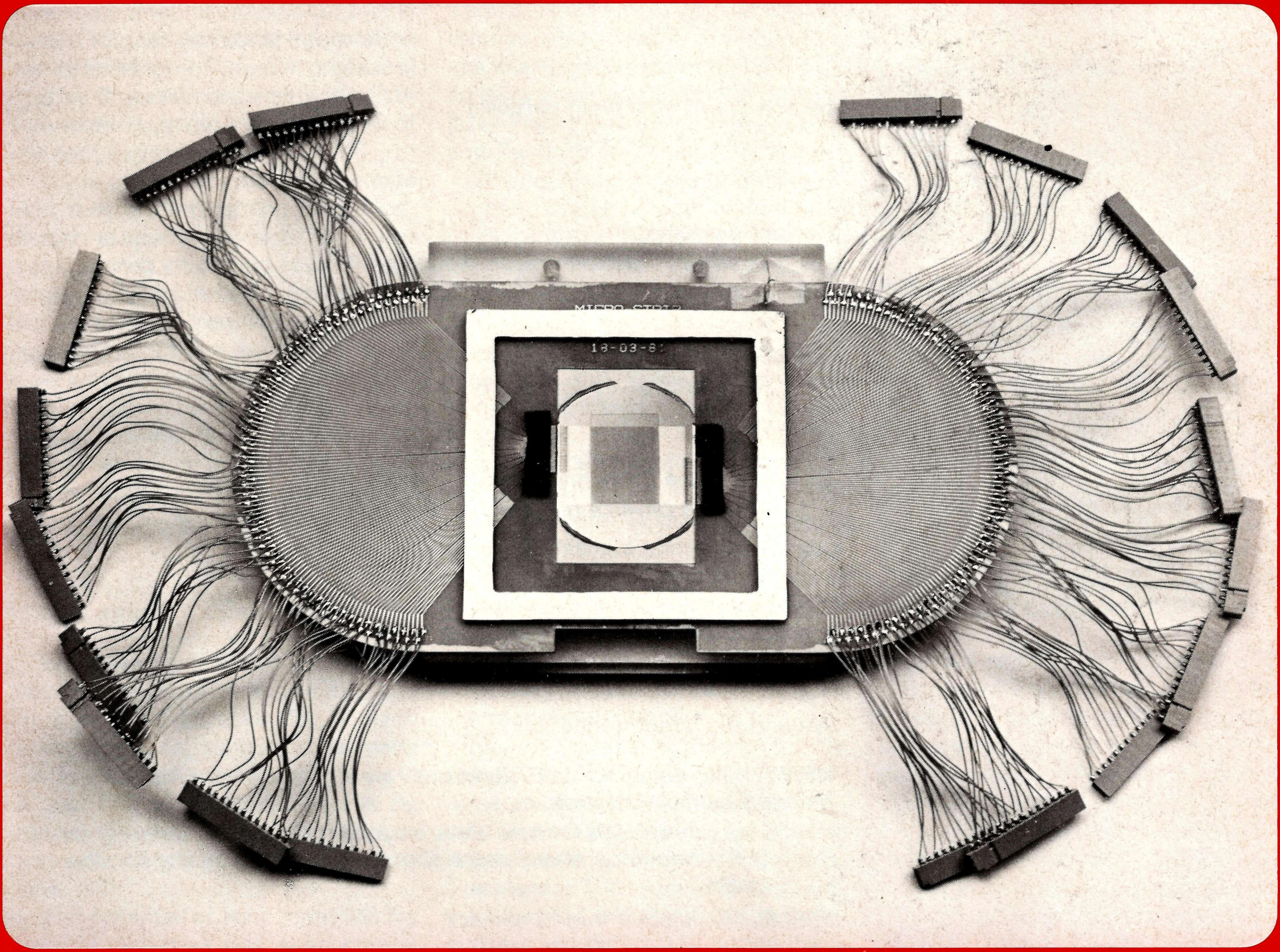
CERN COURIER



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Editors: Brian Southworth, Gordon Fraser, Henri-Luc Felder (French edition) / Advertisements: Micheline Falciola / Advisory Panel: M. Jacob (Chairman), U. Amaldi, K. Hübner, E. Lillestøl

VOLUME 22 Nº 2

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Around the Laboratories

Cover photograph: The elegant array of the semiconductor detector which has recently given good results at CERN. See page 47 for a round-up of this and other recent developments in techniques for detecting particles. (Photo CERN 514.11.81)

Laboratory correspondents:
Argonne National Laboratory, USA
W. R. Ditzler
Brookhaven National Laboratory, USA
N. V. Baggett
Cornell University, USA
N. Mistry
Daresbury Laboratory, UK
V. Suller
DESY Laboratory, Fed. Rep. of Germany
P. Waloschek
Fermi National Accelerator Laboratory, USA
R. A. Carrigan
KfK Karlsruhe, Fed. Rep. of Germany
M. Kuntze
GSI Darmstadt, Fed. Rep. of Germany
H. Prange
INFN, Italy
M. Gigliarelli Fiumi
Institute of High Energy Physics, Peking, China
Tu Tung-sheng
JINR Dubna, USSR
V. Sandukovsky
KEK National Laboratory, Japan
K. Kikuchi
Lawrence Berkeley Laboratory, USA
W. Carithers
Los Alamos National Laboratory, USA
O. B. van Dyck
Novosibirsk Institute, USSR
V. Balakin
Orsay Laboratory, France
C. Paulot
Rutherford Laboratory, UK
J. Litt
Saclay Laboratory, France
A. Zylberstejn
SIN Villigen, Switzerland
G. H. Eaton
Stanford Linear Accelerator Center, USA
L. Keller
TRIUMF Laboratory, Canada
M. K. Craddock

Copies are available on request from:
Federal Republic of Germany —
Frau G. V. Schlenther
DESY, Notkestr. 85, 2000 Hamburg 52
Italy —
INFN, Casella Postale 56
00044 Frascati
Roma
United Kingdom —
Elizabeth Marsh
Rutherford Laboratory, Chilton, Didcot
Oxfordshire OX11 0QX
USA/Canada —
Margaret Pearson
Fermilab, P. O. Box 500, Batavia
Illinois 60510
General distribution —
Monika Wilson
CERN, 1211 Geneva 23, Switzerland

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New ways of observing particles

There is a relentless search for new techniques for the detection of particles, pushed by the need to confront new experimental conditions, by the desire to gain additional information (or information of greater precision) and by financial constraints (particularly in the huge detection systems of modern experiments).

Some of them are new in the sense that they are attempting to use detector properties which have not been applied on a wide scale in high energy physics before (semiconductor detectors, Cherenkov ring imaging). Some of them are new in being new ways of exploiting detector properties known for a long time (Geiger cellular arrays, flash calorimeters). All of them show that, as the physics needs evolve, there is no shortage of ideas as to how to respond to them.

Silicon strips

Semiconductor materials, such as silicon, are sensitive to the passage of a charged particle. For a given energy deposit, ten times as many electrons are released in silicon as in a gas. Thus electric signals can be detected in crystals of semiconductors indicating the presence of a particle.

The potential of such materials for particle detectors has been known for a long time. The difficulty has been, and remains, the construction of suitable arrays of tiny silicon detectors and the method of drawing off the signals from such small intricate arrays.

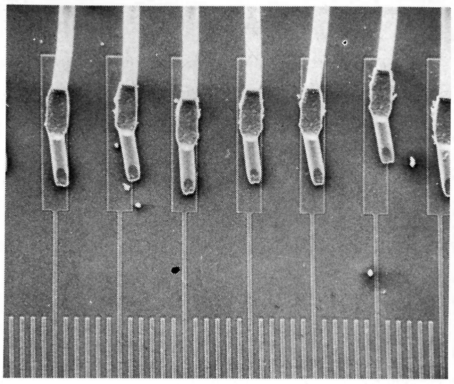
Much progress has been made recently and interest in the technique is growing (as witnessed by the 'Semiconductor Detector Workshop' held at Fermilab last October and reported in our January issue, page 11). Many groups throughout the world, including several at CERN, are working on silicon microstrip detectors.

High accuracies have recently been achieved with high resolution silicon counters being developed for use in an experiment at the SPS by a collaboration of CERN and Munich (Max Planck Institut für Physik, MPI, and Technische Universität, TUM).

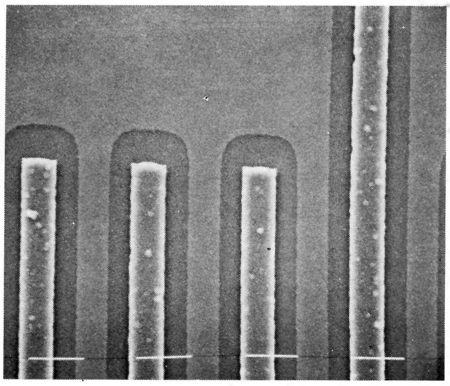
The counters are made of high resistivity doped silicon wafers 300 microns thick. Their sensitive area is 24 mm by 36 mm. Using LSI (Large Scale Integration) techniques (thermal growth of silicon dioxide, high resolution photolithography, ion implantation and aluminium evaporation), 1200 diode strips of 36 mm length with a pitch of 20 microns have been fabricated onto the silicon crystal. Aluminium wire of 25 microns diameter is used to connect these diodes to a printed circuit card using the technique of ultrasonic bonding. To identify which strip has been traversed, capacitative charge division is used and it is then not necessary to connect every diode to the readout electronics.

Several problems had to be solved. Although submicron structures are built industrially, it is difficult to produce devices of several square centimetres without defects. The team at TUM succeeded in building counters with 1200 diode strips without any defect and on the basis of this experience, European industry has been approached to build such counters. Special technology had to be developed to achieve low 'dark current' (the inherent electronic noise in the semiconductor) so that the counters can be used at room temperature without loss of resolution due to noise. Last but not least, a mechanical mounting had to be built, to permit the relative positioning of the counters to a few microns.

Photographs taken with an electron microscope at CERN showing details of the intricate connections which have to be made on the silicon wafer in the semiconductor detector. 1 — wires, about 120 microns apart, are bonded onto the wafer. 2 — an enlarged view of the strip pattern on the wafer. The strips are 20 microns apart.



1.



2.

The electronic chain for amplifying and recording the signals has to be sensitive to a fraction of the 30 000 electron-hole pairs produced by high energy particles traversing the silicon crystal. Such a chain has been developed by CERN and MPI—Munich and a background noise as low as 600 electrons has been achieved in the experimental setup.

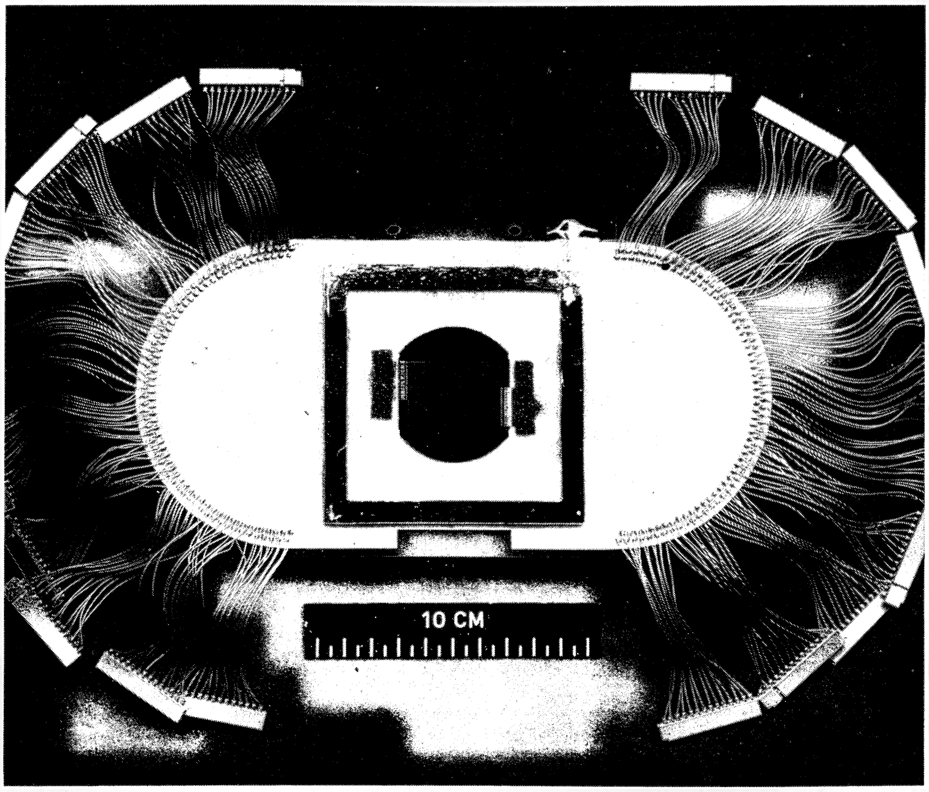
Three counters, equipped with 600 channels of electronics, were installed in front of a spectrometer at the SPS (the NA11 experiment) and tested in November. An efficiency in excess of 99.8 per cent, a spatial resolution of 10 microns and a two-particle separation of approximately 100 microns were achieved. The counters worked satisfactorily for beam intensities of several million particles per SPS spill. Test data were taken with 175 GeV negative pions incident on a copper target using the silicon counters and the NA11 spectrometer. Multiprong interactions could be reconstructed.

A complete setup of six counters was installed during the latest SPS shutdown. The group now plans to integrate simple data processing electronics directly onto such a detector and to explore ways of making large area counters, on the basis of what it is already possible to produce in industry where 10 cm crystals are routinely processed.

The collaboration hopes to use these newly developed detectors as a powerful tool in the study of the production and decay of heavy flavour (charm and beauty) particles. Miniaturization of forward spectrometers for conventional fixed target physics and high resolution vertex detectors around colliding beams are tempting goals for the future.

The semiconductor detector, with fan-out card and connections, which has recently given good results at CERN.

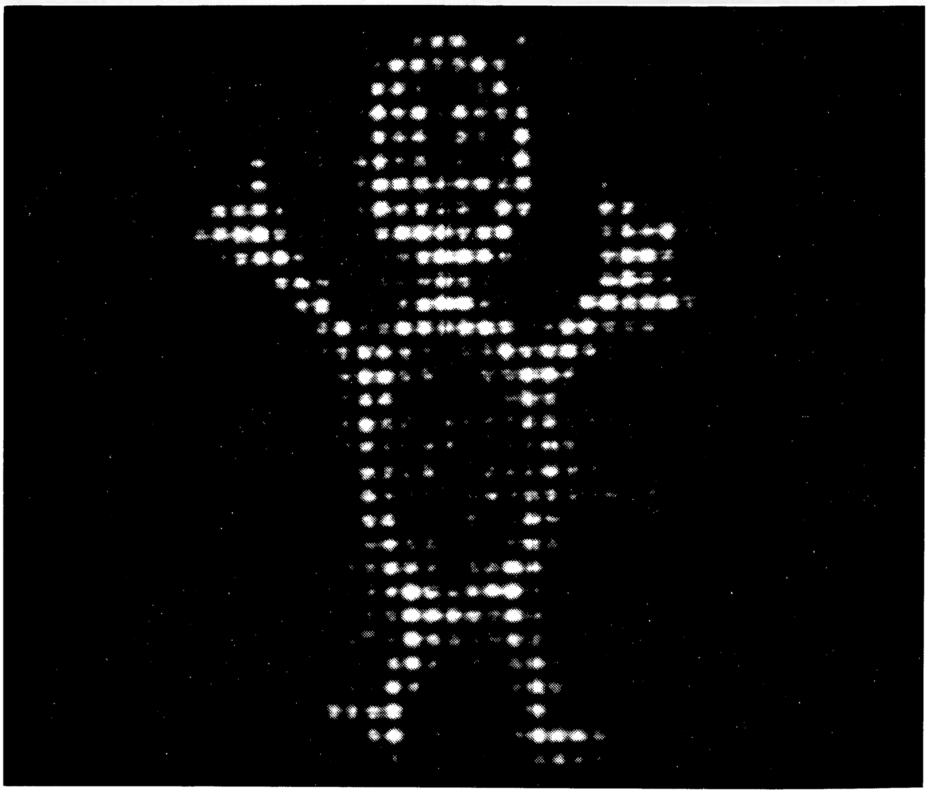
(Photo CERN 516.11.81)



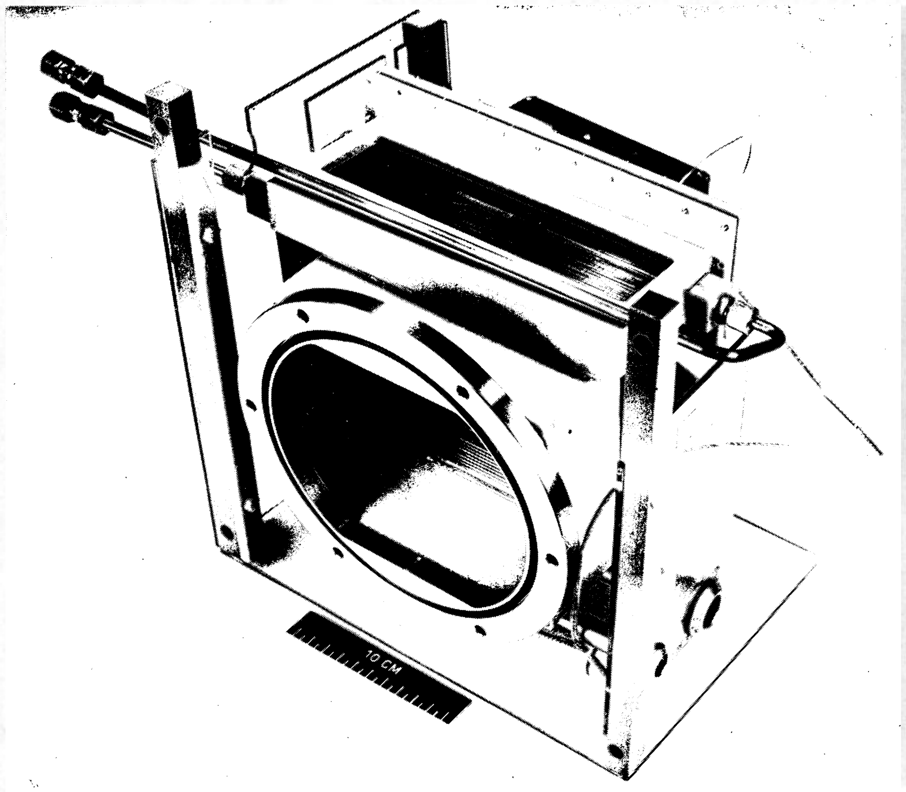
Back to Geigers

The Geiger-Müller counter was one of the first particle detectors. It recorded the passage of a charged particle via the ionization of gas around an anode wire. The voltage was high enough to provoke considerable amplification and, since the resulting signal was strong, the detector was appropriate to the Stone Age of electronics before high quality amplifiers were readily available. The main disadvantage was a long 'dead-time' following a discharge before the counter was ready to record the passage of another particle.

Increasing knowledge of the mechanisms of gas discharges and ability to construct counter structures more easily now make it possible to use the advantage of the Geiger counter while minimizing its disadvantage. The tricks are to select an



An amusing demonstration of the abilities of the Geiger cell array. The image was 'drawn' on the array with a point radioactive source 'pencil' and the picture transmitted to a TV screen.



The photon detector prototype which has been used in developing the Cherenkov ring imaging technique. Inside the quartz window can be seen the wires which define the drift field, and on top are the wires which give the multiwire proportional chamber signals.

(Photo CERN 164.12.81)

appropriate gas (helium instead of argon to speed the amplification process by increasing ion mobility) and to reduce the distances travelled in the counter (by subdividing in small cells). In this way dead-times are restricted to individual cells.

Some work on cellular arrays of Geiger counters have been under way at CERN (E. Gygi and Fritz Schneider) with the aim of producing a fine-grained detector at a reasonable cost. So far it has proved possible to cope with rates as high as 10^4 particles per cm^2 per s in cells with 1 cm spacing. Using helium plus a little ethyl alcohol the recovery time can be as low as 80 microseconds. Signals remain high enough to dispense with amplifiers so that the cost per cell is about one Swiss franc.

The test array is constructed of stainless steel anode wires 50 microns in diameter spaced 1 cm apart. Earthed metal strips are interspersed between the wires. Perpendicular to the direction of the wires, insulating material, 2 mm thick, completes the division of the array into 1 cm^2 cells. There are 1 cm^2 cathode pads positioned above and below, from which signals are read by cheap C-MOS shift registers. Dead areas exist because of the spacers and their effects so that overall efficiency is about 70 per cent for a beam incident perpendicular to the anode planes.

