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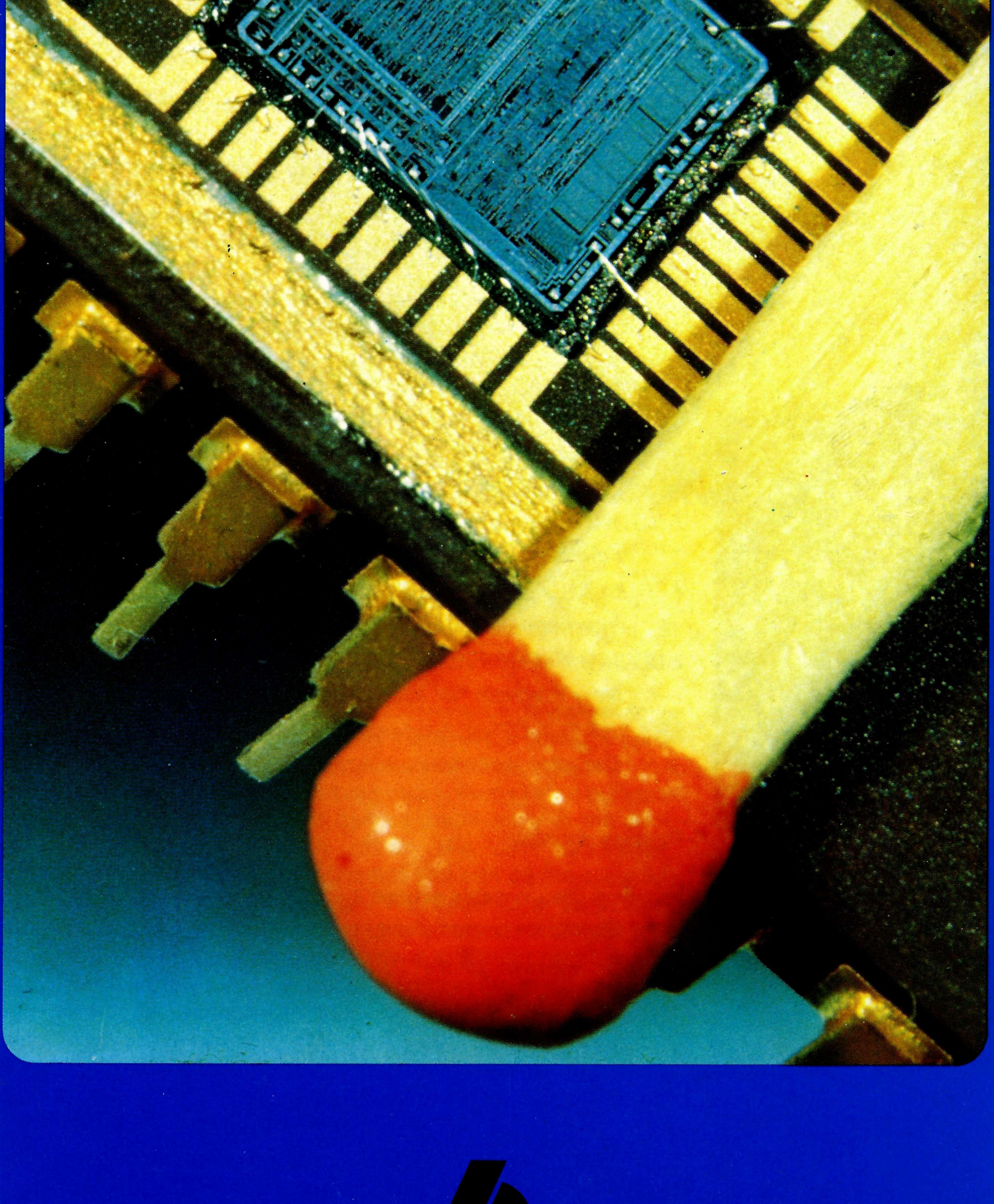

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Around the Laboratories

Physics monitor

Cover photograph: A 'microprocessor' beside a match head. These tiny data handling units are having a significant impact in high energy physics experiments. Conference report on page 235. (Photo Motorola)

Microprocessors

At the recent Microprocessor Conference at CERN, many 'poster' sessions included hardware exhibits which provided a useful balance to the oral presentations.

(Photo CERN 231.5.81)

In a relatively short time, modern semiconductor technology has made a significant impact on the methods of particle physics. Nowhere has this been more evident than at the first ever Topical Conference on the Application of Microprocessors to High Energy Physics Experiments, held at CERN from 4-6 May.

During recent years, new methods have been perfected which enable complex electronic logic to be mass-produced in small integrated circuits or 'chips', whose dimensions are typically measured in millimetres. The dramatic rate of progress in this field has provided logic units capable of carrying out increasingly complex operations at higher speed and at lower cost. Using these units, designers are producing custom-built systems to meet an ever growing variety of requirements.

Among the purists, the word 'microprocessor' is generally taken to mean a fairly complete programmable processing unit with a fixed instruction set and assembled on a ngle chip. In some cases the capabilities of these devices can even rival those of minicomputers, or perhaps in the near future even mainframe computers.

As well as using such commercially-available processors, physics also exploits purpose-built micro systems. In particular, the availability of 'bit slices' – microprogrammable units – has provided a highly useful new brick for building intelligent systems.

In the concluding talk at the Conference, C. Verkerk of CERN pointed out that the general objectives of all this activity are to improve the quality of an experiment, either in terms of the data it produces, or its running conditions.

In modern particle physics, where more, and bigger, experiments are searching for rarer and rarer events amid ever increasing event rates, these objectives seem to be especially relevant. Thanks to modern LSI microcircuitry, substantial progress is being made.

