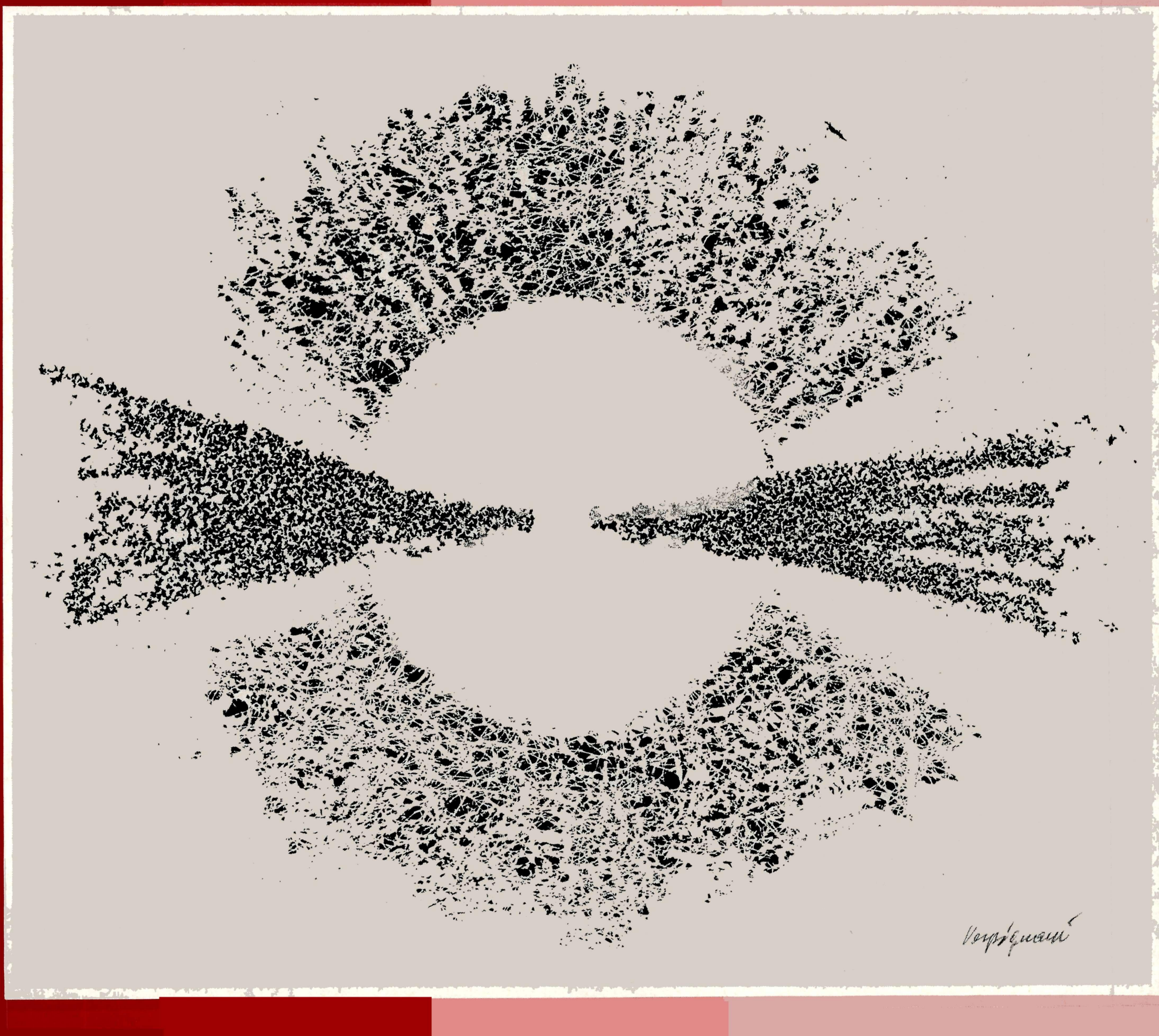
CERN COURIER

NO. 3 VOL. 16 MARCH 1976



CERN COURIER, Journal of High Energy Physics, is published monthly in English and French editions.

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Printed by: Presses Centrales Lausanne
1002 Lausanne, Switzerland
Merrill Printing Company
765 North York, Hinsdale, Illinois 60521, USA

Published by: European Organization for Nuclear Research,
CERN, 1211 Geneva 23, Switzerland
Tel. (022) 41 98 11
Telex 23698

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Cover photograph: A vision of electron-positron annihilations by the Italian painter Renzo Vespignani which brought some artistic relief to a scientific week at Frascati at the beginning of March. A Meeting, sponsored by ECFA, was held to discuss the experimental programme at the 19 GeV electron-positron storage ring, PETRA, which is being built at the DESY Laboratory.

And another?

At the New York meeting of the American Physical Society in February a Columbia/Fermilab/Stony Brook team, lead by L.M. Lederman, presented evidence for the existence of a particle which they have called Upsilon. The fascination of this new object lies in the fact that it is the heaviest yet seen (around 6 GeV) and is surprisingly stable.

The team was looking at the production of electron-positron pairs from a beryllium target hit by 400 GeV protons from the Fermilab accelerator. The experimental technique is very similar to that used by the Brookhaven/MIT team of S.C.C. Ting in unearthing the famous J particle at 3.1 GeV. Sifting out electron-positron pairs from the spray of particles emerging from a bombarded target is experimentally very tricky but, like Sam Ting's team at Brookhaven, Leon Lederman's team at Fermilab have several years of experience at this difficult game. The Columbia contingent, for example, was busy studying 'heavy photons' at Brookhaven in 1968.

The detection system, installed in the Proton Center Laboratory at Fermilab, consists of a double arm spectrometer symmetrically positioned at the target. The arms are identical and each consists of a collimator, a magnet, scintillation trigger counters, multiwire proportional chambers, scintillation hodoscopes and, finally, a lead/lead glass calorimeter which is the main detector for electron identification and energy measurement. The aim of the experiment was to search for high mass particles extending beyond the mass range which is available to the MIT/Brookhaven team and the IISN/IPN Orsay team at CERN. The Fermilab experiment can scour the mass region from 2.5 to 20 GeV.

When an electron and positron are spotted and their properties measured, it is straightforward to calculate the mass of the object from which they could have emerged. If the same mass occurs repeatedly, it is likely that a particle of that mass exists, one of the ways in which that particle can break-up being to produce an electron and a positron. This was the route to the J particle — measurements on the emerging electron and positron repeatedly added up to an object of mass 3.1 GeV.

Moving to higher energies, the probability of seeing electron-positron pairs is expected to fall rapidly. For example, one theory predicts that at 10 GeV there will be only one heavy photon which can give an electron-positron pair for every 10 000 heavy photons at 2 GeV. Even at 2 GeV such a photon crops up only once in a million interactions in the target. This underlines how difficult it is to extend the search to higher energies.

The search began in the summer of 1975 and the equipment was tamed so that good data could be taken from about Autumn. The 3.1 GeV particle was seen clearly. The first interesting observation was that the electron-positron pairs were considerably rarer than expected. They were seen at a rate of about one every two days with 5×10^9 interactions in the target per pulse.

By the time the preliminary findings were made known in New York, 27 events in the 5.5 to 10 GeV range had been measured. The excitement comes from the fact that eleven of these events cluster between 5.8 to 6.1 GeV. The experimenters estimate that there is a 50 to 1 chance that this means a particle of mass 5.97 GeV which can decay into an electron-positron pair.

It also looks as if the particle, called Upsilon, is surprisingly stable. Such a heavy object should have so many ways in which it could break up, that it should not hang around for long. Something special about its properties would be needed to ensure long lifetime. This recalls the J/ψ story again. The high stability of the 3.1 GeV particle is assumed to be the result of a special property known as charm. J/ψ cannot easily get rid of charm and hence is highly stable. The charm property is assumed to be carried by a new type of quark — charmed quark.

If Upsilon is confirmed and its stability is high, what is the cause this time? Is charm appearing again in some other combination? Do we need another property to explain Upsilon? Will this imply yet another quark? We have already had a hint that our list of leptons might have to grow beyond four with evidence for a new heavy lepton at the Stanford SPEAR storage ring. Is this a hint that our list of sub-hadrons (the quarks) might also have to grow beyond four?

The evidence for Upsilon is impressive but needs more bolstering before any of these questions can be seriously tackled. The team at Fermilab may switch over to the detection of muons in the spectrometer arms, looking for the Upsilon decay into a positive muon and a negative muon. This decay is expected to occur at a rate some 5 to 10 times higher than the electron-positron decay but it can be even more difficult to sort out from the background. Another help towards increasing the rate is that a forthcoming reshuffle in the Proton Center Laboratory should give the experiment 100 times the present proton intensity onto their target.

More information is eagerly awaited because the evidence for Upsilon has already given the melting pot another good stir.

Members of the team are David Hom, Leon Lederman, Hans Paar, David Snyder, Jeffrey Weiss and John Yoh from Columbia University, Jeffrey Appel, Bruce Brown, Charles Brown, Walter Innes and Taiji Yamanouchi from Fermilab, and Dan Kaplan from Stony Brook.

Computing at CERN

Our most recent full review of developments in the field of computing at CERN dates back to the March 1972 issue. The subsequent years have been more concerned with consolidation than with further major developments and briefer news in our pages, which has up-dated the 1972 review, has seemed adequate. During the past year there have been tortuous debates to try to map out the major features of the computing facilities which could cater for the foreseeable needs of the research programme at CERN.

In June 1975, these plans had advanced to the stage where the first authorizations for purchase of new computers could be requested from the relevant Committees. However, the probable budget restrictions of the next few years, which became clearer in the discussions prior to the December Council meeting, made it necessary to reappraise these plans and it is a considerably reduced scheme which finally received the approval of the Scientific Policy Committee and the Finance Committee at the end of February. The time seems ripe to describe the estimated needs and the plans which have been drawn up to meet them.

The ability of computer systems to handle the vast quantities of data pouring out from the high energy physics experiments is a crucial element of the Laboratory's research facilities. As the experimental programme grows or becomes more complex, the computing service has to keep in step. In 1975 the burden of work grew to the extent that the main central computers, based on a CDC 7600 which came to CERN in 1972, became 'saturated'. With the start of the experimental programme at the 400 GeV proton synchrotron on the horizon, it has become urgent to increase the available computing capacity and to match it to the evolving requirements of the experimental programmes at the CERN machines.

The present central computing service

The present central computing service, which has a 6500 and a 6400 as 'front-end' machines to the 7600, took longer to tame than expected. By now, however, it is working well with, usually, less than 5 % unscheduled down-time and periods of ten hours between the occurrence of faults. The volume of work is reflected in the fact that it has handled as many as 14 500 jobs in a single week involving the mounting of over 2500 magnetic tapes. Another measure of quantity, though not necessarily of quality, is the fact that in a year it churned out information on about 40 million pages of computer paper. The CERN Computer Newsletter calculated that this 'ecologically horrendous consumption' is equivalent to a stack of paper 4 km high or a strip stretching from CERN to Vladivostok!

Support of the experimental programme absorbs almost 80 % of the central computer use (65 % going to electronic type experiments and 15 % to bubble chamber experiments). This volume represents only about 40 % of the total computing required to back up the experimental programme. About 60 % is carried away to national computing facilities in the Member States, particularly to well developed computer centres such as Rutherford, Daresbury, Saclay, Munich and Karlsruhe...

The CDC 7600 has three very fast fixed disks directly attached to it but all other peripheral equipment is linked to the front end machines. To cope with the physical spread of the CERN site, making access to the power of the central computers easier, the system has tentacles reaching out into many areas of the Laboratory where RIOS (Remote Input Output Stations) are installed. There are eleven of these stations equipped with teletype, display screen, card-reader and line-printer, enabling users to submit jobs to the central computers without moving far from their place of work.

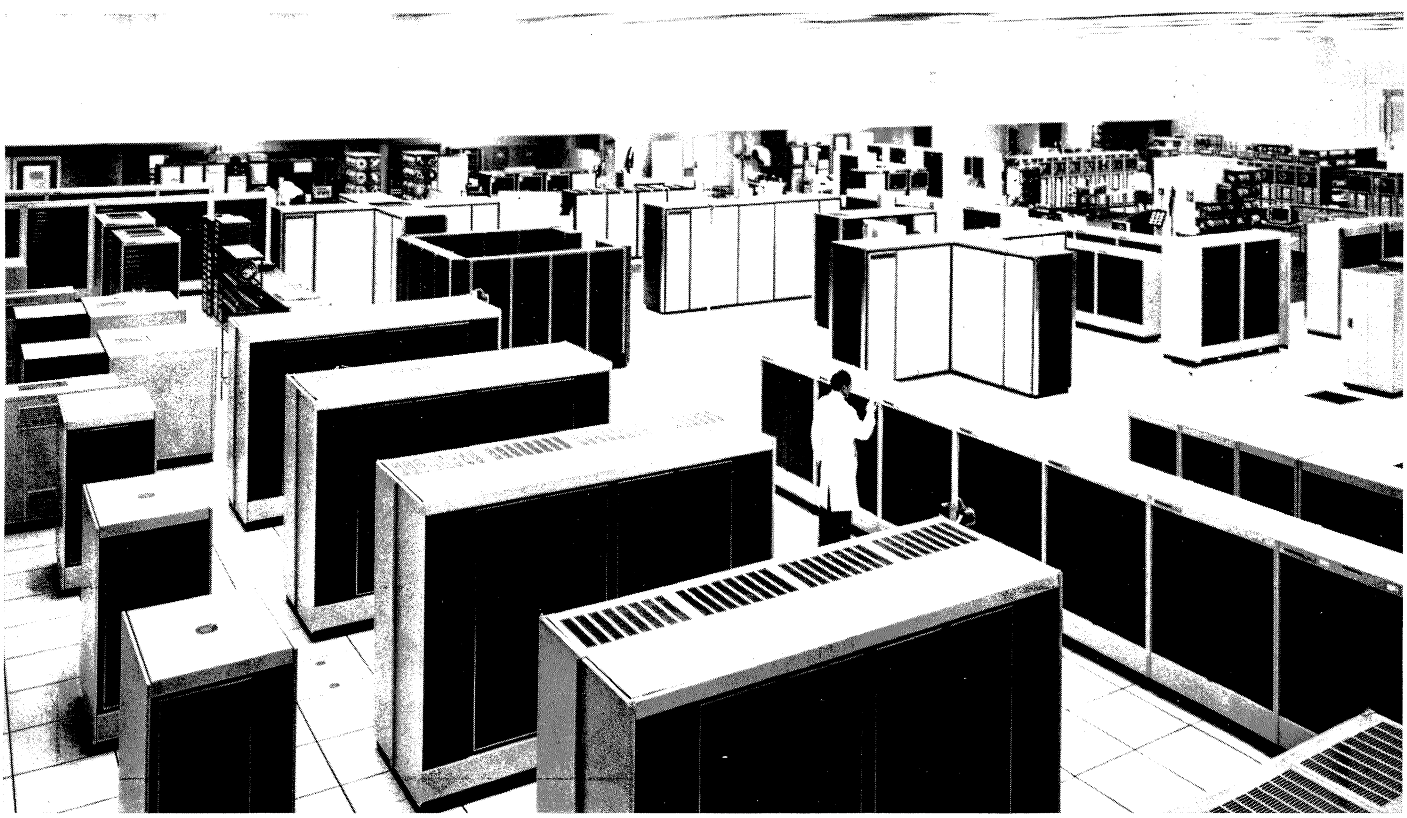
The computer centre also has what is called the FOCUS system — a network of high speed links to small computers on-line to experiments. The progress of an experiment can thus be checked much more thoroughly by using the power of the large computers rather than by using the small computer alone.

In addition, sprinkled around the site are many other computers (bringing the total to over 200, involved in bubble chamber film measuring systems, accelerator control, administration...). They range in size from large on-line computers, (such as the CII 10070/EMR 6130s attached to the Omega spectrometer and the ISR Split Field Magnet detectors) to a host of mini-computers (such as Nord 10s, HP 2100s and PDP 11s).

Trends in computer use — volume, date storage and accessibility

We should turn now to the trends which have dictated the proposed extension of the central computing facilities and the philosophy behind their future use.

We start, of course, with the physics. In general it is moving to the investigation of high energy phenomena with the operation of the Intersecting Storage Rings being supplemented at the end of this year by the start of the SPS. These phenomena have the feature of higher multiplicity — many more particles emerge from higher energy interactions — and the computer programs have to pick out information on more particles and have to sort the wheat from the chaff in interactions of greater complexity. The programs for pattern recognition



CERN 161.11.73

The computing centre at CERN where the main burden of the computing service is taken by a CDC 7600 computer, 'front-ended' by a 6500 and a 6400. In 1975, the capacity of the existing service became saturated and, particularly to confront the added load of the start of the experimental programme of the 400 GeV proton synchrotron in 1976, a further extension of computing capacity is needed.

grow in complexity correspondingly.

In addition to greater complexity, they have to cope with a greater volume of data. The new detection systems, particularly multiwire proportional chambers and drift chambers, are able to record multiparticle events and in addition they can take data at much faster rates. It is already not unusual for an experiment to accumulate a thousand magnetic tapes of data and this trend is unlikely to ease off. The Split Field Magnet multiwire detection system is beginning to look at high multiplicity events with a high data taking rate and absorbs some 23 % of the total computing time. This is a guide to the future.

One interesting approach to the problem of coping with such volumes of data is the use of special digital hardware processors (see the report of the Frascati Instrumentation Conference in the June issue 1973). These are devices to tackle specific tasks in handling the data pouring out from the detectors. They can take over repetitive calculations doing sums in parallel rather than in sequence. Such calculations occur in pattern recognition, for example, and can be handled faster and cheaper by the processors than by using the big computers. Processors can also be used in event selection, saving further computer time by rejecting events on simple criteria.

