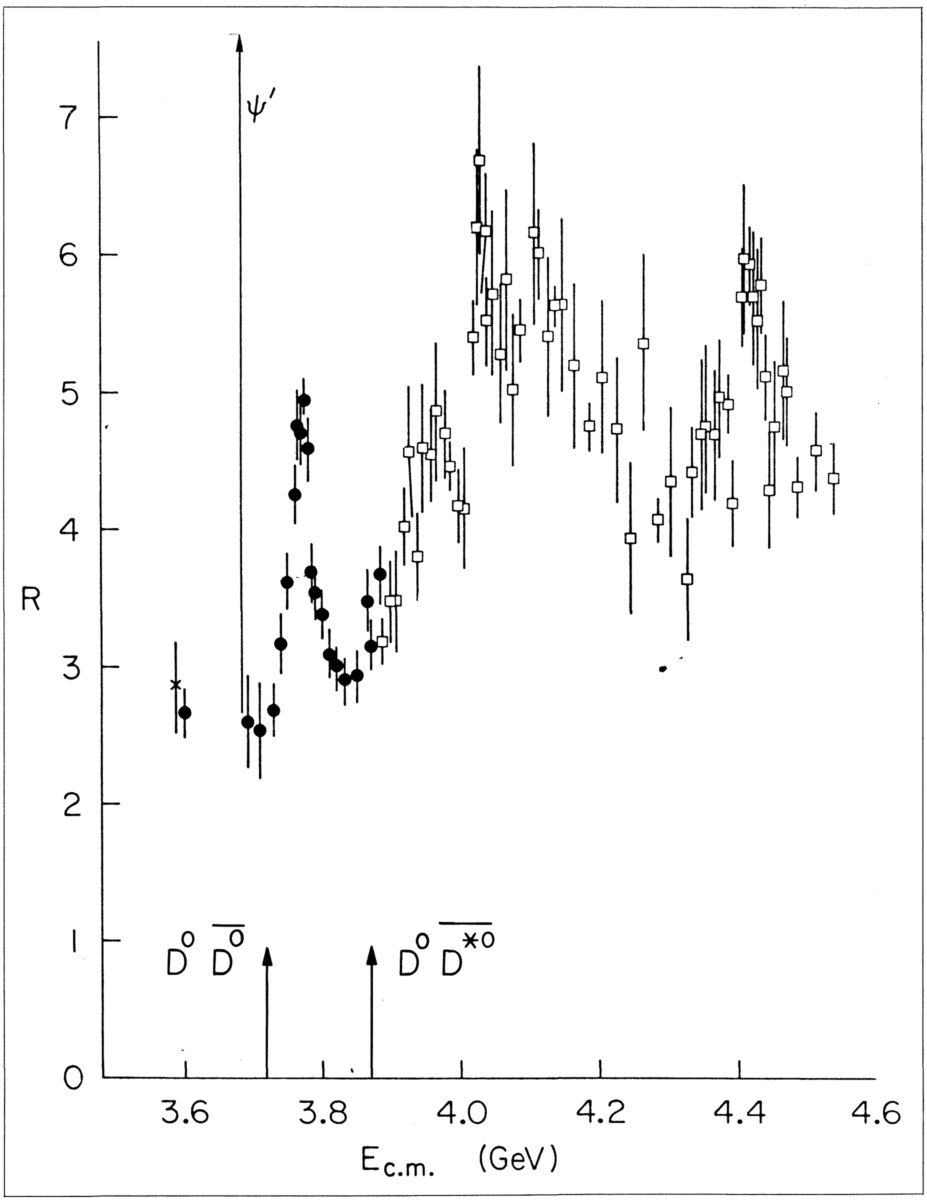
*A site / landscape plan of the Berkeley / Stanford electron-positron storage ring project, PEP. The linear accelerator injector comes in from the left. The ring surrounds the existing research facilities at Stanford and the interaction regions (2, 4, 6, 8, 10) are clearly picked out.*



*A January aerial view from approximately the same viewpoint as the plan. Site work on PEP is now well advanced.*

*(Photo Joe Faust)*

*Cross-section of electron-positron annihilation into hadrons compared to muons in the centre of mass energy region from 3.6 to 4.6 GeV, as measured at the SPEAR storage ring at Stanford. The black circles, which show clearly the (3772) resonance, are the new data from the Lead Glass Wall collaboration. The other points are earlier data from the SLAC/LBL collaboration. The thresholds for producing pairs of D mesons are indicated.*



same tunnel, of energy 200 GeV or higher. Decisions on which route to take will obviously await PEP first operation and developments in technology and physics.

## Measurements on D meson

The 'Lead Glass Wall' collaboration at the SPEAR storage ring has used electron-positron annihilation data taken at the ψ (3772) resonance to make new measurements of the masses and decay branching ratios of the charmed D mesons. The collaboration, led by Lina Galtieri and Martin Perl, includes physicists from the Lawrence Berkeley Laboratory, Northwestern University, The Stanford Linear Accelerator Center, Stanford University, and the University of Hawaii. They discovered the ψ (3772) in the spring of 1977 as a peak in the cross-section for electron-positron annihilation into hadrons just above the threshold for pair production of charmed particles.

The resonance decays predominantly into $D\bar{D}$ and provides D mesons whose energy and production cross-section are well known. It has made possible the measurement of absolute branching ratios of the D meson for the first time; previously, only the products of production cross-section and branching ratios had been measurable.

The precise knowledge of the energy of the D mesons from the decays permit a very clean separation of the D signal from the background and a mass determination about five times more precise than was previously possible. With these new measurements, the mass difference between the charged and neutral D mesons can now be clearly resolved. The new measurements are — $D^0$(1863.3 ± 0.9) MeV/$c^2$ and $D^+$(1868.3 ± 0.9) MeV/$c^2$.

The electron identification capability of the Lead Glass Wall has been used to measure the inclusive cross-section for electron production in hadronic events at the ψ (3772) and to infer from that the semileptonic branching ratio of the D mesons into electrons (plus anything) is 7.2 ± 2.8 %.

If one assumes that the semileptonic branching ratios into muons and electrons are equal, then about 36 % of the neutral D decays and 20 % of the charged D decays are accounted for. The collaboration is still working on sorting out some remaining decay modes which are harder to identify because of low acceptance and/or high background.

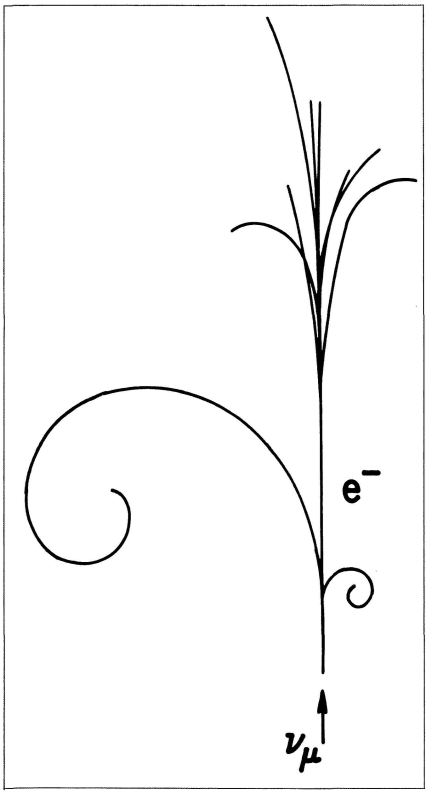
The decay of the ψ (3772) also provides information about the spin of the D mesons. The angular distribution of the D's show a $\sin^2(\theta)$ dependence, which is consistent with the D's having spin zero. Information on the Ds has thus been considerably increased.

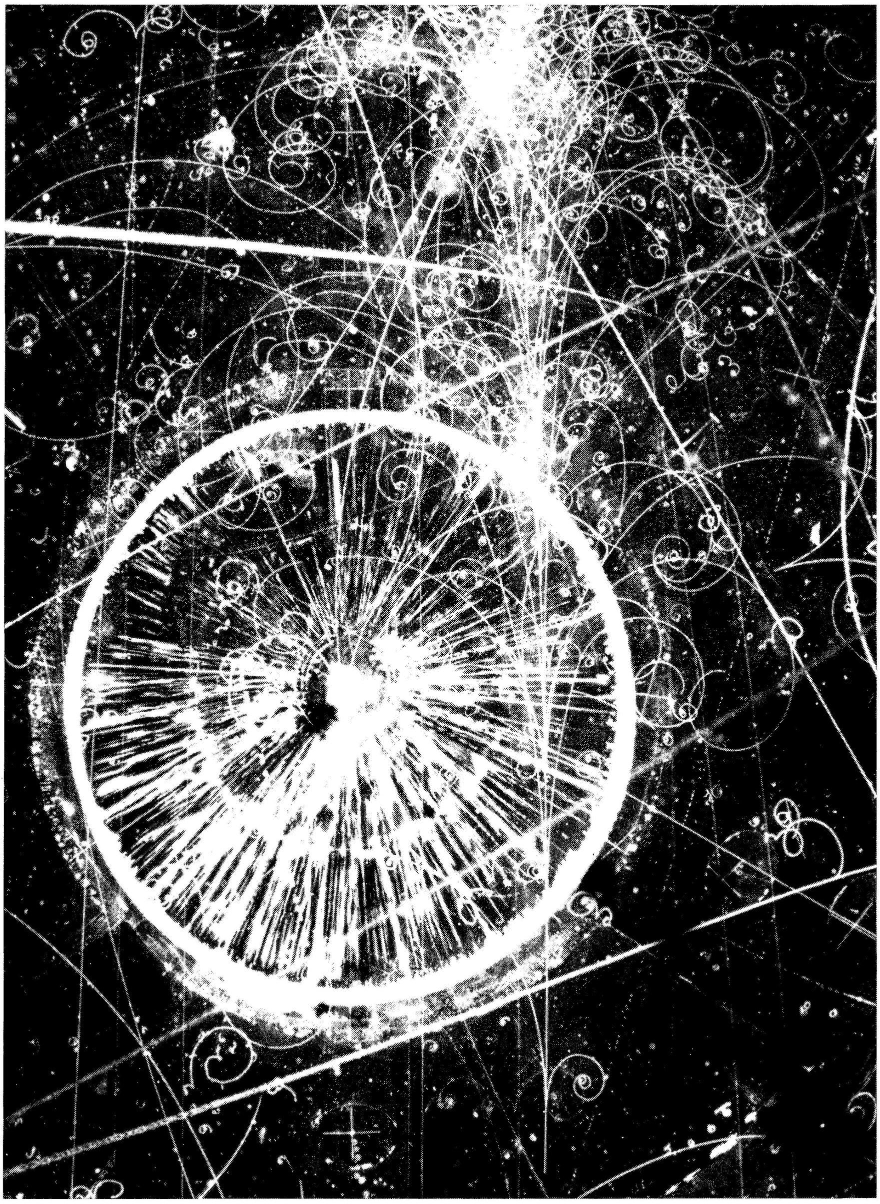
## FERMILAB
## Dileptons and charm in neon

The Fermilab 15 foot bubble chamber, filled with a neon-hydrogen mixture, has recently been used for two highly successful neutrino runs. A Columbia/Brookhaven group has found many muon-electron events while a Berkeley / Fermilab / Hawaii / LRL / Washington / Wisconsin group has taken more than 330000 pictures with the External Muon Identifier specially arranged to give good efficiency for detecting muon pairs.

The Columbia / Brookhaven collaboration has detected many examples of charmed particle decays. The charmed particles are observed both through their semileptonic decays (as, for example, when the D meson is produced in conjunction with a

*An example of the very rare neutral current event where a neutrino interacts with an electron without converting to a muon. It was taken in the Fermilab 15 foot bubble chamber while it was filled with a neon mixture for a Columbia / Brookhaven experiment. The electron has a measured momentum of about 30 GeV.*





negative muon and then breaks into fragments including a kaon and a positron) and through their hadronic decays (such as the reaction where the D breaks up into neutral kaon and a positive and negative pion).

The experiment used the horn-focused wideband neutrino beam. The 15 foot chamber was filled with a heavy neon-hydrogen mixture to give an active target of 25 tons. The 40 cm radiation length and 125 cm nuclear interaction length of the mixture allows good identification of the particles produced in neutrino interactions.

Electrons are identified by bremsstrahlung followed by conversion of the radiated photon into electron-positron pairs. Hadrons have a high probability of interaction and muons are recognized as tracks that leave the chamber without interacting. The 3 T magnetic field of the chamber provides a measurement of the charge and the momentum of the particles. Strange particles can be detected by the presence of vees. Up to now about 150 000 photographs have been taken with, on the average, one neutrino interaction per picture.

A total of 164 $\mu^-e^+$ events have been observed in the experiment so far from about two-thirds of the available pictures. One of the most striking features of charm is a dominant decay into strange particles, as postulated in the Glashow / Iliopoulos / Maiani (GIM) model. In this experiment the muon-electron events were accompanied by 33 neutral strange particle decays (vees). In normal charged current neutrino interactions, 164 events would be expected to have about ten vees; the observation of 33 demonstrates that the events are significantly correlated with strange particles.

Dilepton events have also been observed in the $\mu^-\mu^+$ channel in counter experiments at both Fermilab and the CERN SPS. It is the correlation with strange particles in the bubble chamber that identifies the source of the dilepton events in neutrino interactions as the semileptonic decays of charmed particles. Correcting the 33 vees for branching ratios, detection efficiencies, and the fact that charged strange particles also must be present, implies that between 1 and 1.5 strange particles are produced per muon-electron event, in good agreement with the prediction of GIM.

The 33 vees contain 23 neutral kaon and 10 lambda decays, indicating that both charmed meson and charmed baryon production is being observed. The rate of the events is about half a percent of all charged current neutrino interactions implying that the total charm production is something like 5 to 10% of all neutrino interactions, again in good agreement with the expectations of GIM.