Many Conference speakers emphasised the specific goals of particle physics micro applications. If a good rejection of unwanted information can be made early in the decision chain, the data is initially enriched. If this can be done quickly enough, the dead time (when the data acquisition system is unable to accept more incoming data) can be reduced and the rate at which interesting events can be recorded increases. With such a data sample, the subsequent off-line data handling and processing load becomes less onerous. The ultimate goal would be event analysis in real time, with experiments indicating their results as they went along.

At the Conference, invited speakers summarized the micro developments at the major Laboratories (CERN, DESY, SLAC, Fermilab, Brookhaven and Cornell), while shorter presentations summarized individual projects. Very striking was the diversity of projects either in operation or still in the development stage. User groups appear to be adopting micro solutions piecemeal, there being only a few examples of ready-to-use micro systems which have so far attracted widespread interest.

Many speakers indicated the attraction, almost fascination, which these micros have. With high energy physics becoming increasing centralized, micros, according to Verkerk, provide small groups or even individuals working at their home institutes with a means of contributing directly to a large experiment at a remote Laboratory. While this activ-

The 168/E microprogrammed processor which emulates the IBM 370/168 mainframe computer. First developed at SLAC, it is now being considered for some 50 physics applications worldwide.

(Photo CERN 586.3.81)

ity is welcome, Verkerk asked whether the resulting proliferation of systems is really necessary.

At the front end of experiments, data acquisition increasingly uses very fast programmable micro preprocessors as a flexible means of treating initial raw data to supplement the efforts made so far using hardwiring alone. This has been brought about by the emergence of large detectors at colliding beam machines, such as those at PETRA, and through the widespread use of big calorimeters.

After initial triggering by fast hardware logic, the next objective is to reduce the data rate further by additional methods such as look-up table techniques, hardwired processors, or specially developed processors. At DESY, there is a proliferation of look-up tables using fast read-only memories and similar devices. At Fermilab, with many experiments searching for small effects at high event rates, several examples can be found of sophisticated hardware triggering.

After hardwiring has absorbed the brunt of the incoming data rate, the use of microprogrammed devices for further event selection and other tasks seems to be on the increase. However many speakers at the Conference emphasised the programming difficulties encountered in this sector.

One method of sidestepping programming problems is to design a processor which emulates the working of a commercial computer. One of the notable examples is the 168/E, which emulates the IBM 370/168. First developed at SLAC, it is now being considered for about 50 applications worldwide. As well as handling off-line number crunching at respectable speeds, this processor has also been successfully demonstrated on-line, for example at the Split Field Magnet at CERN and in the hybrid bubble chamber at SLAC.

Another successful emulator described at the Conference is MICE (MICprogrammable Engine) developed at CERN and which can process even faster than the PDP 11 it emulates. One example of its use is in the read-out and processing for a positron camera for medical applications, providing three-dimensional imaging in real time – computer assisted tomography – hence its name CAT and MICE!

At the moment, triggering in physics experiments has to be largely restricted to hardwiring. Truly programmable devices can only cope once the useful event rate has been reduced to about 10^4 or less per second. While the frontier of programmable intelligence is gradually being extended, physicists can still only dream of the day when they will have fully programmable triggers with on-line event analysis providing digital displays of the physics parameters!

Mini betas at DESY

Klaus Steffen seated on one of the mini-beta quadrupoles at DESY's PETRA electron-positron collider.

(Photo P. Waloschek)

After two and a half years of operation, the PETRA electron-positron ring at DESY has reached a remarkable level of performance. In April, the rate of useful particle collisions recorded in the four running experiments was nearly three times higher than last year. The number of events collected per day now corresponds two months of running back in 979. Peak luminosity has reached 1.6 x 10^{31} per cm^2 per s and luminosity per day is well over 700 events per nanobarn.

A major improvement of the machine was achieved with the addition of focusing quadrupole magnets in so-called 'mini beta' sections. These have been installed to squeeze the beam in the four collision regions and are now in routine operation.

The ideas developed at DESY to improve focusing have proved to be feasible and moreover compatible with the requirements of the experiments mounted at the collision regions. In practice, the new mini beta sections have not degraded any achine parameters; in particular the beam lifetime of several hours has remained unchanged. This confirms previous calculations and increases confidence that the PETRA machine is now well understood.

The present techniques used at PETRA to achieve record electron-positron collision rates have come a long way in the twenty years since Bruno Touschek proposed counter-rotating beams of electrons and positrons stored in a single machine.

By improving the focusing at the crossing points to reduce the transverse dimensions of the stored beams, the 'target density' of one beam seen by the other is increased. This procedure has been used in all electron-positron storage rings over the last ten years, and is also profitably applied in the CERN Intersecting Storage Rings to improve the proton-proton collision rate (see March issue, page 59).

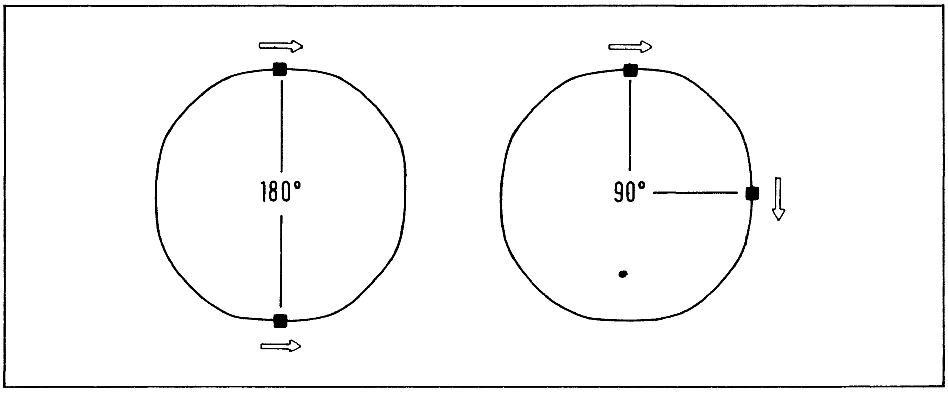
But it is not only the transverse dimensions of the beam at the interaction point which are important. The beam divergence is also relevant because of the effects of one beam on the other. The electromagnetic field of one bunch affects the particles in one travelling in the opposite direction and causes a nonlinear focusing disturbance. Above a critical current, one beam may destroy the other (usually the weaker). This is usually referred to as the beam-beam limit, and can be reduced by increasing the beam divergence at the collision point.