The tests have been encouraging enough to make it worth pursuing the technique for possible use in a shower calorimeter.

Running rings round particles

The Cherenkov effect has been known since the 1930s and Cherenkov counters have been a standard tool for particle identification for many years. They use the phenomenon of the emission of light by charged particles passing through appropriate media. The angle of emission of this light is directly related to the particle velocity and, knowing the particle's momentum by measuring its curvature in a magnetic field, the Cherenkov velocity measurement gives the particle mass and thus its identity.

The technique has been used in several ways, the most popular for many years being the threshold Cherenkov counter. By tuning the medium through which the particle passes (for example, by changing gas pressure) the presence or absence of Cherenkov light (detected by photomultipliers) indicates whether the velocity of the particle exceeds a particular threshold value. A more refined use of the technique is to measure the angle of the light emission with respect to the particle direction — the precise velocity can then be determined. This can be done fairly readily when dealing with a parallel monochromatic beam (for example, the use of the CEDAR detectors in beamlines at the SPS). A more versatile application would be possible if the Cherenkov ring of light could be detected and measured irrespective of its size and position.

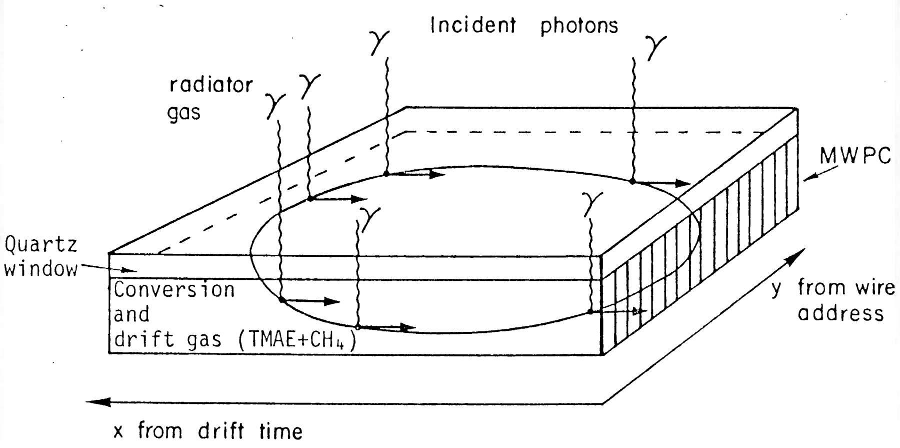
This task is now being pursued by several groups, prompted particularly by a paper of Tom Ypsilantis and J. Séguinot in 1977 on 'Ring Imaging Cherenkov' counters (sometimes abbreviated to RICH counters). They benefit from new ways of detecting the Cherenkov photons.

We have previously reported the work led by F. Sauli at CERN (see November 1980 issue, page 341). The recent news from this collaboration (Saclay / CERN / Fermilab / Stony Brook) is that one of their detectors has been successfully operated in a test beam at Fermilab. They succeeded in separating pions, kaons and antiprotons in a 200 GeV beam. As mentioned in our earlier article, they used triethylamine (TEA) as the vapour to convert the Cherenkov photons and a multi-step avalanche chamber to measure the ring.

Another tack has been followed by a CERN / Collège de France / Ecole Polytechnique / Uppsala group. They have concentrated during the past year on the use of tetrakis-dimethylaminoethylene (TMAE) as the vapour in which photons would convert and on the use of the time projection chamber (TPC) technique, as pursued at Berkeley, to measure the ring. Tests in a beam at the CERN Proton Synchrotron have given very encouraging results.

Photons enter the vapour through a quartz window. The TMAE absorbs them over a path length of about 15 mm and (with about 50 per cent probability) produces a single electron-ion pair per photon. The electrons drift in an electric field (paral-

A drawing of the photon detector indicating the roles played by the components (see photograph on previous page).

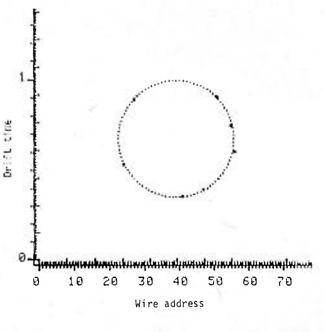


lel to the quartz window) up to a multiwire proportional chamber. The two coordinates of the incoming photon are thus located via the wire receiving the electron and via the drift time before reaching the wire.

The work is aimed at producing detectors appropriate for the LEP experimental environment able to identify simultaneously and over a large solid angle many charged particles with energies in the 1 GeV region and a few 'leading' particles with energies of up to some tens of GeV. The demonstration that TMAE is an appropriate photoionizing agent helps because it has a lower threshold for photon conversion than TEA (5.4 eV rather than 7.5 eV). This allows organic gases and freons to be used as radiator and more practical materials (like quartz) can be used for the windows rather than substances (like monocrystalline calcium fluoride) which are transparent in the far ultraviolet. The demonstration that the TPC technique is appropriate for the ring imaging makes it feasible to measure several rings simultaneously, even when they are overlapping.

It is now intended to produce an array of RICH counters to cope with a large solid angle to test the ability to detect several particles emerging from an interaction in a jet.

A ring image from tests with the photon detector.



Doing GUD

At the end of October a workshop entitled 'Physics and Astrophysics with a Multikiloton Modular Underground Track Detector' was held in Rome. Its aims were to bring together experts from different fields who had an interest in 'underground' physics (there were about 150 participants), to review the present situation, to compare alternative detection techniques and to present a preliminary project for a big modular detector being prepared by Italian physicists (particularly from Frascati, Milan, Rome and Turin). Usually known as GUD (Giant Underground track Detector), this project is one of the few underground experiments we have not yet described in the COURIER. It fits well in an article on detectors since it intends to use flash tubes in huge calorimeters.

Flash tubes as particle detectors were proposed in 1955 by Marcello Conversi (a leader of the GUD project) and A. Gozzini. The idea was to fill the gaps between parallel capacitor plates with stacks of glass tubes filled with neon at a pressure of about half an atmosphere. A particle passing through the array makes the tubes it traverses sensitive for about 1 ms, and a high voltage pulse applied to the plates, triggered by coincidence counters above and below, causes the sensitive tubes to flash. The track is then photographically recorded.

This technique was the precursor of the spark chamber, which won out, particularly since the spatial resolution of the flash tube detector is limited by the tube size. However they do have some advantages which make them interesting for underground experiments. Each tube is an independent detector, so that detection reliability should be high. They can record events with virtually any number of tracks and any track direction. They can now be read out digitally as well as optically by using the electric discharge which propagates via photoionization along the full length of a tube. They are also comparatively cheap.

The technique was used in the 1960s, particularly in cosmic ray experiments, and about ten years ago Conversi proposed the substitution of plastic tubes for the neon variety. Recently magnetostrictive readout of inductive pick-up probes has been developed at Fermilab and successfully used in a neutrino experiment.

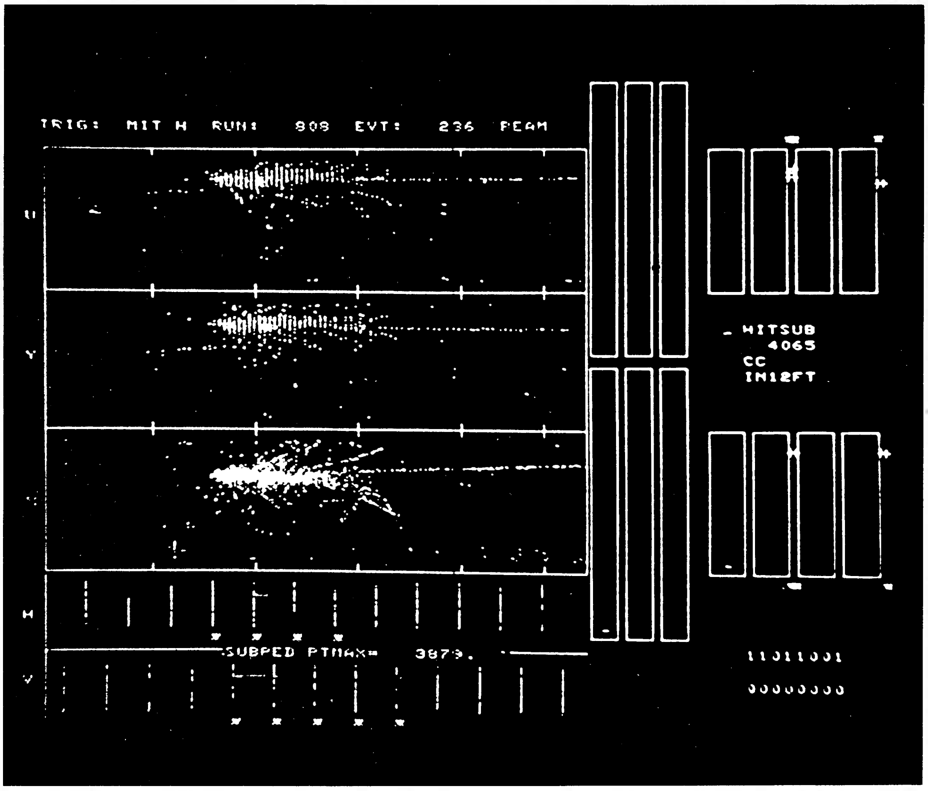
The GUD project aims to make use of a huge hall (up to 100 m long by 25 m wide and 20 m high) deep under the Gran Sasso (about 4500 m water-equivalent), situated about 100 miles from Rome. The aim is to build a detector of at least 10 000 tons.

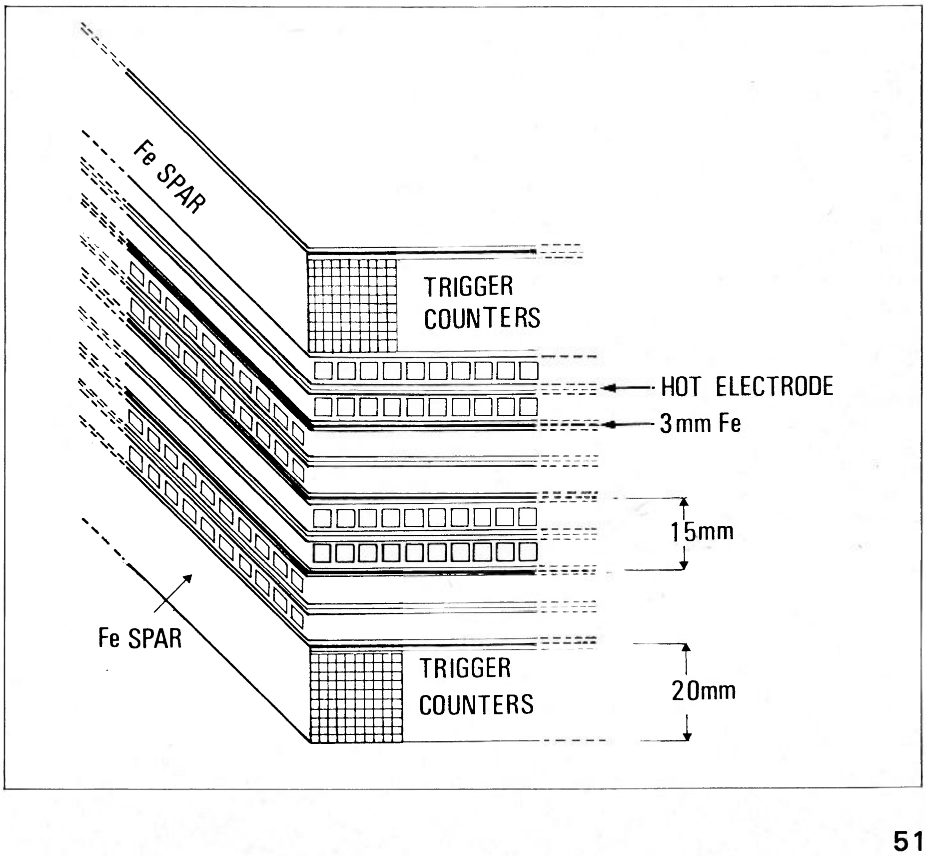
A preliminary proposal for the structure of the detector has eight flash chamber calorimeter modules totalling more than 12 000 tons in an 18 m cube. There would be some ten million sensitive cells of 4 mm^2 cross-section triggered by planes of fast resistive plate counters and interleaved with 3 mm-thick metal plates. The structure is modular so that its construction could progress in phases. The complete detector would be like a huge coarse-resolution triggerable bubble chamber.

A wide variety of physics questions can be confronted and the detector's size would increase the chances of picking up rare events. According to present predictions, hundreds of proton decays could be recorded. Information could be gathered on neutrino oscillations, gravitational waves and rare cosmic ray events. It could be a very big window through which our Universe could be viewed.

Above, an example of the signals from a 350 ton flash calorimeter installed at Fermilab showing a 110 GeV neutrino event with three stereo views involving 5538 flash cells. This technique is envisaged for the GUD underground experiment detector.

Below, a drawing of the proposed structure of a 9 m³ module of the GUD underground detector. The small squares represent the banks of flash tubes.





Collider workshop

The promise of initial results after the start of operations at CERN's SPS proton-antiproton collider and the prospects for high energy hadron collisions at Fermilab (Tevatron) and Brookhaven (ISABELLE) provided a timely impetus for the recent 'Topical Workshop on Forward Collider Physics', held at Madison, Wisconsin, from 10–12 December. It became the second such workshop to be held, the first having been in 1979 at the Collège de France, Paris.

The 100 or so participants had the chance to hear preliminary results from the UA1, UA4 and UA5 experiments at the CERN SPS collider (see January/February issue, page 3), together with other new data, including that from proton-antiproton runs at the CERN Intersecting Storage Rings.

As clear from the title of the Workshop, interest centred on interesting physics from collisions whose products are confined in the 'forward' angular region — within 30° in the centre-of-mass. Nowadays, angle has been replaced by rapidity as a convenient variable, and this region corresponds to ±5 rapidity units at the SPS and ±6 at the Tevatron, excluding a small central zone.

If they exist, long range correlations (similar phenomena seen under quite different kinematical conditions) should be observable in this angular range. Other expected processes include production of weak bosons (the W and Z), heavy flavour(s), and maybe Higgs particles. However the copious production of pions under these conditions makes for high backgrounds when trying to pick out electrons and muons, and sophisticated detection techniques are needed.

The UA1 and UA5 results were presented by A. Kernan and R. Meinke respectively. The data as presented show three striking features. The distributions of charged particles follow KNO (Koba/Nielsen/Olesen) scaling, even at relatively high multiplicities. In contrast to the ISR data, some evidence for long range correlations is seen. The average transverse momentum per particle increases to 500 MeV.

The UA1 experiment was able to report relatively copious production of events with high transverse energy. Previous experiments, notably the NA5 study at the CERN SPS (see May 1981 issue, page 155), found that such processes are relatively abundant. Klaus Pretzl reviewed the NA5 study with a calorimeter trigger. Events have been seen with transverse energy of up to 18 GeV out of 22 GeV available in the centre-of-mass, over a rapidity range of ±0.8. Jet production is certainly not evident.

A related question is the effect of fluctuations in the high multiplicity tail of the particle distributions. This might be the reason why the events with large transverse energy appear to contain many particles with low energy. These fluctuations can produce peculiar neutral to charged pion ratios and angular distributions. This might mean that particle jets are there but are hard to find.

Related theoretical progress was reported by Geoff Fox, who has been busy (with Robert Kelly) calculating QCD effects in hadron-hadron collisions, including gluon 'bremsstrahlung'. He finds that if the products of high transverse momentum collisions are selected using a total transverse energy trigger, rather than having a planar jet structure, they are instead isotropic, with many gluons being radiated. This may be an explanation for the non-appearance of jets under NA5 conditions. It could mean that clean separation of jets from background is difficult. Further data from the proton-antiproton collider experiments will shed more light on this question.

Cosmic ray experiments have events in and beyond the energy range attainable in the colliders. However this was the first time that laboratory and cosmic ray data could be explicitly compared. Two cosmic ray findings are now confirmed — the rapidity plateau now extends to ±4, and average transverse momentum per particle rises to 500 MeV. Peculiar events, such as the much-publicized Centauro, have not yet been seen at collider experiments, but could arise as a result of large high multiplicity fluctuations.

New cosmic ray data from the 'Fly's Eye' detector now operational in Utah were presented by G. Cassiday. This uses an arrangement of mirrors and photomultipliers to observe the radiation produced by extensive air showers. It allows the interaction point in the atmosphere to be located and thus determines the absorption length of the proton-nucleus collision. The aim is to measure total proton-nucleon reaction rates down to millibarn levels at up to 100 TeV in the centre-of-mass. Early results suggest that the total reaction rate is still rising, even at these energies.

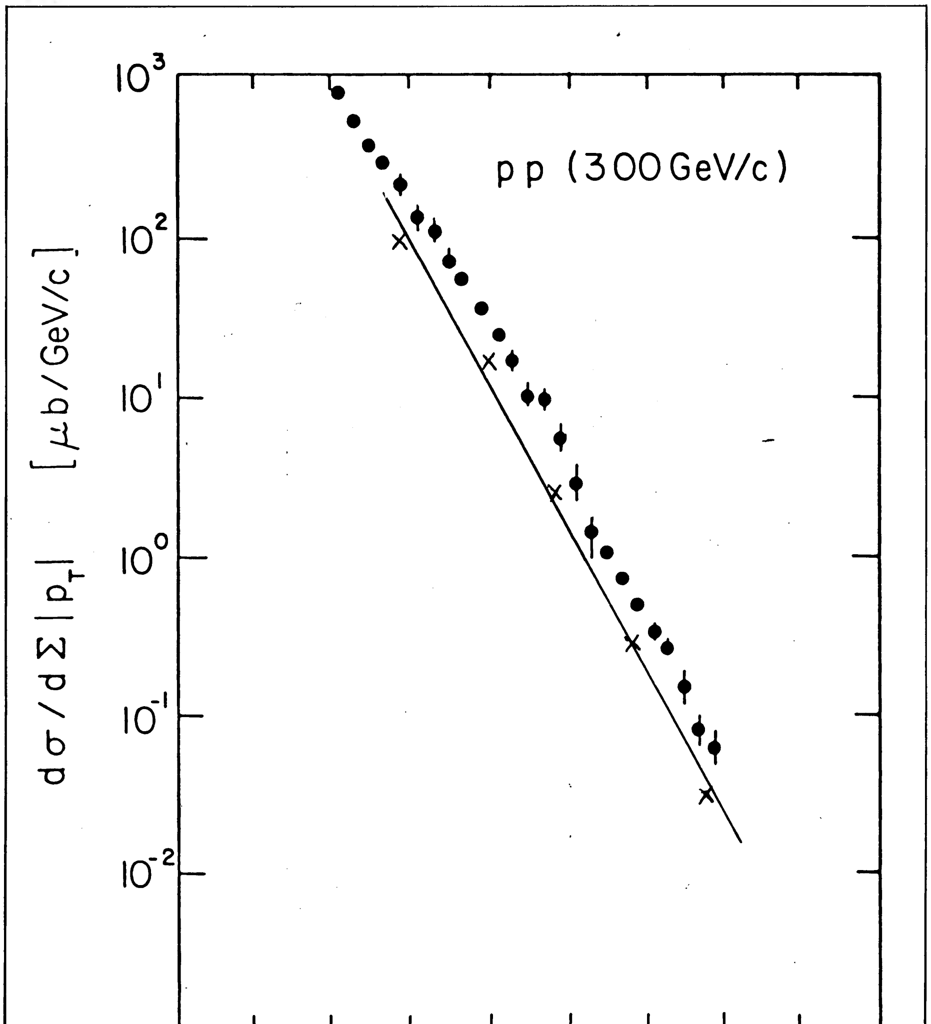
Less spectacular but still important are the antiproton results emerging from the CERN ISR. Data were presented by P. Grannis, M. Block and L. Camilleri.

With hadron colliders promising new discoveries, theorists were able to provide substantial input. One field ripe for further study is heavy flavour production. Stan Brodsky presented ideas of intrinsic flavours in the nucleon which result in heavy flavour production at large energy transfers. This could explain the relatively high charm production levels observed at the ISR, but production of heavier flavours (beauty and top) would provide an exacting test. (These ideas have to be reconciled with recent data from Fermilab and from the European Muon Collaboration's study of charm production by high energy muon beams at the SPS.) While there is some evidence for beauty production at the ISR (presented at the meeting by D. Dibitonto), discovery of top flavour production at the SPS collider would help complete the picture. Also drawing on the high charm production levels seen at the ISR, M. Jacob and R. Horgan have predicted that forward-produced top particles should indeed show up at high energy proton-antiproton colliders. At the Madison meeting, R. Odorico presented other arguments to explain the observed charm production levels. Further studies at colliders will certainly be useful in solving this problem.