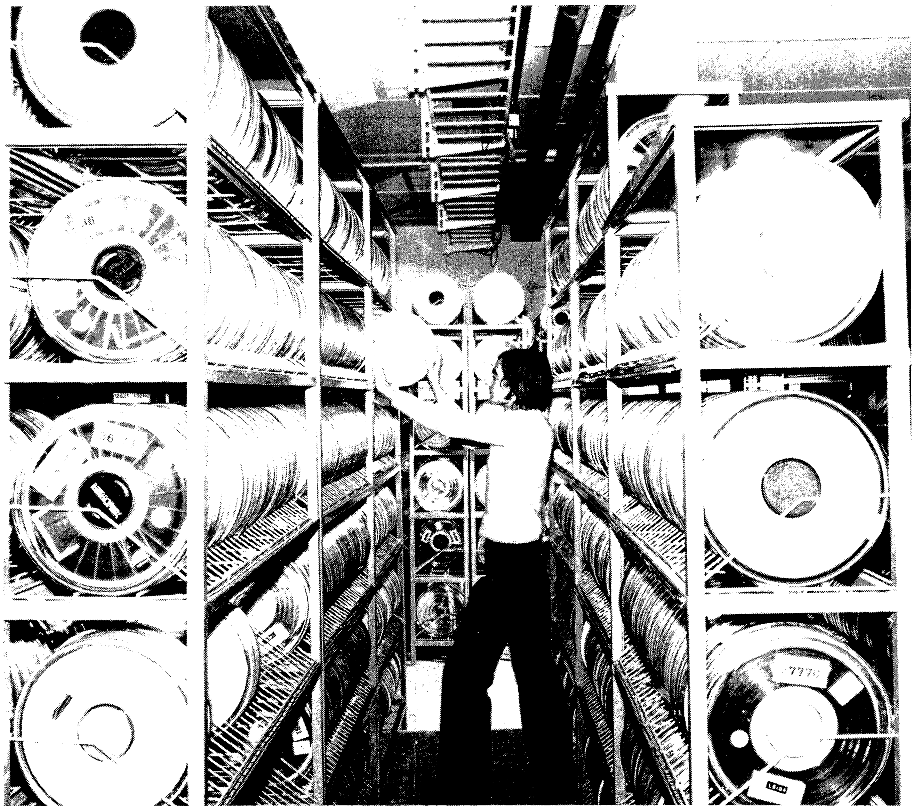
Hardware processors developed at CERN have been tested in a charmed particle search experiment in intersection region I-6 of the ISR and other processors are being developed for an experiment which will begin at the SPS next year. It is difficult yet to assess the full impact of these processors on the problems of data reduction but it is hoped that they will make a substantial dent in the volume of computing needed for the experiments.

One of the important problems to be overcome in the future computing facilities at CERN is that of data storage. Another consequence of the evolution of physics as described above is that the present vast store of information on magnetic tape can only get vaster. There are over 95 000 tapes already in store at CERN and they are being added to at a growing rate — 10 000 in 1974, 20 000 in 1975. Other methods of storage have been investigated (see March 1972 issue) but none was commercially available a few years ago which could reliably meet CERN's needs. However, recently IBM has started to deliver mass storage devices with an on-line capacity of up to 3×10^{12} bits.

There have been considerable advances also in 'conventional' magnetic tapes. The types normally used at CERN have been improved to hold information with a density of 1600 bits per inch and tape units now exist capable of handling 6250 bpi with better techniques for writing information on and reading information off the tape. Such high density tapes are in successful use, for example, at Daresbury, DESY, Rutherford, Stanford . . .

One technique, the use of video tape capable of holding several hundred times the information of a normal magnetic tape, has been tackled at CERN itself. Successful operation of an IVC video tape unit incorporated in the data acquisition system of the experiment mentioned above in intersection region I-6 of the ISR was reported in the November issue. Other appropriate video tape units have recently come onto the market.

There is another major concern and that is to make the computing power more easily accessible to the experiments and to all other computer users throughout CERN. This calls for a high speed data communication network bringing all the smaller computers into contact with the big central computers. Such networks, on a smaller scale, have already been very



CERN 223.3.74

A reflection of the data storage problem is this collection of tapes. Over 95 000 are already in store and they are being added to at a growing rate. 10 000 found their way onto the racks in 1974, and 20 000 in 1975.

successfully implemented for example at the Daresbury and DESY Laboratories.

The new generation of experiments need on-line access to large computers much more than has been necessary up to now. The FOCUS system, mentioned above, has helped present experiments to do some checking as to how their data was looking. This becomes more important when the capital investment in the detection system goes up, when the data becomes more complex and when the data taking rate is increased.

The future computing facilities at CERN

The future computing facilities at CERN are designed to respond to these needs. First of all, additional central computing capacity will be provided to cope with the volume of computing which will be generated by the research programme. Secondly, the central computer will confront the problems of data storage by being able to handle high density magnetic tapes and possibly later by being linked to a mass storage device. Thirdly, a high speed data communications network will be provided to make more computing power available on-line to the experiments.

The provision of more central computing capacity will be met by an IBM 370/168 with 3 megabytes of memory. The new computer will be installed at CERN by the end of 1976 and it is an important objective to bring it into action as quickly as possible since the SPS experimental programme will add to the existing computing load as from that time. Fortunately the 370/168 is a proven computer configuration with over 300 of them already in operation (150 in Europe). Training of CERN staff will begin soon and IBM is expected to provide appropriate on-site support.

This additional computing power is less than was envisaged a year ago when the acquisition of a second CDC 7600 was part of CERN's plans. Priorities will therefore have to be assigned in allocating computing time and, in general, it is likely to be running experiments that have first call. The experimenters will have to carry a higher percentage of the computing load back to their Laboratories in the Member States.

The IBM 370/168 will handle high density (6250 bpi) magnetic tapes on six of its ten tape drives. Initially, it will have two printers and one card reader with options for extensions in terms of tape units and printers and of the addition of more memory or a fixed head disk. A further major option is the addition of a mass storage device of 0.82 × 10^{12} bits capacity.

The provision of a high speed network will be based on the use of small computers joined by high speed data links. The computers will act as concentrators linked to experimental area support computers, switching data streams from their sources to their desired destinations.

The installation of a network covering the CERN site will take some time and will not be in operation for the start of the SPS experiments in the West Area. These experiments may begin linked to the computer centre via the FOCUS system.

The network will be a general purpose facility. It has to be flexible, so as to cope with the wide variety of needs, and it has to be easily extendible to cope with future needs, some of which cannot be predicted at the moment.

A possible future element of the network which could become heavily used in the future is a 'gateway' out to other Laboratories. At present, Rutherford (who have an extensive 'work station' network of their own external to the Laboratory) and Saclay have post office telephone line links from CERN, through which their experimental teams can pass data to their home computers. There is a drawback in that the speed of data transmission over telephone lines is not high (9.6 kbits/s). The possibility of direct microwave links has been tested at Daresbury and the possibility of using other communication links (for example, using satellites) is being studied. These would be capable of some Mbits/s. There are European-wide discussions on these questions at the moment and we will be coming back to them in the near future.

Thinking about PETRA experiments

While bulldozers and scrapers were busy cutting the tunnel for the electron-positron storage ring, PETRA, at the DESY Laboratory far to the north, physicists from all over Europe (plus some from Japan, Israel and the USA) sat together in the Frascati sun to discuss experiments and detection systems for the new machine. Frascati was a very appropriate place to talk about storage rings since it houses ADONE — the first of the large electron-positron machines.

The meeting was sponsored by the European Committee for Future Accelerators, ECFA, and was organized by DESY and the Italian Istituto Nazionale di Fisica Nucleare, INFN. There were some 200 participants and only limited space kept the number down, indicating the great interest in higher energy electron-positron physics.

Like the Meetings organized by ECFA at Tirrenia to discuss the experimental programme at the SPS a few years ago, the aim was to have the participation of the whole European high energy physics community in the preparation of the PETRA programme.

There is one significant difference, however — the SPS is being built at CERN as a European machine, PETRA is being built at DESY which is a national Laboratory in the Federal Republic of Germany. It is the first time that European participation to this extent has been invited in the exploitation of a national machine. This reflects both the scale of the experiments which will exploit the machine (they are almost all likely to call for an investment of manpower and finance that requires international collaboration) and also the degree of integration which has been achieved in the high energy physics community.

PETRA (Positron Electron Tandem Ring Accelerator) will bring electrons and positrons up to collision energies of 2 × 19 GeV moving into an unpredictable range of physics. A number of introductory talks tried to convince the audience that theoretical physicists are not without imagination as to what might happen at PETRA energies but rarely have experimental results from an accelerator in a new energy range matched the predictions. They have usually led to surprising discoveries that had not been envisaged. It was perhaps with this in mind, that Professor A. Gigli, President of INFN, ended his opening address with the question 'What comes after PETRA?'

Gus Voss, who is project leader for PETRA, has not much time to be thinking so far ahead at the moment. He described progress up to the beginning of March and an updated version of the PETRA proposal was distributed. The major further change which emerged at the Frascati Meeting is to increase the length available for detection systems at the collision regions from 10 m to 15 m. Slides showing the excavations on the site and the first tunnel sections ready for casting in concrete were a reminder that the time available for bringing the initial experimental programme into shape is not long. A tight construction schedule plans to have colliding beams in July 1979. This is a challenge to the experimenters as well as the machine builders.

Electron-positron physics has exploded in interest since the Brookhaven, DESY, Stanford discoveries of the new family of heavy stable particles. The news from Fermilab, reported in our opening article this month, adds still more fuel to the fire. A completely new chapter in particle physics has opened and colliding beams are ideal for carrying the studies further. They are available at present up to collision energies reaching about 7 GeV. PETRA will hold beams with energies between 5 and 19 GeV and a collision energy range to 38 GeV will be open for investigation. The Berkeley/Stanford storage ring, PEP, will cover a similar energy range and its completion date is not likely to be far behind PETRA.

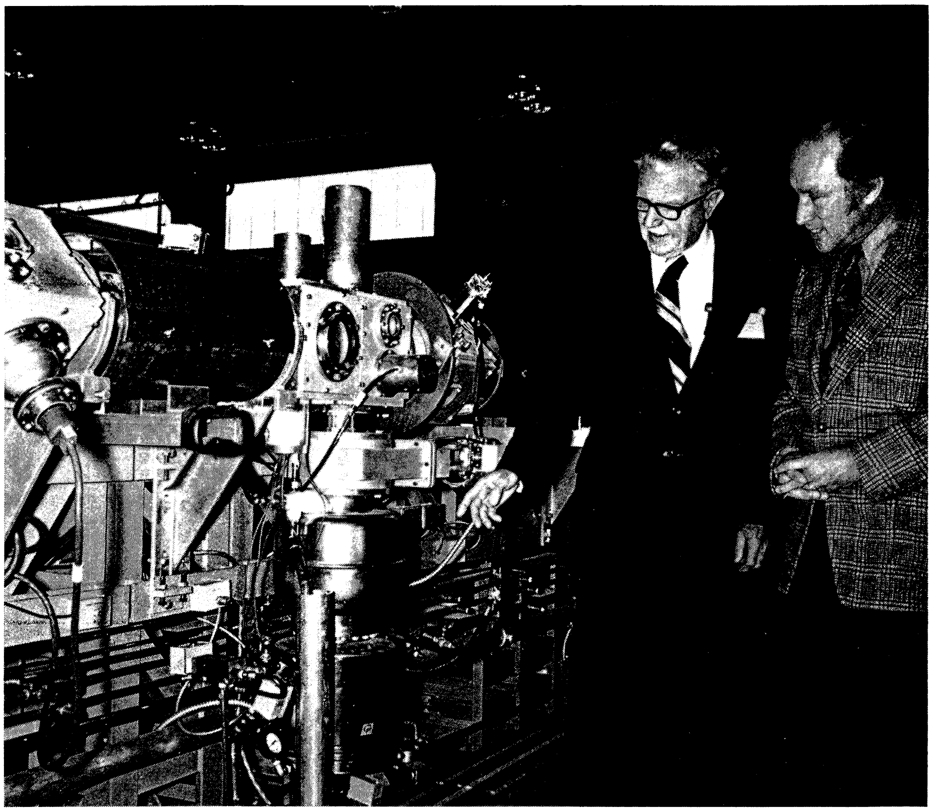
Reaction products from colliding beams fly from the point of collision into the surrounding sphere more or less uniformly (a theme which influenced Renzo Vespignani in his drawing on our front cover). Almost all of the detection systems for experiments presented to the Meeting tried to surround the interaction point as completely as possible. Proposals on detectors came from various European laboratories with one also from the University of Tokyo. Since the detection systems need to be ready in three years' time, the experimenters are really caught between two alternatives. Either they build a detector with conventional techniques with confidence that it will be ready in time, or they use more adventurous techniques (such as the aerogel Cherenkov counter or microchannels for a streamlined detector) and take the risk of higher costs and longer times. The discussions on detection systems, begun at the Meeting, will continue. Many contacts were made at Frascati which are likely to be the basis of the collaborations for the experiments.

In his concluding remarks, Helwig Schopper, Director of the DESY Laboratory, announced that a PETRA Programme Committee PPC will soon be established taking into account the opinions of an ECFA Advisory Committee and of the Extended Research Committee of DESY which has international participation. Proposals for the first generation of experiments should be submitted by the end of July 1976 following letters of intent which should be sent in as soon as possible (at the latest before the end of April). A Workshop on the PETRA programme will be held at DESY from 6-11 September and decisions concerning the first installations are anticipated in October.

Around the Laboratories

Canadian Prime Minister Pierre Trudeau (right) is introduced to the intricacies of the negative ion injection line at the TRIUMF cyclotron. The Prime Minister performed the official dedication of TRIUMF on 9 February.

(Photo Vancouver Sun)



TRIUMF Dedication and polarization

The official dedication of TRIUMF was performed by the Prime Minister of Canada, the Rt. Hon. Pierre Elliott Trudeau, on 9 February. The ceremony, which took place on top of the 5 m thick, 30 m square concrete shielding roof of the cyclotron vault, was attended by federal and provincial cabinet ministers, representatives of government funding agencies and officials of the four founding universities, as well as by an audience of over seven hundred staff and friends from TRIUMF, the experimental teams and the contracting companies.

During his speech Mr. Trudeau announced that the Canadian government will provide extra capital funds to bring the proton beam up to full intensity. At present the beam current is limited to 1 μA by the amount of shielding available. The extra funds — several million dollars — will make it possible to raise the beam current from the 520 MeV cyclotron to the design aim of 100 μA. The remainder of the shielding will be installed, the high current beam line completed and the 180 kW beam dump and thermal neutron source constructed. This work should be completed within the next year and a half.

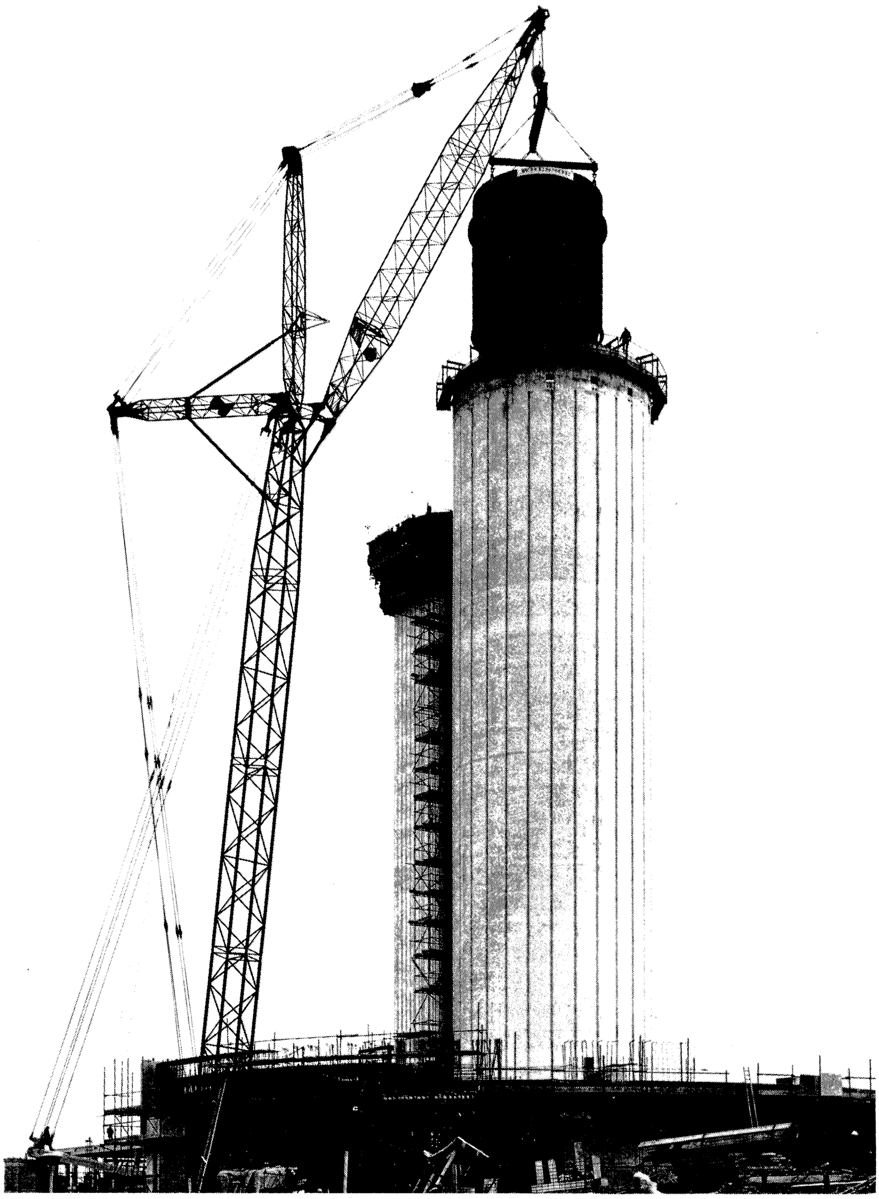
In announcing the federal grant, the Prime Minister gave two reasons for supporting the project: 'We must try to protect the best and to maintain a solid basis from which we can go forward in better times when we have more money to spend. Second, we must give priority to those projects that give the greatest value to society in relation to expenditure.'