To attain high luminosities near the beam-beam limit, a small beam size and a large beam divergence are required at the collision point. The ratio of beam size to divergence is usually called the beta value, so this parameter should be particularly small at the collision point.

In electron storage rings, beam size could be reduced in principle by increased quadrupole focusing everywhere. This reduces the product of beam size and beam divergence which, according to a general beam transport law, for a given machine is constant around the ring. Instead, the beta ratio can be made locally very small by focusing the beam with strong divergence into a narrow spot (beam waist). In machines without low beta sections, a reduction of the beam cross-section (over the whole machine) has never provided significant gains in luminosity, due to the limitations imposed by beam-beam interactions.

Initially, it was considered essential to leave a lot of free space for the experiments and place the quadrupoles far from the crossing points.

Two possible schemes worked out for PETRA by Gerhard Ripken to compensate for the effects of the magnetic fields of detectors without using compensating magnets. Mutually opposite detectors need fields which are equal and opposite. Detectors at 90 degrees need their fields to be equal and in the same sense.



The high beam divergence then led to the construction of quadrupole lenses with large aperture.

Though it was always understood that the luminosity could be improved by reducing the space between the final focusing elements, it was only after quantitative arguments had been presented at DESY by Klaus Steffen that the situation was sufficiently clarified and the present successful system was found. The stored beam has a natural energy spread and increased focusing introduces an energy dependent disturbance to the particle orbits, called 'chromaticity'. This depends critically on the length of the sections with high beam divergence and must be compensated by sextupole magnets placed around the ring. These sextupoles introduce nonlinear effects which end up reducing the useful aperture available for stable particle trajectories. This eventually results in a drastic reduction of the beam lifetime.

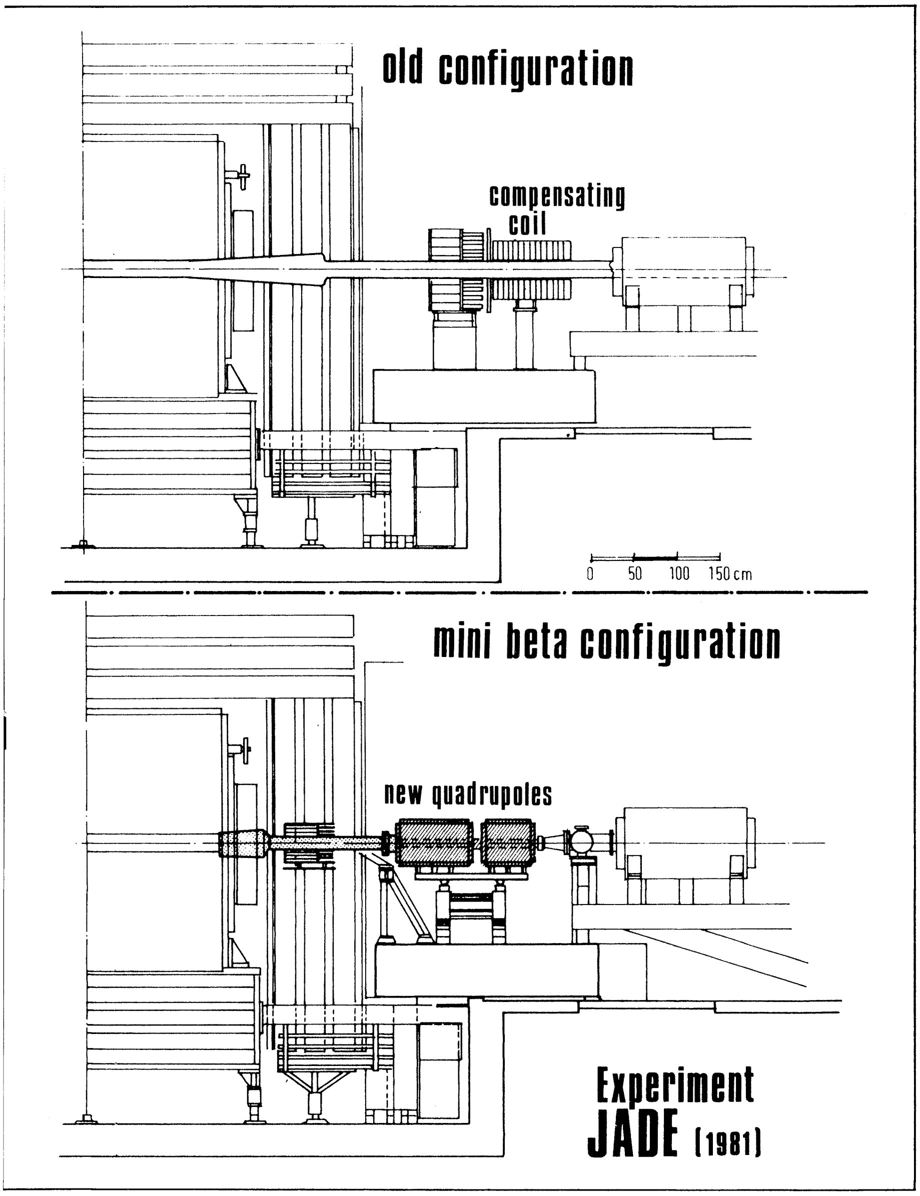
A geometry and system of beam optics which takes all this into account has now been tried out at PETRA. In this 'mini beta' system, the beta value at the four interaction points has been reduced, and at the same time the distance between the quadrupoles either side of the intersection has been reduced from 15 to 9 metres. As expected from chromaticity considerations, there was no deterioration of beam lifetime or other machine parameters. The higher divergence of the beams merely increased the background for the experiments and required better adjustment of the beam positions. Up to threefold gains in luminosity were measured.