The signature for the hadronic decays of charmed particles in this experiment is the production of a muon accompanied by a vee. A sample of about 1800 events, with a muon and a visible neutral kaon to two pion decay, has been used to search for the lightest charmed meson, the D. The mass distribution shows a peak corresponding to the decay $D^0 \rightarrow K^0_s + \pi^+ + \pi^-$, with a $D^0$ mass of 1850 ± 15 MeV. The peak has about 60 events above background, with a statistical significance of over four standard deviations, and has a width consistent with the mass resolution of the experiment.

The experiment has also observed three examples of the rare process of neutrino-electron scattering. These events are very clean since the background is negligible. Ten to twenty such events are expected in the full experiment.

The analysis of the recently completed Berkeley / Fermilab / Hawaii / LRL / Washington / Wisconsin experiment is now under way. It is expected to yield several hundred dimuon and muon-electron events. The experiment is the first at Fermilab to make use of a new device installed inside the bubble chamber called the Internal Picket Fence. This consists of sixteen proportional wire planes that cover a nineteen square foot area. They are coupled with the two plane External Muon Identifier to give particularly good muon identification.

## New operating mode

A new mode for accelerator operation has been implemented at Fermilab to take advantage of a new pricing schedule by the local electric utility company. The operation consists of running two different cycles depending on the time of day.

With the pressures for energy conservation, the need to improve the utilization of electricity generating capacity increases. One way is to achieve 'load levelling' by time-of-day pricing for the power customers, since much of the generation equipment to achieve peak power involves smaller, less efficient units. The utility serving Fermilab started time-of-day pricing for large consumers in October 1977. The financial incentive consists of a 0.394 cent surcharge for every kWh used during peak hours (between 0900 and 2200 for week days) and 0.4 cent credit for every kWh used during off-peak hours. The swing is about 25% of the base charge per kWh delivered to Fermilab.

Fermilab is in a good position to take advantage of the new pricing scheme. Prior to the charge, the Laboratory typically used 75 MW with an eleven second 400 GeV cycle time and a 1.25 s flat-top. Since November the peak period utilization has been 55 MW with the off peak being somewhat higher than 85 MW. The peak period cycle time varies from 18 to 22 s, depending upon general site wide requirements. During off-peak periods the cycle time has been as low as 8 s.

The new regime has required considerable adjustment on the part of both accelerator operators and experimenters. Running at the higher level has also put stress on the accelerator, exposing some elements requiring improvement. The savings, however, make the effort worthwhile. During the first year, it is projected that the same number of protons can be accelerated for about $ 8.2 M as opposed to $ 8.6 M using the old schedule.

# Physics monitor

## Pandemonium in nuclear physics

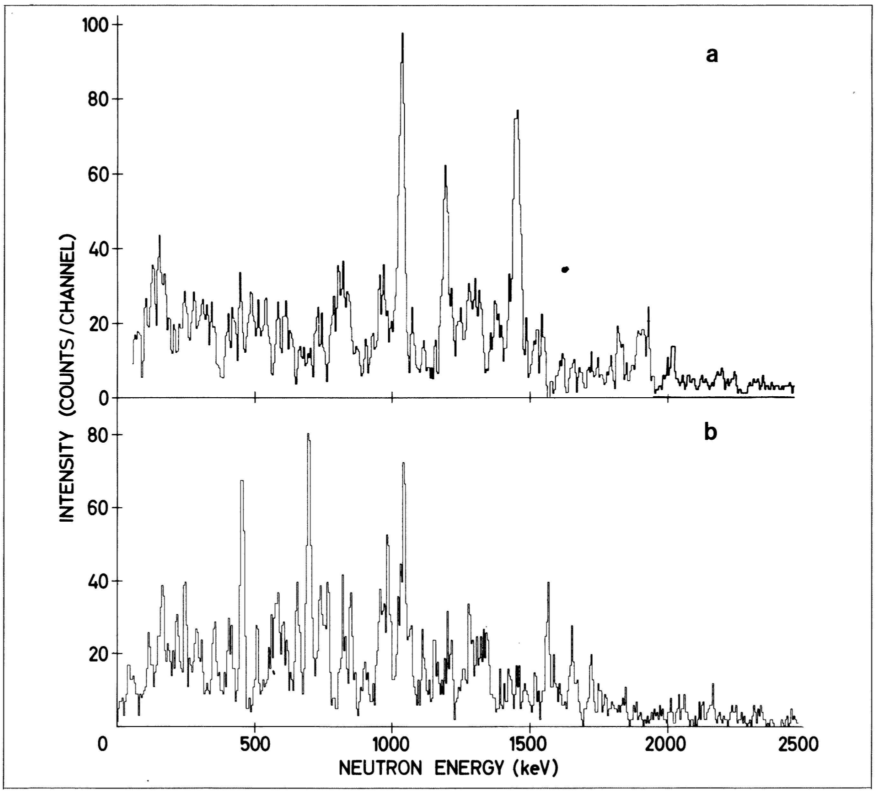
'Pandemonium easily breaks out in nuclear physics', according to some recent studies by the ISOLDE (Isotope Separator On-line) collaboration at CERN on highly unstable nuclei.

For non-English speaking readers, and perhaps some English readers too, it is worth recalling that 'pandemonium' (from the Greek meaning 'all the demons') was the name given by the poet John Milton to the underworld. In his 'Paradise Lost' published in 1667, he wrote '...a solemn Council forthwith to be held at Pandemonium, the high Capital of Satan and his Peers'. In modern English, the word has come to mean utter confusion.

The word should not, of course, be taken in either sense when applied to CERN... Pandemonium in the ISOLDE studies is a fictitious chemical element whose nuclear behaviour can be simulated. Using this picture, it has been shown that the densely packed energy levels in highly unstable daughter nuclei (formed in the beta decay of nuclei which are far from stability) can produce radiation spectra with 'bumps' which are understandable by statistics alone.

Although this lesson is not new, the pandemonium prescription for simulating the behaviour of densely packed energy levels in highly unstable nuclei has underlined that physicists have to be careful when 'bump hunting' in gamma ray and other decay spectra of these nuclei.

From time to time, 'anomalous' effects have been reported in, for example, the gamma ray spectra of daughter nuclei formed in the beta decay of highly neutron deficient states. These anomalies had been attributed to unknown weak interaction effects. Using pandemonium, the ISOLDE group has shown that these effects can also be produced in fictitious nuclei with no special structure simply as a result of the quantum mechanics of very closely packed energy levels.



*'Pandemonium' in nuclear physics! The ISOLDE group at CERN has developed techniques for simulating the behaviour of a fictitious unstable nucleus, 'pandemonium', with densely packed energy levels. The top energy spectrum (a) is that of neutrons following the beta decay of antimony-135 (half-life 1.7 s), obtained by a Mainz/Berkeley collaboration. At the bottom (b) is the result of pandemonium simulations. Pandemonium has no special structure, but still gives noticeable fluctuations, reminiscent of nuclei such as antimony-135.*

Techniques for handling closely packed energy levels were first developed in neutron physics, where the bombardment of heavy nuclei neutrons encounters states separated in energy by just a few electron volts. To handle the energy level spacings and transition probabilities from one energy level to another for such states, statistical methods were developed. Simple laws describe what can be observed by a continuous probability distribution.

The same techniques can be used for the highly unstable nuclei formed in the beta decay of neutron deficient or neutron rich parents. Here again the energy level spacings can range from a few electron volts, so that hundreds of thousands of separate levels may be populated in a decay scheme. In a nucleus near stability there would be just a few energy levels and few transitions from one level to another.

In dealing with such complicated spectra, the ISOLDE group has, for some years, been developing mathematical techniques similar to those used in the study of electrical and acoustical noise. In the same way that this noise produces distinct observable effects, so complex nuclear spectra can have erratic fluctuations.

This nuclear 'noise' is the result of energy level spacings and of the transition probabilities which govern the intensities of the observed spectral lines. The underlying probability distribution of these intensities is highly asymmetrical and this produces observable intensity fluctuations.

Because of this asymmetry the majority of the transitions will have low intensity and will disappear into an unresolved 'background' but an occasional high intensity transition will produce a 'bump', which may tempt nuclear spectroscopists to believe that they have found a new resonance.

It is important to emphasize that, though statistical techniques can be used to study these complex nuclei, the structure of the nuclei themselves is not statistical. The structure is of course fixed but is so complicated that it cannot be described in conventional quantum mechanical terms.

The pandemonium project, undertaken by the ISOLDE group in 1977 in collaboration with J.C. Hardy, a visitor from Chalk River (Canada), exploited an interruption in the experimental programme, due to a fault in the target, to develop a theoretical model of nuclear spectra to make the statistical features more transparent to spectroscopists. Instead of analysing real data, the idea was to generate 'pseudo-data', whose features could then be compared with the behaviour seen in experiments.

In the pandemonium calculations, Monte-Carlo simulation is used to generate the nuclear energy level scheme and the transition probabilities of a structureless, fictitious nucleus. The 'results' are obtained by folding in the appropriate detector response curves and using more Monte-Carlo methods to generate counting statistics.

The results are remarkably similar to the spectra measured in actual experiments, containing a number of quite sharp peaks. This shows conclusively that unstable nuclei with densely packed but otherwise unremarkable energy level structures can produce remarkable decay spectra. These fluctuations, at least in pandemonium, are simply the result of the many competing allowed transition channels and are not due to any additional structural effect.

The inventors of pandemonium point out that there is no new physics in their model. However, they have shown how some previously reported anomalies can be removed. They also propose studies of pandemonium spectra as an acid test for the interpretation of real spectra.

Any nuclear structure effects deduced from real data should be extracted by a technique that would also give an accurate description of the structureless pandemonium. In the words of the ISOLDE group, the simulations 'provide a situation that Nature cannot match. Since the existence of pandemonium is confined to a computer program, we can know with complete certainty all its relevant properties'.

## No axions, but what instead?

As the premier candidate for a workable theory of strong interactions, quantum chromodynamics was long thought to obey the conventional rules of field theory. New developments have shown that this is not the case, and additional mechanisms could be needed to patch it up.

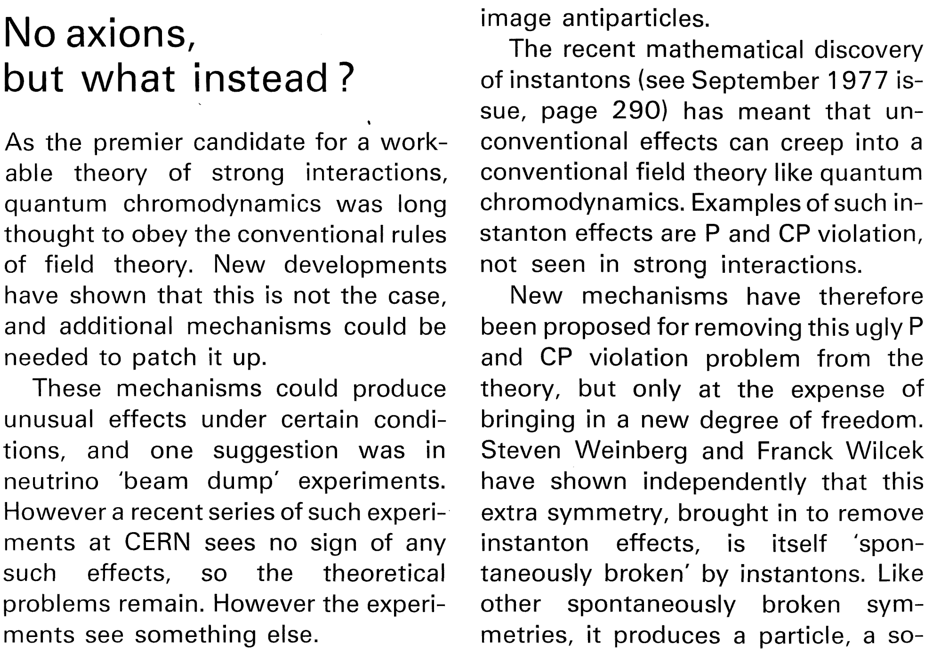
These mechanisms could produce unusual effects under certain conditions, and one suggestion was in neutrino 'beam dump' experiments. However a recent series of such experiments at CERN sees no sign of any such effects, so the theoretical problems remain. However the experiments see something else.

In the same way that quantum electrodynamics uses the exchange of photons to describe the electromagnetic behaviour of point particles, so quantum chromodynamics proposes gluon exchange as a recipe for calculating the inter-quark forces at work in hadronic reactions (see November 1977 issue, p. 380).

Because it is modelled along the lines of conventional quantum field theory, quantum chromodynamics was thought to satisfy the strong interaction requirements for invariance under parity, or space reflection, symmetry (P) and under the combined charge-parity symmetry (CP) which switches particles into their mirror-image antiparticles.

The recent mathematical discovery of instantons (see September 1977 issue, page 290) has meant that unconventional effects can creep into a conventional field theory like quantum chromodynamics. Examples of such instanton effects are P and CP violation, not seen in strong interactions.

New mechanisms have therefore been proposed for removing this ugly P and CP violation problem from the theory, but only at the expense of bringing in a new degree of freedom. Steven Weinberg and Franck Wilcek have shown independently that this extra symmetry, brought in to remove instanton effects, is itself 'spontaneously broken' by instantons. Like other spontaneously broken symmetries, it produces a particle, a so-



*A positron track seen in the BEBC bubble chamber during the recent neutrino 'beam dump' experiment at the CERN SPS. This and similar unexpected electron tracks are apparently produced by the neutrinos coming from very short-lived particles which manage to decay inside the beam dump material.*

called 'Goldstone boson', to commemorate the symmetry breaking.

For the new anti-instanton symmetry, this Goldstone boson would be electrically neutral, light (estimates put the mass almost anywhere below 1 MeV) and would have spin zero with negative parity, hence the name 'axion'.

One suggestion was that axions might show up in neutrino 'beam dump' experiments. At the end of the 1977 experimental programme at the CERN SPS, just such a series of experiments was carried out (see January/February issue, p. 16).