Mr. Trudeau also commented on the co-operative nature of the TRIUMF project, which is a joint venture of the Universities of Alberta, British Columbia and Victoria, and Simon Fraser University: 'What I like here' he said, 'is that this is a project shared by four Universities. When I used to be connected with Universities, I always found it worrisome that each University considered it had to be a specialist in everything. We were spreading ourselves very thin and we did not have much depth. I understand that there is now a move amongst Universities to create centres of excellence and I certainly want to encourage this. The fact that four Universities co-operated on this project is something which pleases me very much and which makes me think that governments and tax-payers will be using their money more usefully here than by trying to have Universities which are all things to all students.'

The day following the dedication, a polarized beam was accelerated in the cyclotron for the first time. A polarization of 40 % was detected by scattering from carbon at 350 MeV, in agreement with that expected from the polarized ion source — a Lamb-shift negative hydrogen ion source — in the operating mode that was used. The intensity of the extracted beam was 20 nA out of 200 nA leaving the polarized source. When a solenoid short is repaired, it should be possible to raise the polarization to 80 %. The polarized source itself was built by G. Roy at the University of Alberta and installed and commissioned by J.L. Beveridge, P. Bosman, G. Dutto and S. Jaccard.

DARESBURY Towering NSF

The twin towers of the Daresbury Nuclear Structure Facility are a new feature on the north Cheshire skyline. Construction of the tower which will



The world's highest capacity crane lifts a pressure vessel section into the Van de Graaff tower at Daresbury. The sections weigh about 50 tons. Construction of the buildings to house the Nuclear Structure Facility (NSF) is well advanced. The photograph indicates progress on the Van de Graaff tower, the adjoining service tower and an experimental hall at the base.

contain a large tandem Van de Graaff and of its adjoining access tower has reached the top section where the injector room will be situated.

The NSF is designed to provide a wide variety of beams, from protons to the heaviest ions, for use predominantly in nuclear physics experiments. With a terminal potential of 30 MV, beam energies will be considerably higher than is possible from any other tandem machine. Negative ions injected at the top of the machine will be accelerated to the positive central terminal where they will be stripped of electrons and further accelerated away from the terminal to the bottom of the machine. A bending magnet will there fan them out into experimental areas.

To achieve such a high voltage, a thorough development programme on breakdown phenomena, on suitability of materials in high voltage environments, etc . . . has been carried out. A pilot machine (single-ended Van de Graaff with a voltage of 10 MV) has been used to test components under conditions as close as possible to those in the NSF. An important innovation is the use of a 'laddertron' (a string of conductor bars like the rings of a ladder linked at each end by insulating beads) rather than the traditional belt to convey charge to the central terminal.

The twin towers are the most striking sign of construction progress at present. Their size is dictated by the dimensions of the pressure vessel which encloses the accelerator structure. The vessel stands 45 m high and is 8 m in diameter. Vessel sections, weighing 50 and 75 tons, have recently been lowered into the tower, using one of the world's highest capacity cranes, and are now being welded together. After cleaning, a pressure test will follow using water for safety reasons rather than air. Sulphur hexafluoride gas will eventually be used at 7 atmospheres pressure when the machine is operating.

The roof is now being built on one of the experimental areas. It is here that sections of the accelerator stack will be assembled. Stack legs, of which there are eight per section, are being manufactured. They are made of glass insulators protected by annular spark gaps. A full length laddertron is almost complete and will be tested in a new tall building, just over half the height of the NSF tower, which the Risley Laboratory of the UKAEA had the forethought to build (for completely different purposes). The building is available for these tests for about a year from the end of March.

Two important magnets are crossing the Atlantic en route for Daresbury. One will provide the 90° bend (1.25 m bending radius) at the top of the machine to inject ions into the accelerator. The other will provide the 90° bend (1.65 m bending radius) at the bottom of the machine to direct ions to the experiments. This latter magnet has to be of high optical quality since it will serve as a spectrometer magnet in stabilizing the central terminal voltage. Accuracies of one in 10^4 are required and the tricky job of minimising the effects of differential hysterisis will be done at the Laboratory.

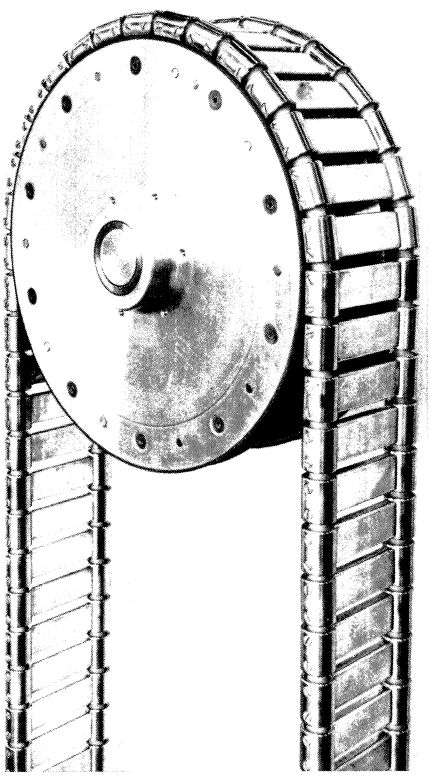
The pilot machine is being used to test accelerator components including, at present, the liquid freon system which will be used for cooling the central terminal. The conditions at 10 MV in the pilot machine involve voltage gradients higher than those which will be experienced in the NSF itself. Many other components — electronics, shorting units, surge filters, etc . . . are also at the test stage.

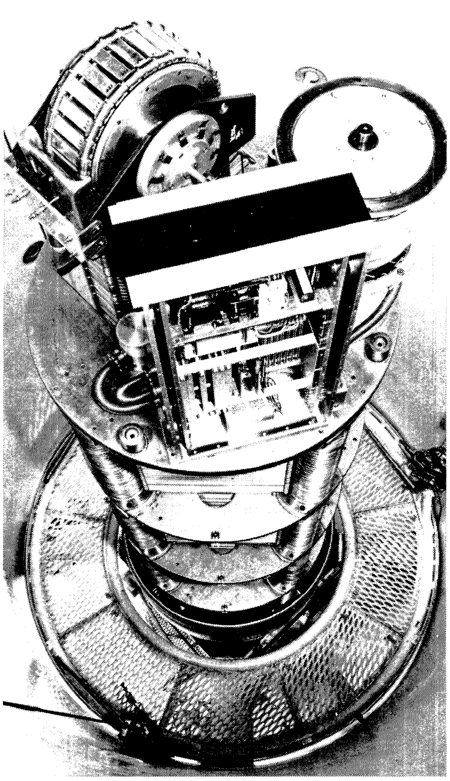
A User Committee was set up about a year ago and has been participating particularly in design decisions relating to the experimental areas. Specialist

Close up view of the laddertron, a string of conductor bars linked at each end by insulating beads, which will be used, rather than the traditional belt, to convey charge to the central terminal of the NSF.

Below is an inside view of the Pilot Machine which is being used in a thorough development programme on breakdown phenomena to back up the design and construction of the NSF.

(Photos Daresbury)





study groups have been set up on ion sources, beam lines, on-line isotope separators, spectrometers, and data handling systems. The aim is to be ready with equipped experiments when accelerated ions become available.

The NSF will nicely compliment the abilities of the other heavy ion machines in Europe — the Darmstadt UNILAC and the Caen GANIL. It will provide ions of very precisely known energy which is continuously variable over a considerable range. The d.c. ion beams will have very low energy spread. These classical properties of a Van de Graaff machine will be ideal in many categories of nuclear physics research.

BROOKHAVEN
10^{13} protons and how they are used

10^{13} protons per pulse have been accelerated through the 33 GeV Alternating Gradient Synchrotron at Brookhaven National Laboratory. This intensity is one of the goals of the AGS Improvement Programme, a rejuvenation exercise on the machine which is now 15 years old. The achievement was delayed by the budget and staff cuts of recent years but has come along at a very suitable time to feed a series of interesting experiments. On 9 February, 1.09×10^{13} was reached and intensities around 10^{13} were sustained throughout a physics run. This review of how these protons are used at Brookhaven has been compiled by H. Foelshe and D. Lowenstein.

The 1975 summer shutdown was used to repair and improve components throughout the machine. A new reentrant type ion source was completed and a new ceramic accelerating column was installed and tested up to 800 kV in the preinjector. The 200 MeV linac was given a thorough overhaul. The power amplifier systems, the multi-stem drift tubes and the r.f. pick-up probes were extensively reworked. In addition, a high energy electrostatic chopper was installed and new pulsed quadrupoles and steering magnets were added to the beam transport system between the linac and the AGS ring.

In the ring, an r.f. gap was installed at the L20 superperiod position to evaluate its use as a widebunch monitor. This device will be used to measure the induced image currents as these currents flow through resistors arrayed around the gap. A bandwidth of over 300 MHz is expected from previous bench test measurements. An ionization beam scanner (IBS), built at CERN, was also installed at this position.

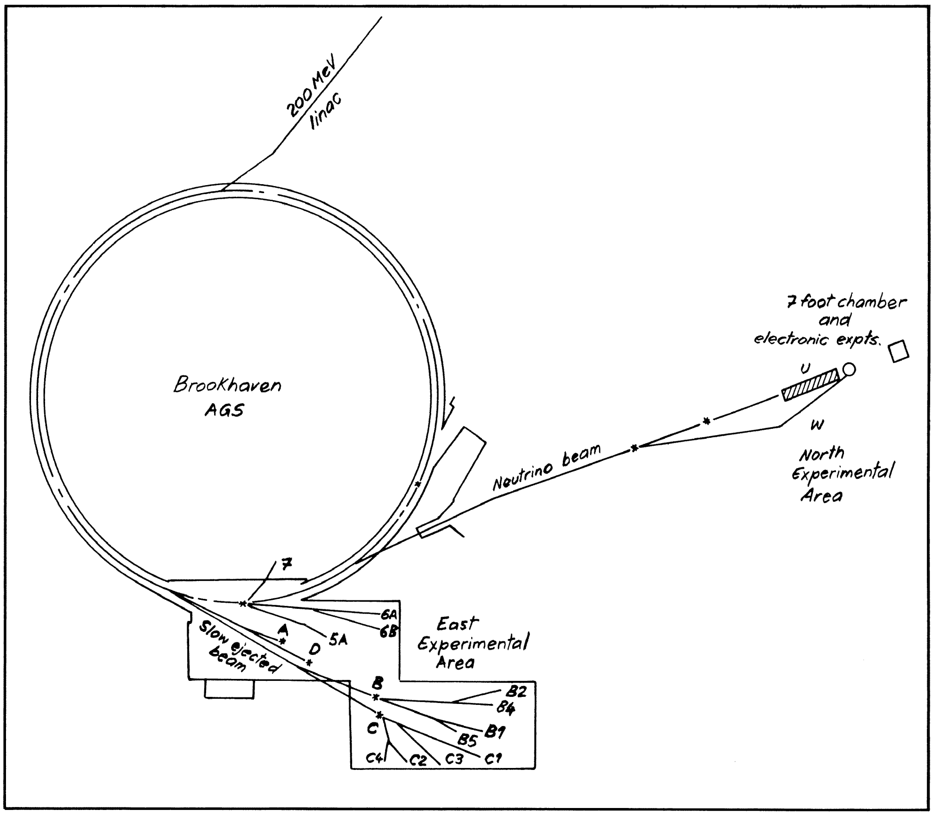
To keep in line with the present cultural trend for youthful appearance, as well as aiming for more reliable operation, the main control room was given a partial facelift. An enormous number of cables, racks, etc. were removed and a more modern computer oriented beam extraction console was installed. With the rising cost of electrical power over the last few years (now reaching about $27/MWH), the AGS has installed a computerized system to operate the beam transport magnet power supplies more efficiently.

The switchyard of the slow extracted beam has been computerized as well as the low energy separated beam at the C target station. This updating of the magnet controls had already been completed in the previous year for two secondary beams emerging from the B station and the fast extracted beam to the neutrino area (including the 8° superconducing dipole magnet). During this year, the remaining secondary beam controls will be updated.

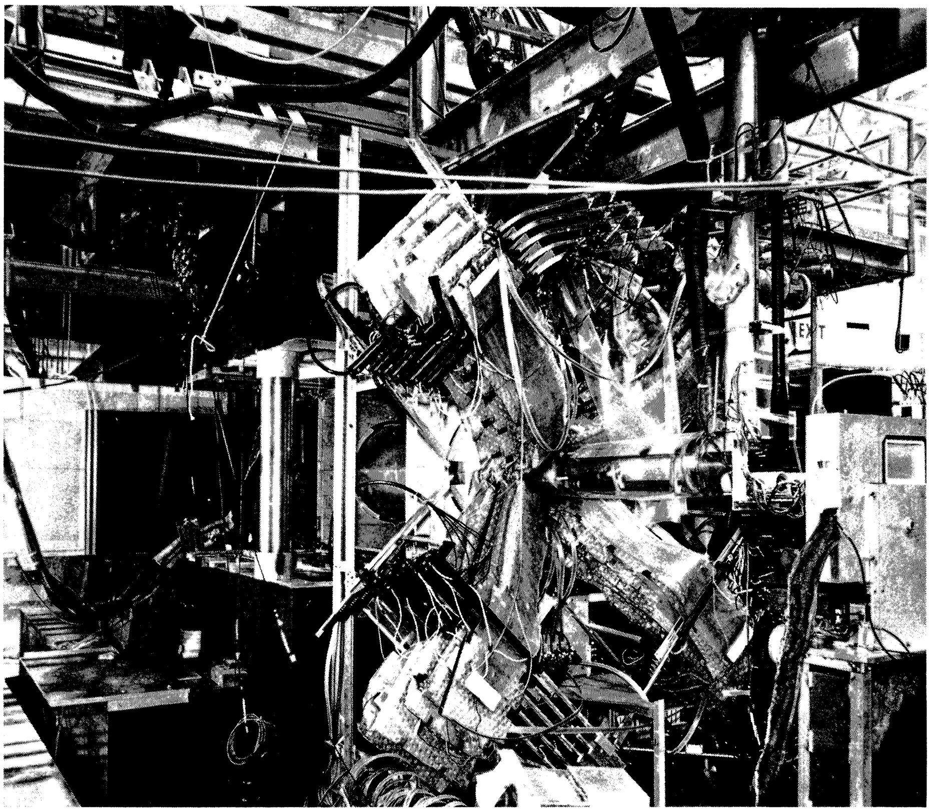
The net result of all these improvements to the AGS complex has been a large increase in the number of protons available for high energy physics. In 19 operating weeks since the summer of 1975, the AGS delivered 2.58 × 10^{19} protons. In the previous fiscal year (Fiscal Year 1975 from summer 1974 to summer 1975), 3.5 × 10^{19} protons were delivered in about 33 operating weeks while 2.85 × 10^{19} protons were produced for a 40 weeks programme in Fiscal Year 1974. There are, on average, 0.6 to 0.8 × 10^{13} protons every 2.5 s spilled over 700-800 ms.

Now that the AGS is a veritable proton factory, it can happily support three target stations simultaneously in the switchyard of the slow extracted beam plus one internal target station, all located in the East Area. In December 1975, twelve experiments were able to take data in the East Area and nine of these could operate at the same time. Averaged over the year, the number of simultaneously operating experiments is 7 to 8 in the East Area and, in order to use the limited electrical energy and other basic resources efficiently, every effort is made to keep this number as high as possible.

The East Area programme comprises all the electronic detector physics with the exception of the neutrino physics which is pursued in the North Area with the 7 foot bubble chamber and one or two electronic experiments. The East Area and the North Area runs are separate in time, alternating three times a year. Unfortunately, the bubble chamber programme has received a serious set back due to a recent structural failure of the chamber supports. The neutrino physics will be curtailed until the summer. On the positive side in this area, the recently developed dichromatic narrow band neutrino beam has been commissioned with great success and the basic operating parameters of the 7 foot bubble chamber with a neon-hydrogen



Experimental area layout at the Brookhaven Alternating Gradient Synchrotron. The 33 GeV synchrotron has topped 10^{13} protons per pulse and is feeding experiments via a slow ejected beam, a neutrino beam and an internal target.



The Multiparticle Spectrometer (MPS) at the Brookhaven synchrotron. Cylindrical spark chambers are located in the large magnet aperture and their read-out 'tails' project on the side nearest the camera. The support arm for the liquid hydrogen target passes along the axis around which the tails emerge.

(Photo Brookhaven)

mixture (80 % neon, 20 % hydrogen) have been established.

The previous year was a remarkable one for physics. Hot on the heels of the J/ψ discovery by the MIT/Brookhaven group came the observation of a charm particle candidate from the 7 foot chamber by a Brookhaven group. The physics programme is varied but the main item has been the search for charm and other stable states. The MIT/Brookhaven group has pursued charm in several different ways. They used their pair spectrometer, in which the J/ψ was observed, to study the spectrum of hadron pairs with and without an associated muon. Their first observation was the surprisingly simple behaviour in hadron pair production (with masses over 2 GeV/c^2) from proton-nucleon collisions. They reported that, for 28.5 GeV/c protons incident on beryllium, the measured cross section decreases in proportion to the mass and can be considered in three groups (π^- p), (π^+ π^-, $\bar{p}$p, K^- p) and (K^- π^+, $\pi^+\bar{p}$). The astonishing feature of the measurements is that the yields within a group are the same to $\pm$ 20 % while the cross sections for the groups are separated by a factor of about ten one from another. A further pair spectrometer has been set up by a Princeton group to look for charm in antiproton-nucleon collisions at 12.5 GeV/c. They are taking data.