In the past, the quadrupoles used for low beta sections were placed rather far from the crossing points and had to have large apertures. Now the problem is to make them small and place them as near as possible to the crossing points. However there are limits to which the focal length of these quadrupoles and the gap between them can be reduced while still leaving enough space for the experiments. The strength of the quadrupoles is limited by steel saturation, or, in the case of superconducting magnets, by breakdown effects. For high luminosity, the bunch length (which depends mainly on the accelerating frequency) should not be much longer than the low beta beam waist, otherwise parts of the bunches cross over where their transverse dimensions are not small. Eventually, beam-beam effects limit the extent to which the beam can be squeezed.

In the new PETRA configuration, conventional quadrupoles of sufficient aperture reach beta values of about 5 cm without excessive chromatic distortion. For smaller betas (or higher energies) stronger quadrupoles are required, and these can be built using superconducting techniques. Future plans, recently reported by Klaus Steffen and Gus Voss, already include slim superconducting devices without iron yokes and which are likely to provide further significant luminosity improvements. These may even be made compatible with the magnetic fields of the detectors and placed inside them. These developments are certainly interesting for experiments using the next generation of storage rings, like LEP, to compensate for the low reaction cross-section expected at very high energies.

Along the beam pipe near to the bunch crossing points, the space available for focusing magnets is limited by the requirements of the experiments. Fortunately most reactions in which an electron and a positron annihilate into an intermediate virtual photon can be analysed while ignoring a small cone around the incident beams. Other types of interaction require the observatio of particles emerging very near to the beams. These include most of the electromagnetic interactions (like the elastic scattering used to monitor luminosity) and some higher order processes in which the incoming particles emit photons which then interact themselves (two-photon physics).

Measurements near to the beam are in any case quite difficult due to the geometrical requirements of the vacuum pipe and to the high background level in this region. In addition, in many detectors so-called 'compensation coils' impose further limitations. Placing strong quadrupoles in the same regions would cause further complications. For PETRA, a solution has been found which completely eliminates the



Substitution of the compensation coils of the JADE detector at PETRA. The new quadrupoles have resulted in a threefold increase in luminosity.

compensation coils and makes space available for new quadrupoles.

Compensation coils are used to cancel the effects of magnetic detector fields on the beam. In particular, longitudinal fields like those of the usual solenoid magnets, placed in regions of high beam divergence, must be compensated to avoid coupling vertical and horizontal oscillations of the beam particles. Particles moving not exactly parallel to the (longitudinal) field describe helical trajectories not foreseen with the usual beam optics. These must be corrected by other longitudinal fields.

These problems have been investigated at DORIS and PETRA. In January 1980 Gerhard Ripken, who had earlier studied the problem for DORIS, proposed trying to compensate the longitudinal fields of different detectors with each other, without recourse to compensation coils. He used a storage ring simulation program called PETROS to check his ideas.

For PETRA, the result was that detectors at 90 or 180 degrees to each other around the ring stood a good chance of mutually compensating. Detectors opposite each other should have the same (integrated) longitudinal fields in opposite directions, while detectors at 90 degrees should have the same fields, but in the same direction (as seen by a circulating particle). The situation at PETRA is complicated by the fact that one of the detectors (Mark-J) has no field on the beam at all. The other three can be adjusted so that two pairs compensate each other: JADE with half the field of CELLO (at 90 degrees) and TASSO with the other half of CELLO (also at 90 degrees). All three fields are directed the same way long the beam. Anton Piwinski and Albin Wrulich tried this configuration and, with the help of the experimental groups, it worked first time.

Since then, studies and preparations have been undertaken to substitute all compensation coils at PETRA with quadrupoles and to add quadrupoles to Mark-J. These modifications were carried out at JADE and TASSO last winter so that these detectors can now compensate each other. CELLO still keeps its compensation coils, but quadrupoles have been added at Mark-J, with the excellent luminosity results already mentioned.

A system to increase DORIS luminosity using the mini beta scheme has been proposed by Klaus Wille. Following these ideas, the new ARGUS detector is being built with an integrated system of quadrupoles and compensation coils. The second DORIS interaction region will also be provided with new quadrupoles, bearing in mind a non-magnetic experiment like LENA, which could be proposed in the near future. The distance between the new quadrupoles will be 236 cm, compared with the original 512 cm. The new configuration, called DORIS II, should be ready next summer to provide a tenfold increase in luminosity.

LEP takes to the hills

From 1-7 June the focal point of thinking about the European project for a very high energy electron-positron machine, LEP, moved up into the Swiss mountains. The European Committee for Future Accelerators, ECFA, organized a 'General Meeting on LEP' at the alpine resort of Villars. This was in the long tradition of ECFA meetings which try to ensure a broad consultation of the European High Energy Physics community before major decisions on CERN projects are taken. Over 400 physicists gathered at the Palace Hotel where they were very agreeably immersed in the happy Club Méditerranée ambience.

The Conference was successful beyond expectation and left the feeling that the contacts and discussions had moved LEP significantly further towards its goals. Above all it demonstrated again the keenness of the community to become involved in the experimental programme of LEP and the great belief in the scientific promise of the machine. (For a description of the project and its physics aims, see March 1980 issue, page 5.)

If authorization for LEP is forthcoming from the CERN Member States in the very near future, it is hoped to start the huge task of tunnelling the machine in the spring of 1982. The construction schedule aims for first colliding electron-positron beams at the end of 1987. These two dates were crucial to some of the discussions at the Meeting. First of all the design of the underground experimental halls will soon have to be fixed, since they need to be included in the civil engineering contract and, secondly, the time necessary to decide on the experimental programme and to build large and complex detection systems is not too long. Out of the many interesting discussions we will therefore restrict ourselves here mainly to those relating to the civil engineering decisions and particularly the evolution of the experimental programme.