By considerably reducing the neutrino flux from conventional pion and kaon decays, these experiments planned to look for unconventional neutrino-type sources to explain the numbers of multi-muon events accumulated in ordinary neutrino experiments.

No such unusual source of multi-muon events was found, and no axion effects were seen either. This means that either the axion is more elusive than was first thought, or that quantum chromodynamics will have to be patched up some other way.

In the CERN beam dump experiments, the BEBC and Gargamelle bubble chambers report remarkably high numbers of events with electrons, rather than muons, while the CERN / Dortmund / Heidelberg / Saclay muon counters find different spectra to those seen in conventional neutrino experiments.

These results are attributed to very short-lived secondary particles which manage to decay before they are absorbed in the metal of the beam dump. The observed effects cannot be explained in terms of phenomena involving the tau heavy lepton, or similar heavier leptonic states, but the transient secondaries could have the characteristics of charmed mesons.

However estimates of the production levels of these particles do not tally with previous results on charm production deduced from the Fermilab experiment on 300 GeV proton interactions in emulsion. Whether this difference can be resolved remains to be seen, but at this stage the possibility of the effects being due to some new particle cannot be ruled out.

A recent beam dump experiment at Fermilab has also provided evidence for short-lived, weakly decaying particles.

## Young accelerators look at the old

As well as providing high energy particle beams for experiments, particle accelerators can be used as very sensitive mass spectrometers to isolate small quantities of rare isotopes. Through their acceleration process, from ion source to emerging beam, they can sift out isotopes of a precisely defined charge to mass ratio and reject all others. As early as 1939, Luis Alvarez and collaborators used the Berkeley 60 inch cyclotron in this way to isolate helium-3 and tritium.

After a lapse of some thirty years, interest in this technique seems to have revived. One of the first examples of this revival was an attempt to isolate integrally charged quarks using the Berkeley 88 inch cyclotron. This search was unsuccessful but it was possible to set an upper limit on their occurrence at one per $10^{14}$ protons. Another group using the tandem Van de Graaff at Brookhaven for a similar search, this time for superheavy nuclei, and concluded that their natural abundance was less than one part in $10^{10}$.

Although these experiments did not give positive results, they pointed the way to further use of accelerators for isolating very small amounts of naturally occurring isotopes and thus new methods of radiocarbon dating of very old objects.

Radiocarbon dating of an object involves the measurement of the concentration of the radioactive isotope carbon-14. This isotope is continually being formed in the atmosphere in the bombardment of nitrogen nuclei by slow neutrons coming from cosmic rays. The carbon isotope undergoes beta-decay with a half-life of 5600 years and its production and decay are in dynamic equilibrium, so that it is found in a fixed concentration in the atmosphere.

Through carbon dioxide, this radioactive carbon finds its way into living material. However, when organic material dies, carbon dioxide is no longer taken in from the atmosphere and the carbon-14 level begins to fall as a result of its radioactive decay. Thus by measuring the residual level of carbon-14 in samples of wood, bone, fossil, etc., estimates can be made of their age.

The standard method of radiocarbon dating now used consists of counting the beta-decays of the residual carbon-14. It was developed by Willard F. Libby and earned him the Nobel Prize for Chemistry in 1960. Because the method is indirect, measuring the decays rather than the actual residual level of carbon-14, it requires samples to be large enough to give adequate counting statistics. Also the low counting rates from very old samples with low levels of carbon-14 limit the archaeological timespan which can be covered. Nevertheless, samples of several grams of material up to tens of thousands of years old can be dated by this technique.

The aim of new direct measurement techniques now being developed at Berkeley and Brookhaven is to extend the versatility of radiocarbon dating. After initial experiments with tritium, the Berkeley group working at the 88 inch cyclotron turned their attention to the detection of carbon-14. Interference with atmospheric nitrogen, which has the same charge to mass ratio as carbon-14, proved to be a nuisance but a method has now been developed to eliminate the nitrogen effects by absorption in xenon. As a result, the group estimates that carbon-14 can be separated from nitrogen-14 down to one part in $10^{14}$.

A group at Brookhaven using a Van de Graaff to separate ions developed a negative ion source which eliminates effects due to nitrogen. Using this technique, carbon-14 has been detected in a milligram sample and specimens from the US Geological Survey dating back 70000 years have been checked. Other tests using Van de Graaff techniques have been successfully carried out at McMaster University in Canada.

These developments have already aroused the interest of archaeologists, geologists and historians. As well as enabling samples hundreds of times smaller than usual to be examined, the techniques could allow the lower concentrations of carbon-14 in older specimens to be measured. While conventional methods usually reach their limit at about 60000 years, this direct detection could extend radiocarbon dating to 100000 years.

# People and Things

## *Resignation of Bob Wilson*

*On 9 February Professor Robert R. Wilson resigned as Director of the Fermi National Accelerator Laboratory in protest against the 'inadequate' funding of the programme at Fermilab. The announcement was made by Norman Ramsey, President of the Universities Research Association, which manages the Laboratory. The URA reluctantly accepted the resignation at its Board of Trustees meeting on 16 February.*

*Main points from his letter of resignation are — The future viability of Fermilab is threatened because the funding has been below that necessary to operate the existing facilities responsibly... Present operation is at about half the capacity to do physics... The scheme to increase the proton energy to 1000 GeV through the application of superconductivity has been confounded by indecisive and subminimal support, as have the modest proposals for intersecting beams... No additional money has been identified for Fiscal Year 1978, nor does the President's budget for Fiscal Year 1979 indicate more than a cost-of-living increase in operating funds. It does propose that the Tevatron project become a construction project costing $ 39 million but the rate of funding indicated for Fiscal Year 1979 would require at least $ 5 million more to keep the Tevatron project moving at an acceptable and economic rate.*

*Professor Wilson indicated that he wished to continue to work on the*

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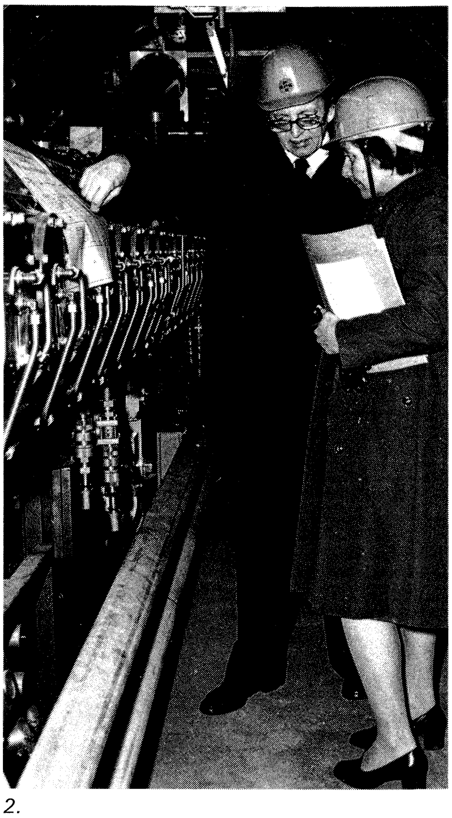


2.

*1. Professor R.R. Wilson*

*2. On 13 February the British Secretary of State for Education and Science, Mrs. Shirley Williams, visited CERN. She is pictured here during a tour of the 400 GeV proton synchrotron with Michael Crowley-Milling, Leader of the SPS Division.*

*(Photo CERN 223.2.78)*

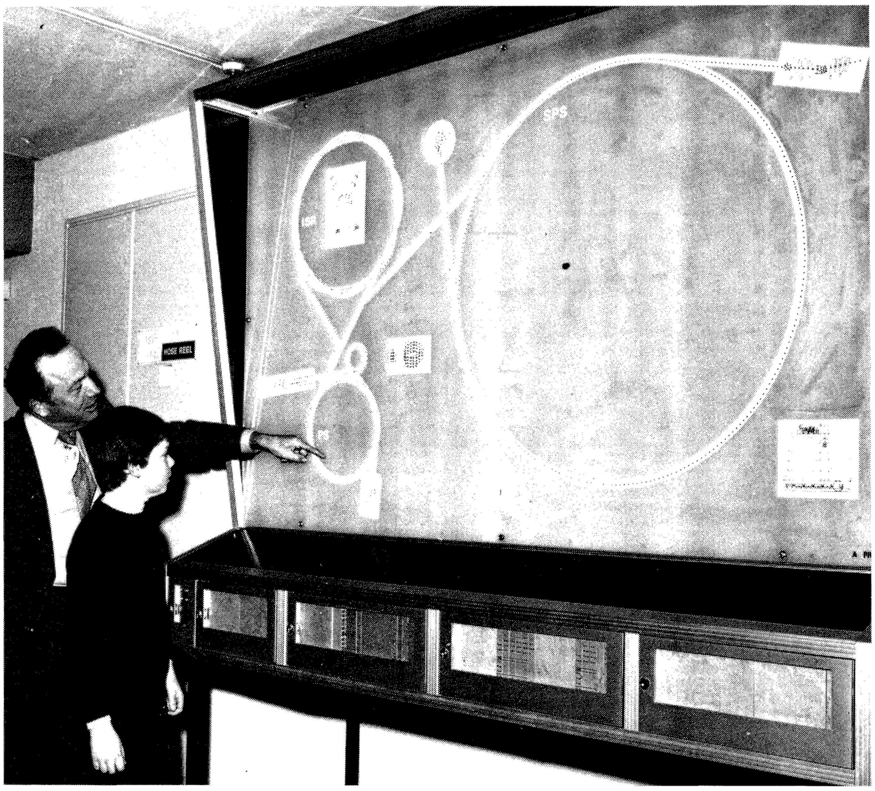
*Tevatron, a project which he initiated as an improvement programme for Fermilab, and hoped that the gesture of his resignation would help increase support for the Laboratory.*

*It is typical of Bob Wilson that he should go out from being Director of Fermilab with a bang rather than a whimper. He has led the Laboratory in dramatic style since it came into being in June 1967. During his term of office he has added the world's highest energy, highest intensity proton synchrotron to his previous similar achievement with the electron synchrotron at Cornell. Almost all features of the Laboratory (the aesthetic, the ecological, the hierarchical, the style of experiments...) are stamped with his powerful personality and he will not be an easy man to follow. We salute his great achievements during his years as Director of Fermilab.*

## *ICFA Meeting*

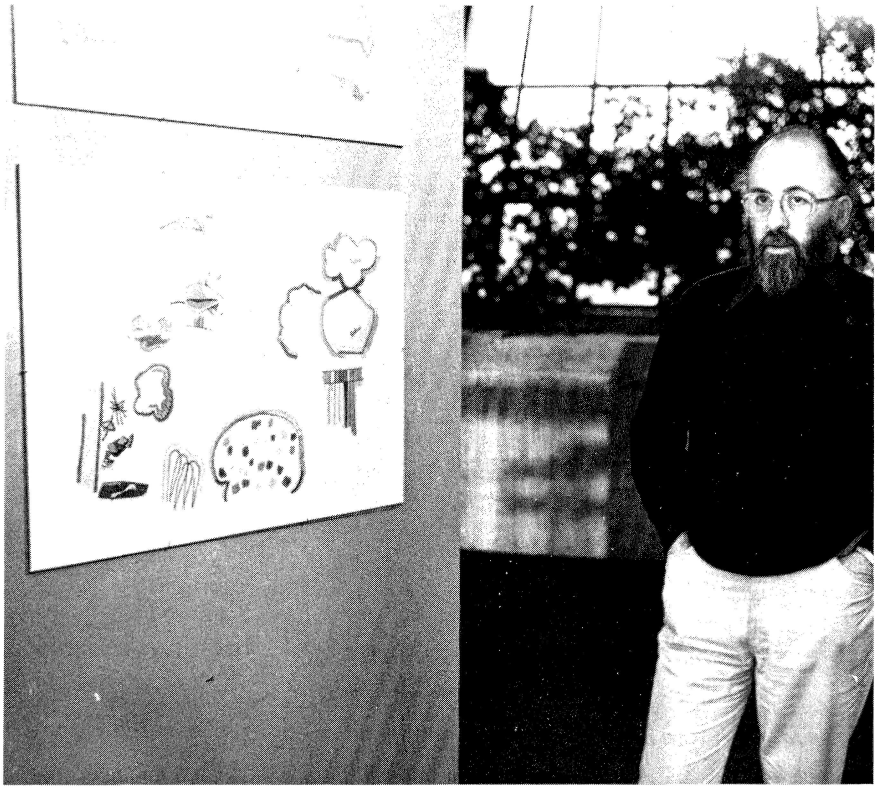
*The International Committee for Future Accelerators, ICFA, met at CERN on 27 January with representatives from Japan, Soviet Union, USA and Eastern and Western Europe. The Meeting was opened by Ned Goldwasser following the death of the ICFA Chairman, Bernard Gregory, to whom tribute was paid. The major aim of ICFA is to discuss world-wide collaboration in the construction of an accelerator, often referred to as the VBA (Very Big Accelerator).*

*It had been intended to pursue this aim by setting up Study Groups but at the January Meeting it was decided instead to hold Workshops on particular aspects of the VBA project. The first will be held at Fermilab in October on present limitations of accelerators and detectors. A second may follow in the Spring of 1979 at Serpukhov on progress with superconducting magnets and superconducting radiofrequency cavities. A third may cover*