At Madison, latest calculations on the production of weak bosons, Higgs particles, etc., were presented. Hopefully at future such meetings theorists will be able to fit the observed data.

These meetings are now a regular feature of the particle physics scene, the next one being scheduled for 10–12 June in Rome.

(We are grateful to D. Cline for providing us with the material from which this report was compiled.)



Data (upper points) from the full wide-angle calorimeter of the NA5 experiment at CERN using a large transverse energy trigger. The relatively high reaction rates observed are difficult to reconcile with production of well-defined particle jets. Initial new calculations (by Geoffrey Fox and Robert Kelly) including gluon bremsstrahlung appear to provide a promising fit to the data at these transverse energies.

Fastbus timetable

Now being groomed in Laboratories in Europe and the USA is Fastbus, the new physics data acquisition system designed to cater for the developing requirements and new technologies of the next generation of high energy physics experiments. But while this painstaking development work for the production version of the system continues, a pioneer Fastbus application in an actual experiment is already in operation at Brookhaven (see October 1980 issue, page 301).

The ideas behind Fastbus first appeared in public in 1977, when the Nuclear Instrumentation Modules (NIM) Advanced System Study Group produced a report outlining future requirements for a physics data acquisition system. The NIM Fast System Design Group set about compiling a detailed Fastbus specification, while in parallel ESONE (European Standards in Nuclear Electronics) set up its Advanced System Study Group.

An initial Fastbus specification appeared in July 1980, and it is hoped that a further (hopefully definitive) version will soon be endorsed by the appropriate international standards committees.

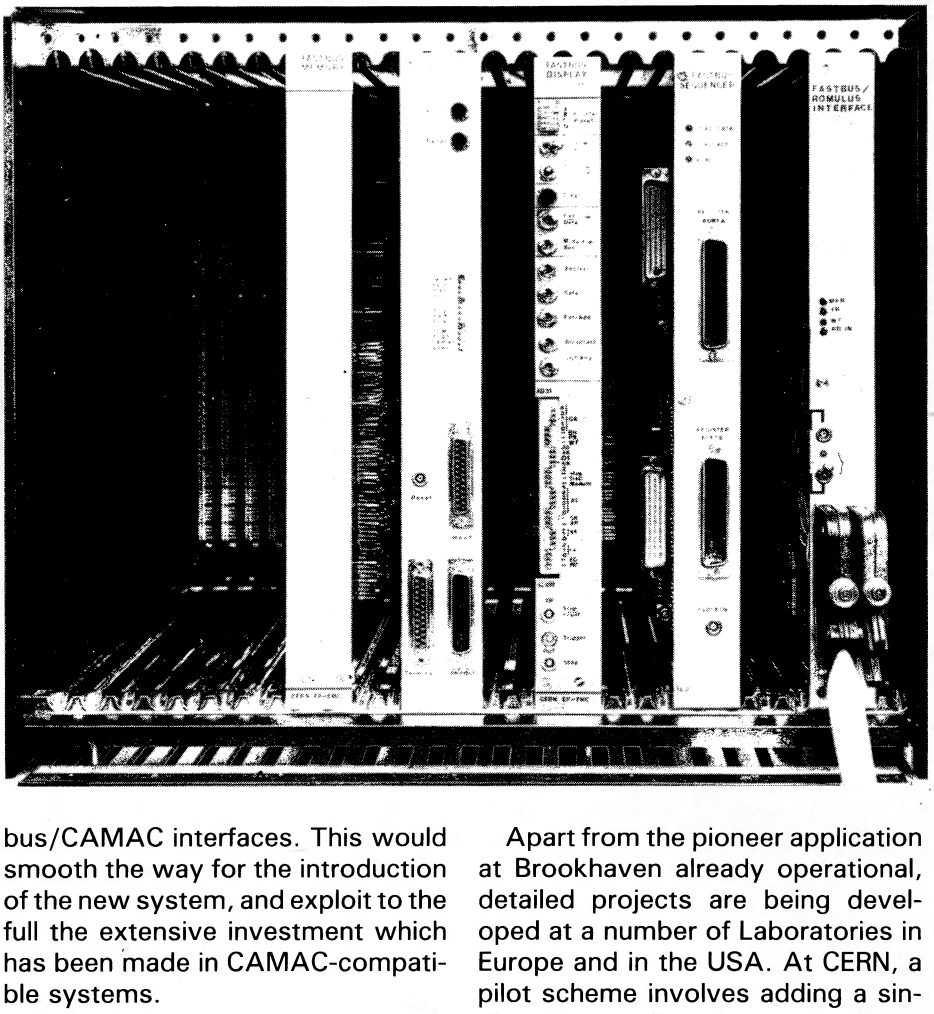
The system is designed to handle large quantities of data and/or high data transfer speeds. It provides sophisticated multiprocessing capabilities and a large communications bandwidth handling a considerable amount of data in parallel. It is a natural means of complementing hardwired electronics to provide fast trigger logic. Commercial electronics firms are showing an interest and already several US companies are becoming involved.

Fastbus is primarily intended to replace CAMAC in the more demanding areas of data acquisition. However a lot of initial effort at CERN is going into the development of Fastbus/CAMAC interfaces. This would smooth the way for the introduction of the new system, and exploit to the full the extensive investment which has been made in CAMAC-compatible systems.

Basic Fastbus elements ('segments') can be packaged, CAMAC-style, in crates, and as cable segments to connect several crates together. On an individual segment, multiple sources of command are possible. Processing can take place in parallel on independent segments, but segment to segment hook-ups can be arranged as and when required. Asynchronous 'handshaked' (acknowledged) communications protocols cater for different operational speeds, and a synchronous mode is available for high speed block data transfers between matched devices. Special facilities can take care of large sparsely-filled data registers.

Apart from the pioneer application at Brookhaven already operational, detailed projects are being developed at a number of Laboratories in Europe and in the USA. At CERN, a pilot scheme involves adding a single-crate small-angle trigger to the existing CAMAC electronics in the European Muon Collaboration's experiment in the North Area of the SPS. This work involves close cooperation with the Gustaf Werner Institute, Uppsala.

The processor contains ten Fastbus modules of different types, controlled by a Fastbus to CAMAC interface. Scintillation counter information is read out event by event using a sparse data scan controller and transferred to the experiment's on-line data acquisition computer. The system is soon scheduled to come into routine operation. With an eye to the future, a larger system is also being produced.



Prototype modules for CERN's Fastbus pilot project.

(Photo CERN 1.2.82)

Diversity at the Brookhaven AGS

The physics programme at the Brookhaven AGS is thriving and has been running at the rate of 25 weeks per year for the last two years. It is expected to run for a comparable period in the present fiscal year. The machine runs in two modes — a slow extracted beam that serves counter experiments through four major spigots, and a fast extracted beam serving the neutrino area.

A big attraction is the accessibility of the machine — a group with a good physics idea can get an experiment under way relatively quickly. Variety has also characterized physics at the AGS for many years. Together with some highlights of the past two seasons, it is also timely to give a glimpse of what is to come.

A large neutrino experiment (Brookhaven / Brown / Pennsylvania / KEK / Osaka / Stony Brook /INS-Tokyo) is using a 180-ton completely active detector with excellent spatial and energy resolution to measure the neutrino and antineutrino elastic scattering on electrons and protons. Among the results will be a precise measurement of the electroweak mixing parameter (the 'Weinberg angle'). Data-taking started last year and is expected to continue into 1983. The neutrino-electron elastic scattering rate of three events per day should yield a clean sample of 150 events by the end of the run in this fiscal year.

The fact that the AGS can run at lower energies and still maintain good proton fluxes renders it particularly attractive for neutrino oscillation studies. Two collaborations have proposed major experiments to search for neutrino oscillations with high sensitivity, each using a two-detector configuration. By studying the dependence of the interaction rates of muon and electron neutrinos with distance and energy, limits on the masses and mixing angles of the various known types of neutrino can be inferred. These experiments promise to be among the most sensitive yet proposed at any accelerator.

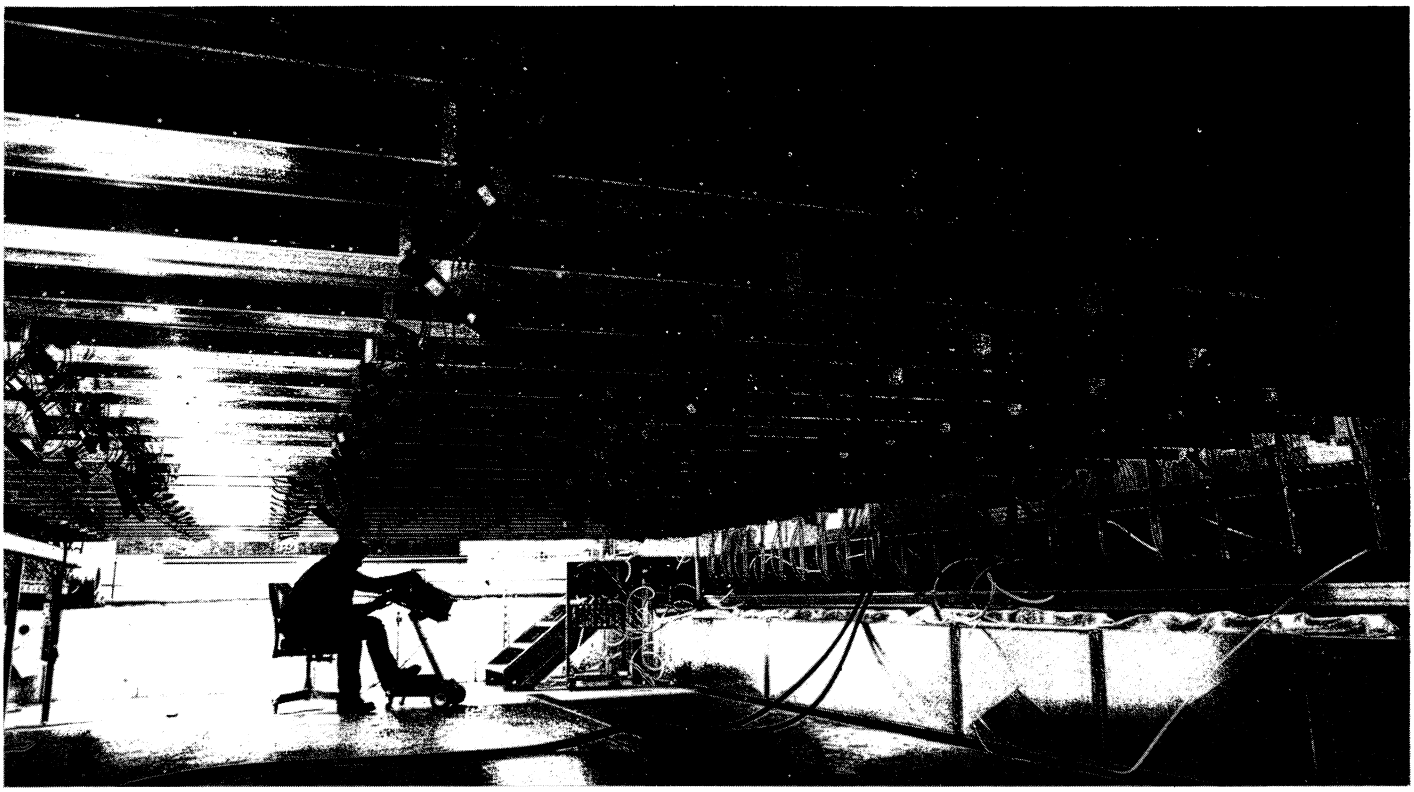
The Brookhaven AGS, currently the scene of a thriving physics programme.

Charge-parity (CP) or time reversal violation was discovered at the AGS in 1963 in the decay of neutral kaons. Since then, no other CP violating system has been found. If the phenomenon is also present in other kaon decays, it should be seen in the component of the muon polarization perpendicular to the decay plane. A Yale / Brookhaven group set out to measure this polarization precisely. The positive kaon decays were detected by measuring the gammas from the produced neutral pion and the energy and direction of the positron from the subsequent decay of the produced muon. The muon polarization was measured in two directions, one being the CP-allowed component perpendicular to the muon momentum and lying in the decay plane. The experiment used a new Fastbus data acquisition system built at Brookhaven, which can handle data at speeds an order of magnitude faster than conventional CAMAC. This system looks like the pioneer of a new standard for high energy physics in the future (see page 54). The data were fully analysed on-line, so that a final answer was available soon after the run was over. 2×10^7 decays were analysed and the measured CP violating polarization was consistent with zero. The same group is tooling up for new and precise measurements of neutral kaon decays. While the CP conserving decays have been extensively studied, CP violating decays are less well measured. These new results should help shed some light on various theories of CP violation.

A Massachusetts / Brookhaven / Minnesota / Michigan group has car-

Setting up the big new neutrino experiment at the Brookhaven AGS, which is looking to make precise measurements of elastic neutrino scattering.

(Photos Brookhaven)



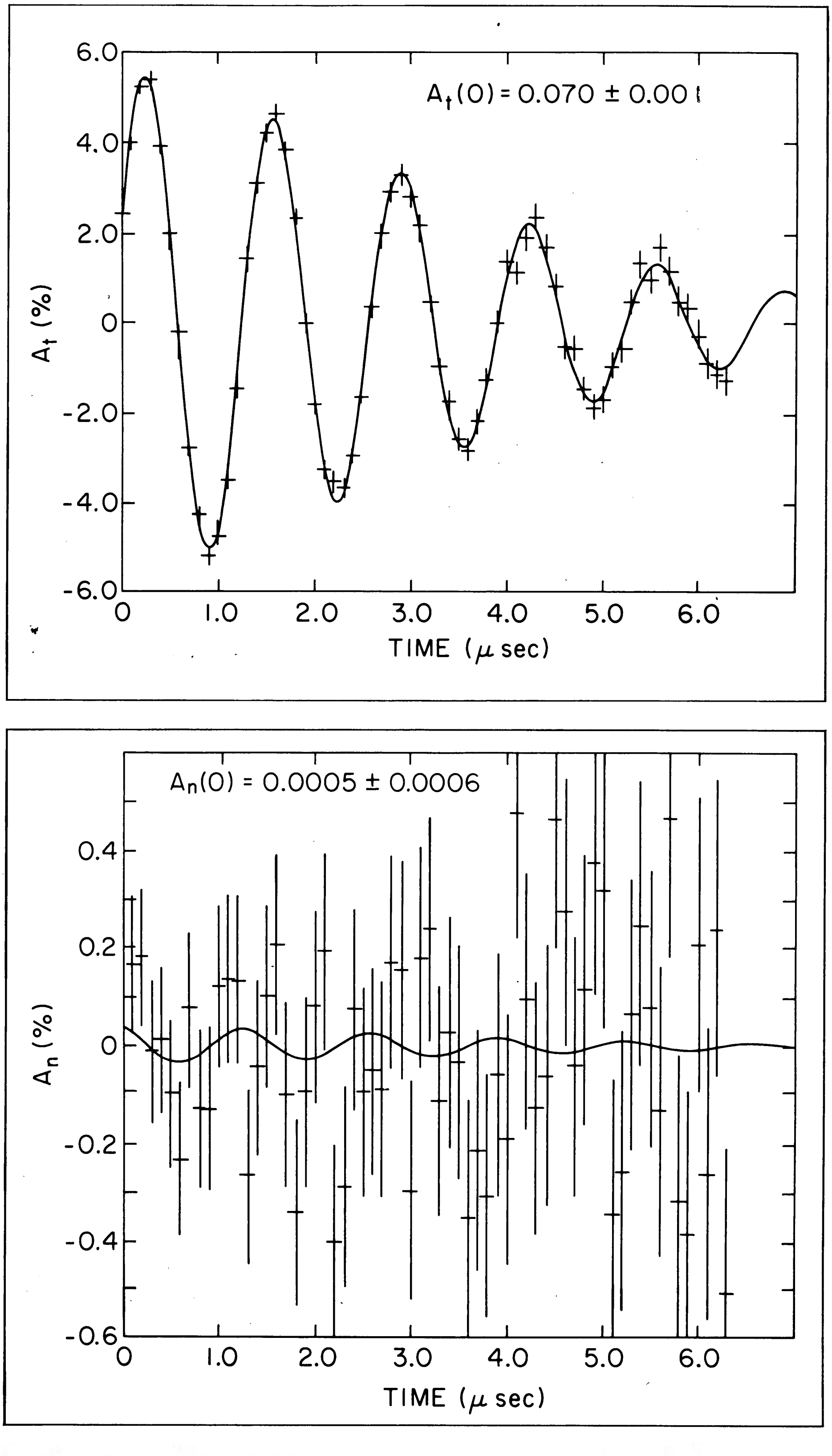
ried out two related experiments in the neutral hyperon beamline. The first measured the polarization of lambdas produced from hydrogen, deuterium and beryllium targets. The polarization was found to be similar in magnitude to that measured at Fermilab and at CERN ISR energies for the same kinematic region. Furthermore the polarization from hydrogen was comparable to that from beryllium, showing that this is not a nuclear phenomenon. By adding two lead-glass arrays to the same apparatus, the measurement of radiative neutral sigma—lambda decays became possible. The goal of the second experiment was two-fold: to measure the ratio of radiative to all decays, and simultaneously the neutral sigma polarization. This result should give a handle on the polarization of prompt lambdas. One should keep in mind that a high ratio coupled with the low analysing power of the neutral sigma could dilute the apparent lambda polarization. Data analysis is proceeding quite smoothly with a very clean neutral sigma signal seen above background.

Both quantum chromodynamics and constituent interchange model calculations will be checked by a Brookhaven / Minnesota / Southeastern Massachusetts collaboration in a new experiment to measure the cross-sections of exclusive two-body final state reactions at 90° in the centre-of-mass system in negative pion-proton interactions. The experiment will use a high resolution spectrometer and will be able to measure the polarization of the decaying particles in the final state. The measurements will be done at incident beam energies of 12, 15 and 18 GeV, high enough for QCD to be relevant, yet at a point where cross-sections can still permit good statistics. The data will augment inclusive measurements obtained at higher energies.

A Columbia / Massachusetts / Mexico collaboration will be venturing into new territory by building a multiwire detector able to select and reconstruct, on-line, completely specified exclusive final states at a rate of 10^5 per second. The experiment will use a high energy neutron beam to study omega minus production with the aim of exceeding 10^5 omegas.

The Multiparticle Spectrometer was used by a Brookhaven / Stony Brook / Pennsylvania group to study inclusive lepton pair production at 17 GeV in negative pion-proton collisions. Charged particles were tracked through the MPS and the electrons identified by two lithium foil transition radiation detectors and two lead scintillator shower counters. Evidence is seen for anomalous electron pair production between

Results for CP-allowed (top) and CP-violating asymmetries in kaon decay. These results were obtained on-line from an experiment using new fast electronics. Note the expanded scale for the CP-violating case.



0.1 and 0.6 GeV. These pairs are not accompanied by an excess of photons and are not caused by specific particle decays. This production seems to be ten times larger than that expected from the Drell-Yan (electromagnetic) mechanisms.

Charm production near threshold in hadronic interactions is being studied by several groups. A Brookhaven / Princeton / Illinois group used a two-arm neutral detector to measure eta-c production in pion-proton interactions. The eta-c is measured through its decay to two gammas. Data analysis is under way and the first results are expected soon. The MPS experiment also was used to search for charm production, triggering on D meson decays. No signal was found at a sensitivity of 100 nanobarns. A New York / Brookhaven magnetic spectrometer is taking data on other charm production and subsequent decays.