LEP is to be built under very different financial conditions to the earlier big CERN projects. No 'new' money is to be made available and the construction is to be financed at existing CERN budget levels. To sustain other research at the same time, such as the programme at the SPS 400 GeV proton synchrotron, shortly to be the scene of high energy proton-antiproton collisions, it is most important to limit LEP costs. This was stressed several times by CERN Director General Herwig Schopper and LEP Project Leader Designate Emilio Picasso. A consequence of the financial constraints is reflected in the definition of Phase 1 of the project – out of the eight collision areas on the machine, only four are to be prepared for experiments at the start of LEP operation.

The 'even-numbered' areas (2,4,6,8) will be equipped first. Of these there are special problems associated with No. 4, deep under the Jura and accessed by a long tunnel. Ingenuity will therefore be needed to construct a detection system from modules which may be a maximum of about 1 x 2 m cross-section. The other three areas will each be accessed by two shafts (one for services and personnel and the other unobstructed for equipment). These experimental halls will be dug in the molasse with construction techniques which have proved successful for the new large underground experimental halls at the SPS.

There were questions on whether money could be saved by reducing hall size, on whether it would help to offset the major access shaft (so that it did not descend into the body of the hall), and on the possible need for side alcoves so as to be able to withdraw the central detector. It is obviously desirable to avoid the use of inflammable gases in the detectors if at all possible because of the high cost of additional safety precautions in the underground areas.

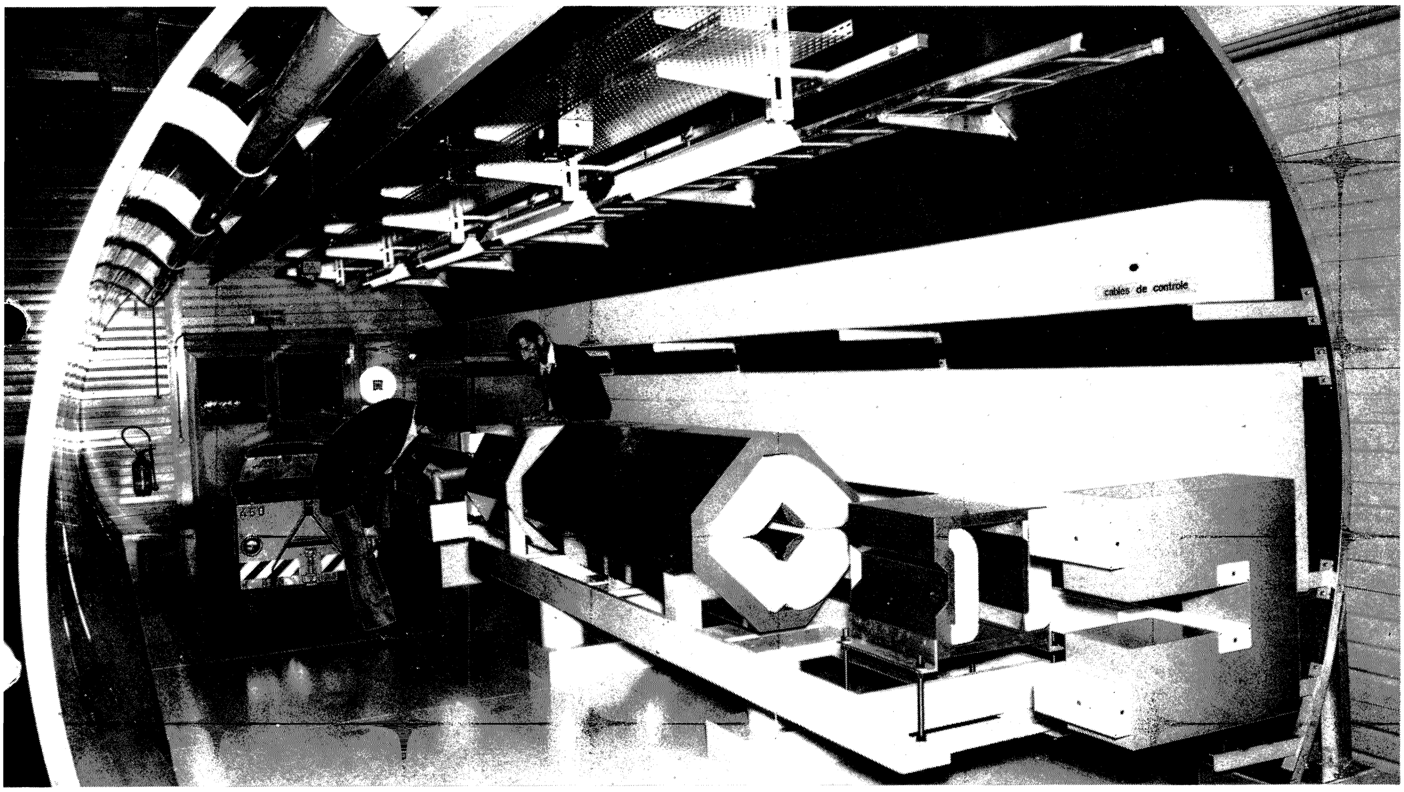
Following PETRA experience, the aim is to build detector systems which can be moved in or out of the machine for repair or modification in a matter of days. The complexities of push-pull arrangements, where two experiments share one area, were rejected. Detectors built so that they themselves shield radiation would enable electronics to be brought to the detector and reduce cabling needs.