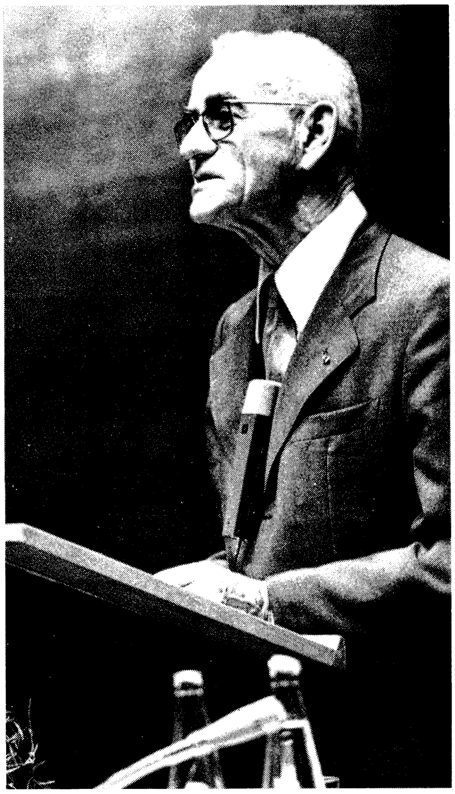
*Emile Sigaud, with his son Fréderic, in front of the animated model of the CERN machines which he conceived and constructed. The model (using LEDs - light emitting diodes) demonstrates the interlocking sequence of operation of the linac, booster, PS, ISR and SPS and the experimental areas which they feed. It is proving of great value in explaining these complexities to CERN visitors.*

*(Photo CERN 451.2.78)*



*Harold Cohen, a painter and artist who now uses a computer as his alter ego, showed his unique method in a lecture at Fermilab. He has taught a computer to create its own art following a set of conventions ranging from simple requirements to stay within the picture to complex balance constraints. The computer draws on a large scale using a computer controlled bug that scurries over paper laid on the floor. The demonstration employed a PDP-11-45 computer ordinarily used at Fermilab for on-line analysis.*

*(Photo Fermilab)*



*A memorial gathering in honour of Bernard Gregory was held at CERN on 27 February. Leon Van Hove, Charles Peyrou, John Adams and Louis Leprince-Ringuet (photograph) all paid tribute to the memory of Professor Gregory.*

*(Photo CERN 500.2.78)*

*the physics aspects of the VBA.*

*John Adams was elected President of ICFA for this year with Owen Lock as Secretary. Two Western Europe representatives, Wolfgang Paul and Guy von Dardel have been replaced by Godfrey Stafford (Chairman of the CERN Scientific Policy Committee) and Marcel Vivargent (President of the European Committee for Future Accelerators).*

## *On People*

*A.I. Alikhanian, Associate Member of the USSR Academy of Sciences and former Director of the Physics Institute at Yerevan in Soviet Armenia, died in Moscow on 25 February after a long illness. Professor Alikhanian was associated with the building of the 6 GeV electron synchrotron, ARUS, at Yerevan and with the development of the transition radiation high energy particle detection technique.*

*Paul Matthews of the University of Bath received the 1978 Rutherford Medal and Prize from the UK Institute of Physics for his contributions to elementary particle physics. Professor Matthews is also the author of one of the popular books on recent discoveries in fundamental physics, entitled 'The Nuclear Apple', and until recently was a member of the CERN Scientific Policy Committee.*

*Basil Zacharov, former Head of the Computing Systems and Electronics Division at Daresbury, took up the position of Director of the University of London Computer Centre at the beginning of March.*

*John Bailey, a leading physicist on the g-2 experiments at CERN who had moved to Daresbury, has joined IKO (the Netherlands Institute for Nuclear Physics Research) at Amsterdam as leader of the Pion-Muon Group. Also working with IKO is former CERN physicist Ron Fortune whose 'Scientific and Technical Services' has been commissioned for a 5 m superconducting solenoid for the muon channel.*

## *Clarke's Law*

*Perhaps best known for his science fiction epic '2001 : A Space Odyssey', Arthur C. Clarke has a considerable literary output behind him including many works as a 'serious' science writer. For example, his paper on extra-terrestrial relays, published in 1945, was one of the pionner works which blazed a trail for today's satellite communications technology. He also developed Clarke's Law:*

*'When a distinguished but elderly scientist states that something is possible, he is almost certainly right; when he states that something is impossible, he is very probably wrong. The only way to define the limits of the possible is by going beyond them into the impossible.'*

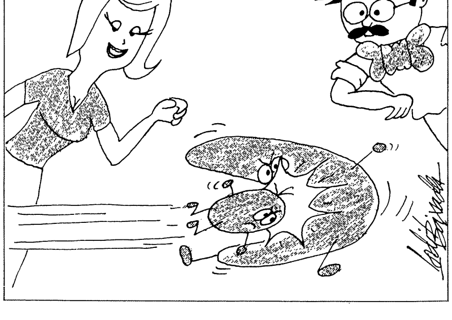
## *CERN in colour*

*On 3 March a series of comic strips on CERN started in the Geneva newspaper, Tribune de Genève. They are running daily for seven weeks presenting the research, the machines and the organizational structure of CERN in a colourful way.*

*This technique of communicating information is spreading rapidly and the most serious of institutions is not beyond the reach of the cartoonist's pen. The project originated from a conversation between Alfred Roulet of the Tribune and Roger Anthoine of the Press and Visits Service. Brian Southworth prepared the scenarios, Georges Boixader did the drawings, Henri-Luc Felder looked after the French version and Leon Van Hove provided encouragement and help.*

*The proton takes on a distinctive smiling character (not so easy when three other individuals are sitting inside you)... the neutrino appears as an elusive ghost... three invented physicists take a visitor around the CERN accelerators and detectors... national archetypes represent the Member States. It is all intended to amuse and to inform about CERN and its work.*

*When the series is complete in the Tribune, albums of the comic strips in both French and English editions will be produced.*



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| Publication date | End of month of cover date |
| Closing date for positive films and copy | 1st of month of cover date<br>The cost of making films and of translation for advertisements are charged in addition |
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All enquiries to:

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# DIRECTOR FERMI NATIONAL ACCELERATOR LABORATORY

The Universities Research Association Board of Trustees has initiated a search for a new Director of the Fermi National Accelerator Laboratory. The Search Committee is now in the process of assembling a list of suitable candidates and welcomes applications and recommendations from the community of High Energy physicists. Universities Research Association is an affirmative action employer.

Communications should be sent to:
**Dr. Harold K. Ticho**
Chairman, Search Committee
Universities Research Association, Inc.
**2100 Pennsylvania Avenue, N.W.**
**Washington, D.C. 20037**

---

### POSITION OPPORTUNITY

# RESEARCH ASSOCIATES IN PARTICLE PHYSICS

The INSTITUTE OF PARTICLE PHYSICS OF CANADA invites applications for Research Associate positions. Openings exist in the Canadian experimental particle physics groups located at Carleton, McGill, Ottawa, Toronto and York Universities. These groups are collaborating in experiments at Fermilab and SLAC.

Applications including curriculum vitæ, transcripts and the names of 3 referees should be sent to:

**J.D. PRENTICE**
Department of Physics
University of Toronto
Toronto, Ontario M5S 1A7
Canada

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### POSITION OPPORTUNITY

# RESEARCH SCIENTIST IN PARTICLE PHYSICS

The INSTITUTE OF PARTICLE PHYSICS OF CANADA invites applications for Research Scientist positions. Applicants should have proven ability in Experimental Particle Physics. Initial appointments will be for three years followed by a review which, if favorable, will lead to a continuing career appointment. Initially Research Scientists will be expected to join one of the existing I.P.P. collaborations at Fermilab or SLAC but the opportunity to initiate new experiments will also exist.

Applications including curriculum vitæ, transcripts and the names of 3 referees should be sent to:

**J.D. PRENTICE**
Department of Physics
University of Toronto
Toronto, Ontario M5S 1A7
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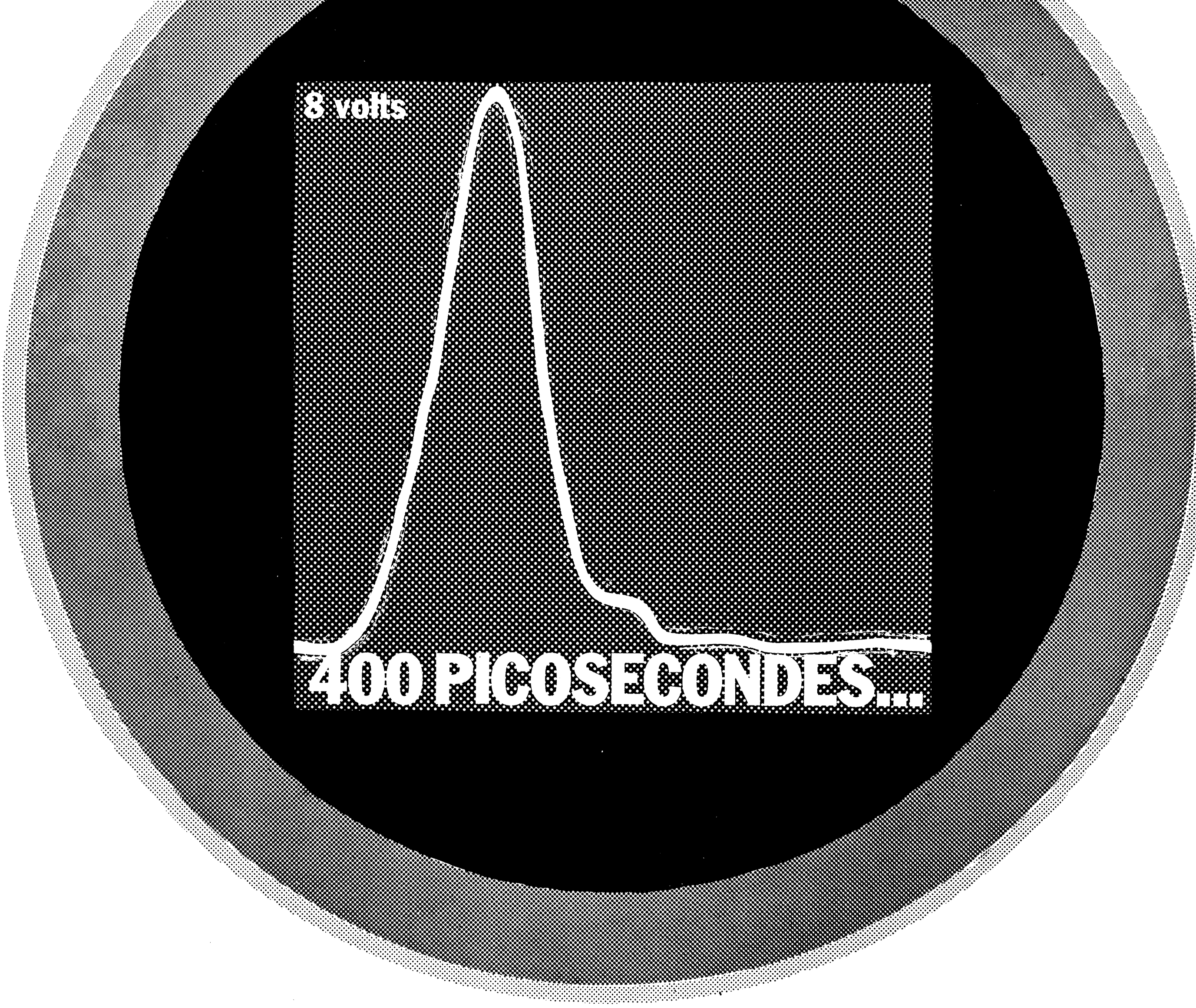

La Chesnay Associés Communications 487

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Ces caractéristiques d'avant-garde ouvrent la porte aux domaines d'applications suivants :

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Ce tube fait partie de la gamme complète de nos tubes à rayons cathodiques.

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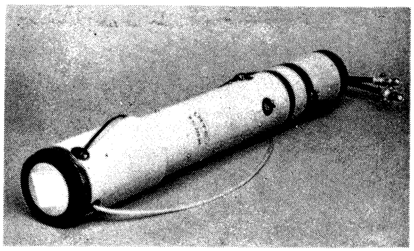
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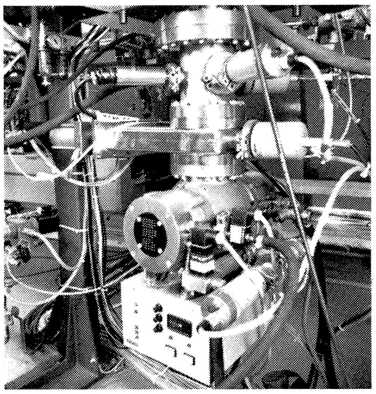

TPU 200 on heavy ions accelerator of the Gesellschaft für Schwerionenforschung (GSI) (Society for Heavy Ions Research), Darmstadt.

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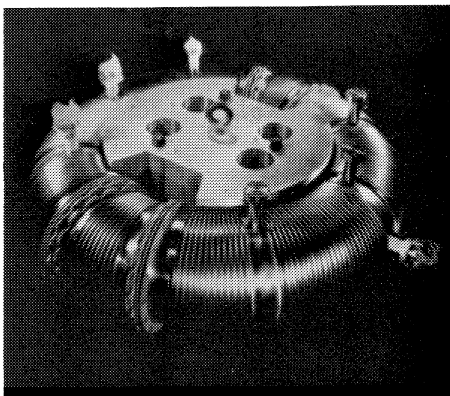

Tokamak for TOSCA experiment at U.K.A.E.A. Culham Laboratory

All-stainless-steel multiple flexible for irradiated fuel dismantling facility – Prototype Fast Reactor, Dounreay.