An upgrade of the MPS is under way. All spark chambers are being replaced by drift chambers for tracking and proportional chambers for triggering. This will increase its ability to handle higher particle fluxes, and with good geometrical acceptance and resolution will make it more efficient for measuring low cross-section reactions. With the advent of QCD and gluons as the binding force in strong interactions, the search for glueballs is in vogue and the MPS will be used for three such experiments. A Brookhaven / City College collaboration will study single and double phi meson production in negative kaon and pion interactions with protons at 22 GeV and probe the phi-phi spectra for the eta-c resonance with a sensitivity of 100 events per nanobarn. With the assumption that the 'disconnected' quark diagram in double phi production is mediated by the exchange of a number of gluons, the experiment sees it as a promising way to look for glueballs where the hadronic background is greatly suppressed. Another collaboration, Brookhaven / Florida State / Southeastern Massachusetts, plans to hunt glueballs through the production at low energy and subsequent analysis of the E(1420) meson, which is now considered by some as a good glueball candidate. A third group, Notre Dame / Brandeis / Brookhaven / City College, plans to run with a negative pion beam at 21 GeV to search for neutral meson production in neutral final states including two kaons, with a sensitivity of 100 events/nanobarn. From spin-parity analysis they hope to determine if these are quark states or glueballs.

The low energy programme comprises several experiments using kaon and antiproton beams at momenta below 1 GeV. Since the first observation of the S(1940) in proton-antiproton interactions at Brookhaven, this baryonium candidate has been the subject of many experiments, the results of which have been sometimes contradictory. The latest effort was carried out by a Brookhaven / Case Western group. The experiment used drift chambers and the time-of-flight technique to measure the proton-antiproton elastic, total and annihilation cross-sections covering the antiproton momentum region from 420 to 680 MeV, thus well bracketing the S meson. The results are eagerly awaited.

The hypernuclear spectrometer was used by a group from Houston / Brookhaven / Torino / Vassar / Carnegie-Mellon to look for sigma hypernuclear states through a charge and strangeness exchange reaction on oxygen and lithium targets. The lithium data show two maxima corresponding to a bound state of a negative sigma, two protons and three neutrons with binding energies of 10 and 22 MeV and widths of 10 and 5-10 MeV respectively, depending on background subtraction. Compared to the previous work on lambda hypernuclei, this result suggests that the negative sigma nuclear potential well is about 8 MeV deeper than that of the lambda nucleus. The oxygen run shows one broad maximum at a binding energy of 15 MeV. A new experiment proposes to observe hypernuclear states through their gamma ray de-excitation spectra using sodium iodide crystals. This should improve the energy resolution dramatically compared to the present kaon-pion energy difference technique.

Sigmas are the subject of two other experiments, one by Yale / Brookhaven / Mt. Holyoke / Pittsburgh, using a polarized proton target to study the asymmetry of the decay of longitudinally polarized positive sigmas (produced by kaons bombarding polarized protons) into protons and gammas. Previous low statistics experiments indicated a large parity violating asymmetry. The experiment expects to obtain a more definite answer.

The other experiment focuses on a precision determination of the negative sigma magnetic moment from the measurement of the fine structure splitting of transitions in exotic sigma atoms formed by the atomic capture of negative kaons. Laminated targets and germanium-lithium X-ray detectors are used to measure the magnetic moment to an accuracy of 0.05 nuclear magnetons. The result is eagerly anticipated in view of recent hyperon data from Fermilab.

Preparations for accelerating polarized protons in the AGS are under way. A new zero degree proton beamline is nearing completion. One group is setting up a polarized proton target and a double-arm magnetic spectrometer to measure the analysing power of proton-proton elastic scattering. This analysing power reflects strongly the structure found in differential cross-sections. In addition, these measurements will be used to calibrate the proposed polarimeters for polarized proton running of the AGS.

The AGS has 20 approved experiments. The range of physics represented in these experiments is impressive, spanning weak, electromagnetic and strong interactions. More important than this diversity is the fundamental nature of so many of these experiments and their promise of surprise. And surprise is what brings us new directions in physics.

(This material was supplied by Yousef Makdisi of Brookhaven's Accelerator Department.)

Santa Fe Linac Conference

Left to right, John Blewett, Lloyd Smith and Frank Cole together at the recent Santa Fe Linear Accelerator Conference.

The 1981 Linear Accelerator Conference, organized by Los Alamos National Laboratory, was held from 19–23 October in Santa Fe, New Mexico. The surroundings were superb and helped to ensure a successful meeting. There were more than two hundred and twenty participants, with good representation from Japan and Western Europe.

The meeting opened with a remarkable reminiscence by Phil Livdahl on the MTA linac project during the Second World War which was aimed at producing nuclear weapons materials. Although classified for many years, this project, which was terminated after a few years of intense accelerator development, had long-lasting results in the training of a generation of accelerator builders. This was a time when new ideas could be tested — even if it meant the construction of a 12 MHz, 60 foot diameter drift tube linac, incorporating drift tubes weighing forty tons and with bore holes large enough for a man to crawl through. This was a time when things could get done — over a five year period the group, under E.O. Lawrence's direction, built four large accelerator prototypes from the Mark I to the A-48, a 7.5 MeV working deuteron linac. And this was a time when successful machines were built without fancy computer programs.

The Conference was forward-looking. Very few papers dealt with existing operating machines but a number of projects and proposals were presented which push the state of the art in all aspects of machine development.

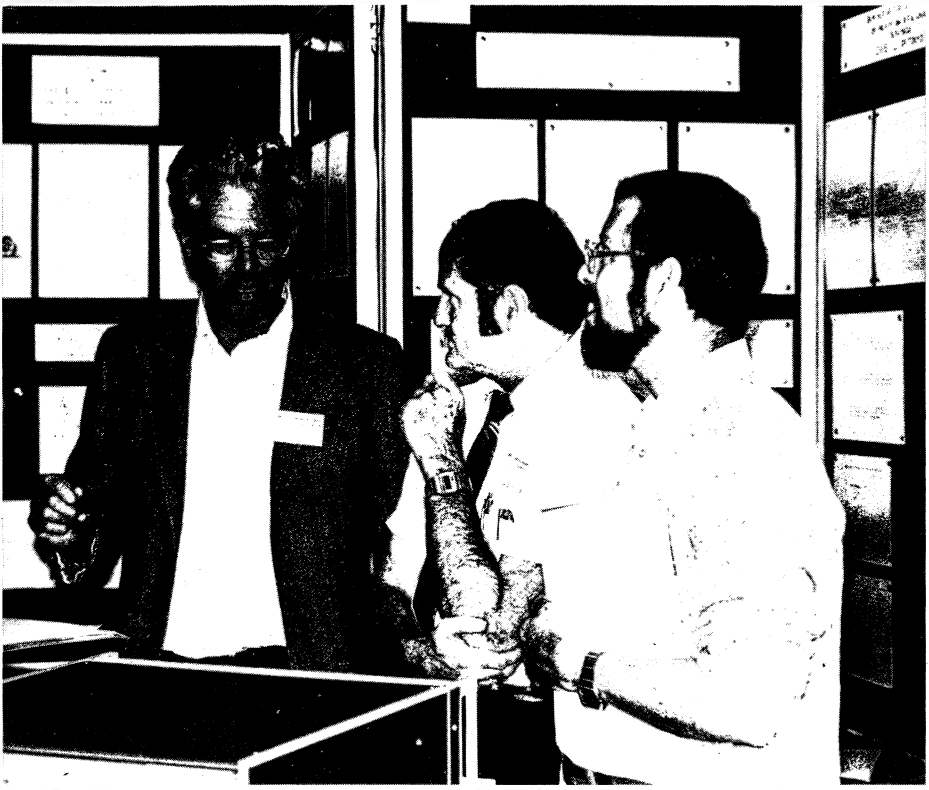
Several papers reported the progress of FMIT (a 35 MeV, 100 mA, 100 per cent duty-factor deuteron linac being developed for Fusion Materials Irradiation Testing). It is the first attempt at c.w. linacs since the MTA project and its development is important to future applications of linacs such as nuclear fuel enrichment which will require GeV beams with hundreds of milliamperes of current.

The major machine development sparked by the FMIT project has been the RFQ (Radio Frequency Quadrupole), for which the first ideas emerged in the Soviet Union. The Los Alamos group enthusiastically pushed RFQ development for application in FMIT and other projects. In principle, it offers enormous advantages over present linac injector schemes, replacing high voltage Cockcroft-Waltons, choppers, and conventional bunchers while offering simplicity and almost 100 per cent bunching efficiency. In three to four years, Laboratories around the world have joined the RFQ development effort. Fourteen papers (out of 110) from seven institutions were presented on the subject. Specific plans are being made to use RFQs in new or retrofitted injectors for several heavy ion and polarized proton accelerator projects.

Another important technological advance is the development of rare earth permanent magnets, which also attracted a number of papers. After a modest beginning (the use of permanent magnet quadrupoles was first proposed at Los Alamos for their PIGMI project) and a fear of losing the ability to adjust quadrupole fields, New England Nuclear Corporation took the bold step of adopting this technology for their 40 MeV proton linac constructed for the production of radiopharmaceuticals. This gave impetus to an entirely new technology of permanent magnet designs — dipoles, quadrupoles, sextupoles and adjustable-field systems. The technology is maturing and will be used extensively on new linac designs. Two commercial com-

Left to right, E.A. Knapp, M.F. Shea and J.D. Hepburn at a poster session.

(Photos Los Alamos)



panies are producing and selling permanent magnets.

Another high point was the advance in understanding beam dynamics. Since the classic work during the late 1960s of L. Smith, R. Gluckstern, R. Chasman and others, theorists were at a loss to explain beam emittance growth phenomena observed in operating linacs. Typically, factors of two to three in emittance growth were measured without obvious explanation.

A number of different approaches are shedding new light. In particular, L. Smith, R. Jameson, I. Hoffman and D. Mittag presented papers on detailed treatment of beam bunch behaviour during acceleration, demonstrating the effect of space charge, mismatching, and tight coupling between transverse and longitudinal phase spaces resulting in the onset of instabilities within the bunch. These mismatches and instabilities lead to emittance growth that appears to be consistent with observation. This work indicates that part of the observed beam emittance growth can be controlled by properly matching the transverse and longitudinal particle temperatures within the bunch or, to use the newly coined term, by 'equipartitioning'. Control of emittance growth will be important as applications of linacs require higher beam currents or current densities.

Frank Cole reviewed 'collective acceleration' which holds the promise of very high field gradients (over 10 MeV/m). However although the physics principles appear sound and the electron ring accelerator (ERA) was pushed fairly hard, this concept has never been thoroughly demonstrated experimentally. Among the many concepts in the USA, the Pulselac at Sandia Laboratory appears to have the best chance for success and interest in this type of linac is sustained, albeit modestly.

Superconducting linacs, promising high gradients and efficiencies also generated much interest ten years ago but their development was plagued by materials problems, contaminants, magnetic field quenches, beam loss quenches and other hazards. Nonetheless, superconducting linac cavities met with some success, particularly as beam separators and heavy ion post-accelerators (for raising the energy of beams in Van de Graaffs) where beam currents are small. It was gratifying to hear two papers from Argonne describing the successful commissioning of their heavy ion superconducting linac booster.

Another paper described first operation of the 40 MeV New England Nuclear proton linac after a four-year construction period. This is noteworthy on two counts — it is the first proton linac built by industry for industrial purposes (production of radiopharmaceuticals) and it is the first using permanent magnet focusing. It is too early to assess success but the linac's performance will be followed with great interest.

A number of proposed linacs are generating good development work. The long-standing Chalk River programme for electronuclear fuel breeding using a 300 mA c.w. 1 GeV proton linac has led to work on high current ion sources, injectors, and the low energy front-end, as well as disc-and-washer (DAW) structures for energies above 150 MeV. C.w. accelerators have to deal with high current densities, multipactoring, thermal effects and the like. A development project called ZEBRA will consist of a 300 mA, 10 MeV front-end linac which eventually might become a demonstration electronuclear breeder.

In similar vein, the most ambitious linac project presently on paper, the SNQ at Karlsruhe, was presented by A. Citron. This is intended to be a spallation neutron source primarily for neutron scattering research and is a 1.1 GeV, 100 mA per pulse, 5 to 10 duty cycle machine. Most interesting was the development of r.f. power sources, such as a 325 MHz, 1 MW klystron. Tests to date indicate impressive tube efficiencies in excess of 70 per cent.

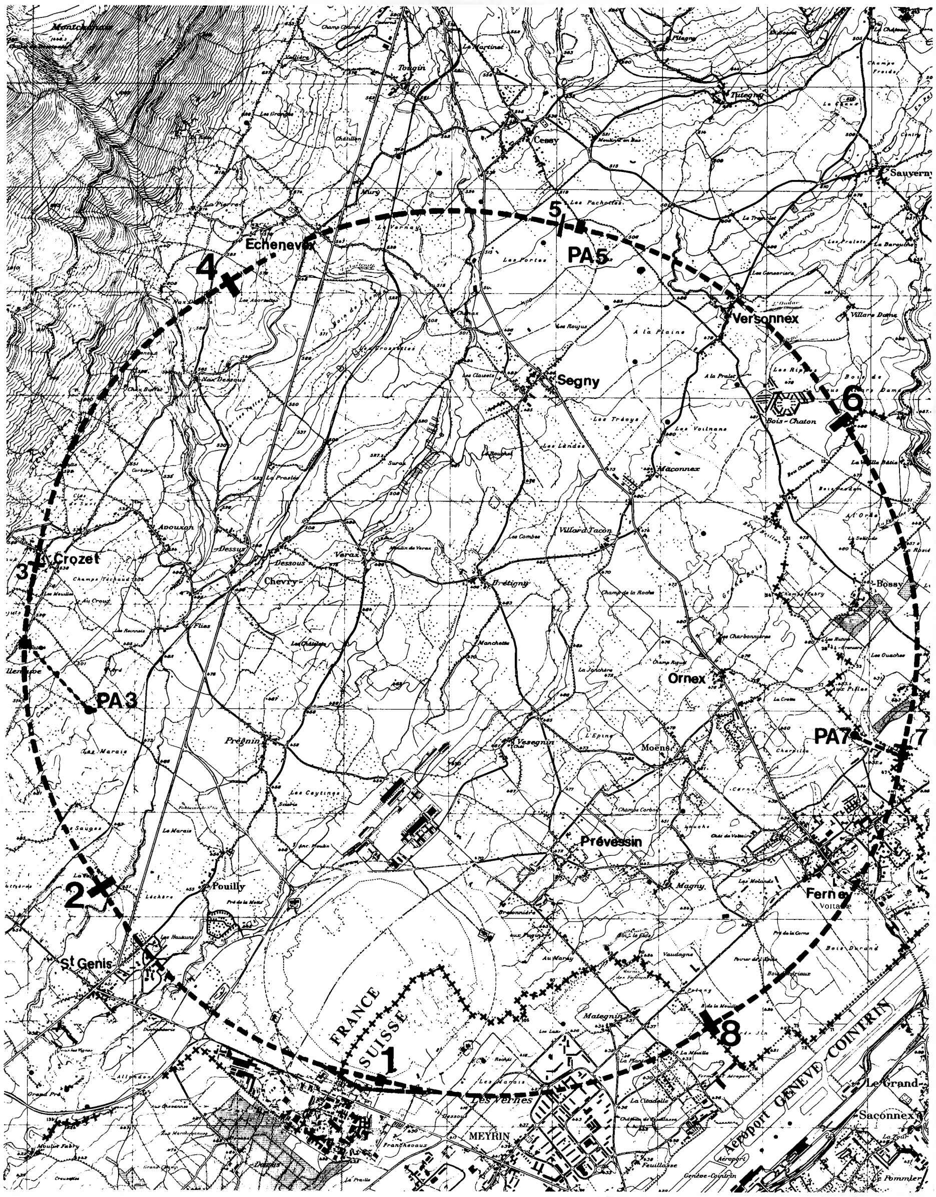
Two papers by commercial firms described some of the work done to improve r.f. power sources, a subject always of great interest because future high-current linac costs may be dominated by the cost of r.f. power. Development of high power, low frequency, gridded tubes at EIMAC was described, as well as work at Thomson-CSF on high power klystrons.

Finally there were reports on electron linear accelerators, where interest centres on two relatively new developments. A number of technically interesting papers dealt with pushing the state of the art in racetrack microtrons where a number of microtron projects have generated fresh ideas. At the other end of the spectrum, SLAC is preparing for the Single Pass Collider. This presents some unique accelerator control problems in the handling of a single intense electron bunch.

The present work and the challenges of new projects promise exciting fare for the next Linear Accelerator Conference in 1984.

(The Santa Fe Conference summary was given by Pierre Grand, and formed the basis for this article.)

Around the Laboratories

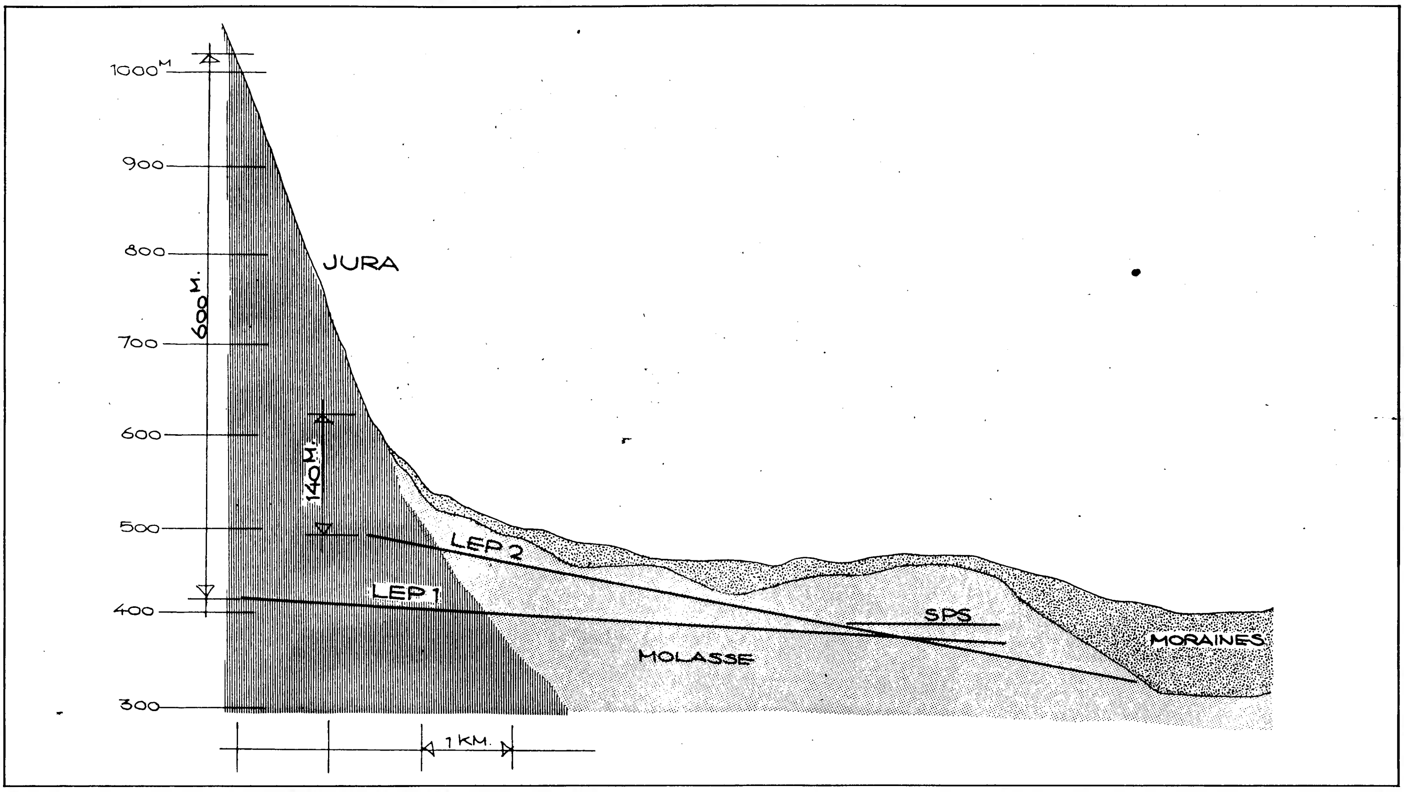


The new proposed location of the 27 km circumference LEP electron-positron ring at CERN. In contrast with previous proposed locations, only 3 km of tunnel passes under the Jura mountains to the north-west. The existing CERN installations would straddle the ring near the point marked '1'. The ring would pass under the French-Swiss border at four places.

CERN
The tilting of LEP

As reported briefly in our January / February issue (page 20), further optimization of the position of CERN's large underground electron-positron storage ring project, LEP, has led to a new proposed location. It has been slid further out from under the Jura mountains in the west and its plane has been tilted so that, to the east, it remains in the molasse which is good for tunnelling.