An important development in the hall and detector design is the recent success of mini beta insertions at DESY (see page 237), increasing the machine luminosity which dictates the number of interactions which can be seen per second. The insertions require quadrupole magnets as close to the beam collision point as possible. The present LEP design has quads as close as 5 m each side, allowing only 10 m for the detector and the tendency is to bring them even closer. Superconducting quadrupoles may be appropriate. It may be necessary to incorporate the quadrupoles in the construction of some of the detectors. Certainly it was the general consensus that the gain in luminosity made it worth living with the problems posed for detector design.

There are two other consequences of having strongly focusing quadrupoles close to the collision region. One relates to a specific type of physics – studies of two-photon interactions require looking close to the beam directions over long lengths of detector. This seems

A mock-up of the LEP tunnel.

(Photo CERN 426.5.81)

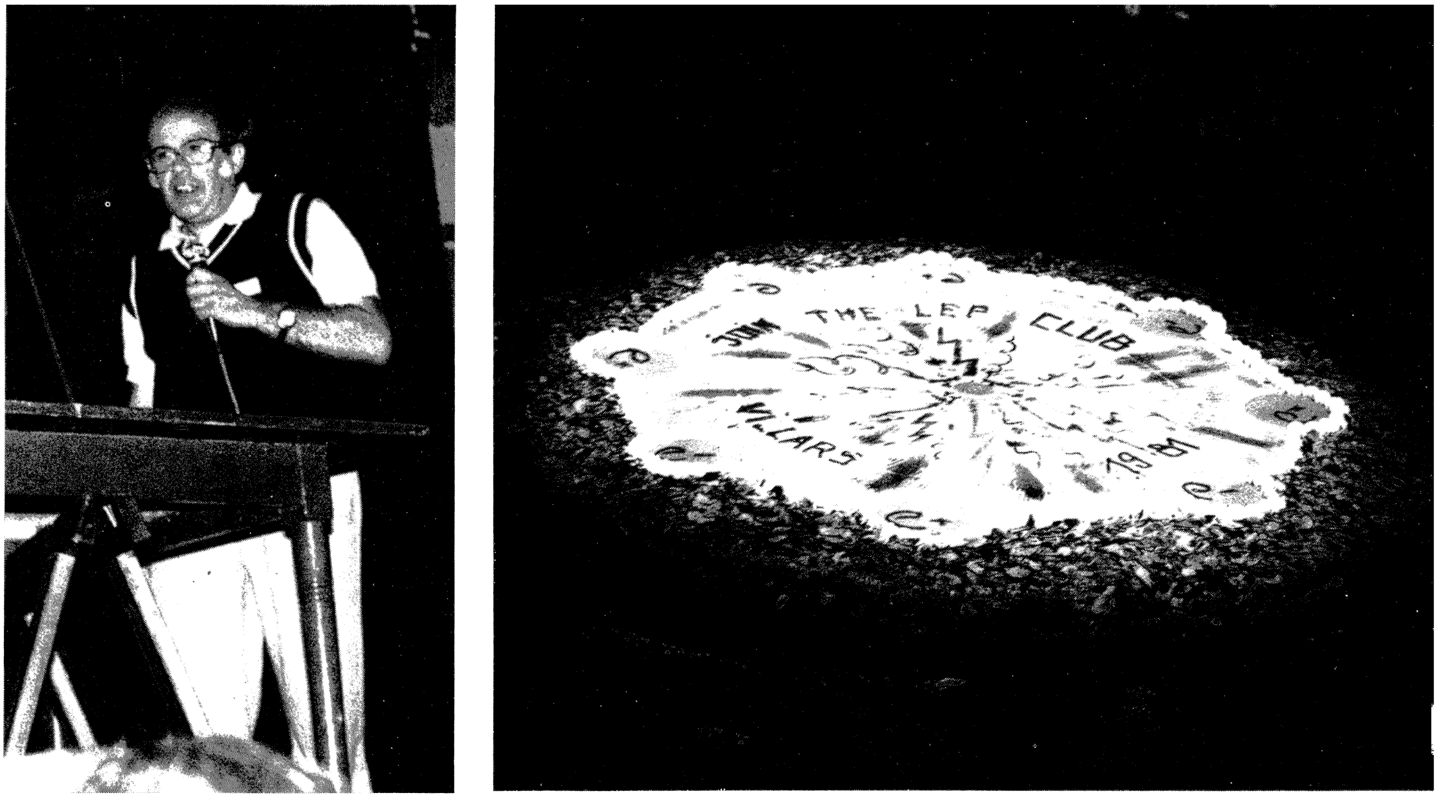


excluded in the initial stages of operation because of having the mini beta quads in the way. Two-photon ysics is likely to be 'second generation' in LEP experiments. However the other consequence relates to all experiments. Synchrotron radiation from the LEP bending magnets can be relatively easily shielded from the detectors since the straight sections are very long. Radiation from the curvature of the particle trajectories induced by the mini beta quads, however, goes through the detectors and could prove to be very troublesome. Further experience at PETRA and PEP should help in finding solutions.

Detector design is posing interesting philosophical as well as practical problems. There is a natural tendency when investigating a new area of physics to be the 'firstest with the mostest'. Since it is possible to define all the characteristics we would like to know about the products of electron-positron collisions, this tendency could lead to all experimental proposals being built around nearly identical 'universal' detectors. There were pleas for at least some detector proposals to be optimized to look at special features of the interactions. In any case it seems desirable to build maximum flexibility into the detectors so that they can be upgraded for more refined studies or adapted to changes in the physics interests. Carlo Rubbia, who had underlined the inclination to build all the detectors out of an identical kit of parts, remarked that 'it is difficult to build an elephant and make it flexible'. To the proposal that the appropriate animal for the analogy was a whale, he pointed out that whales out of water collapse under their own weight – which only goes to show that detection systems cannot always choose to ignore all aspects of the gravitational interaction!