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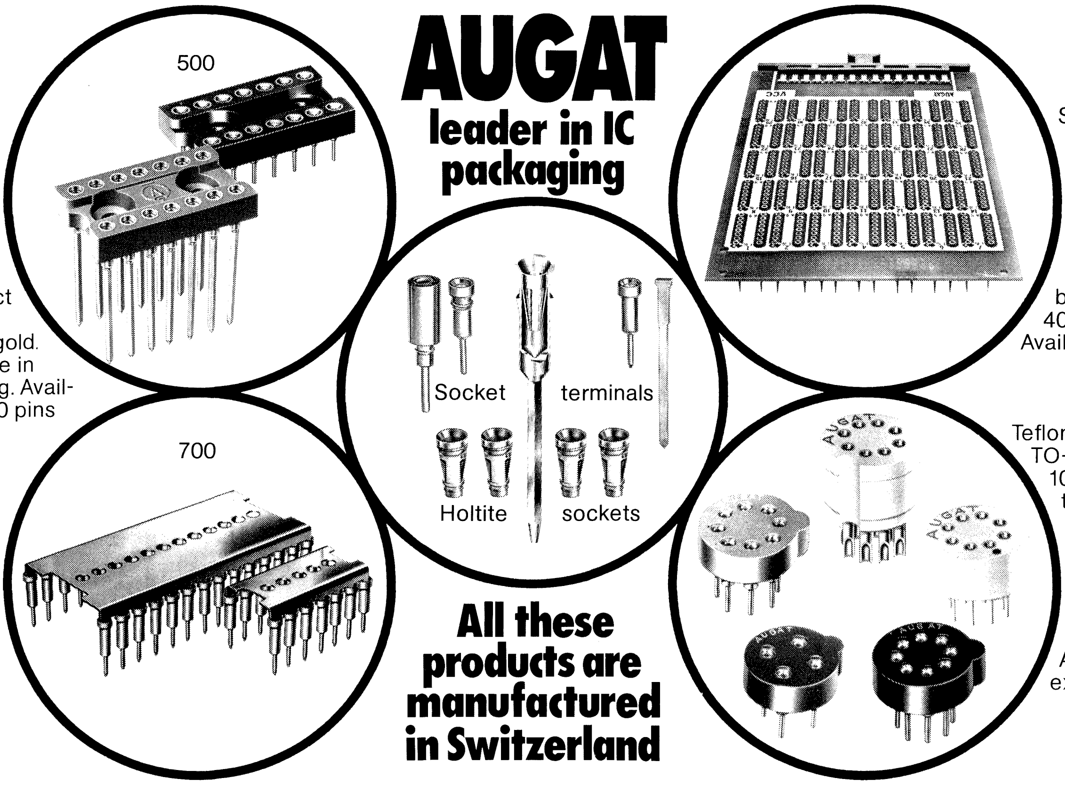

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# And now, Mostek memory systems.

For years, Mostek has been the recognized leader in memory circuit technology and reliability. Mostek set a demanding pace with the industry standard 16-pin package for dynamic RAMs, the first high-performance 4K (MK 4027), and the new standard 16K RAM.

Now with the same commitment to innovative technology, Mostek brings its name to memory systems. It's a natural step for Mostek. High-performance memories, high-volume production, high-speed testers—all assure you more confidence for reliable memory systems.

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*MK 8003.* Mostek Memory System's add-in memory card for the Data General Nova 3. This memory card provides up to 128K x 17 of storage on a single 15″ x 15″ printed circuit board, and uses Mostek's reliable 4116 16K RAM technology. The 8003 is completely compatible in both hardware and software with the Nova 3/4, 3/12, or 3/D. Smaller capacities are available.

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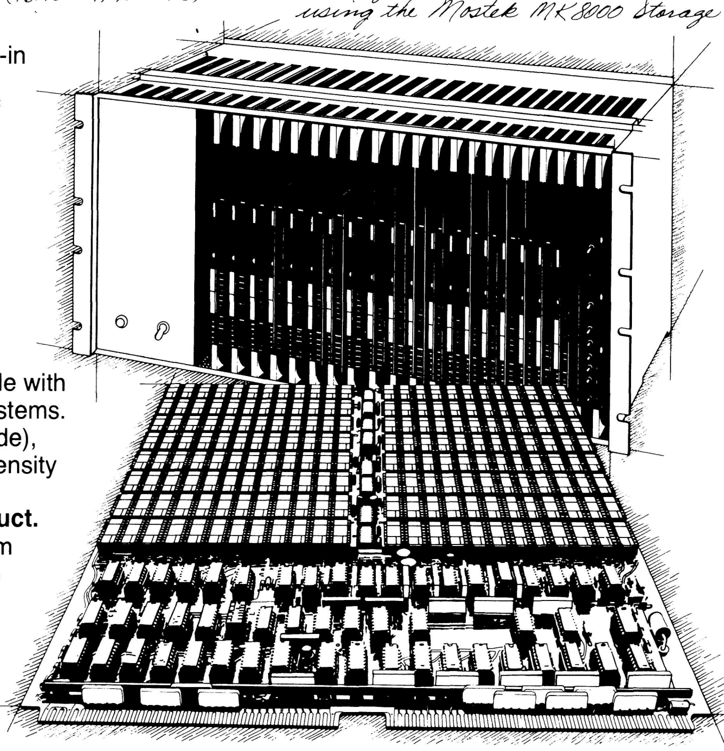

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Capacity: 6 Megabytes + I/O in 12¼" Chassis
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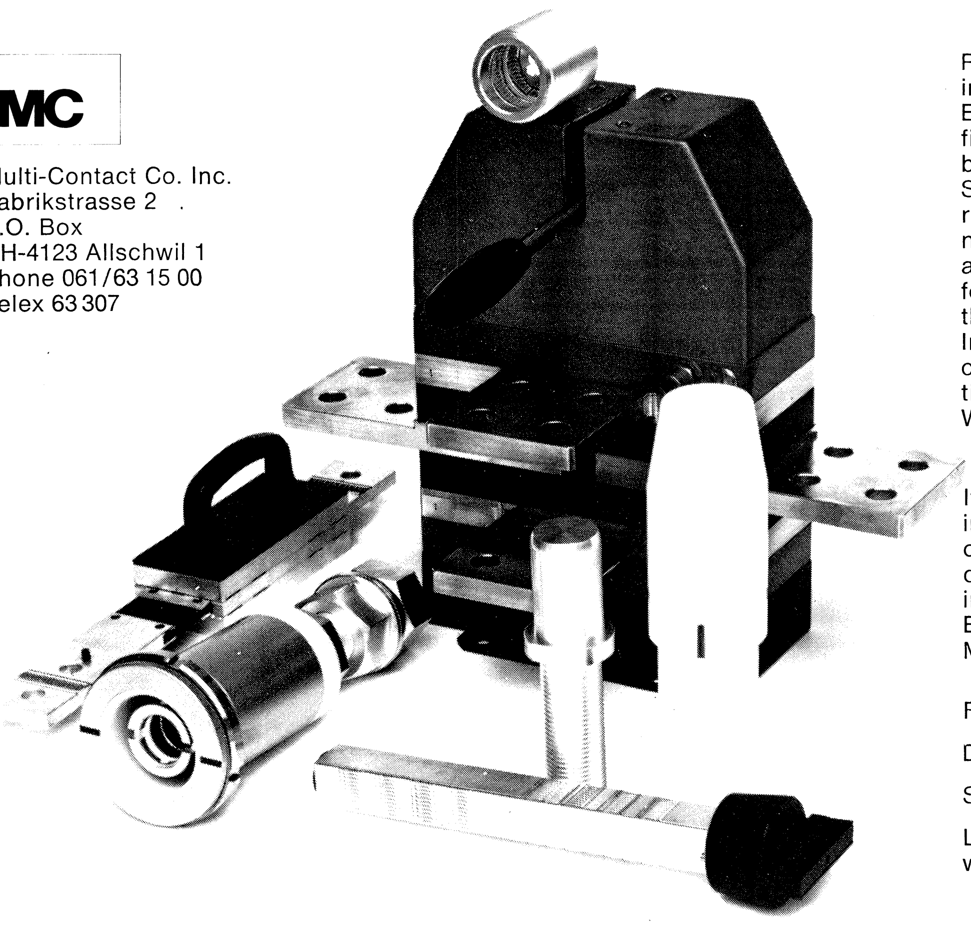

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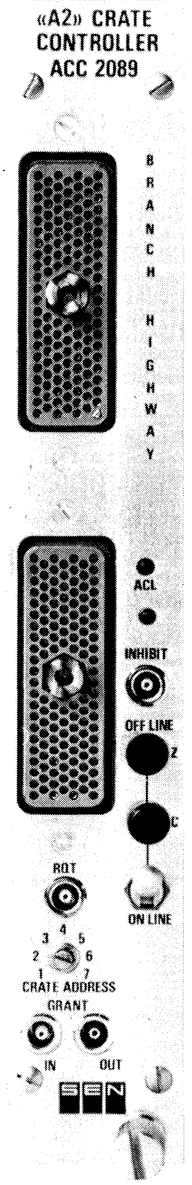
# CAMAC

# INTRODUCING OUR NEW A2 CRATE CONTROLLER

## DESCRIPTION

The A2 Crate Controller has been developed from the earlier A1 unit and has all the same functions plus new control logic for local data handling using a microprocessor. The A2 provides access to the N and L lines, via a rear panel connector, for an intelligent module placed in any normal station. It also handles the remote/local access request conflicts.

Front-end data processing is governed by this module just as long as the main computer does not require access to this particular crate: however, when this occurs, the local processor is released and its status saved. Subsequently the Branch demand is processed. Once the Branch demand has been filled, control returns to local processing.



## SPECIFICATIONS

### Front Panel

| | |
|---|---|
| Crate Address | 7 position switch allows selection of the addresses BCR 1 to 7 of the "A" Crate Controller. |
| ON LINE/OFF LINE | Links the Crate Controller to the Branch Driver. |
| Initialize (Z) | This push button sends Z signal in position OFF LINE. |
| Clear (C) | This push button sends C signal in position OFF LINE. |
| INHIBIT (1) | LEMO RA 00 C50 connector. Accepts 1 signal with TTL level. |
| Request (RQ) | Lemo RA 00 C50 Connector:<br>Indicates RQ signal; TTL level |
| Grant IN (GI) | Lemo RA 00 C50 Connector:<br>Accepts RQ signal output, or other signal according to the priority order; TTL level. |
| Grant OUT (GO) | Lemo RA 00 C50 Connector:<br>Outputs GO signal (TTL) to the next Grant IN input. |
| ACL/RG LED. | LED indicating Request/Grant mode or Auxiliary Controller lockout (ACL)<br>On when in ACL mode. |

### Rear Panel

LAM Grader Connector: 52 pin, double-density Cannon.
Auxiliary Controller BUS (ACB) Connector: 40 pin AMP.

## PHYSICAL

Double width CAMAC module with shield covers on both sides. Fibre-glass printed circuit board with plate-through holes.

Meets electrical and mechanical requirements of EUR 4100e and 4600e.

## POWER REQUIREMENTS

| | |
|---|---|
| + 6V | 2.4A |
| − 6V | 100 mA |

**UK readers please note that all SEN products are now available from SEN Electronics Ltd.**

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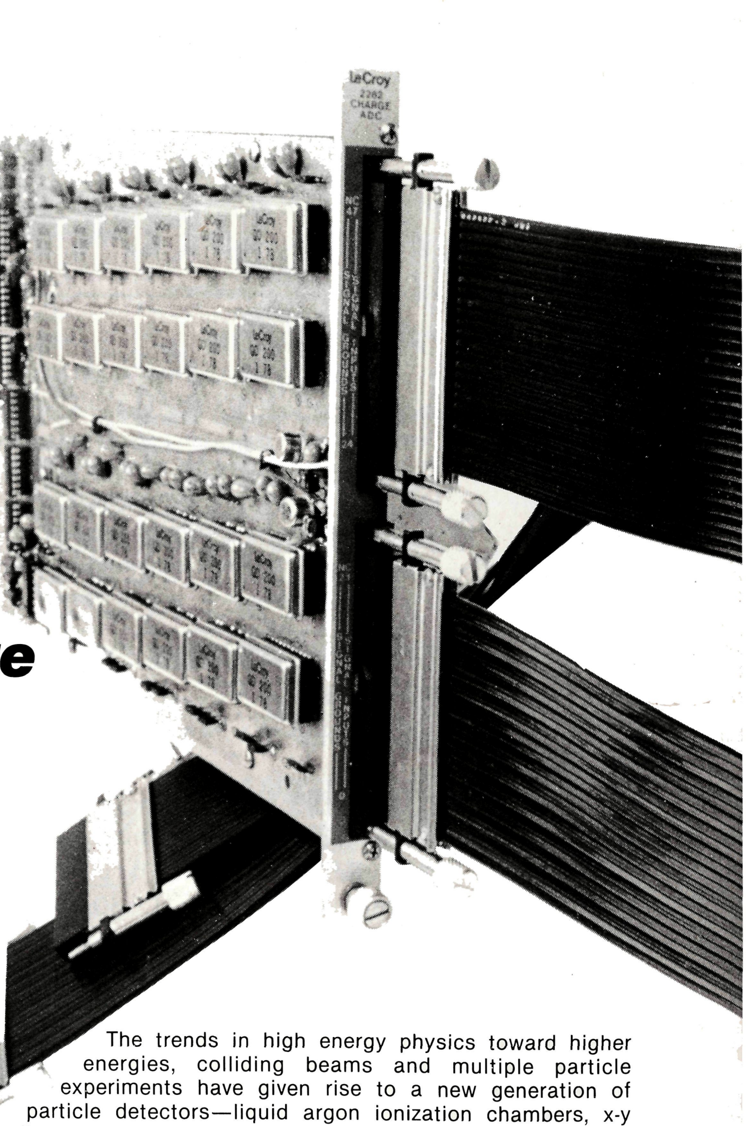
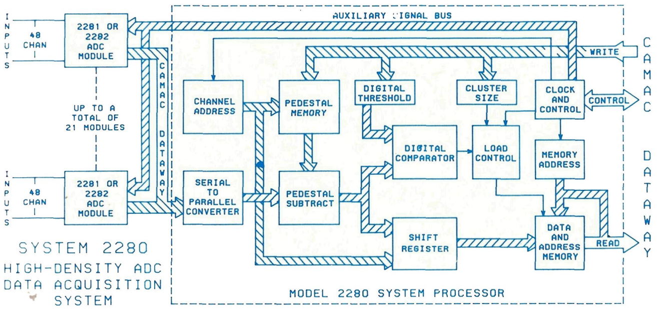
# ADC's by the thousand



# LeCroy's 2280

## *the ADC system designed for the future*



SYSTEM 2280
HIGH-DENSITY ADC
DATA ACQUISITION
SYSTEM

**High density**—1008 independent ADC's per CAMAC crate; 48 per single module.

**Wide dynamic range**—12-bits, current-integrating or peak-sensing.

**CAMAC packaging**—standard CAMAC crate, standard CAMAC readout.

**Low support hardware**—built-in gate and fast clear fanout.

**Data preprocessing**—automatic pedestal subtraction.

**Data compression readout**—only valid data channels are stored for readout.

**Simple maintenance**—socketed hybrid circuit design makes replacement or trouble-shooting easy.

**Low, low cost**—less than $50.00/channel in quantity.

The trends in high energy physics toward higher energies, colliding beams and multiple particle experiments have given rise to a new generation of particle detectors—liquid argon ionization chambers, x-y coordinate wire chambers, and the time projection chamber. To permit the implementation of these detectors, a revolution in data acquisition and readout electronics was clearly necessary, demanding high performance, high density, easy maintenance, and extremely low cost.