The section of LEP which passes deep under the Jura has long been recognized as the riskiest part of the civil engineering programme. Experience of building the SPS 400 GeV proton synchrotron in the underground molasse layer surrounding the CERN site makes it possible to calculate with confidence both the



A schematic cross-section of the terrain around CERN, showing the new proposed location (LEP 2) of the LEP ring, now tilted even more out of the horizontal. This minimizes the distance to be tunnelled under the Jura mountains and makes maximum use of the molasse rock, good for tunnelling. The first proposed position (LEP 1) and the existing SPS ring are also shown.

financial and construction-time implications of tunnelling most of the LEP ring.

However in the previous proposed LEP location there remained some 8 kilometres which passed through limestone formations of the Jura up to 600 m below the surface where up to 20 atmospheres of water pressure could be expected. CERN itself has no tunnelling experience in this rock and outside experts warned of possible problems, none of which were insurmountable but which could have introduced delays in tunnel construction.

The new location became possible on accepting that the accelerator could be built on an incline (about 1.8 degrees). LEP could then be moved to the east towards Lake Geneva, remaining in the molasse (which falls away in the direction of the lake) and emerging more from under the Jura.

Instead of 8 km in the limestone, the tunnel now traverses only 3 km. Also the maximum depth below the surface is reduced to 150 m. This both reduces the maximum water pressure which could be experienced (to some 10 atmospheres) and makes it feasible to intervene from the surface if problems do arise.

Another advantage is that the access to the experimental halls at the eight beam collision regions will be easier. All eight are now in the molasse so that the implications of their excavation are known from experience in building the underground halls for the proton-antiproton experiments at the SPS. The total length of the access tunnels and shafts is also reduced.

There are of course some disadvantages in the new proposed position. The link with the SPS is not as short as before — the length of the bypass which could make electron-proton collisions possible at some later date is doubled (although this has some advantages also). The tilting of the LEP plane introduces some complications for the machine itself such as the need for a more sophisticated pumping system for the water cooling.

The selection of the new proposed position minimizes the possible problems when tunnelling through the Jura. Thus the machine construction can be attacked with increased confidence.

Klystrons give 1 megawatt

While awaiting final authorization for the construction of the LEP electron-positron storage ring, work on prototypes of the major components of the machine has obviously been under way at CERN so as to optimize the design of the ring and to ensure

A Christmas present for CERN — LEP, the large electron-positron storage ring. This genial picture was taken in a mock-up of the LEP tunnel (a section with the radio-frequency accelerating cavities complete with their spherical low-loss storage cavities on top) installed in the exhibition hall at CERN. Georges Boixader and twin sons were on their way to the CERN Nursery School next door to play Father Christmas for the children.

(Photo CERN 364.12.81)

as fast a start as possible in the placing of contracts.

In some ways the most crucial components of the machine are those of the radiofrequency accelerating system. Because of the influence of the large energy loss due to synchrotron radiation from electron and positron beams at high energies, the performance of the r.f. will be the dominant factor determining the power consumption and the peak operating energy of the machine.

Construction authorization is for 'LEP Phase I' which aims to achieve 50 GeV per beam. To cope with higher energies it is presently believed that superconducting cavities will have to be used to keep power needs to an acceptable level. So research and development programmes are under way to build such cavities to provide high accelerating field gradients with low power consumption and giving reliable operation in a storage ring environment. Recent results are encouraging and there will be further news soon.

However superconducting cavities are not yet sufficiently mastered. LEP Phase I must incorporate 'conventional' technology but conventional technology pushed hard to improve performance. One way follows the novel idea from Wolfgang Schnell to install low-loss storage cavities and transfer the r.f. power to them in the intervals when it is not needed for acceleration in the ring cavities. Another way is to improve the performance of the klystron r.f. power sources.

Tests began at 500 MHz using a klystron available from DESY together with a modified version of the PETRA cavity design. Full power was achieved over a year ago and tuners and couplers were tested. A full-scale prototype cavity was then operated at the design frequency, 350 MHz, and was run up to 160 kW (compared to the design figure of 125 kW). A full-scale low-loss storage cavity, built in the CERN workshops, has been added and power transfer at the full 125 kW was achieved in December.

Meanwhile two model klystrons were ordered from two firms. One firm rapidly delivered a vertically mounted type while the other will soon deliver a horizontally mounted type which is closer to the probable final design. Towards the end of last year, the vertical klystron delivered 1 MW output power which is believed to be the highest c.w. power ever achieved in this frequency range. During factory tests in January, the horizontal klystron also reached 1 MW.

The higher performance is a consequence of the impact of computer programming on defining the beam trajectories and of more careful technology to avoid overheating in the klystron. There is also better instrumentation of the klystron including protective devices which allow the power to be turned up without worrying. This latest result is another cause for optimism that LEP will provide more volts per turn than ever achieved before.

Measuring gluons

With the mechanisms of weak interactions better understood (at least for the moment), high energy lepton beams are being used as a fine probe of hadron structure and have given a wealth of information on the quark structure of hadrons. However it is clear that quarks (and antiquarks) carry only about half of the average nucleon momentum, the remainder being attributed to gluons.

This significant gluon content is

The WA1 experiment (CERN/Dortmund/ Heidelberg/Saclay) has measured the gluon distribution of the nucleon from high energy neutrino scattering data. Seen here are the newly-installed upstream modules of the detector with a more elaborate arrangement of scintillators, designed to improve the space resolution of the produced particles and extend the already considerable physics contributions from this major SPS experiment.

(Photo CERN 227.12.81)

expected to contribute to many effects seen in violent hadron-hadron collisions and elsewhere. To make predictions, it is therefore important to know something about the gluon content of nucleons. While gluons do not contribute directly to lepton-quark interactions, there are nevertheless secondary effects due to gluon bremsstrahlung and quark-antiquark pair production which should be reflected, via scaling violations, in the data.

Indications of gluon effects have been seen before, but now the CERN / Dortmund / Heidelberg / Saclay experiment using the neutrino beams from the CERN SPS 400 GeV proton synchrotron has given for the first time a reliable determination of the gluon structure of the nucleon.

The data comes from 94 000 neutrino and 25 000 antineutrino charged-current interactions from the SPS narrow (energy) band neutrino beam together with 35 000 neutrino and 155 000 antineutrino events from the wide-band beam. The sum of the neutrino and antineutrino cross-sections gives the so-called F_2 structure function, which depends on the sum of the quark and antiquark distributions. In addition, antineutrino data at large energy transfers gives a lever on the antiquark distribution.

Through the mathematical convolutions of quantum chromodynamics, these quantities are related to each other and to the gluon structure function, which can be explicitly extracted. It is assumed that four types of quark (up, down, strange and charmed) are involved, and previous results allow the effects of strange and charmed quarks to be accounted for. The extracted gluon distribution does not appear to be too sensitive to uncertainties in these heavy quark contributions.

Muonic molecules

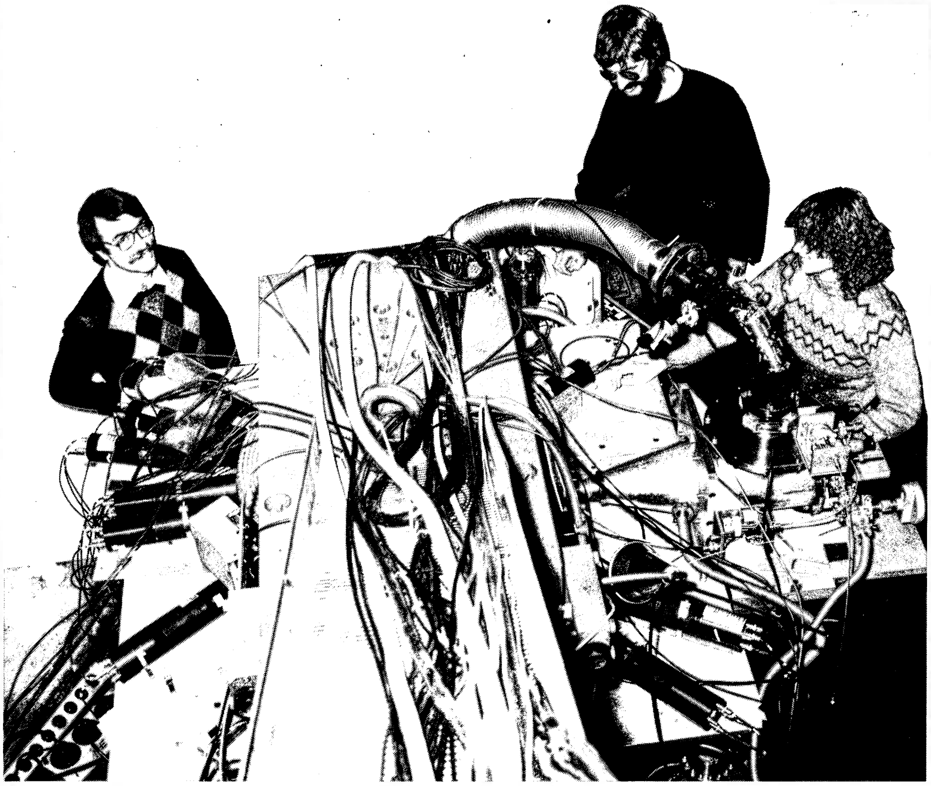
A good example of nuclear physics spin-off is the technique of muon spin rotation. This uses a highly polarized beam of positive muons which, to the possible indignation of accelerator specialists, is made to slow down and actually stop in a target. There the muons begin to precess in a magnetic field, either applied externally or generated inside the target material. A few microseconds later the muons decay radioactively, and in doing so have the good nature to tell which way their spin was pointing — by preferentially emitting a positron in that direction. The positron signals, detected in scintillator telescopes, monitor the precession of the muons in their local magnetic environment.

A great deal of work has already been done using these muons as magnetic probes in solid state physics (see November 1979 issue, page 362), and now the technique is also finding use in chemistry. In many materials the muons are able to pair up with electrons to form 'muonium', a hydrogen-like atom with a muon, rather than a proton, as its nucleus. Like ordinary atomic hydrogen, muonium is highly reactive and can attack organic molecules, breaking a chemical bond and forming almost equally reactive 'free radicals'.

In new experiments at the CERN 600 MeV synchro-cyclotron, a number of new muonic radicals have been produced and studied. Their muon spin rotation spectra are simpler than those usually expected in magnetic resonance techniques and may be readily interpreted in terms of the radicals' magnetic and chemical properties. Some of these properties are particular to the novel species — for instance there is an interesting isotope effect in one of the magnetic characteristics which

Left to right, Ricardo Tedeschi, Steve Cox and Alyson Hill at the muon spectrometer used in muonium chemistry studies at the CERN 600 MeV synchro-cyclotron.

(Photo CERN 148.1.82)



shows that the exact shape (or 'conformation') of the molecule, and its modes of vibration or rotation, must be altered when a proton is replaced by a muon. Other properties are intrinsic to the original substance. For instance measurements of chemical reaction rates (in these experiments the initial stages of polymerization) are made possible, but are not otherwise influenced by the muon.

It appears from the muon spin rotation spectra that there must be other ways, less well understood, in which the muon can associate with organic molecules. This is being investigated by experiments on a number of substances with different electronic properties.

One of the members of the collaboration who initiated these studies at CERN is Sir Geoffrey Allen, former chairman of the UK Science and Engineering Council, now Research Director of Unilever.

FERMILAB
Injector improvements

During the recent shutdown for Doubler / Saver installation at Fermilab, an extensive programme was completed in the Booster accelerator to reduce horizontal closed orbit errors. The closed orbit errors were reduced by approximately a factor of two. Preliminary measurements indicate a much larger useful aperture in the Booster and much more easily controlled chromaticity and betatron tune working points. Plans call for longitudinal and transverse beam quality measurements to be made as soon as possible after the Main Ring is operational.

Record intensities have already been achieved after only brief studies in the Booster. The new record is 4.3×10^{13} protons / main ring cycle (13 pulses) with 6.7×10^{13} protons delivered from the Linac. The previous record during the spring of 1981 was 4.1×10^{13} protons / cycle with more than 7×10^{13} protons / cycle from the Linac. That record was achieved after extensive changes were made in the vertical closed orbit and a new low level r.f. system installed and then only after long and elaborate tuning. Before the improvement programme was started two years ago, the record Booster intensity achieved during operation with the Main Ring was 3.45×10^{13} protons / cycle with 8.3×10^{13} protons / cycle injected from the Linac. Further improvements in intensity and beam quality are anticipated in the near future.

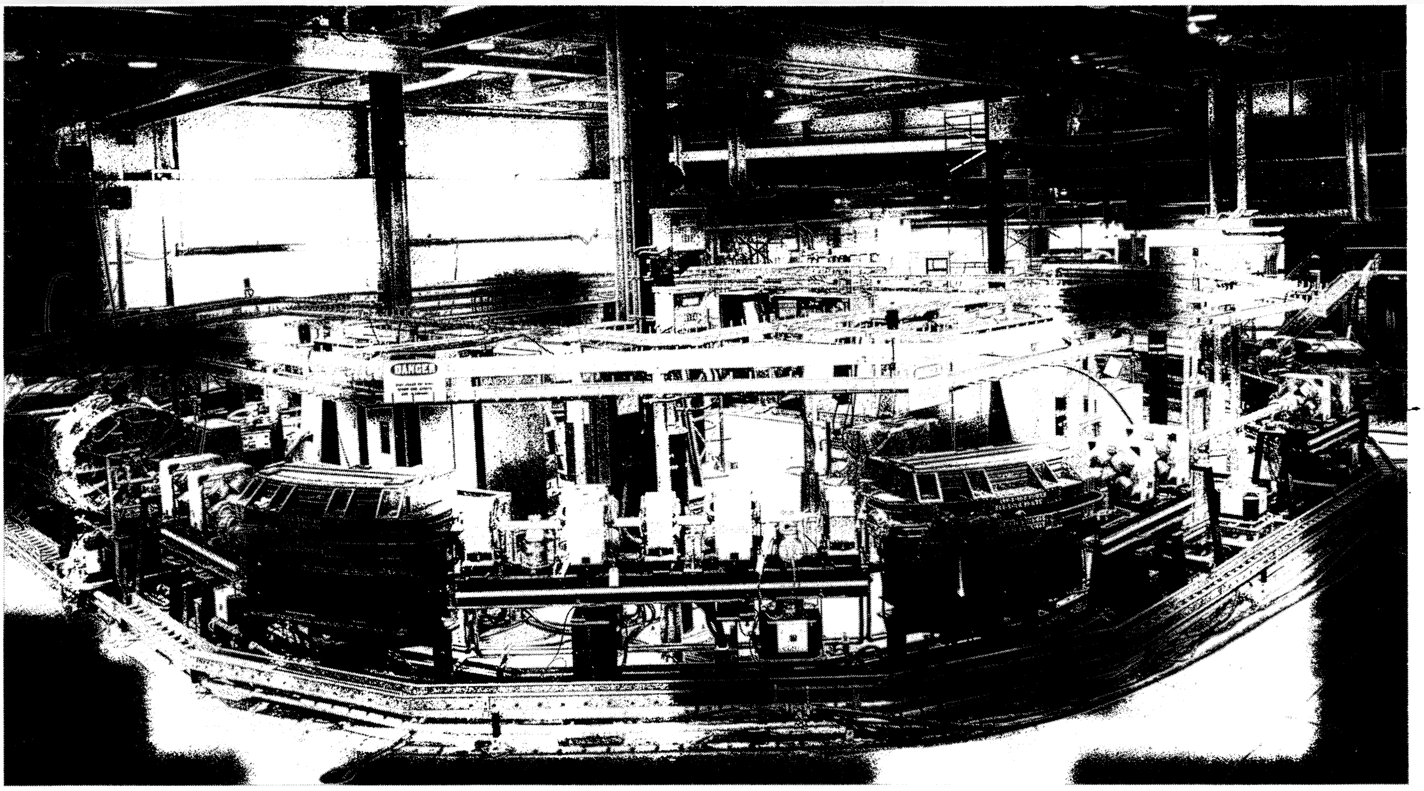
Modifications have also been made on the 8 GeV line from the Booster to the Main Ring. This line was originally constructed using largely standard design main ring magnetic elements. That design necessitated some compromises. In particular it was necessary for the beam to enter one of the principal quadrupoles off-centre because of the size of the quadrupole. This introduced substantial quadrupole steering. That quadrupole has now been replaced by a smaller one so that the beam now enters on-centre.

BROOKHAVEN
Making synchrotron light work

December was a period of major accomplishment for Brookhaven's National Synchrotron Light Source. First, a beam of electrons survived multiple turns in the vacuum ultraviolet electron storage ring. Less than 24 hours later, synchronized radiofrequency capture was achieved, and then the cycling Booster Synchrotron injector began accumulative charging of the VUV ring. When

The vacuum ultraviolet ring of the National Synchrotron Light Source at Brookhaven National Laboratory, now confidently handling circulating beams.

(Photo Brookhaven)



the ring reached the saturation level prescribed by the present beam lifetime of about two minutes, it had attained a current 30 times higher than the Booster Synchrotron.

Following last August's milestone of limited circulating beam in the VUV ring, NSLS personnel spent several months rebuilding a defective Booster Synchrotron main power supply, upgrading the injector to a 600 MeV ejection energy level, and working on the X-ray storage ring systems. When the Booster-VUV system was again turned on, multiple turn survival in the VUV ring was somewhat elusive for a while. The commissioning process was made significantly more difficult by the inability of the beam position monitoring system and standard current monitors to detect the early turns during the 'noisy' period caused by turning off the fast injection kicker magnets.

To solve these problems, a sequence of periods of around-the-clock machine studies was scheduled. This resulted in a narrowing-down of the details of the beam transfer in the VUV ring and its limited number of turns trajectory. The fine structure of the magnet ring field distribution was also reexamined, leading to a minor modification of the ring excitation parameters.

For the VUV ring, the next step is to refine and substantiate the machine parameters, remove the provisional aperture limiting beam monitors and restore ring pressure to its original 10^{-9} torr pressure. That should increase the present lifetime limited current saturation level of about 10 mA circulating beam by an order of magnitude.

With these recent accomplishments, part of the focus at the NSLS can now be shifted back to the further commissioning of the X-ray storage ring system. The next planned step is to resume machine studies of beam transfer into that storage ring.

MICHIGAN
Superconducting cyclotron in action

In November the 500 MeV superconducting cyclotron at Michigan State University came into operation — the first machine of its type to be brought into service. Eventually it will be used in tandem with an 800 MeV superconducting cyclotron, scheduled for completion in 1985. Together they will give considerable potential for nuclear physics research to the newly created US National Superconducting Cyclotron Laboratory. Construction of the 500 MeV machine was funded by the US National

Science Foundation, and extensions are being funded through the Department of Energy. (The project was described in the March 1981 issue, page 63).

Commissioning began early in November, and on the 13 November the first internal beam (of carbon ions) was obtained. A week later the first nuclear reactions were observed (using a deuterium beam to circumvent vacuum problems) and on 24 November the beam was accelerated out to full radius at 500 MeV. The tests were led by Merrit Mallory and Edwin Kashy of the Laboratory staff, together with consultant Jack Riedel. Operation of major machine components was as anticipated. Ions cleared the intricate central region after injection and stable orbits were achieved in the field of the superconducting magnet, while the r.f. system could accelerate the ions in these orbits.

At the time of writing the vacuum system is being improved to push the pressure down to 10^{-7} torr and the r.f. is receiving attention to cope with unbalanced coupling capacities in the central region. Beam studies, including extraction studies, will then continue. Proposals for experiments have been received and the experimental programme is expected to start shortly.

(Meanwhile construction of a superconducting cyclotron is nearing completion at the Canadian Chalk River Laboratory. It could be in operation later this year.)

The coil trim of the 500 MeV superconducting cyclotron at Michigan State University. The accelerator, first of its type in the world, is now in operation.

Henry Blosser, Director of the US National Superconducting Cyclotron Laboratory, puts a finishing touch to the machine. He is seen here between the upper and lower pole tips of the magnet installing the 'Dee' electrodes (which in this case are shaped more like giant commas).

(Photos MSU)

People and things

Nick Samios

On people

The J. Robert Oppenheimer Memorial Prize is shared this year by Maurice Goldhaber, Brookhaven Distinguished Scientist and former director of the Laboratory, and Robert Marshak of Virginia Polytechnic Institute and State University. The Prize is awarded annually by the Center for Theoretical Studies, Coral Gables, Florida.

Italian theoretician and former CERN Director Sergio Fubini has been awarded the degree of Doctor honoris causa of the Science Faculty of the University of Heidelberg.

Former Los Alamos Theoretical Division Leader Peter A. Carruthers has been named a Fellow of the American Association for the Advancement of Science.