Axial field magnet configurations, which have not been widely used up till now, may be one way of ensuring flexibility. The use of superconducting magnets was strongly endorsed – by now it is felt that superconductivity is a well-proven technology which would, overall, save money and also have some direct advantages in the detector itself by allowing the use of thinner coils. New detector techniques, such as the 'micro detectors' which are beginning to make their appearance, could also help to ensure flexibility and differences in detector configurations. They would no doubt be pressed hard before the final decisions on detectors are made.

Another option in the experimental possibilities which affects detailed machine design is that of beam polarization. This can be viewed much more optimistically as



Left, LEP Project Leader Designate Emilio Picasso reviewing the present status of the high energy electron-positron colliding beam project at the Villars meeting.
Right, adding to the enjoyment of the meeting was a huge cake, made by the Palace Hotel staff in honour of their guests, appropriately inscribed 'Join the LEP Club'.

(Photos CERN)

a result of the successful work at PETRA (see July/August 1980 issue, page 196). Though pursuit of the implications of this option was encouraged, enthusiasm was restrained, possibly tempered by the realization that experiments at the SLAC Linear Collider at 50 GeV will get polarization 'for free'. Latest news (reported by David Leith) from the Collider was that new intensity records have been achieved from the electron source and ground has been broken for construction of the damping ring.

The heavy burden of data analysis which will be confronted at LEP, much of it concerned with the rejection of unwanted information, is obvious. In the same area, the communication of a huge volume of information around collaborations involving some 150 physicists in widely scattered research centres is another new requirement. ECFA already has a Data Handling and Processing Working Group in action, and its Chairman, Egil Lillestøl, reported on the activities of ten pilot projects which have standardization as one of their aims. This will simplify work in the large collaborations, facilitate the task of small groups in these collaborations, and cut costs. These aims are accepted by everyone – which is not the same as saying that suitable standards have already been agreed. For example, three memory management systems are currently operated (HYDRA, Z-BOOK and BOS). Everyone agrees that a single new system, drawing the best features from all three, is necessary. Arriving at that system is not so easy.

The schedule to have experiments already for the start-up of LEP was agreed. By the beginning of next year a short letter of intent (including such things as physics aims, outline detector design, the collaborating groups, cost estimate and any special requirements) should be sent to CERN. A LEP Experiments Committee will be set up. Discussions can be launched on the basis of the letters, and by about mid-1982, there will be a call for proposals. The first experimental approvals are likely about mid-1983. This then allows three and a half years for detector construction, which is not a long time.

For 1987, only four collaborations can expect to have experiments on the floor at LEP. However that is certainly not the end of the story. More collision regions will be opened up as physics interests become clear and money becomes available. The machine's performance will hopefully be steadily improving and it has to be remembered that LEP is optimized for operation near 100 GeV rather than 50 GeV.

Hans Boggild launched himself into the limerick:

'There once was a place called Villars
where there was more than one star,
They talked about LEP
And the future of HEP
But decisions were made in the bar.'

It was certainly in this relaxed environment that many discussions on collaboration were held. The nuclei of several collaborations have already formed and the final teams each look like involving some 150 or more physicists. No significant problems concerning the incorporation of small groups or of physicists from non-Member States of CERN are apparent. The interest in LEP is thus manifest in the clearest possible way.

Around the Laboratories

CERN
SPS back in action

The 400 GeV proton synchrotron, which shut down on 16 June last year, is back in action after a major acelift. The eleven month stop was scheduled in order to prepare the SPS for its new part-time role as a proton-antiproton colliding beam machine. With the necessary modifcations largely complete, first priorty was to re-establish reliable fixed arget operation, and first 400 GeV protons were accelerated mid-May. By 22 May, experiments in both the West and North Experimental Areas were once more supplied with beams.

The length of the shutdown was mainly determined by the civil engineering work for the two large underground colliding beam areas at ong straight sections LSS4 and LSS5, where the proton-antiproton colliding beam experiments will be carried out. In addition, extensive shielded 'garages' were required to enable these experiments to be assembled or modified while the SPS is running for fixed target physics.

For the machine itself, the various services had to be entirely rebuilt around the newly excavated experimental areas. New injection systems were installed to handle the protons as well as the antiprotons, which for colliding beam operation will be njected at 26 GeV instead of 10 GeV for fixed target work.

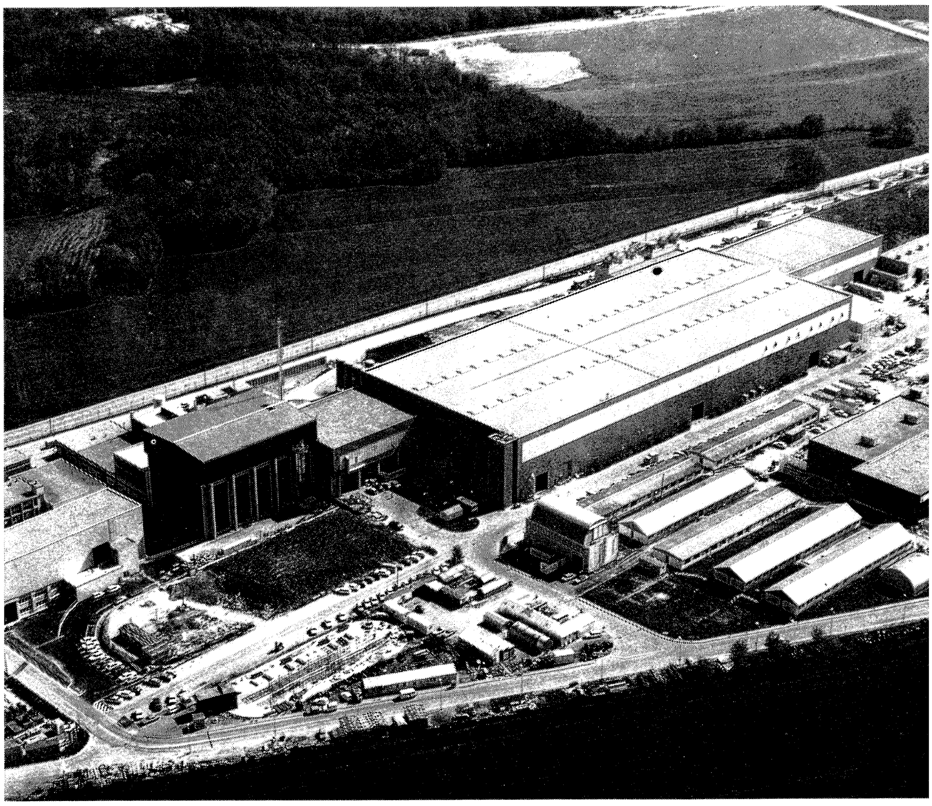
Protons and antiprotons circulatng in opposite directions can be guided by the same magnets, but additional r.f. equipment has had to be installed in LSS3 to accelerate protons and antiprotons simultaneously to the required 270 GeV. New low beta quadrupoles have been put in to squeeze the beams to higher luminosities. About 100 short straight sections have also been re-equipped with auxiliary magnets and beam monitoring equipment. 500 sputter ion pumps and 1000 sublimation pumps have been added to improve the vacuum to 10^{-9} torr. Advantage was also taken of the shutdown to make improvements to the fixed target extraction systems.