LeCroy's 2280 CAMAC ADC system was designed to meet these demands of the future.

The system consists of up to 21 ADC modules (1008 channels) and a system processor for each CAMAC crate and conventional crate controller. The 48-channel ADC modules (Model 2281 Peak/Model 2282 Charge) contain separate 12-bit Wilkinson ADC's. Unlike intricate sample-and-hold designs, the separate ADC system is less subject to interchannel cross-modulation effects, does not rely on specialized low-leakage components, and is less sensitive to noise and RF pickup.

The Model 2280 system processor receives and processes data, making it available for conventional CAMAC readout with other modules in the crate. A data compression technique leaves only valid data and addresses available for readout, minimizing readout time and substantially decreasing the memory requirements of the attending computer.

For complete details, call or write LeCroy or your local sales office.

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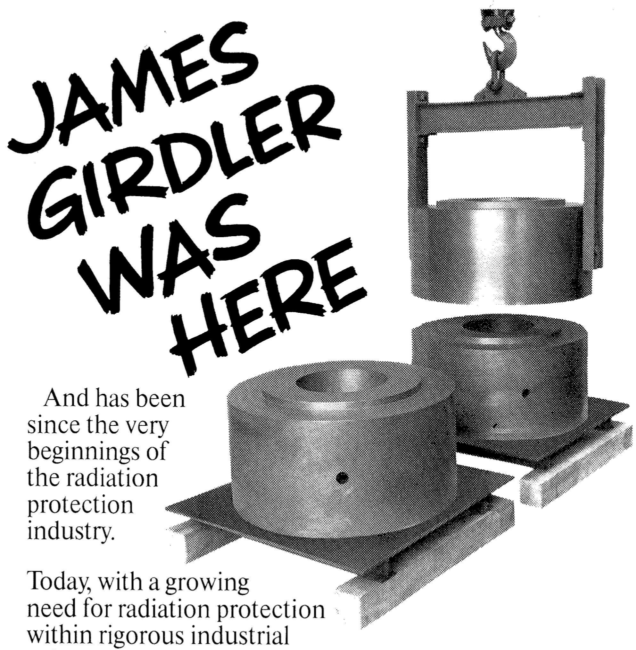
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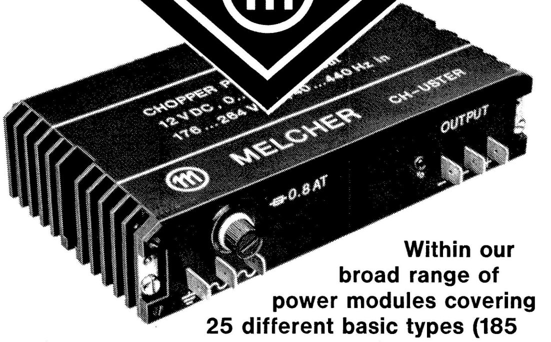
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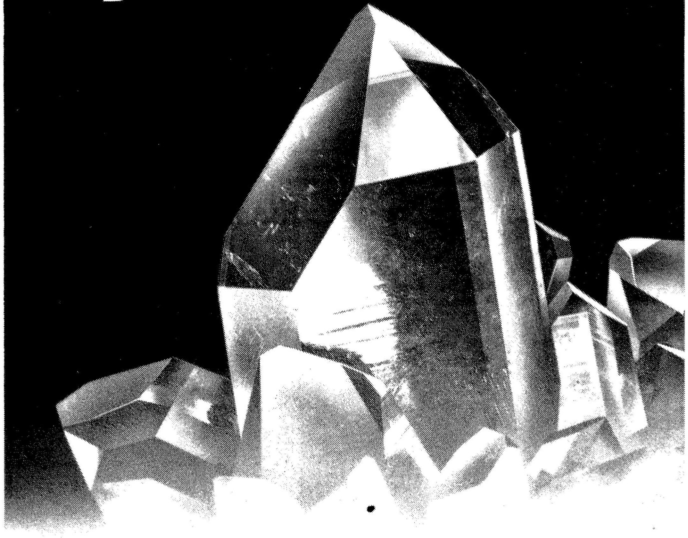

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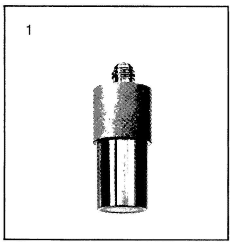
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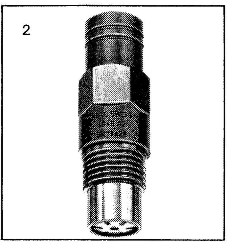
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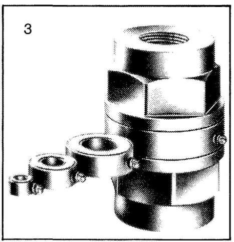
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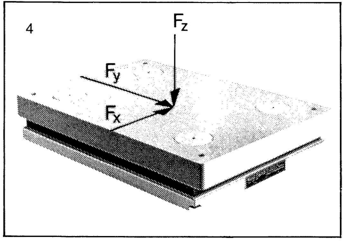
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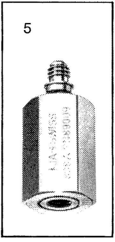
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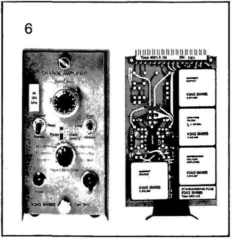

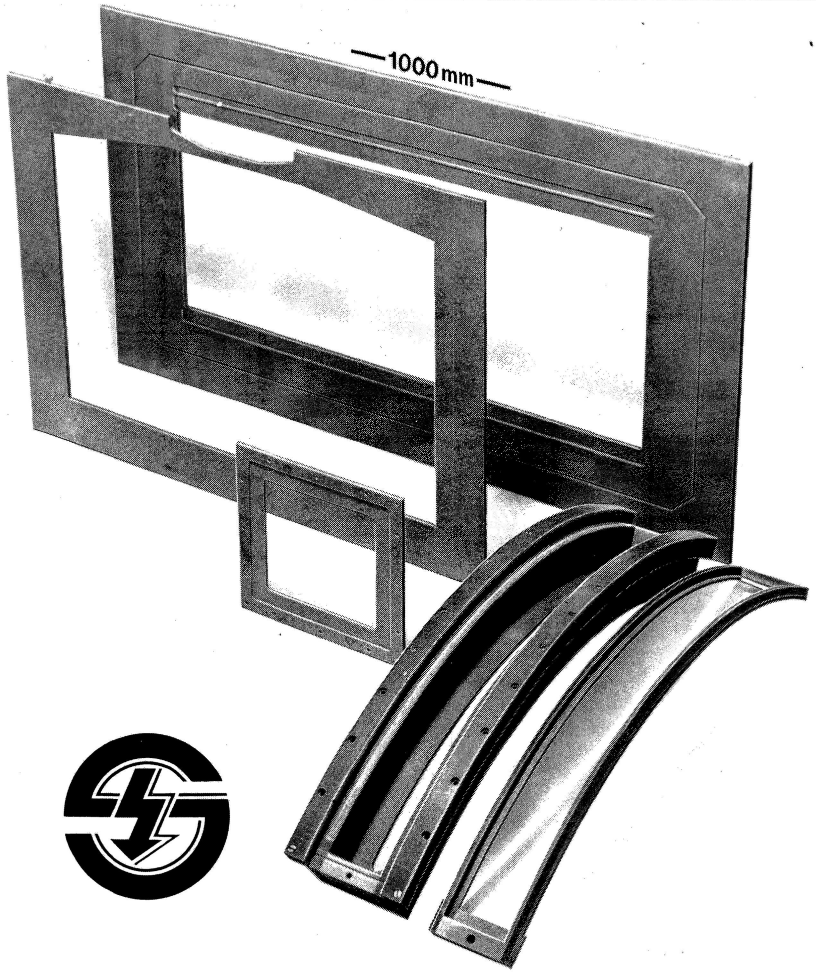
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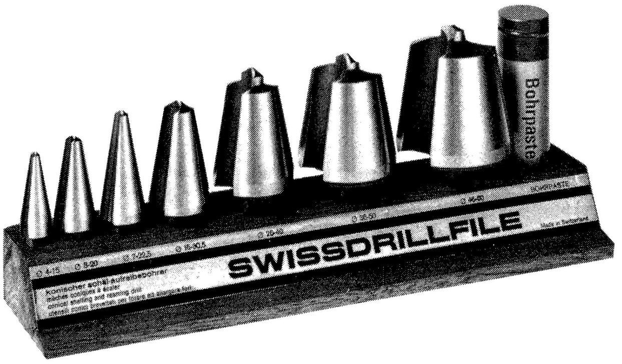

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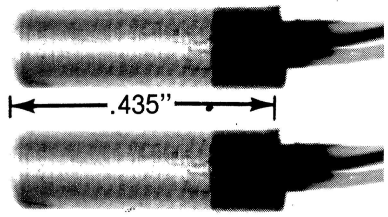

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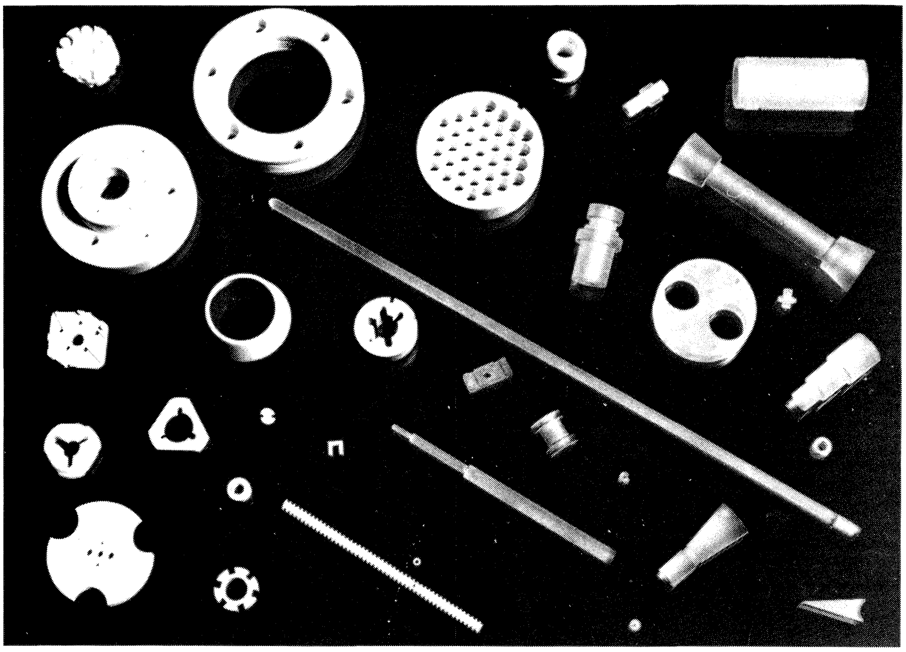

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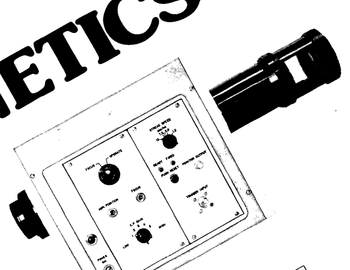

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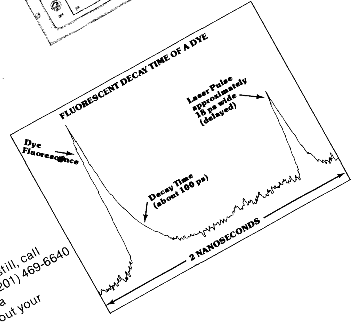

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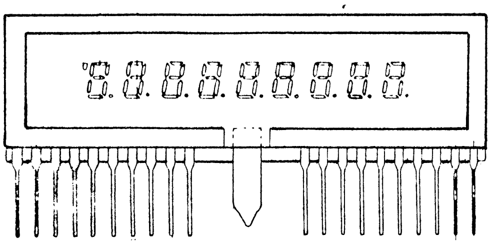

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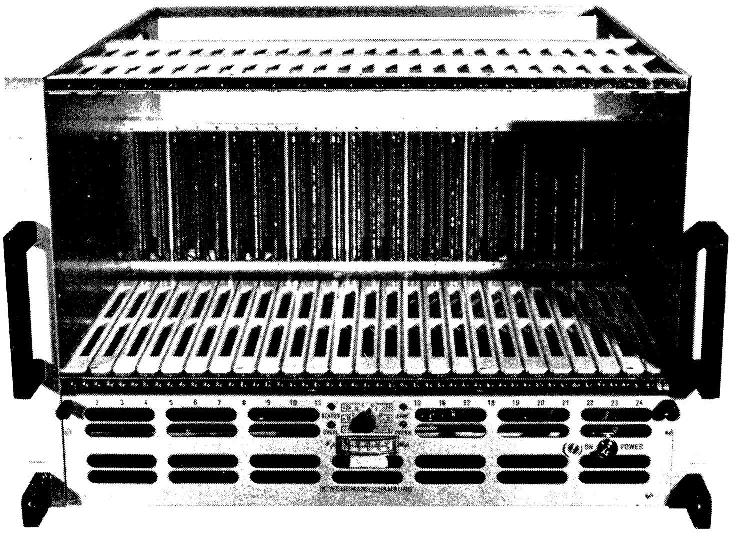