During the past year, there have also been several experiments to look for direct lepton production (Penn/Stony Brook) in pp collisions, search for narrow states in neutron-nucleon interactions (Rochester/BNL) in antiproton-proton collisions around the S (1932) region (Yale/BNL) and in antiproton-proton annihilations at rest (Syracuse / BNL). The Multiparticle Spectrometer (MPS) has also been used to look for new states in pion, kaon and antiproton-proton interactions. Over the same period, the 7 foot bubble chamber has taken 405 thousand pictures of neutrino and antineutrino interactions in both hydrogen and deuterium. These experiments are either completed or at the analysis stage. Two electronic experiments, investigating the isospin character of neutral currents in neutrino and antineutrino interactions respectively, have been completed in and another investigating neutrino elastic scattering is in progress.

The Penn/Stony Brook group has reported that even down to incident proton momenta of 10 GeV/c, they observe direct lepton production from a target and the lepton rate increases as the lepton transverse momentum decreases. The Syracuse/BNL experiment has reported that no clear evidence is found for monoenergetic gamma rays with intensities greater than 1 per 30 annihilations. This is strong evidence against the existence of the 'cosmion'.

The rest of the AGS programme has also been interesting even if not so fashionable. A partial list covers areas such as weak interactions — Ξ^- beta decay (Pittsburgh/BNL), K^o radiative decays (Rochester/BNL), CP violation parameters in neutral K^o decay (NYU); atomic physics — Lamb shift in π,μ atoms (Stanford/NYU), hypernuclear physics (BNL/Lehigh) and strong interactions — K^- p and $\bar{p}$p charge exchange cross section (LBL/Mt. Holyoke), elastic scattering from a polarized target (Yale/BNL).

The future programme is likely to sustain the excitement. Areas such as the search for new, narrow or not so narrow states will be pursued, for example in the MPS, as well as systematic studies of the direct lepton puzzle — single electron and electron pair production (BNL), single muon and muon pair production (Yale/BNL). A very large and accurate spectrometer is planned for hypernuclear spectroscopy (BNL/Princeton) using the low energy separated beam. During the coming year, a high energy unseparated beam to the MPS will be built, with the additional capability of delivering beam to a second area on the experimental floor. This beam will be unique in having four superconducting dipole magnets of the type which would be used in the 200 GeV proton storage rings project, ISABELLE. The present muon beam will be reworked to provide a high intensity pion flux of up to 24 GeV/c.

The coming year at the AGS will be a very busy one. Although most of the glamour in particle physics during the past few years has moved to the higher energy machines, it has been shown again by the recent Brookhaven results, how important it is to have a viable physics programme over a large energy range.

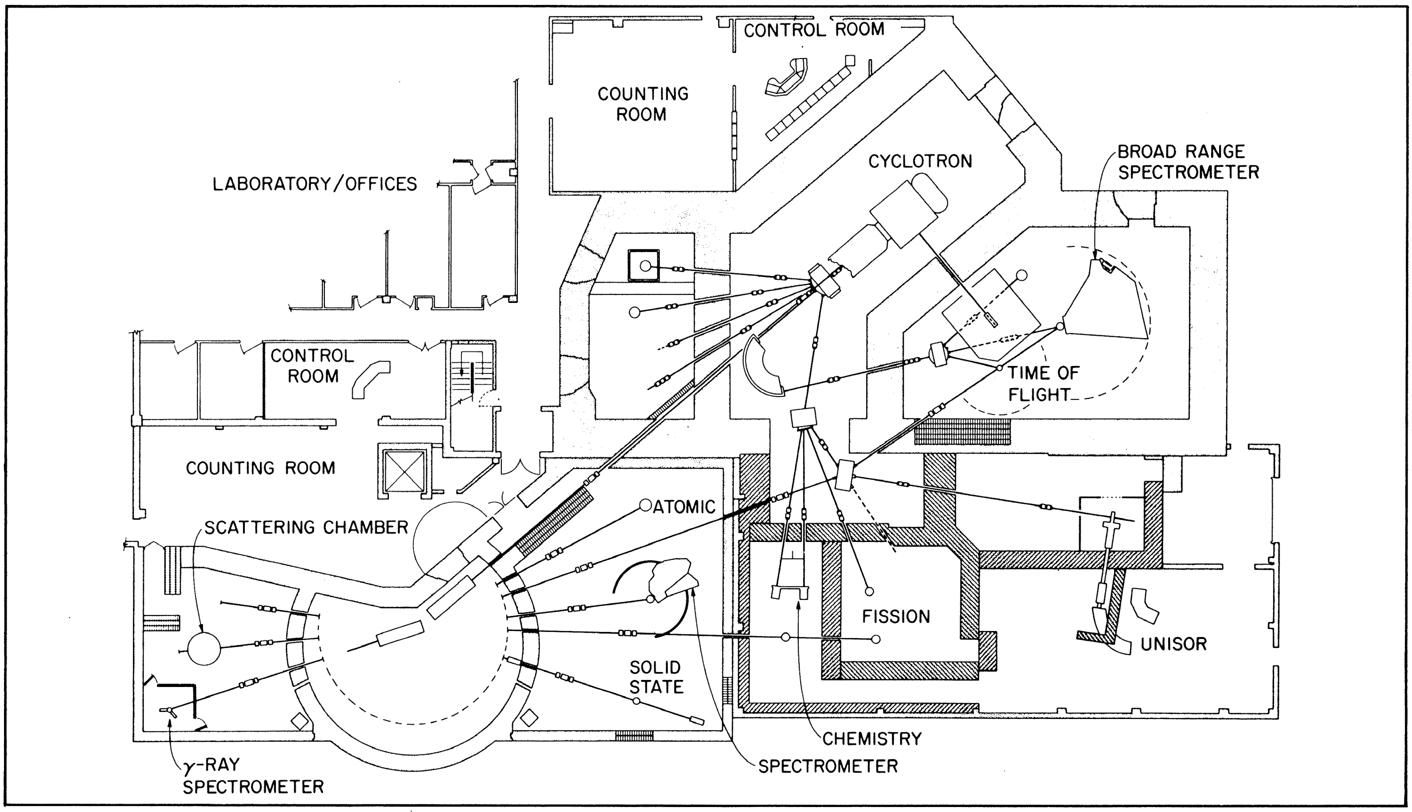
HEP money in the UK

On 17 February a 'Town Meeting' was held in London to discuss the implications of the foreseeable budgets available for high energy and nuclear physics research in the UK. It was organized by the Nuclear Physics Board of the Science Research Council and attended by over 150 high energy and nuclear structure physicists.

It is likely that the Science Research Council will have to reduce the budget assigned to this research from £41.2 million in 1976-77 to around £30 million in 1980-81 (1976 prices). Of the present budget about £19 million is taken up by the UK contribution to CERN, about £2 million goes in direct support of research at Universities and the other half sustains the programmes of the Daresbury and Rutherford Laboratories.

Despite the fact that the CERN budgets are scheduled to be trimmed back by a few percent per year through

A possible configuration of the beam lines and experimental equipment at the Oak Ridge Heavy Ion Laboratory. The base of the tandem is bottom left in the diagram. Experiments could be fed from there or from the cyclotron, located top right, following further acceleration.



to 1979, this will not alter the UK situation very much. Without a change of policy, it will be almost impossible to sustain a national high energy physics research programme at the end of the decade. The likely implications are as follows:

The 5 GeV electron synchrotron NINA at Daresbury will be closed down in 1977. This closure has been anticipated for some time and support for high energy physics experiments has been moving steadily to Rutherford. Daresbury has, however, two challenging projects to keep them busy in the field of nuclear physics and other branches of physics and biology. A 30 MeV tandem Van de Graaff Nuclear Structure Facility and a 2 GeV electron storage ring Synchrotron Radiation Source will be among the finest research facilities of their type in the world and the Laboratory seems to have an interesting programme for many years to come, though more money may be needed in order to operate the facilities at their full potential.

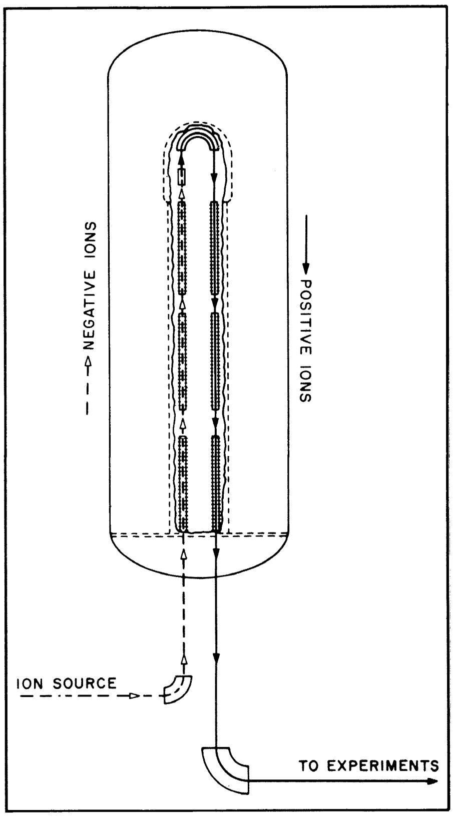
The 8 GeV proton synchrotron Nimrod at Rutherford may have to be closed down in 1978 or 1979. This presents a very difficult situation to the Laboratory which would then have no central research programme of its own on the Nimrod scale. The Laboratory's future had been very closely tied to the EPIC electron-positron storage ring project which did not receive financial backing. Other possibilities are now under examination and we hope to report on them soon.

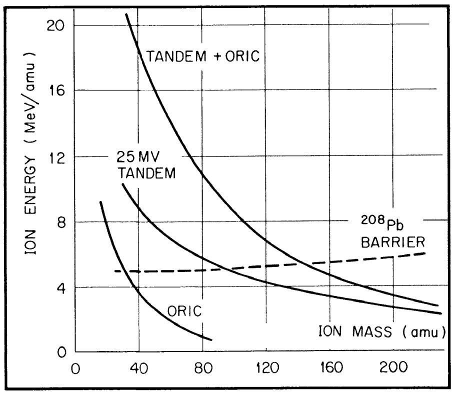
Rutherford will remain the support centre for UK high energy physicists using the CERN facilities and, possibly, the electron-positron storage ring, PETRA, at DESY. However, the money available for these experiments elsewhere, if the full budgets cuts are applied, is unlikely to be sufficient to support more than about a half of the present number of UK high energy physicists.

OAK RIDGE Heavy Ion Laboratory

The USA parallel to the Daresbury Nuclear Structure Facility is at the Heavy Ion Laboratory of Oak Ridge National Laboratory where construction of a building to house a 25 MV tandem electrostatic accelerator is starting this month.

An isochronous cyclotron (ORIC) is already in action at the Laboratory and the purpose of the new tandem is to extend the heavy ion research capabilities. It will be possible to transport beams from the tandem to ORIC for further acceleration. A striking feature of the design is that the tandem is 'folded' rather than linear.





The folded tandem design, first proposed by Luis Alvarez in 1951, to be applied at the Oak Ridge Heavy Ion Laboratory. It has the advantages of reduced length, ground level injector room location, better charge separation via the 180° magnet and lower stored energy. On the other hand the 180° magnet is no easy technological problem and the advantage of reduced length is countered by increased diameter.

Beam energies from the 25 MV tandem plotted against ion mass. Curves are plotted for the existing cyclotron, ORIC, for the tandem alone and for the tandem used in conjunction with ORIC. The dashed line indicates the position of the Coulomb barrier for a lead nucleus. For the accelerated ion to become involved in nuclear reactions with lead it needs to have an energy above this line.

Negative ions leave from the base of the tower, are accelerated to the central terminal where they are stripped of electrons and bent through 180° to be further accelerated back to the base of the tower where a 90° bend fans them out to experiments or directs them to the cyclotron.

Some parameters of the project are as follows: Tower height 160 foot, diameter 45 foot; Pressure vessel height 100 foot, diameter 33 foot; Ion masses which can be accelerated 35 to 250 amu; Analysed beam intensity 1 pμA; Terminal potential from 7.5 to 25 MV. Beam energies as a function of the ion mass for both the tandem alone and the tandem plus ORIC are shown in the diagram. The total project cost is $17.5 million with about $8 million for the accelerator system which is to be built by National Electrostatics Corporation. The scheduled commissioning date is 1979.

It is intended to be a national facility for research in nuclear chemistry, solid state physics, health physics, biophysics and materials damage. The project Director, James Ball, is advised by a Policy Board consisting of D.A. Bromley, H.E. Grove, H.A. Grunder, J.H. Hamilton and J.P. Unik. A user community of some 500 scientists is represented by an Executive Committee with members Marshall Blann, John Rasmussen, John Fox, Edward Zganjar, Sheldon Datz and James Ford. Gene Eichler from Oak Ridge serves as Liaison Officer.

CERN
Machines come on again

The Proton Synchrotron and Intersecting Storage Rings had a two month shutdown at the beginning of the year while a large number of modifications and a general programme of maintenance was carried out (see January issue, page 23). The Linac, Booster and PS Main Ring all came back into action at the end of February as scheduled.

It soon became clear, however, that not enough time and people had been available for all the preliminary hardware tests mainly on equipment needed for beam injection from the Booster to the PS and utilization of protons at high energy. Problems were also encountered with power supplies which had suffered from the fire last year.

Computer control of many parameters was changed during the shutdown in order to cope with the needs of operation with supercycles (one cycle at 10 GeV/c for SPS filling, one or two cycles for 25 GeV/c physics and ISR filling) and intensity modulation. This has been done with the existing PS control computers but the tuning of machine parameters is now lengthy and the need for a new integrated system is even more evident than before to the machine engineers and technicians.

Despite these problems, after ten days of operation, the PS was running with a supercycle and its associated new timing, fast extraction for the g-2 experiment and the 2 m chamber was working; slow extraction for the East Hall and target 1 operations were used for counter experiments and fast extraction to the ISR was operated. Trials have been made of the continuous transfer for the SPS and the static dump line. There is confidence that by 5 April the PS will be ready to supply the SPS, ISR and 25 GeV/c physics users during the same supercycle.

The ISR had their first protons from the PS on 1 March. After only two hours of adjustments there was beam injected in both rings and the orbits were good, confirming that the alignment work carried out during the shutdown was correct.

Pushing for high currents during the next few days, so as to let the experimenters loose again, revealed that something was wrong in Ring II. It was tracked down to an obstacle in the vacuum chamber and on 5 March the relevant sector was opened. The Health Physics people, who were involved because of the high radiation levels, emerged with a piece of wire. By 9 March Ring II was pumped down again and both rings were holding about 20 A of protons. The ISR is back in good health — a record intensity of 38.9 A has been stored.

SPS commissioning programme

While the installation of the CERN 400 GeV proton synchrotron (the SPS)

The heavy liquid bubble chamber, Gargamelle, has been dismantled after its noble service at CERN PS energies where it chalked up neutral currents and charmed particle candidates. It is being moved to the West Area where it will receive higher energy neutrinos from the 400 GeV proton synchrotron. The team responsible for the move are grouped on the chamber body and lean on the substantial coil of the magnet.

components is being completed, preparations for commissioning the large machine proceed apace.

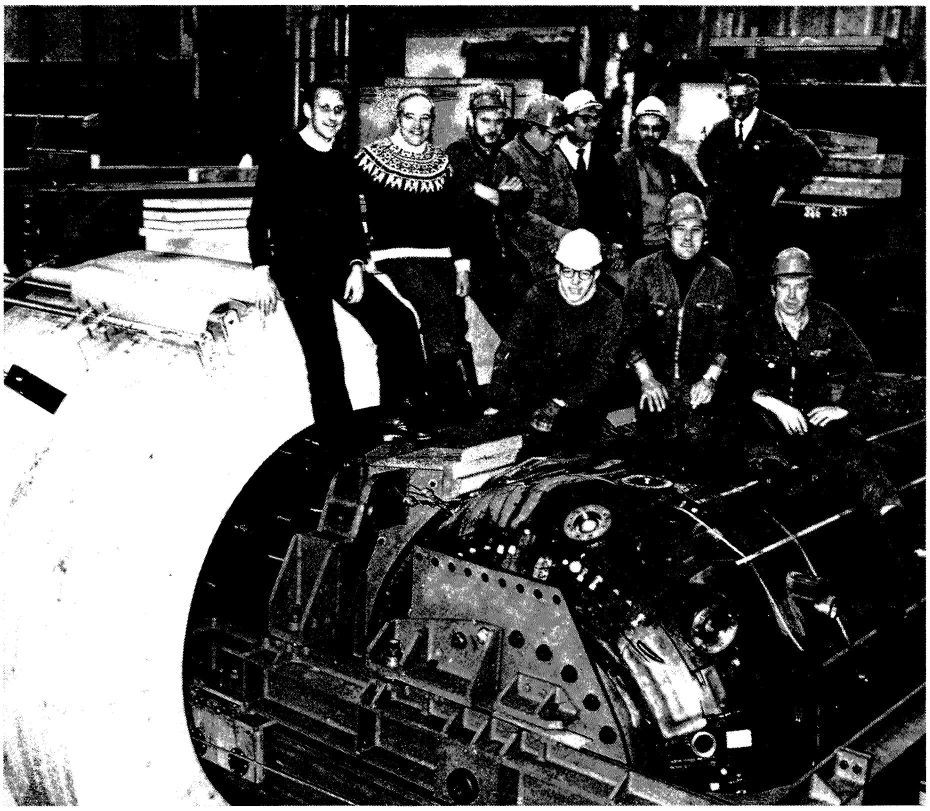
A start has been made at the PS on the operational use of the supercycle (one cycle at 10 GeV/c for sending protons to the SPS followed by one or two cycles at 26/24 GeV/c to fill the ISR and for the various experiments around the PS ring). The continuous transfer equipment, which will be used for ejecting the PS beam to the SPS, is now complete and ejection tests for the SPS begin seriously on 15 March with the ejected beam being sent into an absorber.