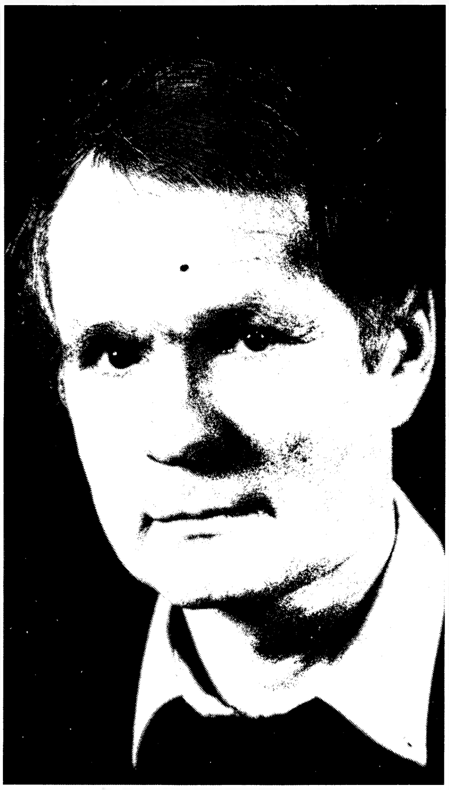
Nicholas Samios has been appointed Acting Director of Brookhaven National Laboratory. Last year he was the Laboratory's Deputy Director for High Energy and Nuclear Physics. Associated with Brookhaven since 1959, Nick Samios has participated in many famous experiments, notably the discovery of the omega minus hyperon. His appointment follows the resignation of Laboratory Director George Vineyard, who announced last year his intention to return to full-time research. After a sabbatical year, Dr. Vineyard will become Senior Scientist in Brookhaven's Physics Department.

At the beginning of the year, Paul Söding became a member of the DESY Directorate. He is responsible for the Research Division and takes over the position held for three years by Erich Lohrmann who is returning to full-time teaching and research.

Paul Söding (49) studied physics and mathematics in Munich and Hamburg, where he was a student of Willibald Jentschke. He was involved in the early antiproton-proton work with the CERN bubble chamber and did his doctorate under the direction of Martin Teucher. In 1966 he moved to Berkeley where he worked in the Alvarez bubble chamber group.

After joining the DESY staff in 1969 he worked on photo- and electroproduction experiments at DESY and Cornell and on bubble chamber experiments at the CERN Proton Synchrotron. When PETRA got under way he joined in the design and construction of the TASSO detector and has since been involved in this experiment. He has also been teaching at the University of Hamburg.

Paul Söding



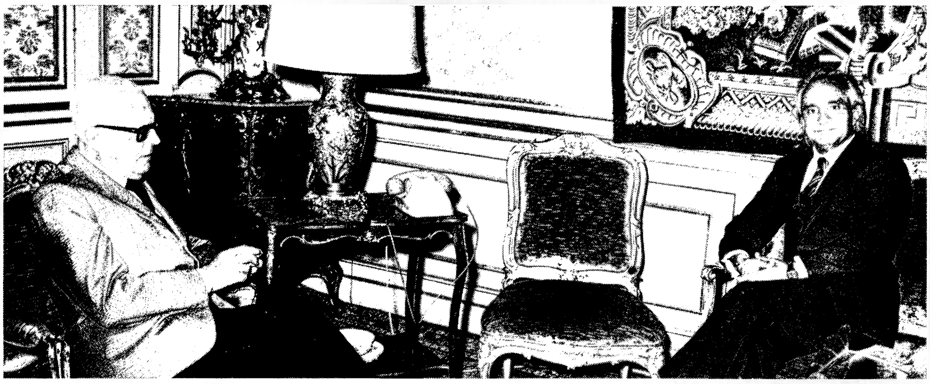
The Otto Klung Prize 1981 was awarded to Gerhard Mack from the University of Hamburg, on the staff of the II Institute for Theoretical Physics on the DESY site. The prize was established by the late Otto Klung, a Berlin merchant, and is awarded alternately for physics and chemistry. Mack's work on quantum field theory and theory of elementary particles, in particular his ideas on lattice gauge theories, has had considerable impact.

Martin Blume of Brookhaven is one of the recipients of the 1981 E.O. Lawrence Award for physics. The Award was given 'for his definitive contributions to the theoretical analysis of magnetic phenomena in neutron scattering and for his work on relaxation and critical phenomena. He was also recognized for his scientific leadership in solid state physics, especially for the emerging research programme based on the National Synchrotron Light Source.'

Among the awards announced by the UK Institute of Physics for this year are the Duddell Medal and Prize to Simon van der Meer of CERN, particularly for his work in the development of stochastic cooling techniques for particle beams, and the Maxwell Medal and Prize to John Ellis, also of CERN, for his contributions to gauge theories. The Rutherford Medal and Prize goes to Oxford nuclear theoretician David Brink.

Milan Vysocansky

With the sudden death of Milan Vysocansky on 27 December, the Institute of High Energy Physics at Heidelberg University lost one of its most active and highly regarded members. After several years of research work at Dubna and Bratislava, he joined the Heidelberg Institute in 1968, where he soon became Head of Electronics Division. As such he went on to play an important role in the preparation of many experiments carried out in his institute's collaboration with CERN. His enthusiasm for his work and his warm personality will be long remembered by his colleagues.



Italian President Sandro Pertini (left) has awarded the gold medal for Science and Culture to Antonino Zichichi (right) in recognition of his 'outstanding contributions in making and promoting science and culture in Italy and abroad'.

Meetings

From 3–6 May, a 'Workshop on Accelerator Orbit and Particle Tracking Programs' will be held at Brookhaven. The focus will be primarily on computer simulation of non-linear magnetic effects as they influence beam lifetime in storage rings. Possible real time applications of these programs will also be covered. Further information from Max Cornacchia, ISABELLE Group, Bldg 902A, Brookhaven National Laboratory, Upton, New York 11973, USA.

1982 CERN School of Computing

The 1982 CERN School of Computing will be held from 29 August to 11 September in Zinal, Valais, Switzerland. This will be the seventh such school and will cover topics of current interest in computing which are relevant to data processing needs in high energy physics. An impressive list of lecturers has already been drawn up, including representatives from universities and specialized research centres. About 80 participants are envisaged, drawn from CERN Member States or from laboratories closely associated with CERN. Further information from Ingrid Barnett, Scientific Conference Secretariat, CERN, 1211 Geneva 23, Switzerland.

50th anniversary of the discovery of the neutron

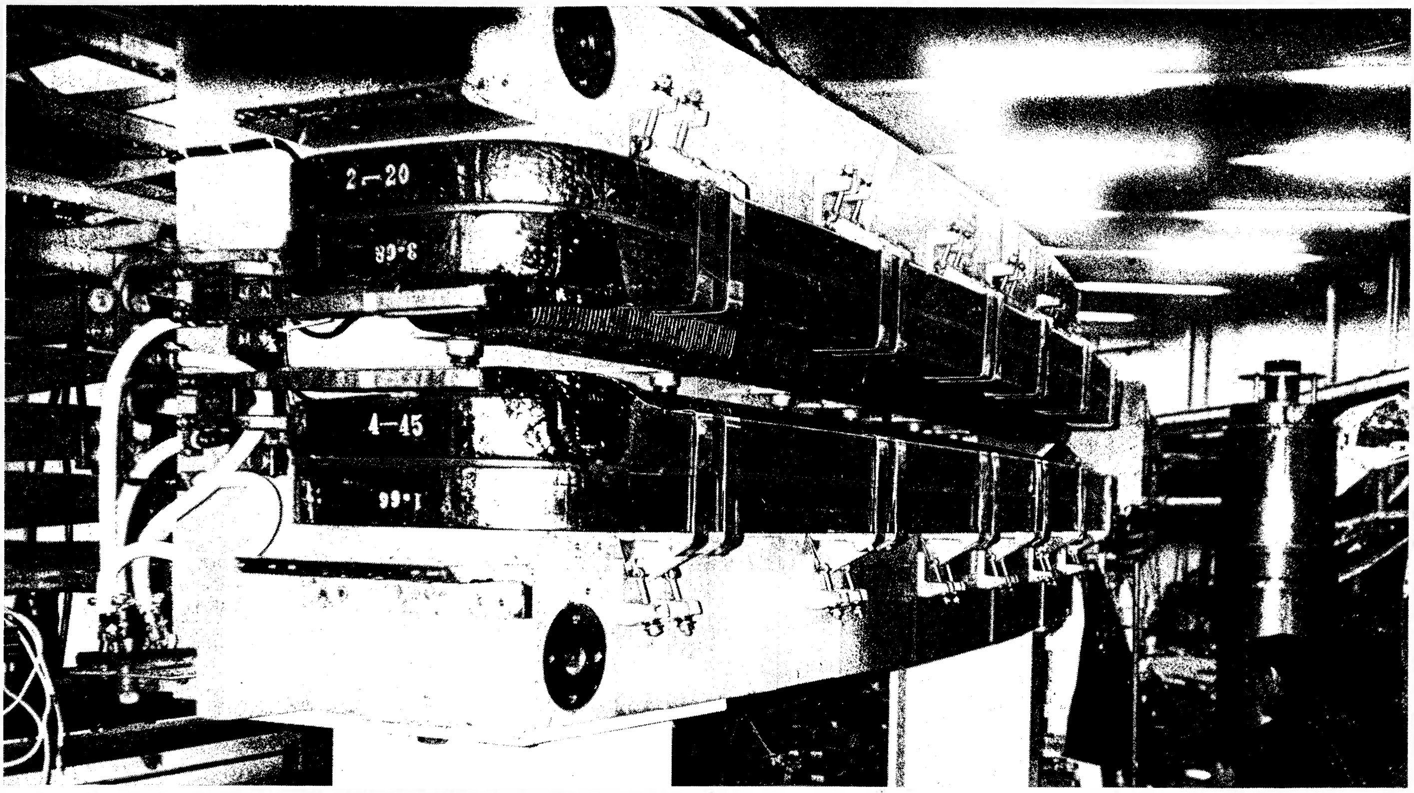
This year marks the fiftieth anniversary of the discovery of the neutron by Sir James Chadwick. To commemorate the event, the UK Institute of Physics, in collaboration with the UK Atomic Energy Research Establishment at Harwell, is organizing an international conference at Cambridge from 13–17 September. The conference will cover all aspects of neutron science, including neutron physics, neutron scattering studies, and

French research and technology minister Jean-Pierre Chevènement (extreme right) seen here on a visit to CERN on 18 December accompanied by (left to right) Director General Herwig Schopper, outgoing President of Council Jean Teillac and Director Robert Klapisch.

(Photo CERN 285.12.81)

One of the rebuilt DORIS–II dipole magnets already remounted in the tunnel, showing the energy-saving double coil (see November 1981 issue, page 397).

(Photo DESY)



neutron technology. The first day will include a special commemorative session with contributions from Edoardo Amaldi, Sir Mark Oliphant, Sir Rudolf Peierls and Wilfred Lewis. In parallel, there will be an exhibition of scientific equipment and other items of historic interest. More information from the Meetings Officer, Institute of Physics, 47 Belgrave Square, London SW1X 8QX, UK.

This anniversary will not go unnoticed in the CERN COURIER.

SLC environment

The layout of the proposed Stanford Linear Collider — SLC (see January/February issue, page 8) has been changed for environmental reasons. The location of the loops bringing the positron and electron beams from the end of the linac to the collision area has been modified so that the main experimental hall would be in a hollow, rather than on a wooded hillside.

Low energy antiproton workshop

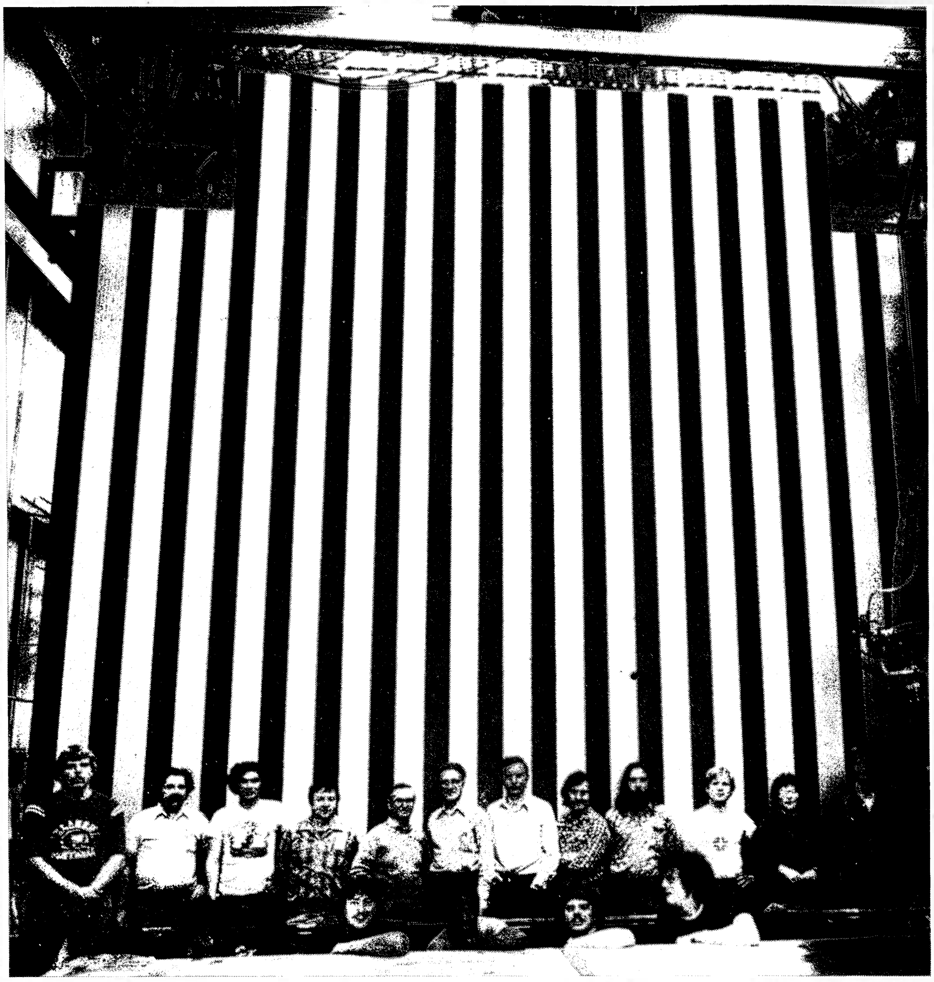
A workshop on physics with low energy cooled antiprotons at the new LEAR ring, currently under construction at CERN, will be held at Erice, Sicily, from 9—16 May. Further information from U. Gastaldi, CERN, 1211 Geneva 23, Switzerland.

Multi-TeV acceleration?

To stimulate interest in the problems of particle acceleration to the multi-TeV range, ECFA is organizing a meeting to review the limitations and prospects of both conventional and novel particle acceleration techniques. It will probably take place at Oxford late in September. Details will be announced soon.

Mistaken identity

On page 448 of our December issue, we published a photograph which purported to show wires being threaded for the new ARGUS detector at DESY. Eagle-eyed readers spotted the mistake — the photograph was in fact an old one showing assembly work for the TASSO detector. Not that the detectors look that different during assembly, it's just that TASSO wires were threaded by men, while ARGUS wires are being handled by women!



The backdrop in this stage setting at Fermilab is one of the large proportional tube planes completed by an MIT group for the muon hodoscope of the Northern Illinois/MIT/Michigan State/Fermilab flash chamber neutrino experiment (see page 51). The construction used extruded aluminium technology perfected by Tom Lyons to achieve the required size.

(Photo Fermilab)

1982 CERN School of Physics

The 1982 CERN School of Physics will take place in Cambridge, UK, from 5-18 September. The closing date for application is 8 April. Further information can be obtained from D.A. Caton, Scientific Conference Secretariat, CERN, 1211 Geneva 23, Switzerland.

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Dr. W.S.C. Williams,
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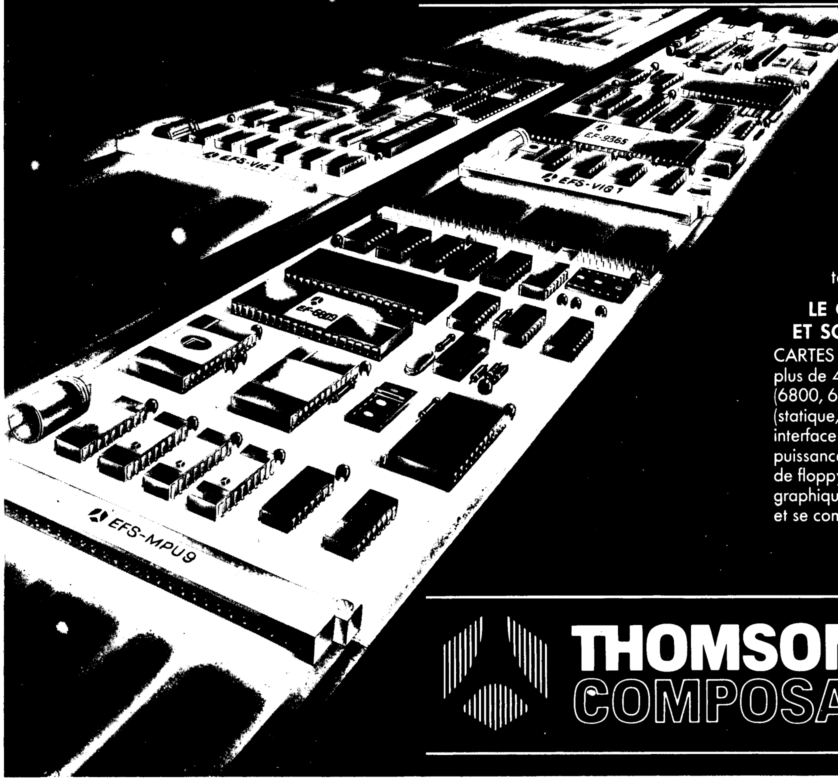

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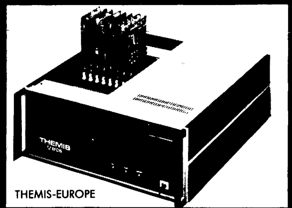

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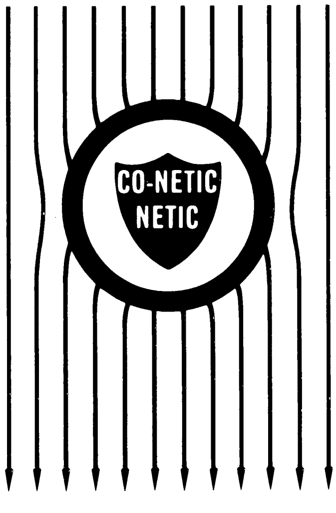

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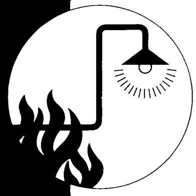

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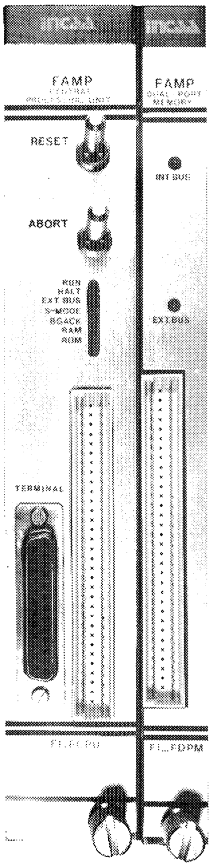

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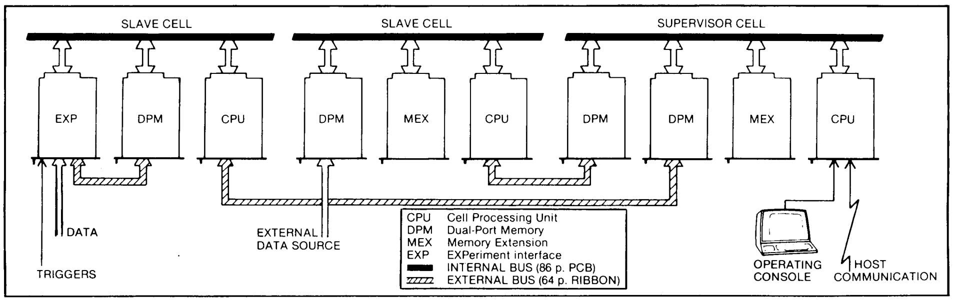