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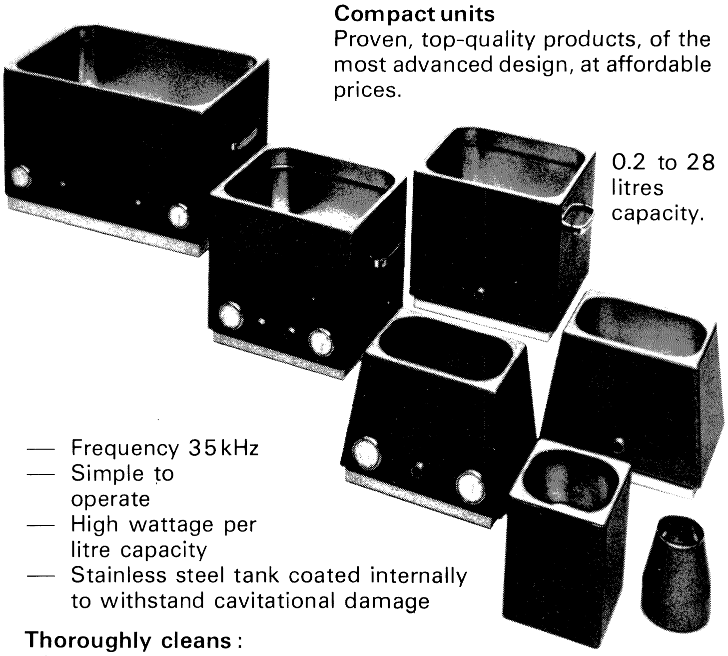

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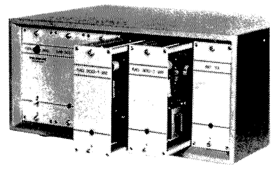

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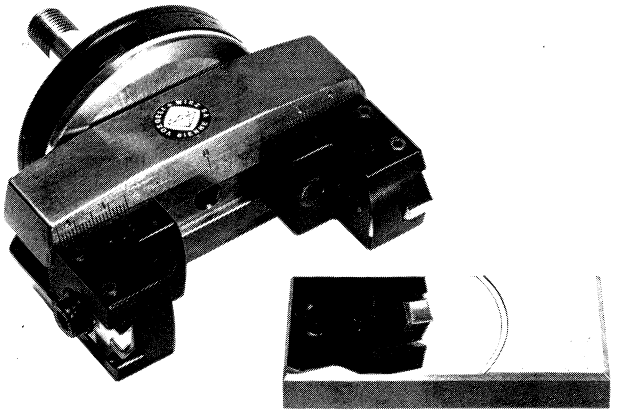

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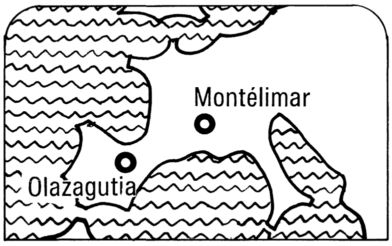

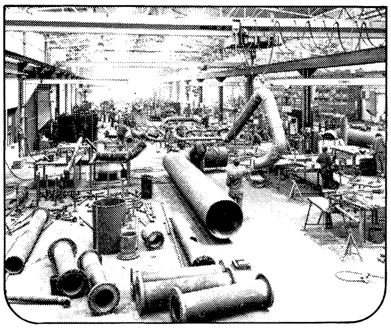

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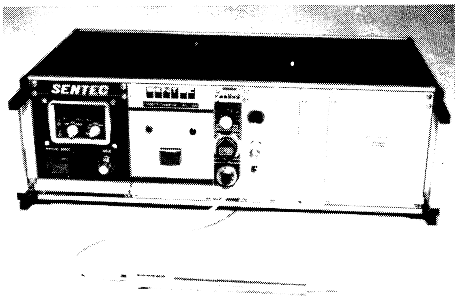

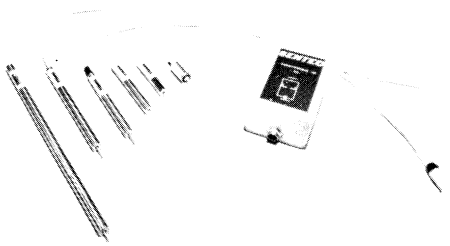

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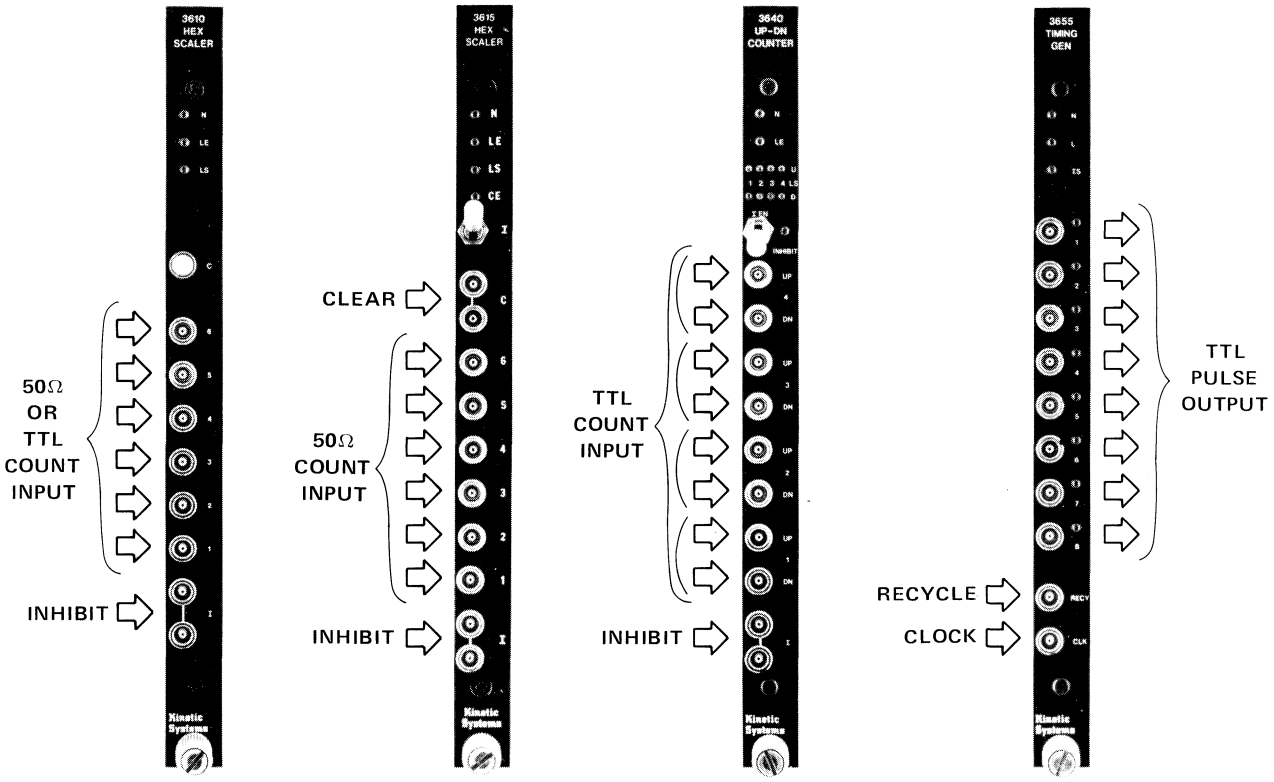

### 3610

**6-Channel, 50 MHz Counter**

- Six independent 24-bit counters
- Counter inputs are 50 ohm terminated or TTL (strap selected)
- Input pulse rate from DC to 50 MHz
- Independent clear by command for each counter
- LAM status bits set on overflow

### 3615

**6-Channel, 100 MHz Counter**

- Six independent 24-bit counters
- Counter inputs are 50 ohm terminated
- Input pulse rate from DC to 100 MHz
- Independent clear by command for each counter
- LAM status bits set on overflow

### 3640

**4-Channel, Up-Down Presettable Counter**

- Four independent 16-bit up-down counters
- Separate up/down inputs for each channel
- Counter inputs are TTL
- Input pulse rate from DC to 20 MHz
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### 3655

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- Eight independent pulse outputs
- Includes eight 16-bit set point registers
- Operates from internal or external clock
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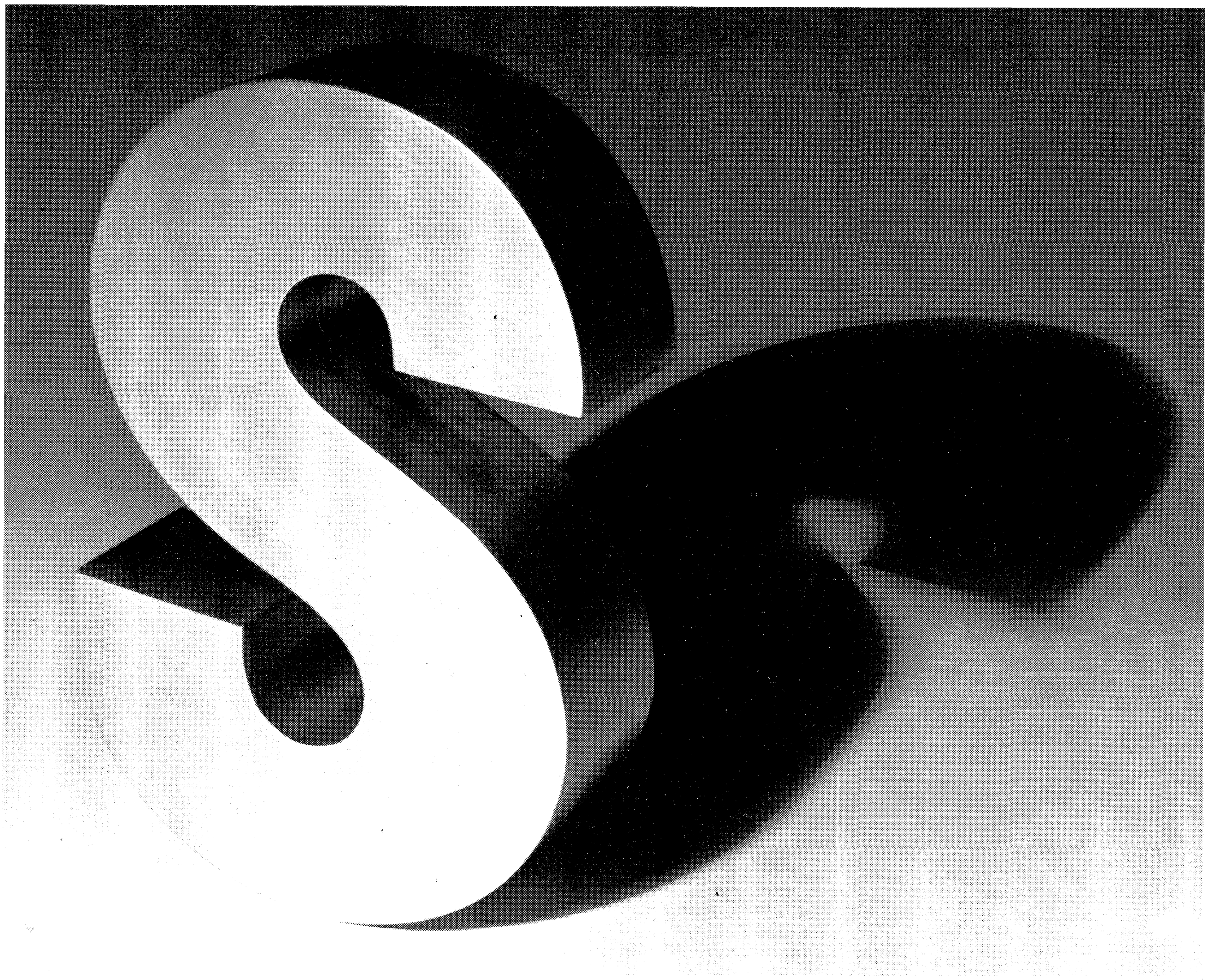

RRA AB Bates

# La meilleure amélioration jamais faite sur le NORD-10

NORD-10 a suscité une assez grande surprise lors de son lancement: un ordinateur de taille moyenne avec des facilités dépassant souvent celles des grandes machines!

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Grâce à de nouveaux composants électroniques et un logiciel optimisé, le NORD-10/S offre une capacité de traitement presque doublée — au MEME PRIX!

Cette amélioration est significative, mais nous considérons comme plus important encore le fait que tout le logiciel développé depuis 5 ans sur le NORD-10 est exécutable sur le NORD-10/S avec les nouvelles performances, et ce, sans AUCUNE MODIFICATION.