A team of operators has already been formed at the SPS, controlling the machine access areas and familiarising themselves with the sophisticated monitoring system.

A simulation exercise has been performed in transfer line TT10 which will take the 10 GeV/c protons from the PS to the SPS and it confirmed that all the equipment is correctly connected to the control systems and operates properly in the absence of protons. The first protons will pass down TT10 as far as the entrance of the 400 GeV machine on 5 April. The following month will be used to match the beam characteristics to the requirements of the SPS and on 3 May the first attempt will be made to inject.

The initial step will be to guide the beam around its orbit in the machine and then, holding the magnetic field constant, to obtain a beam capable of making at least ten turns. This will be the first crucial test, for its results will vitally depend on the uniformity of the magnetic fields which have been achieved in the bending magnets and the accuracy with which the quadrupoles have been aligned over the entire 7 km circumference of the SPS. When this fence has been cleared, a start will be made on the beam acceleration tests and the successive adjustments which will take the protons to the machine's design energy of 400 GeV. The final step will then be to adjust the extraction system and the transfer line which will take the protons to the targets for experiments in the West Area.

No hard and fast time table has been laid down for this work since there is no predicting how long it will take to clear the inevitable problems which the machine specialists will confront in commissioning such a large and intricate accelerator. The physicists with experiments in the West Area are preparing to receive the first SPS beams around the end of the year and no effort will be spared to come up to their expectations.



CERN 101.2.76

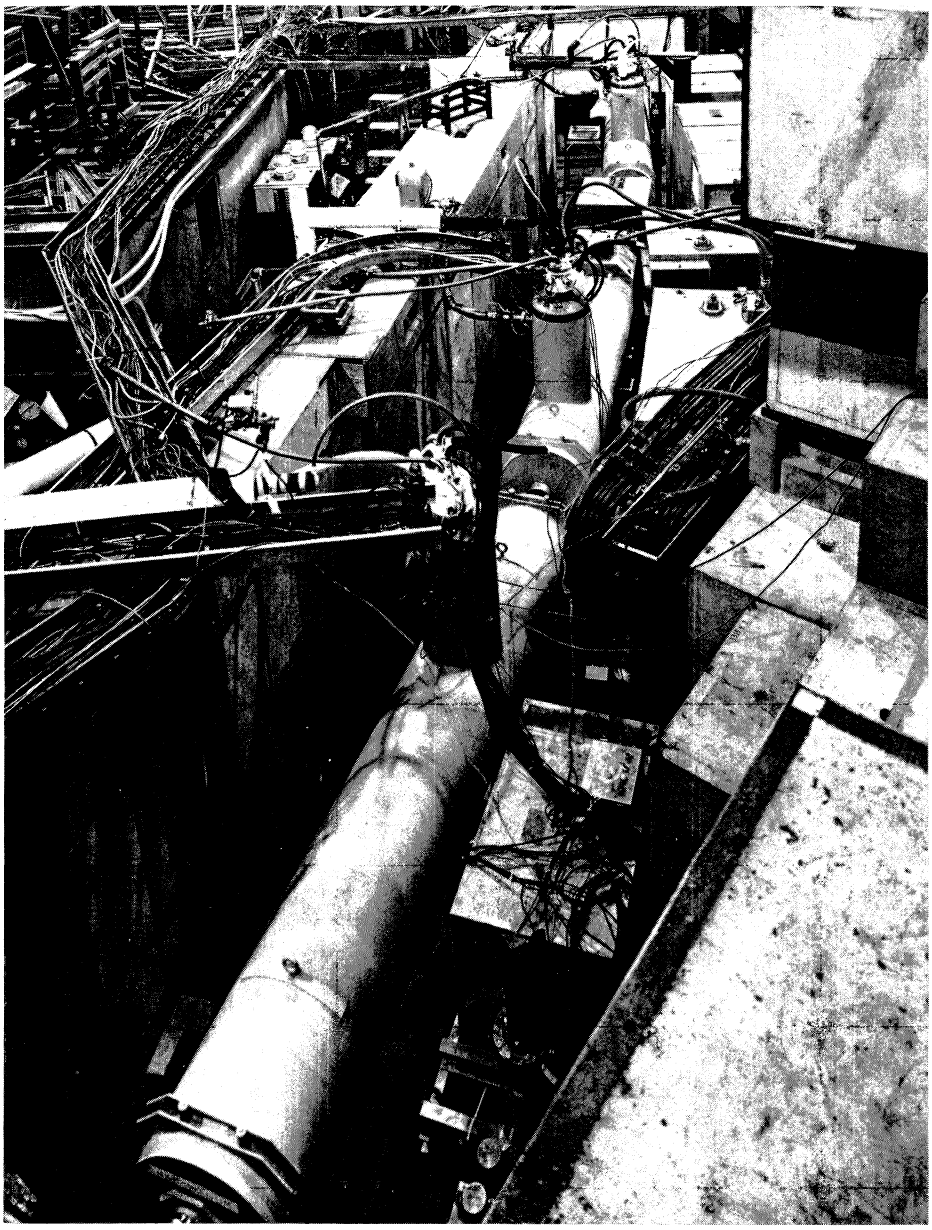
Gargamelle goes West

As we reported in the December issue (page 388), the CERN heavy liquid bubble chamber, Gargamelle, ceased to be used at the 28 GeV proton synchrotron at the end of last year. Within the next few months, it will be moved into the neutrino beam in the West Area where it will be fed by the SPS.

Starting on 5 January, the dismantling of Gargamelle took about two months and, thanks to the work by all concerned, went off without a hitch. A delicate stage will be confronted in April involving moving, with the aid of hydraulic rams, the base of the magnet (some 175 tons of steel) and its re-installation in the West Area on a truncated pyramid of concrete 6.5 m high. After some improvements, the chamber body will be fitted in mid-summer followed by the re-installation of all the electrical, liquid transfer (propane and freon), safety, control and other interconnections. This work will be spread over several months.

On the civil engineering side, the

A portion of the superconducting beam line at the Argonne ZGS. Three of the four cryostats in the beam are visible, each containing three superconducting magnets. The beam line feeds the Effective Mass Spectrometer, which is just visible at the top of the picture, where experiments using 12 GeV/c polarized proton beams are being carried out.



shell of the new Gargamelle hall has been completed. The building covers an area of 600 m² (20 × 30 m) and its height of 21 m is dictated by the raised position of the chamber, centred on the beam axis which is at an angle of elevation of the order of 2.5° (41 mrad). Two of the hall walls are of reinforced concrete capable of withstanding pressures of 500 kg/m², while the other two and the roof are of machined sheet steel with a yield pressure of about 200 kg/m². The concrete base, designed to support the weight of the chamber (1000 tons), is close to the upstream wall and is extended to the side by a support on which will be fitted the expansion system tanks. A four storey annex has already been built against the north wall of the hall to house the control room and services.

The neutrino beam will then pass in succession through a series of large detectors, starting with the 3.7 m bubble chamber (BEBC), followed by electronic detectors and, finally, the Gargamelle chamber.

It was originally intended to dismantle Gargamelle last autumn, but the date was postponed by a few months for the charmed particle search. As we reported in January the initial results of scanning showed up two likely candidates bringing the Gargamelle total to three. The examination of the rest of the batch of 300 000 photographs taken during this experiment should be finished during March.

The list of possible charmed particles seen in bubble chambers has grown to sixteen as follows: Early 1975 there was one event in the Brookhaven 7 foot chamber and one in Gargamelle. By the end of the year there were two more events in Gargamelle and four in the Fermilab 15 foot chamber. Now there are four more events with neutrinos plus four others with antineutrinos in the 15 foot. Both BEBC and Gargamelle physicists are itching to get back at it again.

ARGONNE Superconducting beam line

A beam line of superconducting magnets came into operation at the Zero Gradient Synchrotron during February. The beam, designed to transport 12 GeV/c polarized protons to the Effective Mass Spectrometer, includes ten superconducting dipoles and two superconducting quadrupoles. The twelve magnets are mounted in four separate cryostats, installed alongside the existing 6 GeV/c secondary beam line. Their successful operation is an impressive piece of work in the field of superconductivity.

The magnets were constructed as

A closer look at one of the cryostats used in the superconducting beam line. Magnet power leads, instrumentation leads and cryogenic fluid lines enter the cryostat through the vertical structure on top. The beam line came smoothly into operation in February.

(Photos Argonne)

prototypes for the proposed Superconducting Stretcher Ring (SSR) at the ZGS. The project did not receive funding, so the magnets were put to use in the new beam line. These SSR magnets have a useful aperture of 7.6 cm and, at 12 GeV/c, the dipoles operate at 2.6 T over a length of 91 cm with a current of 160 A. The field integral of the magnets is constant to 0.1 % or better over the full aperture, including end effects. The quadrupoles have a field gradient of 0.3 T/cm over a length of 41 cm at 190 A. Both the dipoles and the quadrupoles are operated at about 85 % of their maximum currents. The training of each cryostat to currents comfortably above the operating point required six quenches or less; the field levels to which the magnets train are retained as long as the cryostat is kept below liquid nitrogen temperature. (The magnets are described more fully in the Proceedings of the 1974 Oak Brook Superconductivity Conference.)

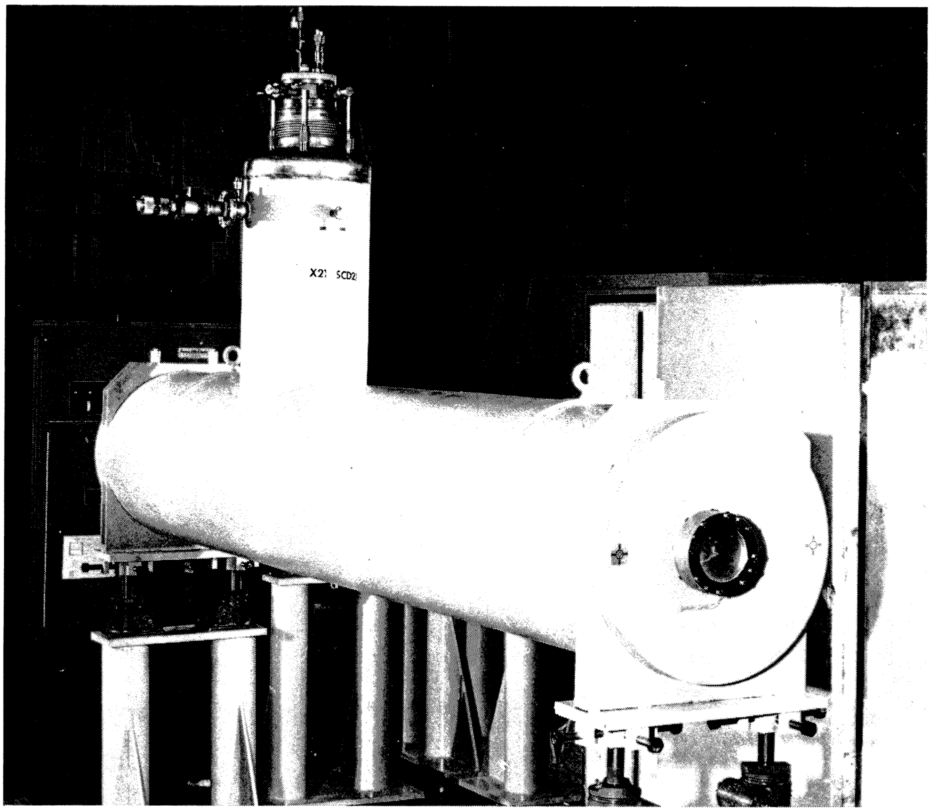
Installation of the beam line began in September 1975 and was completed in early December. Parasitic tuning with diffractively scattered protons began immediately and proceded very smoothly, with high intensity beam reaching the EMS within a few hours. All planned beam tests were completed before the scheduled ZGS shutdown on 3 January. Operation with 12 GeV/c polarized protons began smoothly on 1 February and the beam has operated without difficulty. Liquid helium consumption totals about 7 liters per hour for a total of 12 m of cryostat.

During October and December, the first of the four cryostats in the superconducting beam, installed inside the extracted proton beam shielding, was used to study the intensity of 12 GeV/c proton beams required to quench the magnets. This study was carried out under a variety of beam and cryostat operation conditions. It was found that a single 50 ms beam pulse directed into the coil would quench the magnet if the beam intensity per unit area was greater than 2.7×10^9 proton/cm^2 and if the magnet was at its nominal operating current of 160 A. Repeated pulsing just under this critical intensity would not quench the magnet. This and other data suggest a thermal time constant of about 0.5 s.

Measurements were also made of the intensity required to cause quenching as a function of magnet current; these measurements are still being analyzed. The unique information gained from these tests will be important for the design of superconducting magnets for future accelerators and storage rings.

The beam came into operation in time for the first scheduled month of experiments using 12 GeV/c polarized protons from the ZGS since the achievement of this record energy for polarized proton beams (see October issue 1975). The protons are being used at the Effective Mass Spectrometer (EMS) to study the polarization parameter in proton-proton and proton-neutron elastic scattering. Earlier studies of these reactions, using 2 to 6 GeV/c polarized beams on a deuterium target, showed surprisingly rapid energy variation of the I = 0 t-channel exchanges and the present experiment will carry these studies to higher energies. Future experiments at the EMS will use the 12 GeV/c polarized protons to study the spin dependence of certain inelastic final states.

Other ZGS experiments running during February and using the newly available 12 GeV/c polarized protons are — a 150 000 picture exposure of the 12 foot bubble chamber with hydrogen filling for a Case Western Reserve/Carnegie-Mellon collaboration; studies of large transverse momentum elastic scattering cross sections in pure spin states using a



Professor Bob Siegel, Director of the Space Radiation Effects Laboratory, SREL, swept away by the literary style in vogue because of the USA Bicentennial Celebrations, was moved to circulate a request for experiment proposals at the Laboratory's synchro-cyclotron as follows:

Freshest Advices from Newport News on the Peninsula in Virginia

Notification, which should be construed as a Piece of authentic Intelligence, has been received from the National Science Foundation that the Space Radiation Effects Laboratory (known to the general Publick as SREL) shall continue to operate at its current Level of Activity through 1976, and hopefully beyond. This Laboratory shall thus continue to serve the Community of Scientists and other Practitioners of the highly esteemed Art of fundamental Research as far as the unwearied Diligence of its Staff can enable.

On April 30-May 1, the worthy SREL Program Advisory Committee (PAC) will gather from across the Continent and repair to Newport News, where they will meet in high Congress to deliberate on those Proposals which will have been submitted in good Time by present and prospective Users of SREL. Those from among the Constituency of Scientists who find the Study of Protons, Pions, and Muons at intermediate Energies to be a Vehicle of instructive Amusement should give Thought to submitting Proposals for the Use of cyclotron Time to 11970 Jefferson Avenue, Newport News, Virginia 23606. In these difficult Times the Uncertainties of the Mail make it advisable for the Prudent to submit their Proposals well in Advance of April 1.

Let All be assured that the Distractions of the colonial Capital at Williamsburg shall not serve to cause the Members of the PAC to deviate from the Course of true Virtue during their forthcoming Labours. Yet they will be provided with such Sustenance of which the Chesapeake Bay is capable (that being unsurpassed for both Quality and Bounty) as well as with such Libations as will cause them to review Proposals of Merit with kindly Temperaments moderated by Wisdom and Experience.

As to the Appartenances of Research which are allotted to the Users of SREL, we humbly offer an extensive Equipment Pool including Scopes, standard Logic, pulse height Analyzers and the Like to which many Scientists have become accustomed. An on-line data acquisition System with multi-programming Capabilities is also at the Service of those Users who are knowledgable in the Realm of Bytes and save Taypes. The stopping Muon and Pion Beams are the especial Pride of the Management, and numerous Pieces of ancillary Apparatus are available. The Flexibility of the laboratory Accommodations and the Responsiveness of the Staff are such as to compensate for most real or imagined Deficiencies.

Thus SREL shall endeavour to deserve continued Instances of public Favour, and to be the Scene of numerous Discoveries which may be either curious or important, perchance both.

We remain the Publick's obliged, and devoted Servants.

R.T. Siegel

polarized proton target by a Michigan/Argonne group; and measurements of inclusive particle production asymmetries by a Rice/Minnesota/Argonne collaboration.

SREL
Muons à gogo

The Space Radiation Effects Laboratory, SREL, operates a synchrocyclotron which was modelled on the CERN 600 MeV machine. It was built during the years 1963 to 1965 for use by NASA to simulate the radiation environment in space when information was needed for the space programme. Since 1967 it has been operated by the College of William and Mary and since 1973 has received financial support from the National Science Foundation and the Commonwealth of Virginia.

The machine operates with an internal proton beam of 1.5 to 2 μA and has an extraction efficiency around 5 %. In 1972 it was modified to take helium ions also, accelerating helium-4 to 710 MeV with an internal current of about 0.5 μA and the same ejection efficiency.

There are extensive experimental areas (3700 m^2) where pion beams are installed with momenta up to 400 MeV/c. The major experimental effort however is concentrated on the use of muon beams. A quadrupole muon channel with 28 cm aperture can provide a flux of 100 MeV/c muons of 6×10^5 per s.

Experiments include the study of muonic atoms (Chicago/Ottawa collaboration). They have measured the muonic X-rays of the 5 g to 4 f transition in lead and the 4 f to 3 d transition in barium with an accuracy better than 10 eV.