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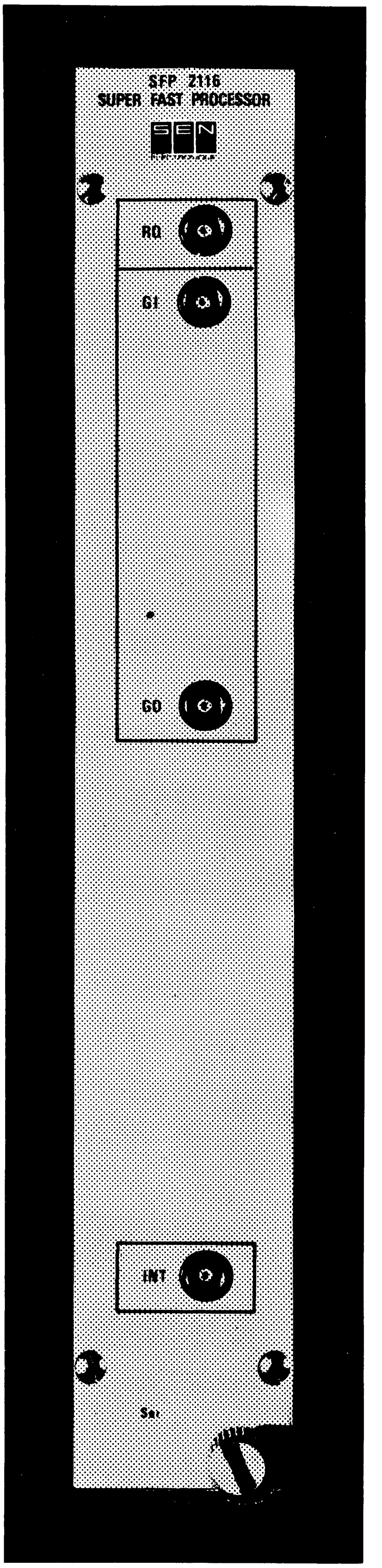
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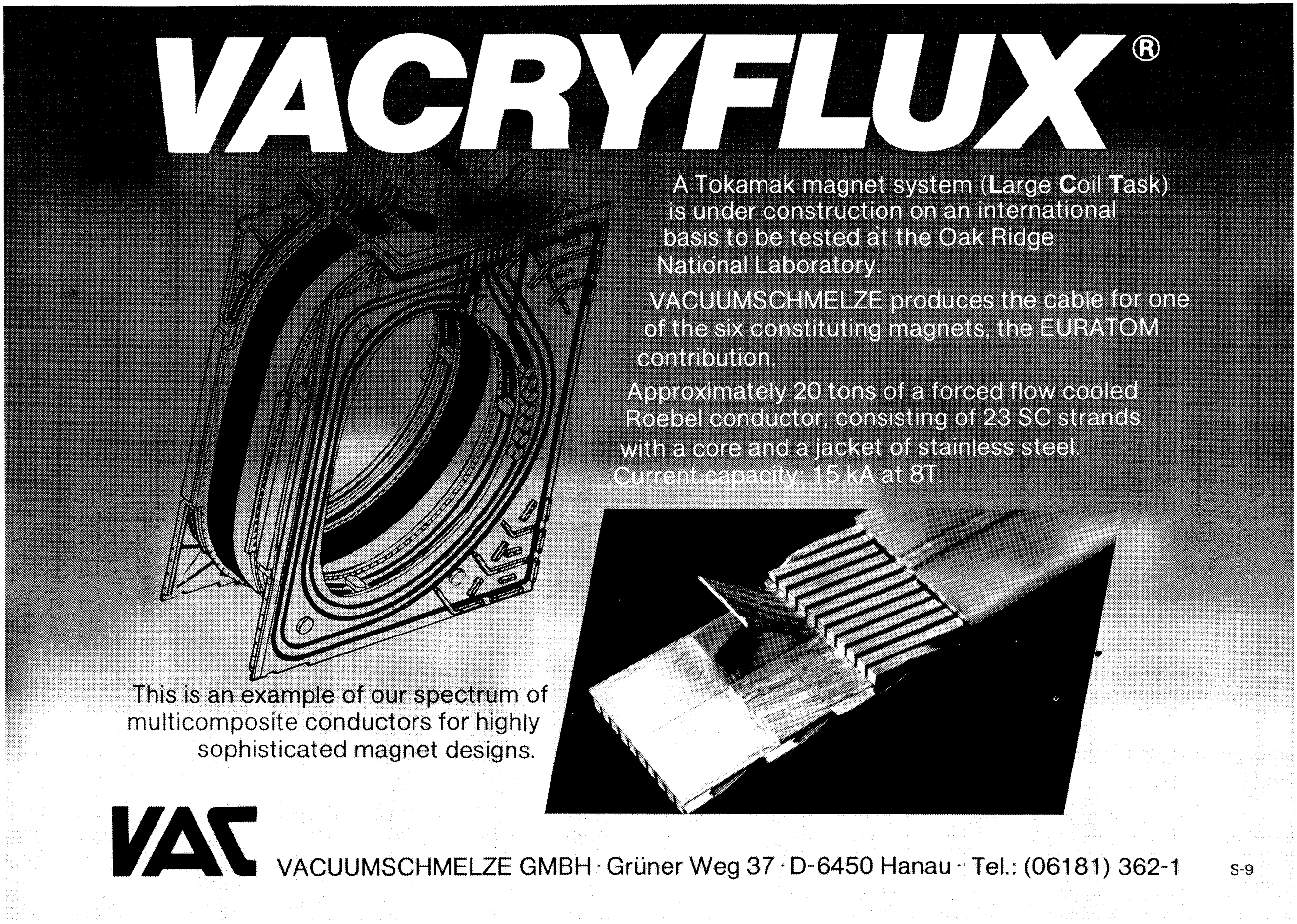

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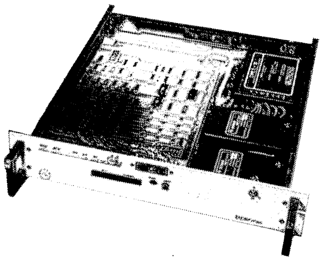

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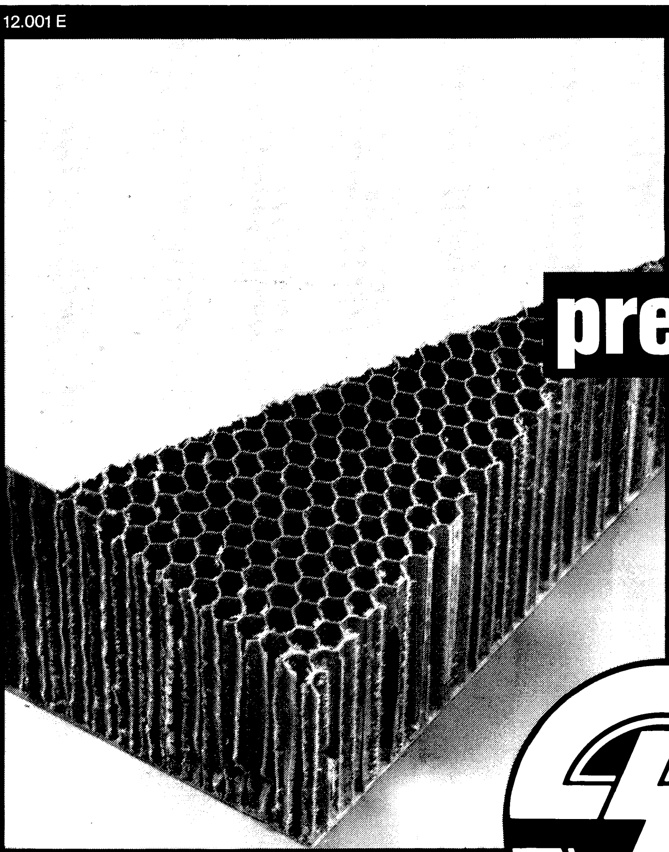

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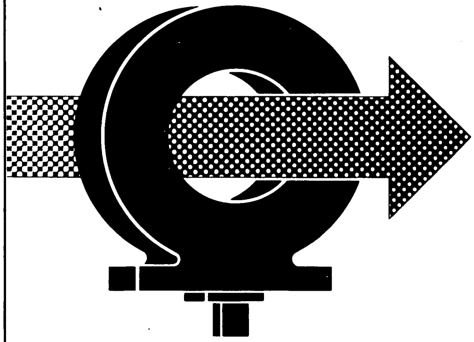

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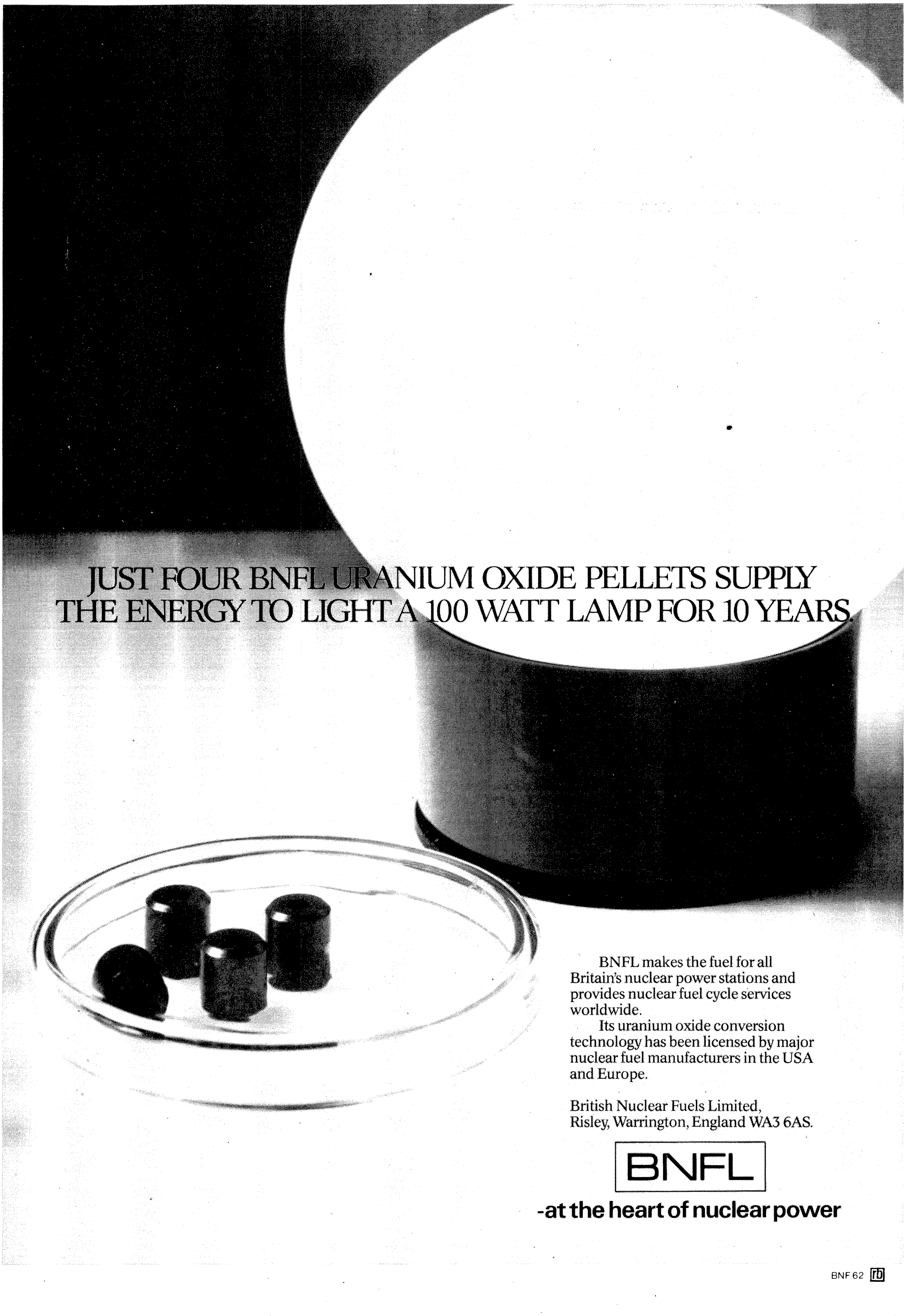

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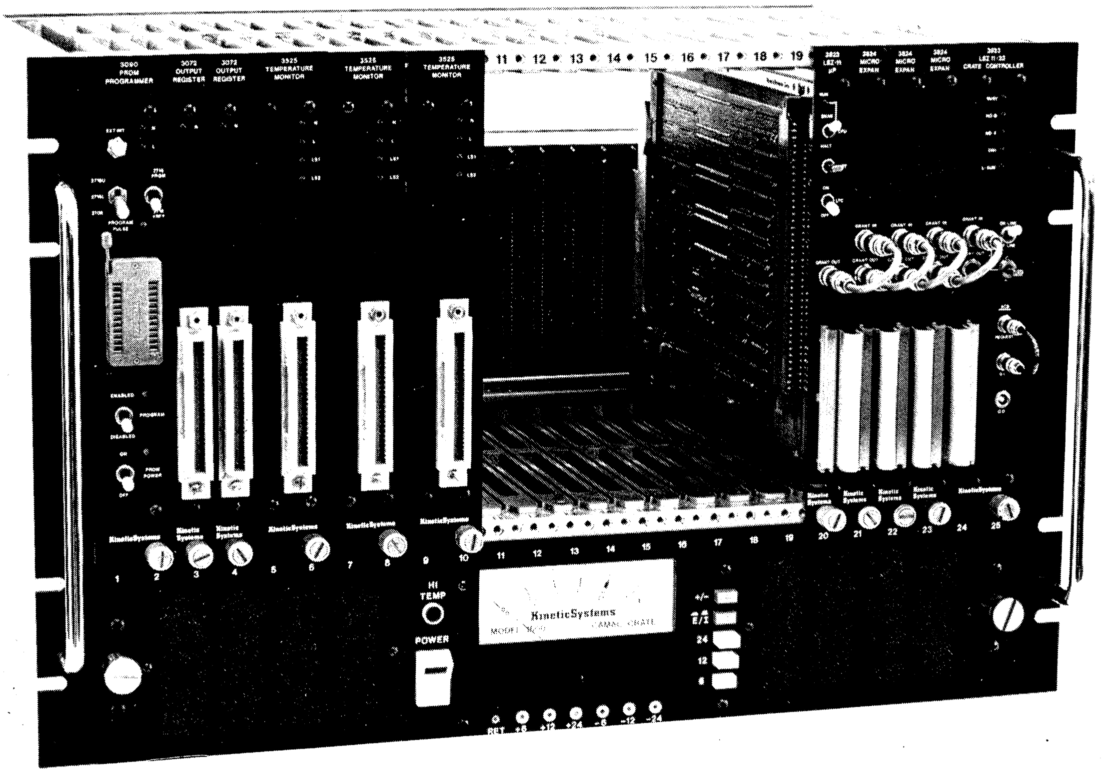

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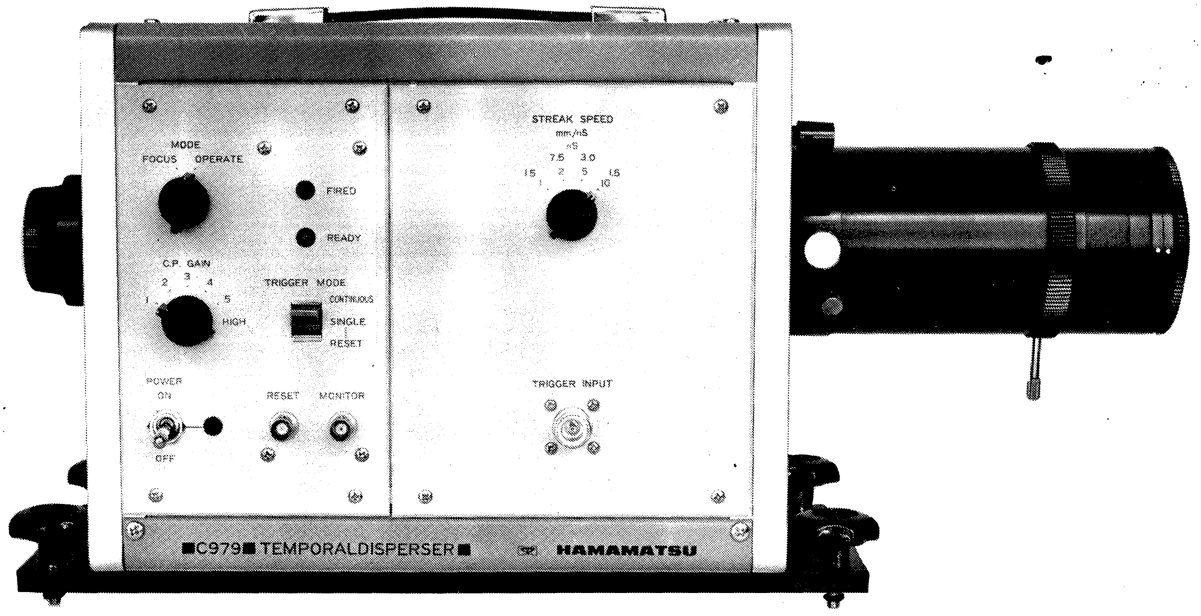
Space (page)	Actual size (mm) width by height	Cost per insertion (Swiss Francs)			
		1 insertion	3 insertions	5 insertions	10 insertions
1/1	185 × 265	1550	1500	1450	1350
1/2	185 × 130 90 × 265	850	820	800	750
1/4	90 × 130	480	450	430	410

Supplement for:	
— each additional colour	1450 SwF
— Covers:	
Cover 3 (one colour)	1750 SwF
Cover 4 (one colour)	2250 SwF
Publication date	1st of month of cover date:
Closing date for positive films and copy	1st of month preceding cover date The cost of making films and of translation for advertisements are charged in addition.
Screen (offset)	60 or 54 Swiss (150 English) Advertisements cancelled after 1st of month preceding cover date will be invoiced.

Advertising space is limited to 50% of contents and insertions are selected on a strict first-come first-served basis.
These rates are effective for the year 1982.

All enquiries to:
Micheline FALCIOLA / CERN COURIER - CERN
CH-1211 Geneva 23 Switzerland
Tel. (022) 83 41 03 Telex 2 36 98

NEW TECHNOLOGY REDUCES PRICES 33% ON STREAK CAMERAS



Now industrial and university laboratories can afford Hamamatsu cameras for time resolved spectroscopy and other fast kinetics research.

New manufacturing technology and increased production volume has permitted a 33% price reduction on fast and slow Temporaldisperser® Streak Cameras. These are the same precise, dependable cameras that have been consistently chosen over the competition in comparative performance tests.

Each Hamamatsu streak camera features a streak tube with a built-in microchannel plate for weak signal amplification of greater than 3 X 10^3. Since no external image intensifier is needed, the camera is dependable, compact and easy to use. Precise shot-to-shot reproducibility is better than 95%.

Your industrial or university R & D laboratory now can afford a streak camera, or an entire system, for fast kinetics research. With the entire Temporaldisperser® System, you'll be able to see results as they happen in the 3 dimensions of intensity vs. time vs. position.

For immediate information about these versatile and affordable streak cameras and systems, call for a demonstration in our Fast Kinetics Applications Laboratory. Or write for our new brochure and price lists.

CALL OR WRITE FOR NEW BROCHURE

HAMAMATSU

HAMAMATSU CORPORATION • 420 SOUTH AVENUE • MIDDLESEX, NEW JERSEY 08846 • PHONE:(201) 469-6640
International Offices in Major Countries of Europe and Asia.

Ventron

Ein umfassendes Angebot an Metallen und Chemikalien

- Metalle von technischer bis höchster Reinheit als Pulver, Stäbe, Drähte, Folien...
- Chemikalien von A-Z (Anorganika-Metallorganika-Organika)
- Standards für AAS und Massenspektroskopie
- Deuterierte Lösungsmittel
- Verbindungen mit stabilen Isotopen....

Fordern Sie unsere Kataloge an!

Ventron GmbH
Postfach 65 40, Zeppelinstraße 7
D-7500 Karlsruhe 1
Tel. (0721) 55 70 61, Tx. 07 826 579 vent d

SOROC TECHNOLOGY, INC.

IQ 130

Das Bildschirmterminal mit mehr Möglichkeiten zu kleinem Preis.

Speziell interessante Konditionen für Wiederverkäufer und OEM-Kunden.