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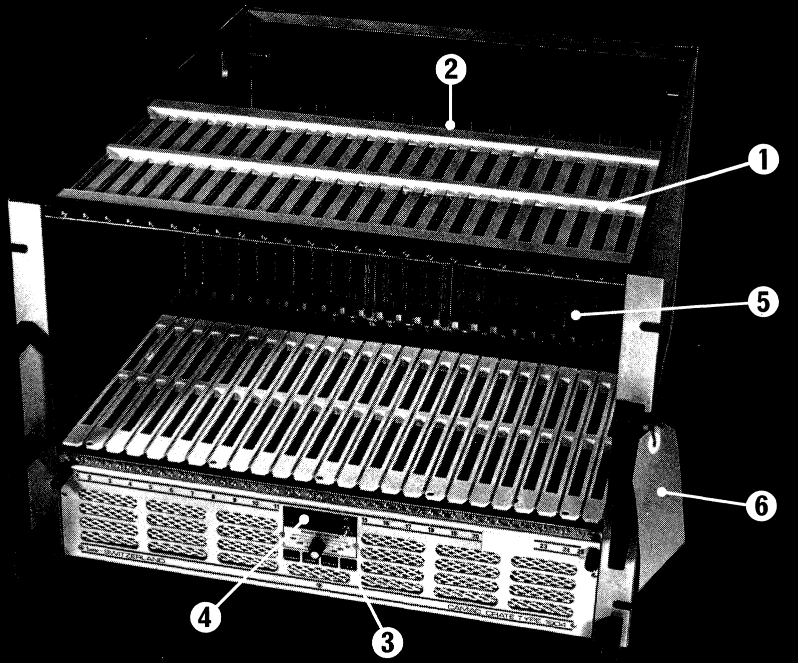
## NORD - une alternative à étudier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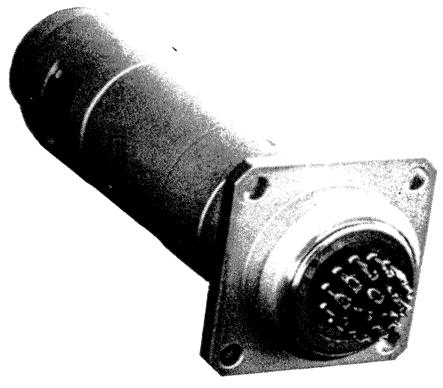

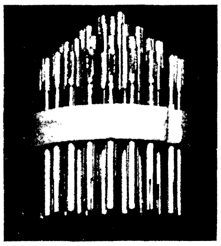

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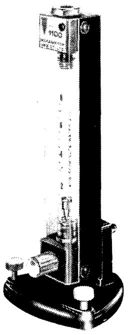
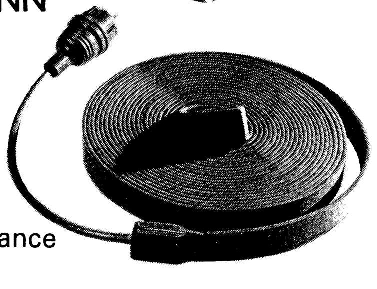
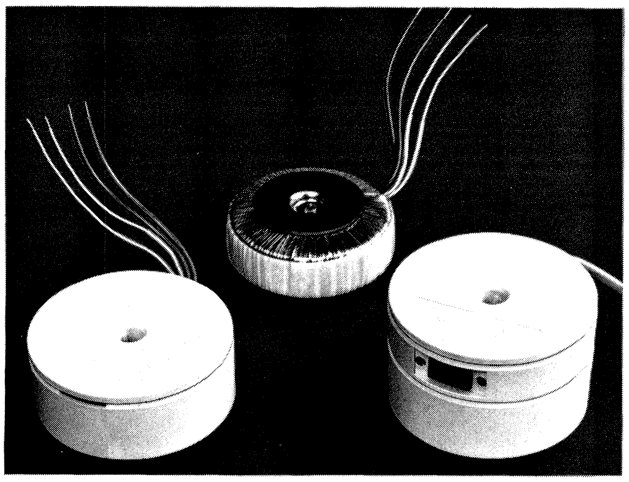




# Leitgeb importe aussi les meilleurs produits suédois!

Sélectionner dans le monde entier pour nos clients les meilleurs moyens de résoudre les problèmes techniques qui se posent à eux, c'est déjà devenu presque un hobby pour les ingénieurs de Leitgeb! Voici, par exemple, un des principaux produits de la société Transduktor Winding AB:



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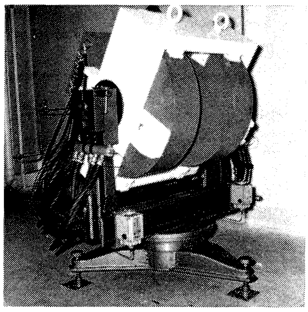

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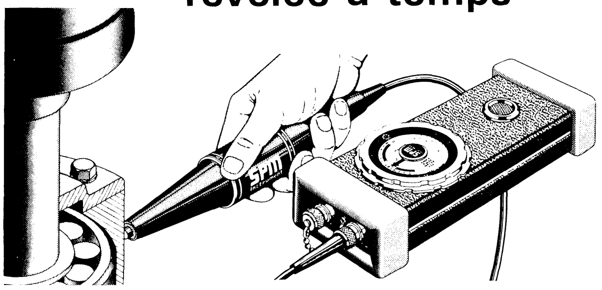

**Le contrôle des roulements avec la méthode SPM est simple, fiable et a fait ses preuves mondialement**

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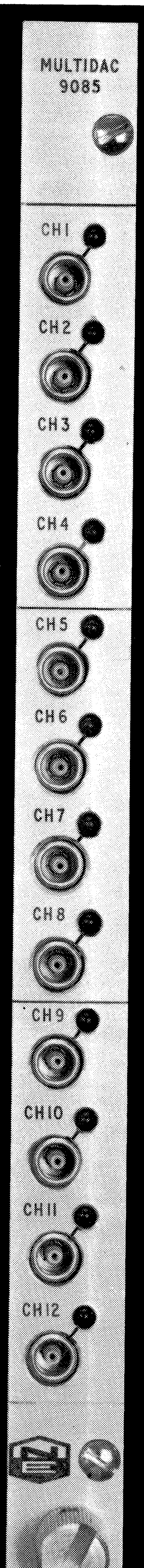
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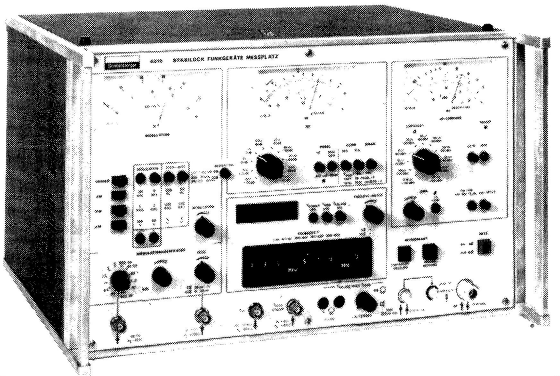

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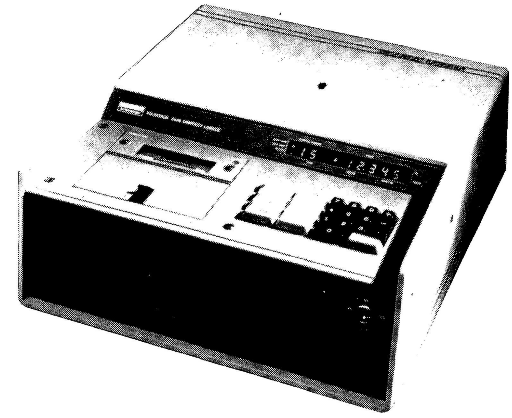

### *Deux voltmètres inhabituels avec traitement «on line» des valeurs mesurées*

De nouveaux horizons s'ouvrent grâce aux nouveaux voltmètres a microprocesseur modèles 7055 et 7065. Outre les fonctions voltmètres-ohmmètres, précises et rapides, ces appareils permettent le traitement «on line» de 8 programmes et 16 présentations des résultats

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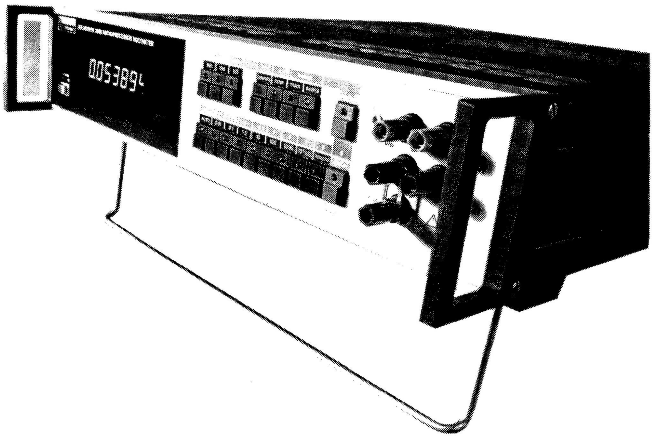

Pour en connaître davantage sur ces appareils européens, demandez-nous une démonstration ou l'envoi d'une documentation détaillée.

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# Bicron spans the equipment spectrum
# •Compton Suppression
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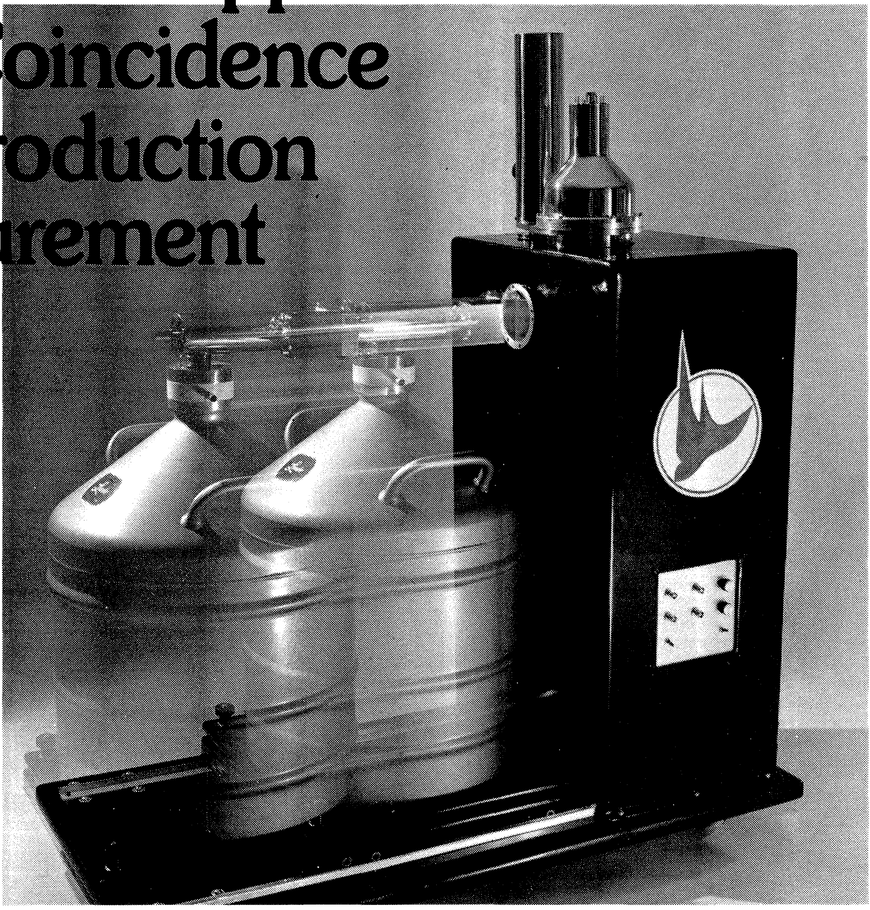
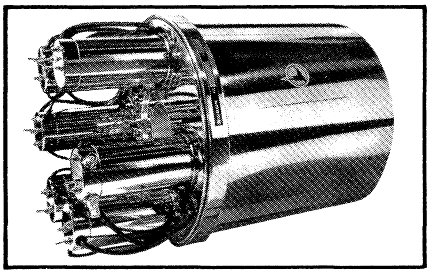


Bicron Model CS-1 Compton Suppressor.

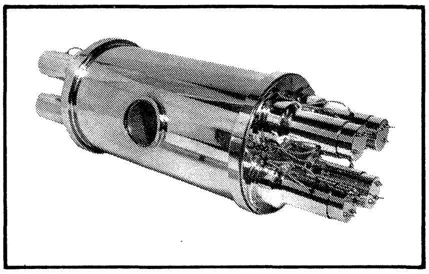
Bicron has addressed itself to the problem of enhancing the sensitivity of Ge(Li) spectrometers by developing NaI(Tl) crystal guard detectors to block Compton scattered events out of the spectrum. This equipment is now available in commercial form ready-to-use, or in major component form for those who wish to "customize" their own systems.

Enclosing of the spectrometer detector within the Bicron NaI(Tl) guard shield, discriminates Compton-related events at various energy levels, and subtracts these spurious events from spectra presented on the pulse height analyzer. Computer calculated efficiencies show that over 94% of all scattered gamma rays escaping the Ge(Li) detector are captured by guard crystals for sample emitted gamma rays up to 2 Mev. Efficiency is even higher at lower energy levels.

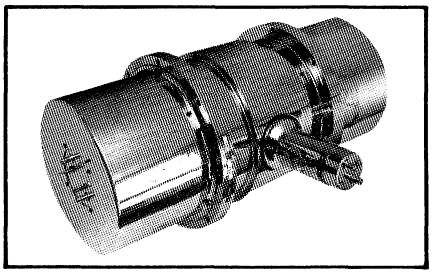
Peak-to-Compton ratio, and final sensitivity of the Ge(Li) spectrometer, is largely dependent on the characteristics and mounting of the detector. In a "worst case" configuration with a heavy 1.5mm thick dead layer, the ratio was approximately 150:1. With a properly specified detector, peak-to-Compton ratios of several hundred-to-one should be attainable. Check your local Bicron representative for full details, or write to Bicron direct.



*Bicron Model 10HW 10 (10″ dia by 10″ long NaI(Tl) crystal) with 3″ dia center well. PHA resolution 10.2% for Cs$^{137}$.*



*Bicron Model 9HW5 (two 9″ dia by 5″ thick NaI(Tl) crystals coupled to two optically separated 9″ dia by 4″ thick pure NaI crystals). Composite resolution, summing all 8 PM tubes, 7.9% for Cs$^{137}$.*



*Bicron Model 9HSW9-X. 9″ dia by 9″ long NaI(Tl) crystals with 3″ ID through center well. Crystal is split in center to form two 9″ dia by 4½″ long optically isolated detectors. Assembly pulse height resolution 7.4% for Cs$^{137}$.*

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