Positive muon precession in solids

(William Mary/Bell Laboratories) has been used to study the internal fields in ferromagnetics, type II superconductors and spin glasses where dilute random alloys have their spin orientations frozen in the matrix. The group is going on to study defects in solids, negative muon precession in biological systems and critical fluctuations in antiferromagnetics (mainly chromium). In addition, muon precession will be used to look at magnetic insulators, transition metals and rare earths.

Muon studies in gases (Yale / Heidelberg) have demonstrated the formation of stable muonic helium atoms, with one electron and one muon in orbit around the helium nucleus, in helium gas at 14 atmospheres with a 2 % admixture of xenon. This analogue of muonium was observed via its characteristic Larmor precession and it is of importance in testing quantum electrodynamic predictions.

A measurement of the rate of asymmetry of radiative muon capture in calcium is nearing completion (William Mary). An external converter is used to materialize the photons and their energy is then measured in a sodium iodide crystal. This makes it possible to suppress the background due to neutrons from muon capture which has disturbed earlier measurements. Over 2500 events were gathered during a run ending at the beginning of March.

RUTHERFORD Zooming in on bubble chamber events

Better bubble chamber picture patch-up was the motivation behind ASPECT — a computer controlled graphics device, developed at the Rutherford Laboratory, which is now being considered for applications in other fields, including magnet design and crystallography. In contrast with other equipment of this type, the device uses its own purpose built hardware functions to perform complex coordinate transformations in real time, thus giving immediate response to operator signals and commands entered via tracker ball input devices.

Two things are making life more difficult in the measuring of bubble chamber film (at the Rutherford Laboratory, this is done on a Hough Powell Device or HPD). One is the move to bigger chambers since each frame of film from a big bubble chamber produces more digitisings than a comparable frame from a smaller chamber. Also, the pictures from big chambers give the viewer a more difficult pattern recognition problem to solve, mainly as a result of the increased density of graphical data. As well as having more tracks per event, these chambers show more events per unit area of film and have more digitisings which result from imperfections.

The second complicating feature is the use of new 'reduced guidance' techniques for digitising events with a minimum of operator input. Added to the demands of the big bubble chambers, this requires a larger number of points to be displayed 'flicker free' in the rescue system which attempts to measure events that have problems going through the HPD.

The viewer needs a system which presents the stored information in graphical form preserving, as far as possible, the accuracy and resolution of the original digitisings so that there is as much genuine picture data as possible available to assist in the patch-up process. The ASPECT device meets these requirements. It can display up to 50 000 points flicker free and zoom in on any required portion of a display. This particular ability to scale and translate two dimensional picture coordinates means that the one in a thousand resolution of the video screen is no longer the limiting factor for displayed resolution.

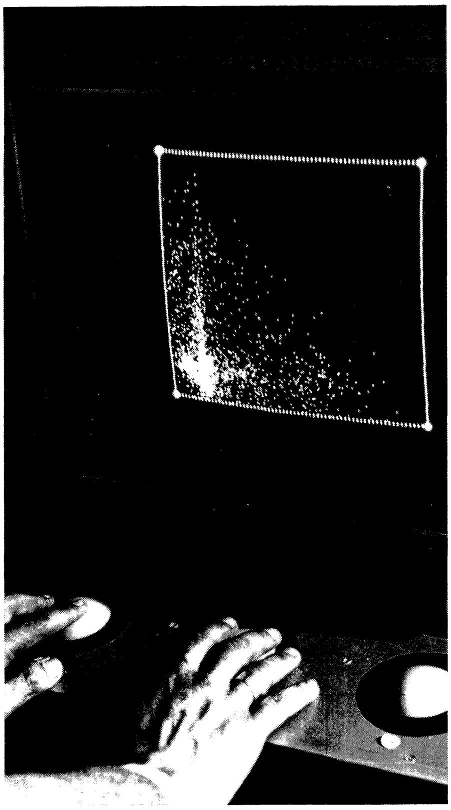
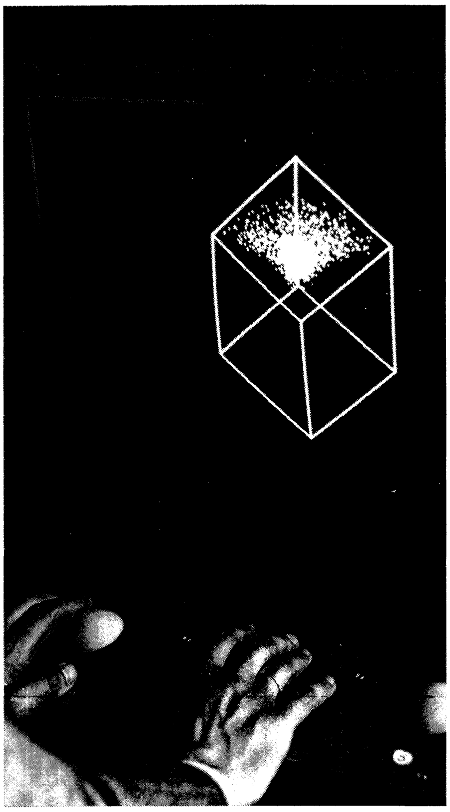
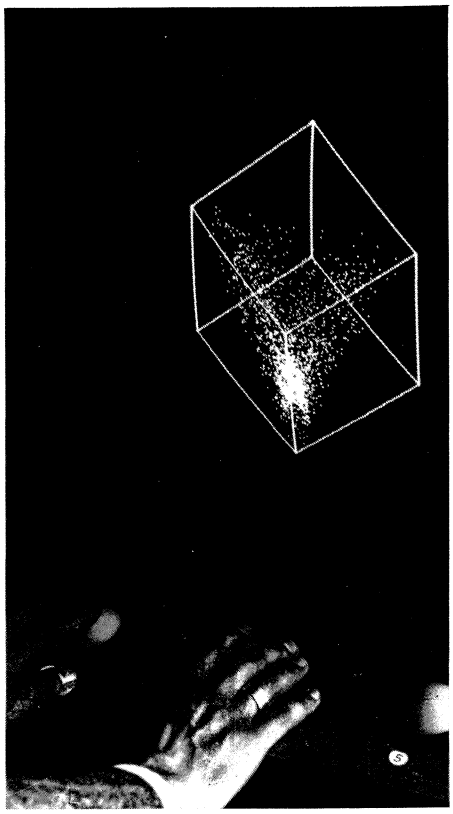
The 'zooming' transformation is done by a digital coordinate processor which can handle full accuracy digitisings from HPDs. In this way ASPECT provides a versatile viewing aperture which can be used to examine complete bubble chamber film frames or the detail contained in any area of film, up to an effective magnification of 500 times. By using a magnification system which acts on the digitally-stored file of x and y coordinates, ASPECT is able to utilize the full potential of the digitising, and the additional capability for lateral translation means that the required magnified area can be kept on screen all the time, enabling the operator to examine any required portion of a picture to a chosen level of detail.

Before commencing design work, the Rutherford graphics specialists decided that additional on-line graphics features could be easily incorporated and might be useful. This far-sighted approach seems to have paid off. As well as providing scaling and translation in real time from stored digital coordinates, the new equipment can also carry out additional coordinate transformations to rotate pictures in two and three dimensions. This enables structures or topologies to be examined from all sides, and with variable magnification.

Both a light pen and a cursor can be used, so enabling a wide range of interactive graphics operations to be carried out. The equipment incorporates hardware which ensures that the cursor 'follows' the light pen, so combining the convenience of a hand held light pen with the accuracy of a cursor

Photographs demonstrating the 3-D capabilities of the computer controlled graphics device, ASPECT, developed at the Rutherford Laboratory. ASPECT displays three-dimensional distributions such as those obtained in experiments looking at three-particle final states. The first picture shows a standard Dalitz plot type of distribution. This can be rotated, using the tracker balls, to investigate the relationships between variables in other areas of the kinematically allowed region.

(Photos Rutherford)

in a way not requiring expensive software which can restrict the capabilities of the main computer system.

Besides its intended uses for bubble chamber work, ASPECT has been of assistance in multi-variable analysis — the 3-D rotational and scaling capabilities make it possible to visually explore three-dimensional space for meaningful interrelationships and structuring between sets of data points. At a recent crystallography Conference held at the Rutherford Laboratory, researchers showed a keen interest in the equipment, indicating that it had significant potential for molecular structure work as it enabled proposed structures to be examined much more easily than with conventional means.

For example, electron density could be displayed on the screen as a three-dimensional contour envelope and a line model of a protein molecule superimposed on it, region by region. ASPECT controls would allow interactive adjustment of the model position and the rotation features would give the crystallographer a full view of what is happening.

As well as displaying 50 000 points in two dimensions, ASPECT can also display 9600 points in three dimensions or 4000 one inch vectors. Based on a HP 1310A display refreshed by an Interdata 7/16 minicomputer, the device is attached to a GEC 4080 computer, itself connected in turn with the main Rutherford Laboratory IBM 360/195 machine. Pictures generated in the main computer can therefore be displayed on ASPECT. A simplified version for the rescuing of bubble chamber events digitised in full guidance mode has been in operation for several months.

It is planned to exhibit ASPECT at the Interactive Computer Graphics (ICG) Exhibition to be held in Geneva from 5-8 October 1976.

FERMILAB
Discussing colliding beams

At the end of January, a small meeting was held at Fermilab to discuss the prospects for colliding beam physics at the Laboratory. Several schemes were considered, including some using the Energy Doubler/Saver where the possibilities have been promoted by R. Carrigan, A. Cline, B. Richter and C. Rubbia.

The possibility of producing interactions between beams circulating in the Doubler and beams circulating in the opposite direction in the main ring was one important topic at the meeting. Such a colliding beam scheme would influence where the Doubler magnets are positioned in the main ring tunnel — the further the two rings are separated, the more difficult it would be to bring beams from one ring to the other, make them intersect and then get them back in place in the 52 m of long straight section. The possibility of installing the Doubler magnets under the existing ring, rather than having them hanging from the roof as initially proposed, is being examined. The scheme could allow collisions between proton beams with energies up to 400 GeV (main ring) against 1000 GeV (Doubler), corresponding to $\sqrt{S}$ values of up to 1260 GeV. Estimates of the luminosity vary widely with the optimists pitching for 10^{30} to 10^{31} per cm^2 per s.

A second storage ring proposal involves the constructing of a 'small' 25 GeV storage ring to intersect the main ring at the straight section upstream of the one where the r.f. accelerating cavities are located. This proposal (from R. Huson, P. Livdahl, R. Stiening, L. Teng, F. Turkot and J.K. Walker) would use conventional magnets and have a ring with the same radius as the present booster.

Interactions would occur as the main ring was ramping, much as the present arrangement with the jets at the internal target area. With the main ring or the Doubler operating at 400 GeV, the system would give $\sqrt{S}$ = 200 GeV. The proponents estimate that an instantaneous luminosity of 10^{31} per cm^2 per s could be obtained. This proposal has been submitted to the Program Advisory Committee as an experiment to search for the intermediate boson, W, which is the particle postulated as the carrier of the weak force. The popular weak interaction theories set the W mass at 80 GeV.

The possibility of antiproton-proton colliding beams at Fermilab was also reviewed at the meeting. This has been promoted by P. MacIntyre and C. Rubbia. An interesting approach is to use a small accumulator ring to collect antiprotons building up the antiproton beam to an acceptable intensity. The basic idea was put forward by G.I. Budker of Novosibirsk many years ago. The initial proposal was to have a race track-shaped field with ends 3 m in radius which would be used to accumulate 2 GeV antiprotons produced in a target bombarded by protons from the main ring. These antiprotons could be damped using a several amp, 1 MeV electron beam. Since the January meeting, ideas have swung to using stochastic cooling, which was developed at CERN, and momentum cooling.

Designers estimate that perhaps 4×10^7 antiprotons could be stored per cycle until about 10^{10} were accumulated. These antiprotons would be injected back into the main ring and accelerated simultaneously with 'right way' protons. On a theoretical basis, antiproton-proton collisions lead to higher intermediate boson cross sections than proton-proton collisions do because of the antiquarks in the antiproton. The proton-antiproton ideas are now receiving very serious attention at the Fermilab.

Future possibilities with proton colliding beams are also discussed at CERN which, with the Intersecting Storage Rings, might be considered their spiritual home. There has been a study, led by K. Johnsen, of 400 GeV proton-proton storage rings (LSR) which could be fed by the 400 GeV proton synchrotron. The use of antiprotons in the ISR has been investigated by K. Hubner, K. Johnsen and G. Kantardjian. Recently D. Mohl, L. Thorndahl and P. Strohlin, together with G.I. Budker, N. Dikansky and A.N. Skrinsky from Novosibirsk, looked at the ISR preceded by an electron cooling ring to increase antiproton intensities. The use of antiprotons in the SPS (again involving an accumulator ring with stochastic and momentum cooling of the antiproton beam) is being promoted by C. Rubbia.

People and things

ISABELLE money

In February it was learned that $950 000 has been allocated as construction planning and design funds to the proposed 200 GeV proton-proton storage rings, ISABELLE, at Brookhaven. The money will be used for further preparatory studies to tighten the cost estimate on ISABELLE. Construction of a half-cell of the storage ring magnet lattice (two dipoles and a quadrupole) is under way and is scheduled for testing by October. The Proceedings of the 1975 ISABELLE Summer Study, in two volumes; are now available.

Berkeley appointments

A bit late in the day, we record some appointments made by the Director of the Lawrence Berkeley Laboratory, Andy Sessler. A new Division has been set up to coordinate all LBL programmes in nuclear science at the 88 inch cyclotron, the SuperHILAC and the Bevatron (Bevalac). It is known as the Nuclear Science Division and is headed by Bernard G. Harvey. Two Nobel prize winners, Luis Alvarez and Glenn Seaborg have been appointed LBL associate directors at large.

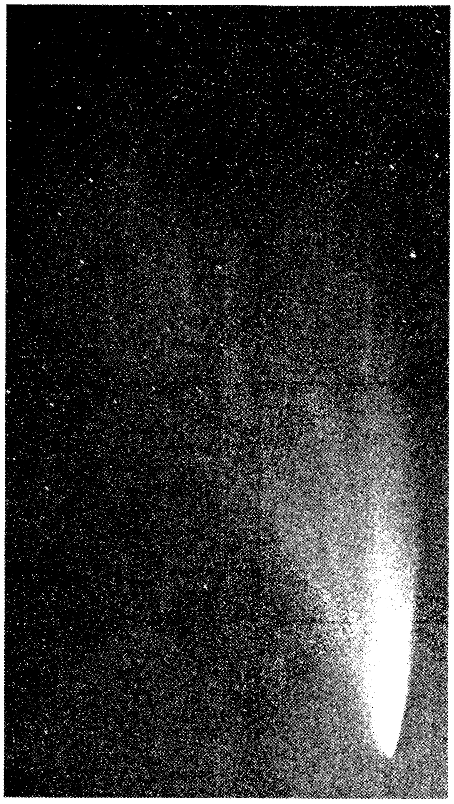
Seeing the light

The slow ejected beam emerging from straight section 62 at the CERN PS passes through a thin window on leaving the ring and traverses an air gap of 6 cm before entering the vacuum tube of the beam line through another thin window. Tests have been carried out to see whether the variation of the ejected beam intensity can be monitored by measuring the light signal which is

Solar panels installed at Fermilab. They are used in the heating system of the house on the right.

(Photo Fermilab)

Comet West, discovered by R. West of ESO (European Southern Observatory) on photographic plates taken with the Schmidt telescope at La Silla Chile (see CERN COURIER November issue page 347), became visible to the naked eye at the beginning of March and could be seen in Geneva just before sunrise. It was the third brightest comet of this century and the brightest since 1927. This photograph was taken by C. Paillard (CERN) and B. Pillet (ESO) on 4 March from La Faucille (a few kilometers from CERN) with a camera on an equatorial mounting lent by the Geneva observatory (exposure time — 7 min). The photo shows the comet's head and a beautiful dust tail more than 15 degrees long.



produced in the air gap as the protons fly through (gas scintillation). Adequate light signals are detected with frequencies varying from d.c. to 1 kHz. A differential light measuring technique can trim off most of the noise which results from protons being lost in collisions in the windows etc. so that the signal is a truer measure of the transmitted beam. Following the successful tests a monitor has been incorporated as a PS beam detector.

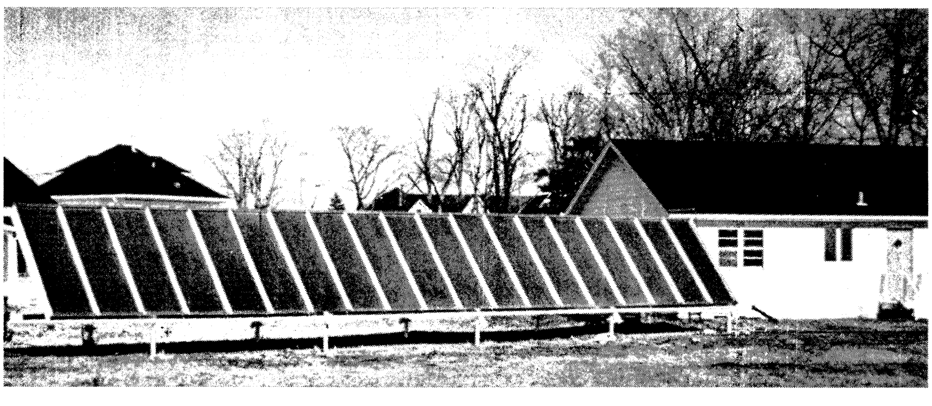
UK SRC Organisation

High energy physics and nuclear physics in the UK are funded via the Science Research Council which was set up in 1965 and looks after basic research in astronomy, the biological sciences, chemistry, engineering, mathematics and physics. The SRC Chairman is Sir Sam Edwards and the Secretary is R.St.J. Walker. There is a Nuclear Physics Board chaired by W.E. Burcham which has five Committees — Nuclear Structure Committee (Chairman, G.R. Bishop), Particle Physics Committee (J.C. Polkinghorne), Film Analysis Sub-Committee (Don Perkins), Nuclear Physics Theory Sub-Committee (R.G. Moorhouse) and a Standing Committee on CERN (John Dowell). Establishments of the Nuclear Physics Board are the Daresbury Laboratory (Director, Alick Ashmore) and the Rutherford Laboratory (Director, Godfrey Stafford). At the SRC Headquarters in London there is an Engineering and Nuclear Physics Division. The Director is Tony Egginton and the Division Head (and Secretary of the Nuclear Physics Board) is Jack Beattie.