Qualität - Kontinuität - Service

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CH-5405 Baden-Dättwil
Telex 54070
Tel. 056 84 01 51

Av. Louis Casaï 81
CH-1216 Genève
Tél. 022 98 78 77

HOTCHKISS-BRANDT SOGEME

groupe THOMSON-BRANDT

25 rue de CHONY - 26500 BOURG LES VALENCE - BP 434 - 26004 VALENCE - Tél. (75) 42.91.42. - TELEX 345741 BRGLV
239 Boulevard ANATOLE FRANCE - 93200 SAINT-DENIS - Tél. (1) 243.32.62.

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Etablissement de cahiers des charges
Travaux de laboratoires :
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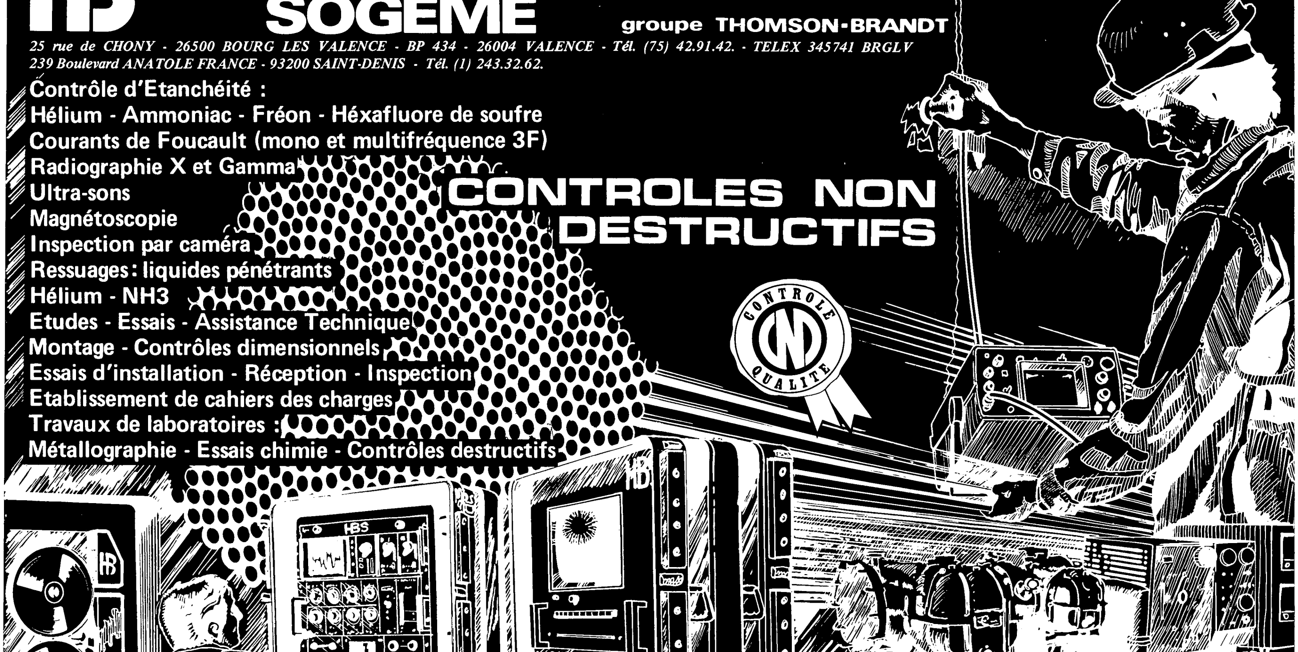
CONTROLES NON DESTRUCTIFS



Radiation Detector Research

Oil and Gas Well Logging Applications

Schlumberger, the world leader in oil and gas well logging services, is expanding its Ridgefield, Connecticut research facility as part of a continuing program to provide new and better measurements for the oil industry. Because of this growth, we now have openings for Ph.D. scientists in our Nuclear Department. In particular, we are looking for a key scientist with at least 5-10 years experience in radiation detectors research to spearhead our advanced detectors program.

The objectives of the advanced detectors program are to track detector technology, develop expertise in new or improved neutron and gamma ray detectors for borehole use, and facilitate their introduction into oil and gas well logging tools. Improved detector capabilities will both enhance existing, as well as foster new logging techniques.

The ideal candidate will possess the ability to find innovative solutions to technically difficult problems, be able to perform independent research and display technical leadership in the field.

Schlumberger-Doll Research supports the oil and gas well logging services of Schlumberger Limited. These services originated with Schlumberger in 1927 and today, company well logging teams operate in about 80 countries.

This opportunity offers excellent salary and company benefits. If you are interested, please send a resume in confidence to: Stephen A. Kvance, Schlumberger-Doll Research, P.O. Box 307, Ridgefield, Connecticut 06877 U.S.A., (203) 438-2631 An Equal Opportunity Employer M/F/H

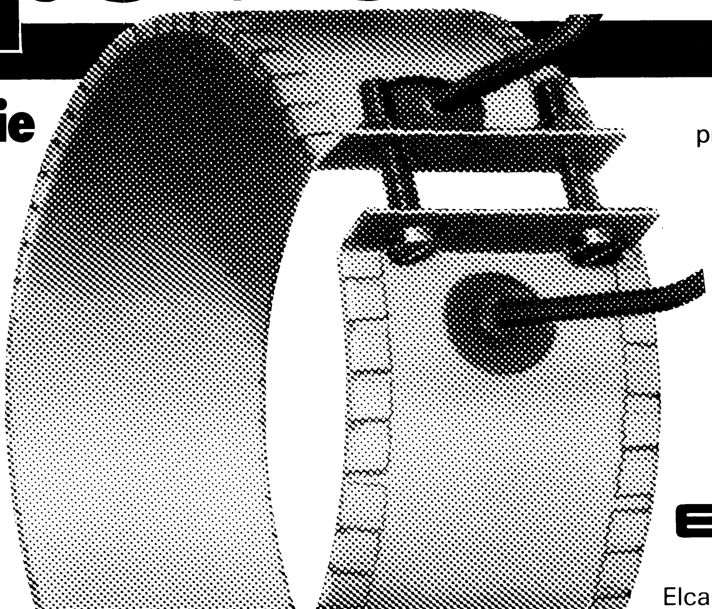
Schlumberger-Doll Research

Schlumberger

Corps de chauffe

pour l'industrie des matières plastiques.

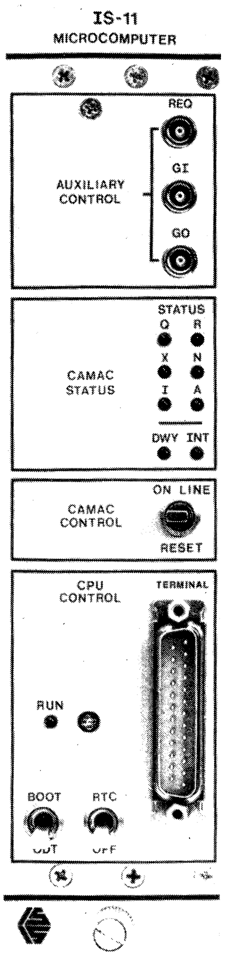
Qu'il s'agisse de corps de chauffe pour cylindres ou injecteurs, de corps de chauffe plats, de cartouches chauffantes, de barres chauffantes rondes ou plates, vous trouverez chez nous la solution qu'il vous faut. Qu'il s'agisse d'une pièce ou d'une série, vous serez servi avec le même soin proverbial. Demandez la documentation detaillée...



... ou soumettez-nous votre problème. Vous verrez que nous conduirons la chaleur là où il vous la faut.

elcalor aarau

Elcalor SA, Dépt. Corps de chauffe
5000 Aarau, Tél. 064-25 33 88
Télex 981 143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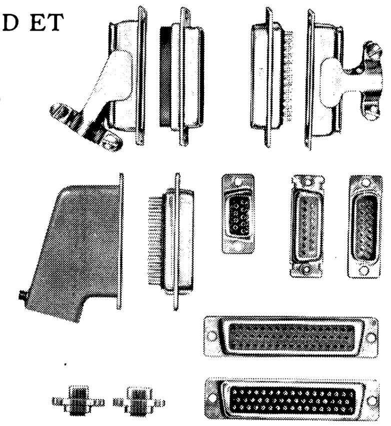
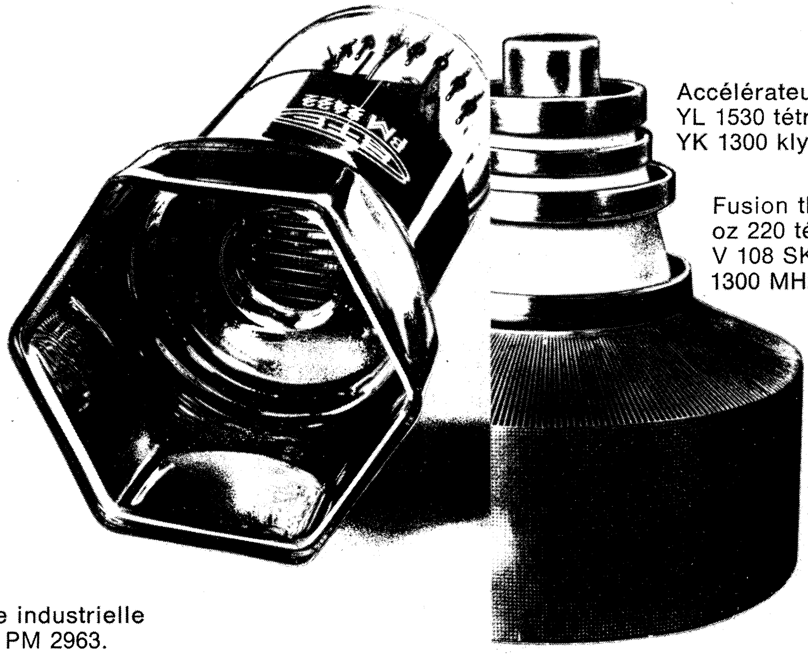
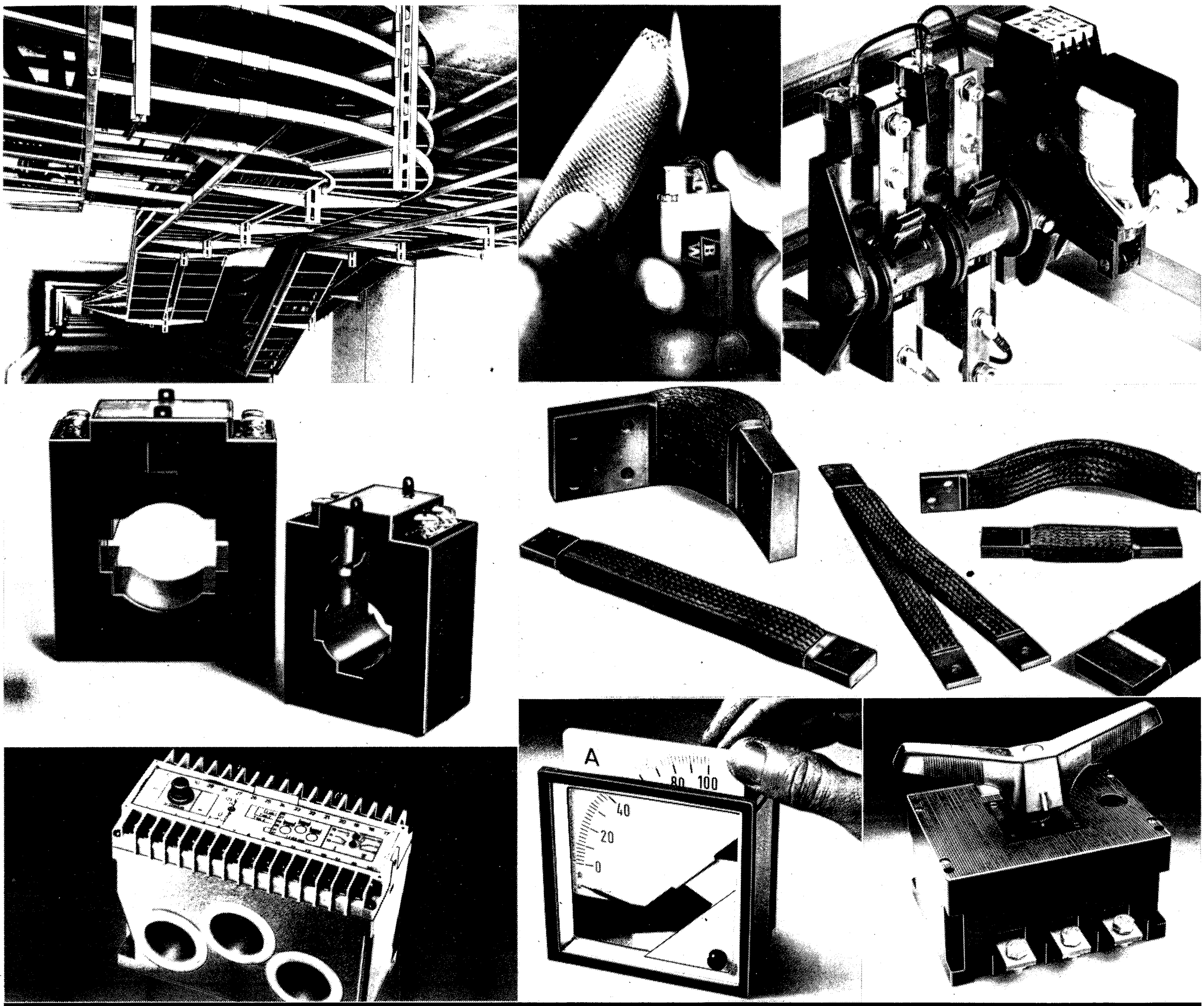





PARTICLE
DETECTION?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Kick the liquid nitrogen habit...

use a DISPLEX® Cold Trap

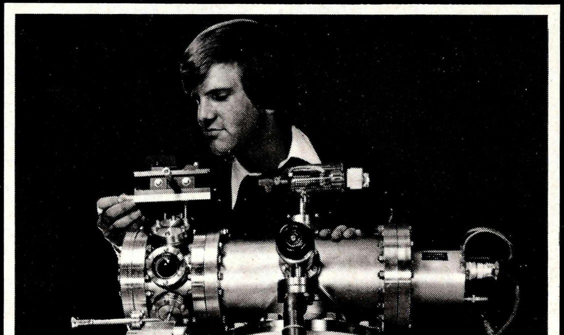
Diffusion pumps have an unending need for liquid nitrogen. And LN_2's not inexpensive these days! The new DISPLEX Refrigerated Cold Trap can quench that thirst forever.

The DISPLEX unit shown here is saving the Cornell Chemistry Facility For Laser Spectroscopy at least 350 liters weekly in LN_2 consumption.*

It's a simple system, comprising a reliable DISPLEX closed-cycle cryocooler with water-trapping panels, packaged in a compact spool assembly. It can replace your LN_2 guzzler in minutes!

- **No more boil-off losses**
- **No more messy (and tricky) fills and spills**
- **No more consummables. A dime's worth of electricity an hour powers it.**

Payback? With steady use, a DISPLEX Cold Trap can pay for itself in as little as six months. Send for details.

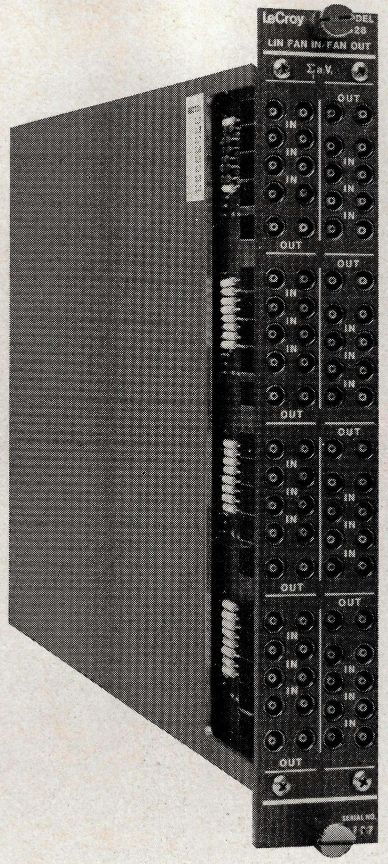


**Cornell had been using more than 50 liters a day in maintaining continuous vacuum on this multiphoton ionization source mass spectrometer used for studies of photofragmentation dynamics.*

Air Products

ADVANCED PRODUCTS
Air Products and Chemicals, Inc.

1919 Vultee Street, Allentown, PA 18103
(215) 481-8355 ● Telex: 84-7416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MODEL 628
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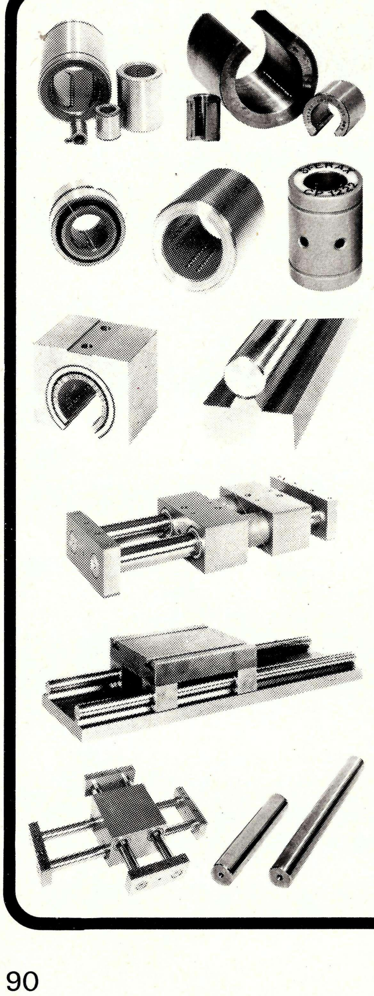
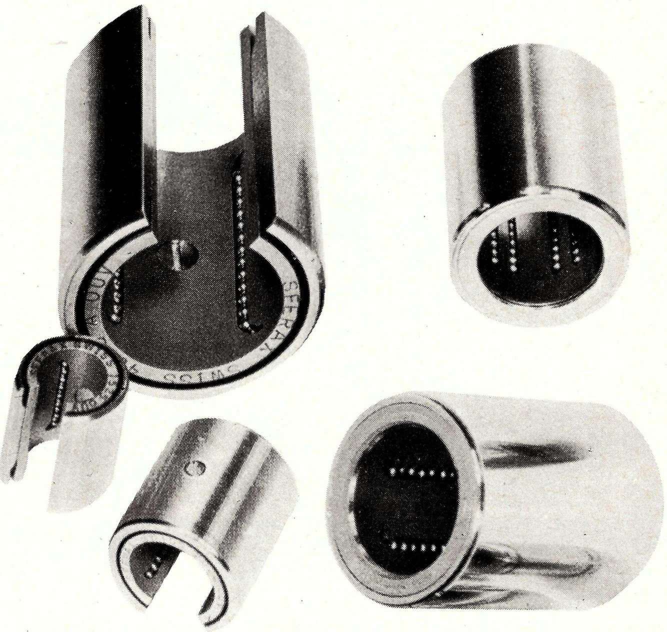
OUT
SERIAL NO.




SFERAX
SWISS

EIMAC's 4CW300,000G Power Tetrode. A new generation of high-performance power tubes.

EIMAC's 4CW300,000G combines all the desired features transmitter designers look for: high peak plate current, low grid emission, low internal capacitances and low internal inductance. This is the first of a new generation of high performance power tubes for LF, HF, VHF and pulse service.

Laserfab pyrolytic graphite grids

The control grid and screen structures of the 4CW300,000G are precision-cut by a laser beam. Each element is monolithic and combines extremely low coefficient of expansion with low structural inductance. These features permit the 4CW300,000G to have a very high transconductance—10^6 micromhos—and allow efficient, high-frequency operation.

Rugged mesh filament

The EIMAC mesh filament provides exceptionally high peak plate current and permits low plate voltage operation. This leads to power supply economy, making the 4CW300,000G the economic choice for 300 KW AM broadcast service or long-pulse switch service, each of which demands a reserve of peak emission.

Improved anode structure

EIMAC's multi-phase cooling technique provides high plate dissipation to extract heat evenly and quickly from the anode, contributing to long tube life and operating economy.

EIMAC expertise

EIMAC's expertise in electron ballistics pyrolytic grid production, thermodynamics and circuit techniques combine to bring tomorrow's tubes for today's transmitter designs. More information is available from Varian EIMAC. Or the nearest Varian Electron Device Group sales office.

Electron Device Group
Varian EIMAC
Application Engineering
Department
301 Industrial Way
San Carlos, CA 94070
Telephone: 415•592-1221, ext. 218

Varian AG
Steinhauserstrasse
CH-6300 Zug, Switzerland
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