Personnel changes at Fermilab

Dr. James R. Sanford, who held the post of Associate Director for Program Planning, will move to the Brookhaven National Laboratory as Associate Director and Head of the ISABELLE Design Study. Jim Sanford contributed a great deal to the organization of the experimental program at the Fermilab and the Director, Bob Wilson, recorded his appreciation of 'this capable friend and colleague who has accomplished so much to make our Laboratory a success.'

In line with the policy of frequent changes in middle management and of involving scientific staff in the administration there have also been some internal changes — Rich Orr who was appointed Assistant Director a year ago moves to the post of Head of the Business Office. Brad Cox has become Proton Department Head in succession to Roy Rubinstein. Quentin Kerns has been appointed Head of the Research Services Department in the Research Division.



Solar energy system commissioned

The Fermilab Solar Energy Club commissioned its first heating system at the end of January. It is installed to heat one of the houses on Sauk Circle which are used to accommodate visitors to the Laboratory. The system has twenty-four 2.5 × 8 foot panels made of black aluminium embedding small pipes through which water flows. On the top surface of the aluminium, tilted at 53° to the horizontal facing the sun, are 8 foot glass tubes placed tightly side by side; behind is fiberglass insulation. The water is pumped to the house for heating. Chairman of the Club is John O'Meara. One of the members, Hank Hinterberger, *Arthur Roberts, Fermilab, (left) and Val Telegdi, Chicago, stars of stage, screen and experimental hall. . . two of the physicists who enjoyed themselves in a cabaret at the February Meeting of the American Physical Society.*

Head of Technical Services, is also developing a system for industrial applications to which we shall return in a future issue.

Several other USA Laboratories are busy in the solar energy field. For example, the Lawrence Berkeley Laboratory has several projects within its Energy and Environment programme. A few people at CERN, in the context of the ESO/CERN collaboration, have considered informally the possibility of solar energy for the Observatory on La Silla mountain in Chile.

Reliable Booster

In 1975 the 800 MeV Booster at the CERN proton synchrotron operated for 4490 hours as PS injector — three times the 1974 figure. The unscheduled beam-off time for the Booster itself was, on average, less than two per cent. The Booster team ascribe this low figure to specific technical and operational measures as part of an appropriately prudent management policy and . . . to plain luck.

Physics is fun

At the February Meeting of the American Physical Society, some of our colleagues put on a cabaret called 'The Physical Revue'. Master of Ceremonies was Marvin Goldberger from Princeton whose wife Mildred was Producer. Stars included Val Telegdi from Chicago doing a travel agent sketch advising a young physicist on the choice of a European Summer School. (He dismissed Schools in Sweden because of the danger from women, in Italy because of the danger from food poisoning, in France because of the danger of having to work at physics and recommended Switzerland where the only danger was linguistics — the School was to be conducted in Romansch!). Arthur Roberts, from Fermilab, who has had a dual physicist/musician career with works played by several orchestras, also had a prominent role singing a medley of songs with sharply observed lyrics. Stage hands included past APS Presidents — I.I. Rabi, Robert Serber, Philip Morse and Chieng-Shung Wu.

Two second flat top operated at Fermilab

The Fermilab main ring has been operating in February with a two second flat top at 300 GeV. This new mode of accelerator operation has been brought into use with virtually no disruption of the physics programme. Counter experiments report that it has been highly successful in decreasing accidental counting rates. A further new mode of operation is planned with a two second front porch at 200 GeV as well as the two second flat top at 300 GeV, giving a net beam spill of four seconds.

Conferences

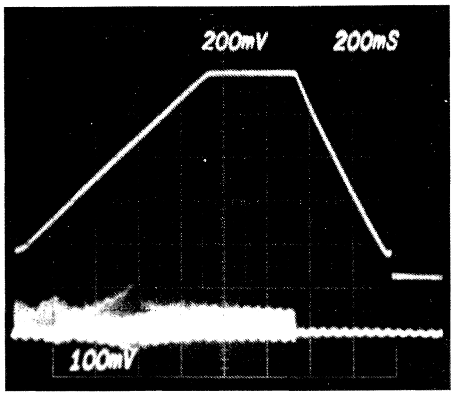
A Gordon Conference on Elementary Particle Interactions — Structure of Nucleons and Search for New Degrees of Freedom — will be held at Tilton, New Hampshire, USA from 16-20 August 1976. The Chairman of the Conference will be Malcolm Derrick of Argonne. Further information from Dr. Cruickshank, Pastore Chemical Laboratory, University of Rhode Island, Kingston, Rhode Island 02881 USA.

A Symposium on High Energy Physics with Polarized Beams and Targets will be held at Argonne National Laboratory on 23-27 August 1976. Emphasis will be on new results on the *spin dependence of interactions at momenta above 1 GeV/c. Other topics are developments in the technology of polarized sources, beams and targets, possibilities in storage rings and the use of spin dependence in the search for new particles. Further information from Prof. M.L. Marshak, School of Physics, University of Minnesota, Minneapolis, Minnesota 55455.*

Polarized target specialists may be interested in a low temperature physics Conference — EPS Study Conference on Dilution Refrigeration — to be held 25-28 September at the University of Lancaster. Further information from Miss C.J. Martin, Department of Physics, University of Lancaster, Lancaster LA1 4YB, UK.

KEK's off

In the early hours of 4 March the proton synchrotron at KEK (the National Laboratory for High Energy Physics in Japan) accelerated protons to 8 GeV for the first time. The emerging beam intensity was measured as a few times 10^{10} protons per pulse. Construction of the accelerator, the first proton synchrotron to be built in Japan, began in 1971. Our Japanese colleagues have displayed their traditional technical proficiency in bringing the machine into action within five years. We will have the commissioning story in our next issue.



Oscilloscope traces, recorded on 4 March, which display the acceleration of protons in the KEK synchrotron to 8 GeV for the first time. The upper trace shows the rise of the magnetic field in the ring magnets during acceleration. The lower trace is from a beam intensity monitor.

CERN ACADEMIC TRAINING PROGRAMME

(1975-1976)

This Programme is organized each year by the Academic Training Committee. Details may be obtained from the Training and Education Service, CERN, 1211 Geneva 23 (Tel. 022/ 41 98 11, Ext. 2844). The programme for each term is published in the CERN COURIER.

3rd Term:

May 11, 12, 13	Some aspects of X-ray astronomy, by B. Rossi (M.I.T. & University of Palermo)
June 1, 2, 3	Principles of operation of multiwire proportional and drift chambers, by F. Sauli
June 8, 9, 10	Filtering techniques, by H. Nureldin (ETH - Zurich)
June 15, 17, 22, 24, 29	Introduction to cluster analysis, by B. Schorr

These lecture series are given at 11 h. 00.

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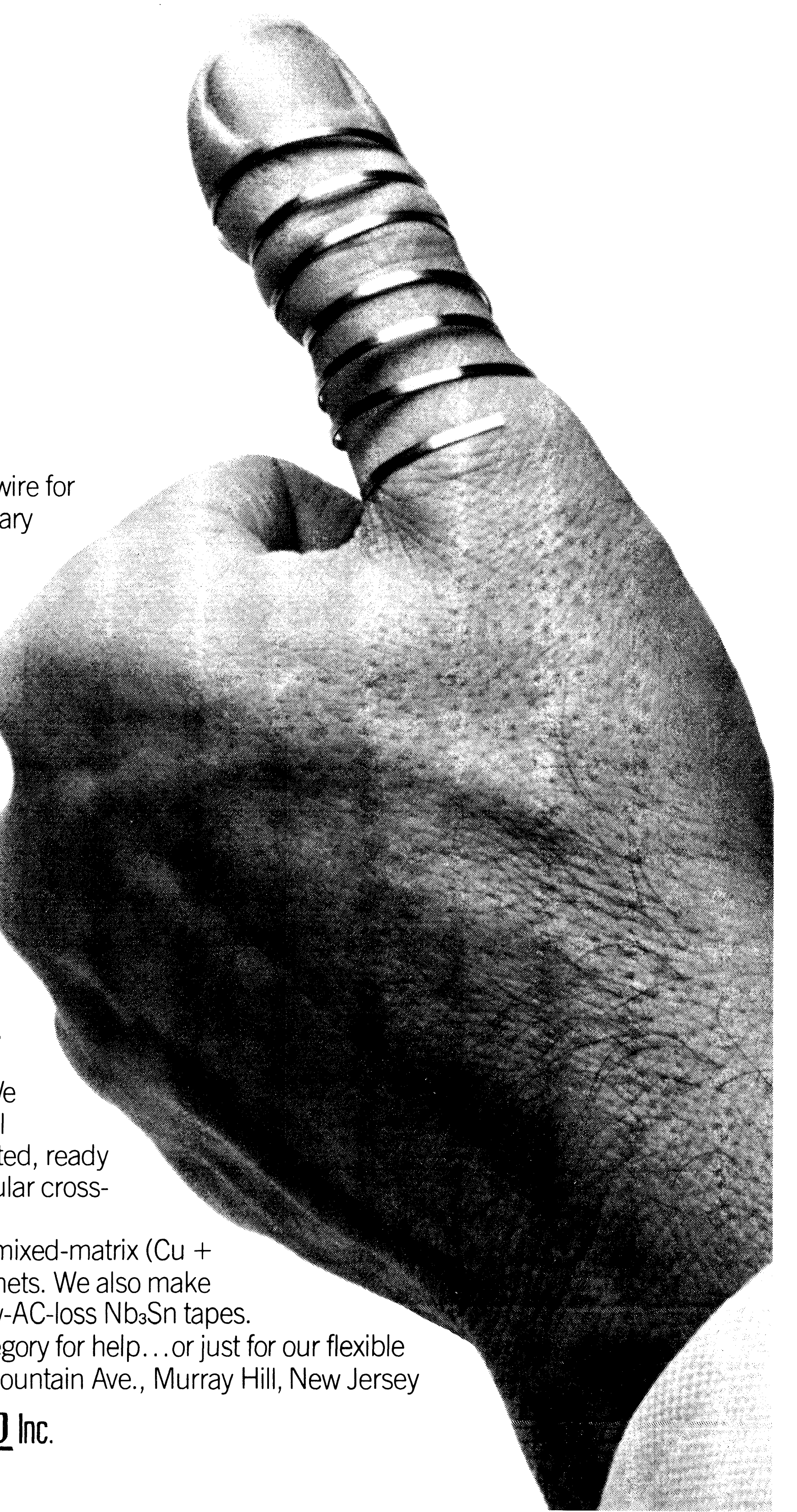

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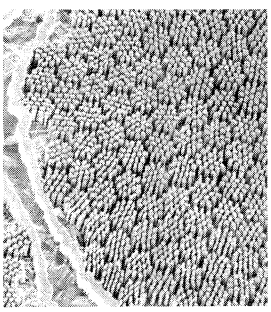

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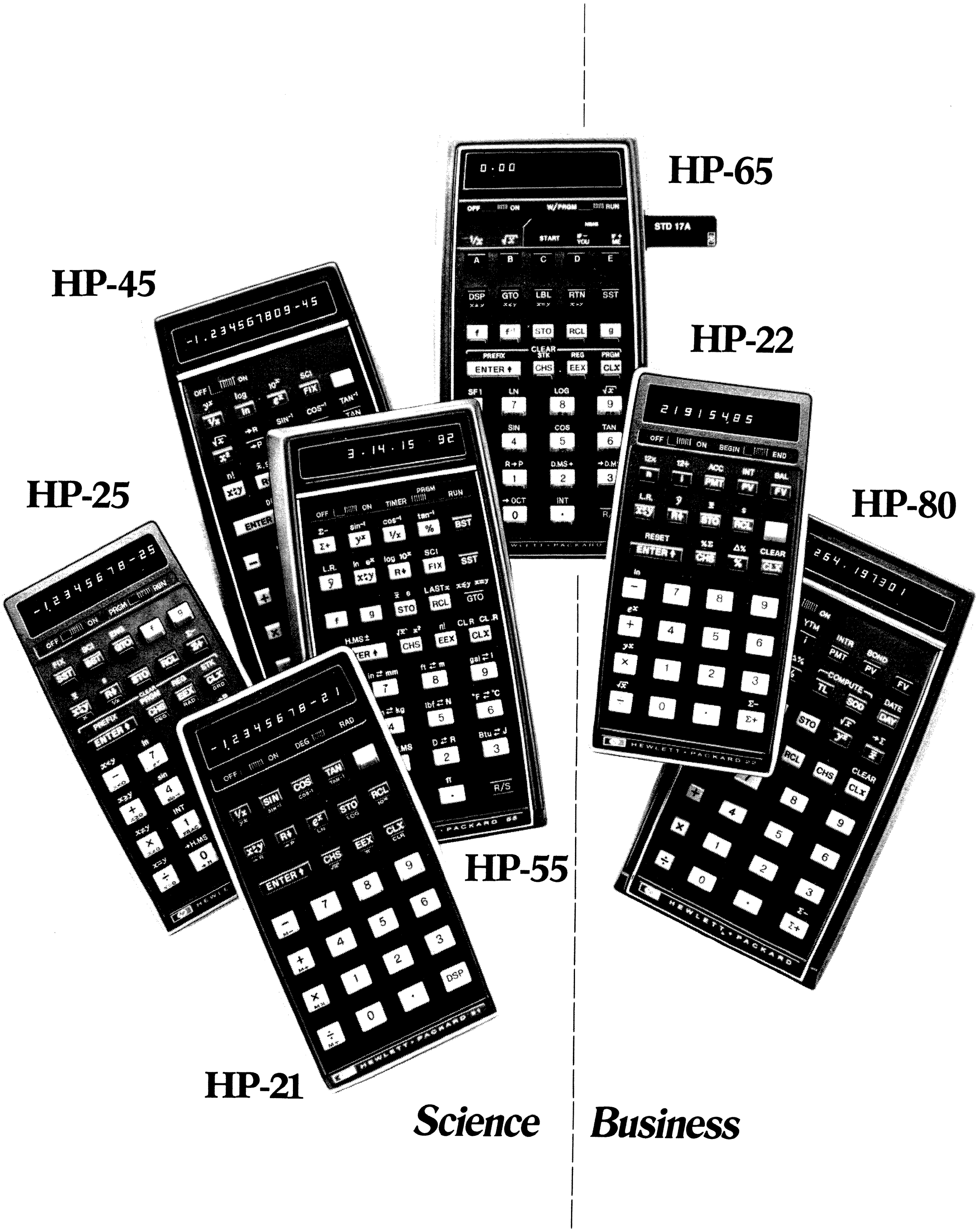

evaluation report

subject	new video monitor driver - type vdd 2081
origin	sen electronique - geneva
distribution	all camac users
utilisation	interactive control consoles (touch panel and display)
description	double width module in camac standard
capacity	24 lines of 48 or 80 characters ram memory 2048 x 8 bit max.
character sets	alphanumeric - 64 ascii upper set graphic - 16 programmable characters incl vertical bar and horizontal dot
other features	blinking facility rereadable ram memory with insert/delete capability compatible ascii (7 bit)
memory access time	500ns. i.e. faster than the camac cycle, no status request required
video output	composite video signal ccir r 308 2 norm
checkpoints	comprehensive character and graphic set word/byte transfer capability for easy direct memory transfers up to 4-monitor fan-out
additional information	sales department sen electronique sa 31 ave ernest pictet 1211 geneve 13 tel: 44 29 40

23359 senel ch

ps has a very interesting price too

New low-cost PLASTIC SCINTILLATOR NE 114

Where experiments require a large number of plastic scintillator sheets, costs can be considerably reduced and yet a good overall performance maintained by the use of the new low-cost NE 114 plastic scintillator.

This new scintillator, specially developed by Nuclear Enterprises for certain high energy physics experiments, has a light output of 70% relative to NE 110 (or three times greater than that of the Plexiglas-type scintillator), while retaining all the other excellent characteristics of NE 110, including an intrinsic light attenuation length of 3.5 to 4 metres, a wave-length of maximum emission of 434mm, and a decay time of the order of 4ns.

The long term stability of NE 114 under reasonable laboratory working conditions is guaranteed for a minimum of 5 years and it is supplied rough cut or machined with polished edges. Sheets up to 4 metres long are now being produced in the Nuclear Enterprises Edinburgh Laboratories where production capacity for plastic scintillators has been tripled in the past year.

Details of cost and delivery for NE 114 and the world's most extensive range of scintillation detectors are available on request.

Illustrated below: Some of the new vats for the processing of NE 114 plastic scintillator at the Edinburgh Laboratories of Nuclear Enterprises.

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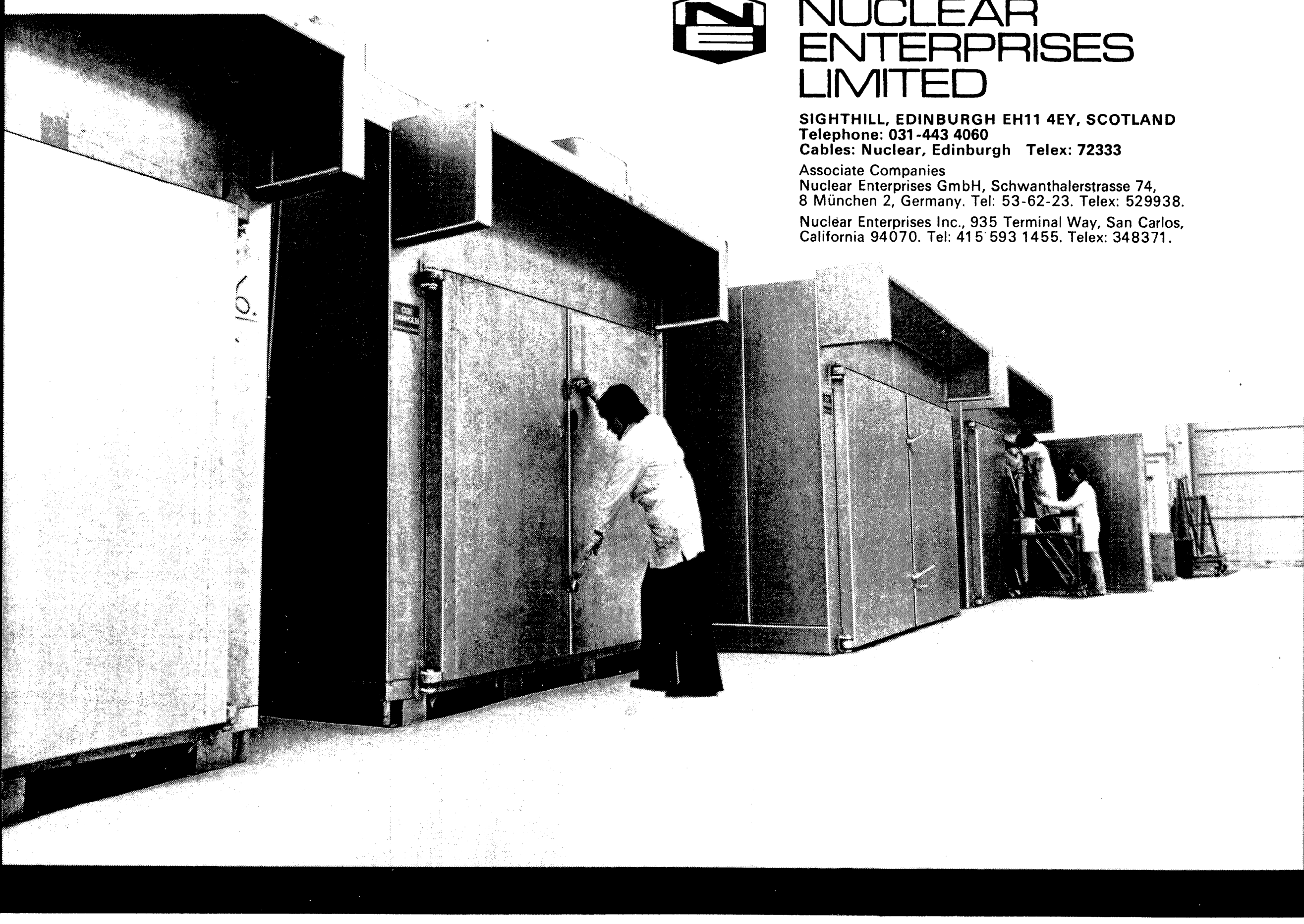
Telephone: 031-443 4060
Cables: Nuclear, Edinburgh Telex: 72333

Associate Companies
Nuclear Enterprises GmbH, Schwanthalerstrasse 74, 8 München 2, Germany. Tel: 53-62-23. Telex: 529938.
Nuclear Enterprises Inc., 935 Terminal Way, San Carlos, California 94070. Tel: 415 593 1455. Telex: 348371.



for solving monitoring and control problems, such as counting, programming and signalling:

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*The patented cabling system provides quick and reliable interconnections.

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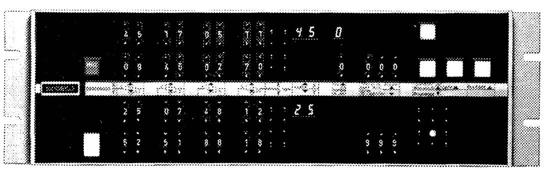

*Servicing is simplified by rapid interchange of complete plug-in units, thus reducing lost production time to a minimum.

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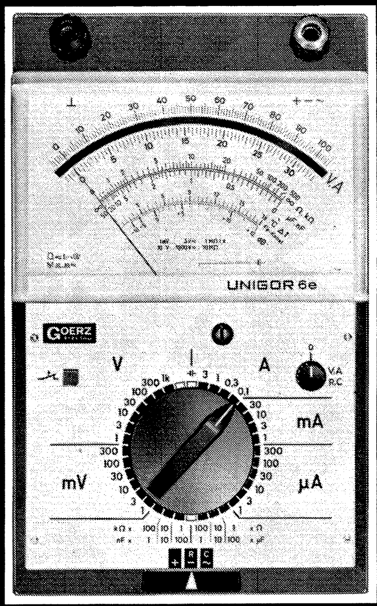

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+6V	at	25A	Total Stabilised Power 200W
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GRENSON ELECTRONICS LIMITED

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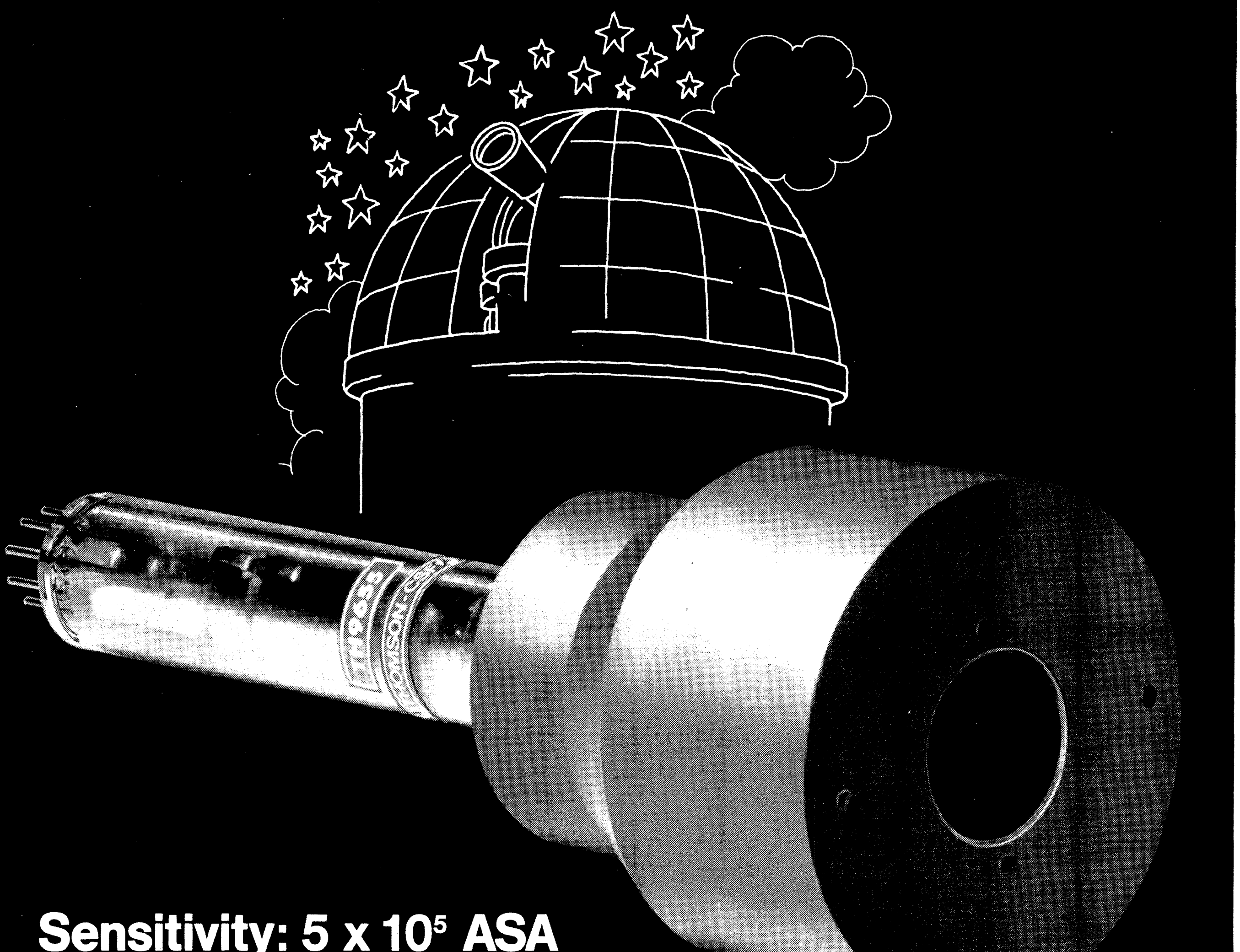

Sensitivity: 5×10^5 ASA
Light level: 5×10^{-5} lux

Light levels required by conventional vidicons prevent their use in numerous industrial-television applications.
These limitations do not apply to the THOMSON-CSF **Nocticon**®. Its exceptional performances enable coping with the ultimate in low-light conditions.
The Nocticon has an S 20 -type photocathode and a silicon-diode-array target, scanned by an electron beam from a gun similar to that of a regular Vidicon.
This structure ensures:
- wide spectral response
- sensitivity of 300 mA/lumen
- low dark current
- low lag
- a large dynamic range.

The Nocticon's design also provides high resistance to damage by intense light and exceptional ruggedness, allowing its use under severe environmental conditions.
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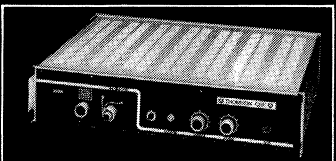
Possible applications for the Super-Nocticon range from photon counting to surveillance on particulary dark nights.



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

THOMSON-CSF

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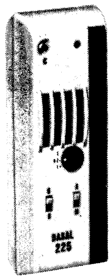
7 mg/cm² (skin dose).



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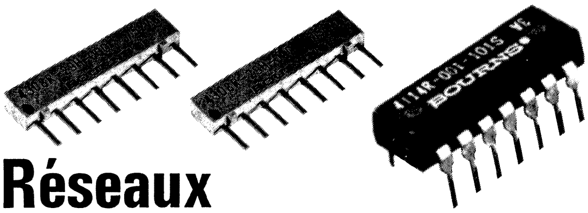

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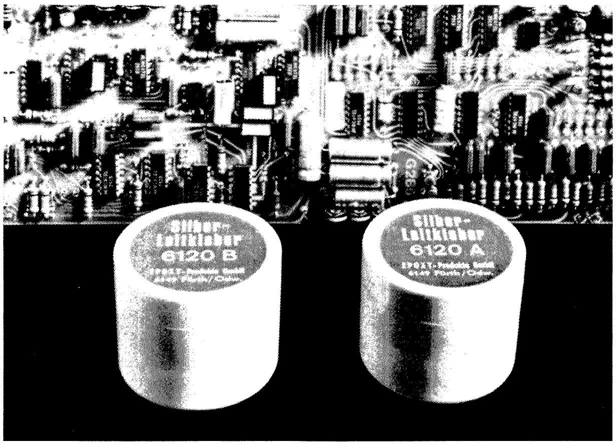

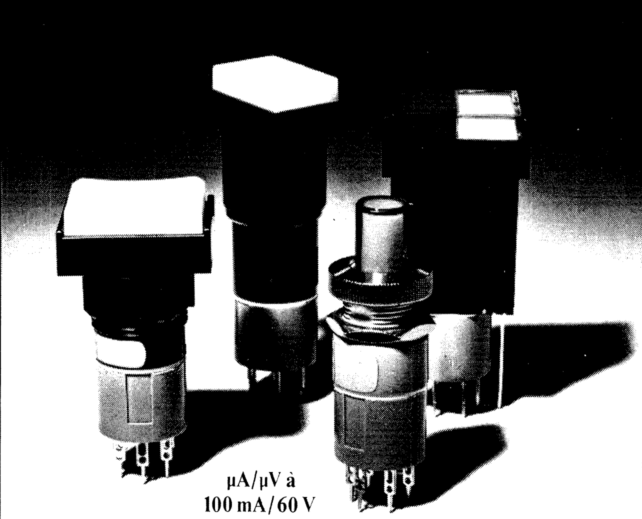

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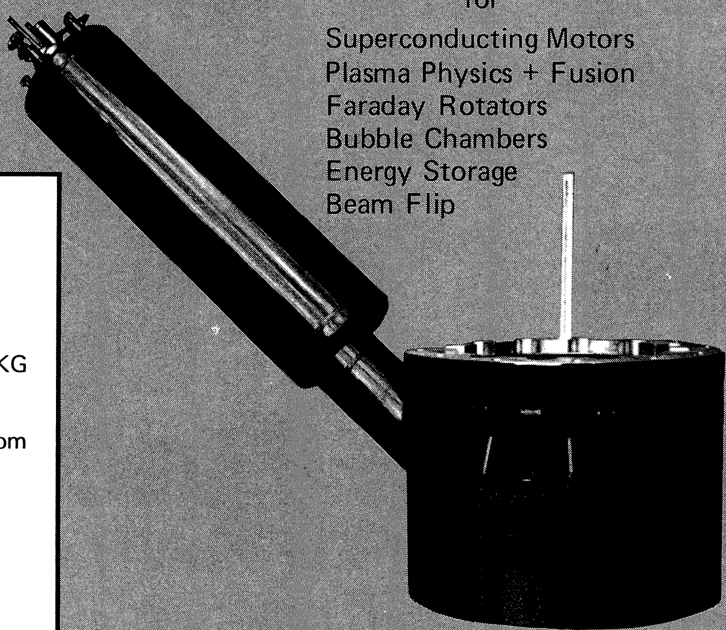

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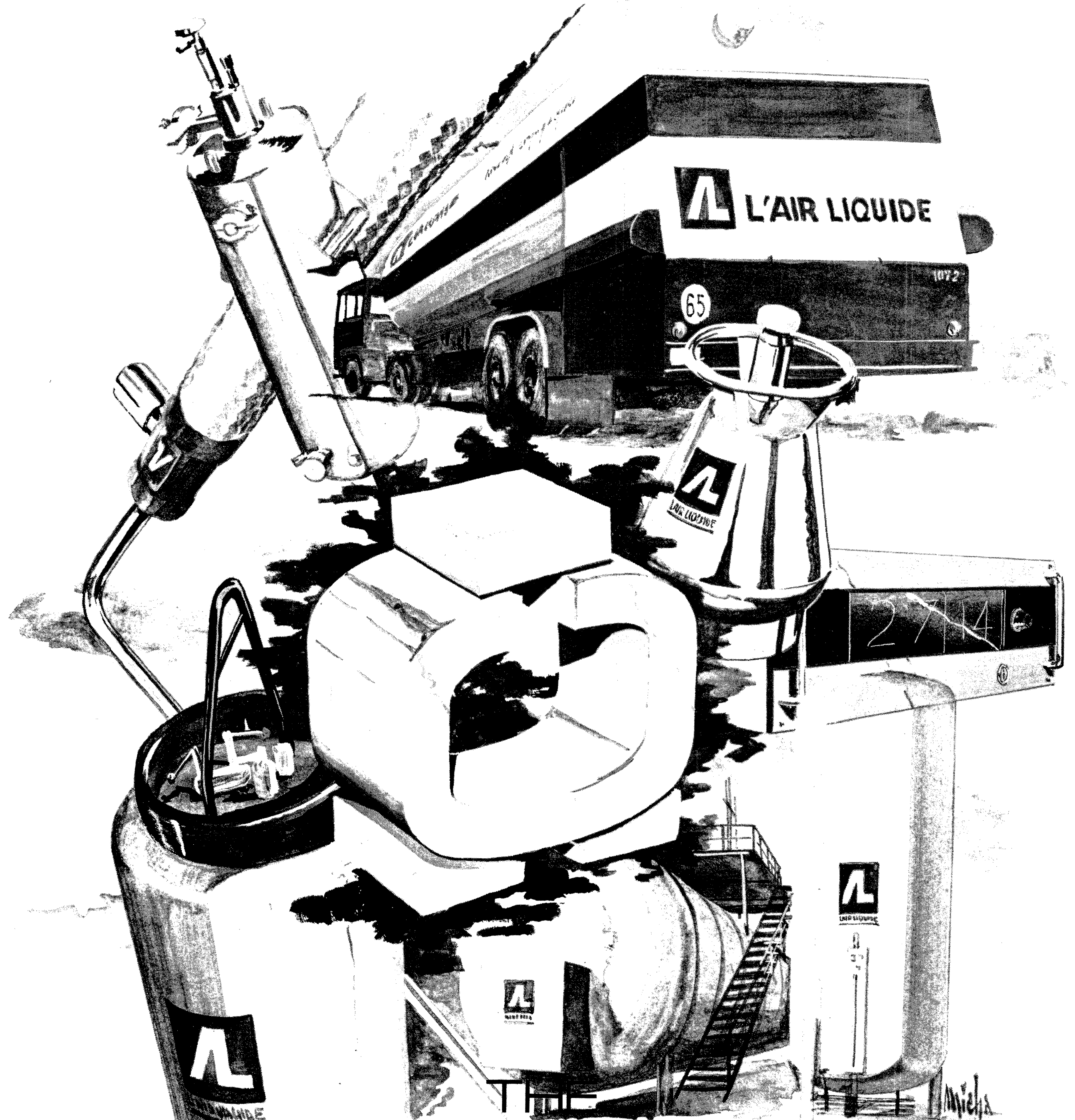

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