With fixed target operation now assured, machine development work can begin with antiprotons. However first proton-antiproton collisions are not expected before October at the earliest.

Meanwhile it has been agreed in principle to upgrade the West Experimental Area at the SPS, which has been in operation since the startup of the machine in 1976. At present, the West Area is served by neutrino beams derived from 400 GeV protons, and by 40-200 GeV secondary beams generated by protons extracted on an intermediate SPS fla top at 250 GeV.

The idea now is to have simultaneous slow extraction at maximum energy to both the North and Wes Areas, doing away with the presen 250 GeV flat top. This would enable the repetition rate of the SPS to be increased by 10-15 per cent, so providing more protons for the whole SPS programme. The neutrino beams and experimental area would remain unchanged.

Apart from the new primary targe which would be required, all magnets, power supplies, transformer and instrumentation already exist. In addition, the placing of the targe underground would also require les shielding, liberating 3 000 tons of iron and 20 000 tons of concrete fo use elsewhere. However the upgrade will involve resiting of all the West Area experimental apparatus, in particular the Omega detector.

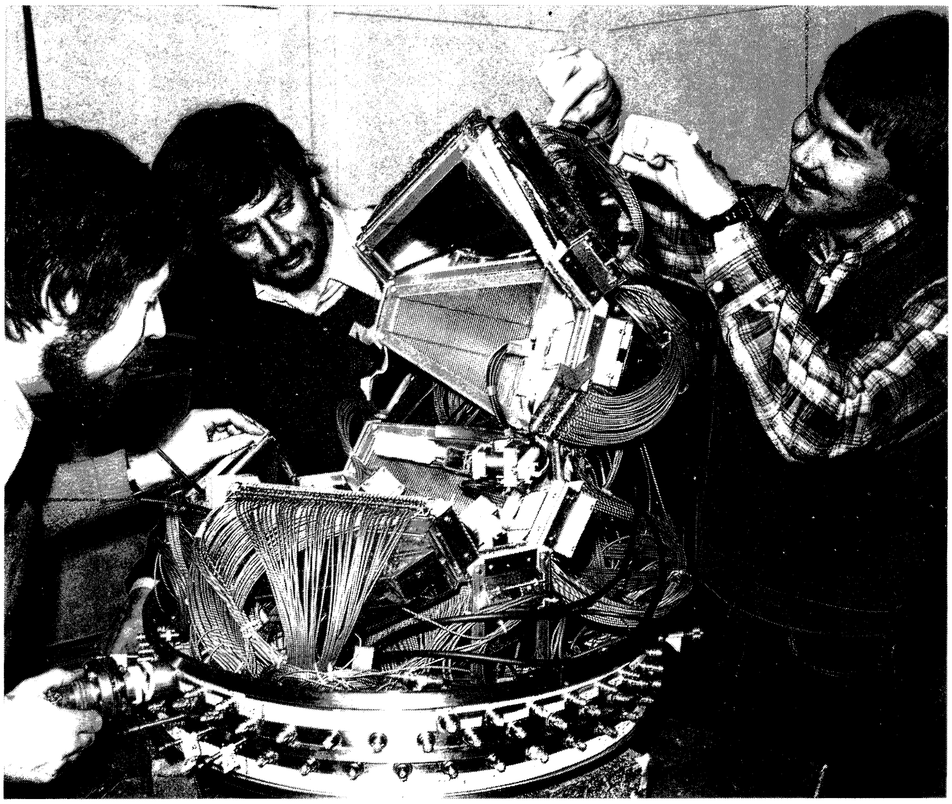


The West Experimental Area of CERN's 400 GeV proton synchrotron. The beams enter the experimental halls from the top right of the photograph. Further downstream is the taller building housing the BEBC bubble chamber.

(Photo CERN 200.5.76)

The so-called 'lantern' detector of the Heidelberg/Darmstadt collaboration which is using ion beams from the CERN synchro-cyclotron for nuclear physics experiments. The detector records heavy fragments emerging from the nuclear collisions.

(Photo CERN 78.3.81)



Ions in the synchro-cyclotron

The 600 MeV synchro-cyclotron at CERN has a notable history behind it in particle and nuclear physics since it came into operation in 1957. In the late 1960s the research programme was considerably extended by the addition of the ISOLDE on-line isotope separator, and in the mid-1970s an improvement programme ensured that machine performance continued to be competitive. With the advent of the LEP project, it is presently intended to reduce operation from about 6000 to 4000 hours per year and to concentrate the experimental programme on ISOLDE and possibly a few other special research topics such as those involving secondary muon beams and accelerated ion beams.

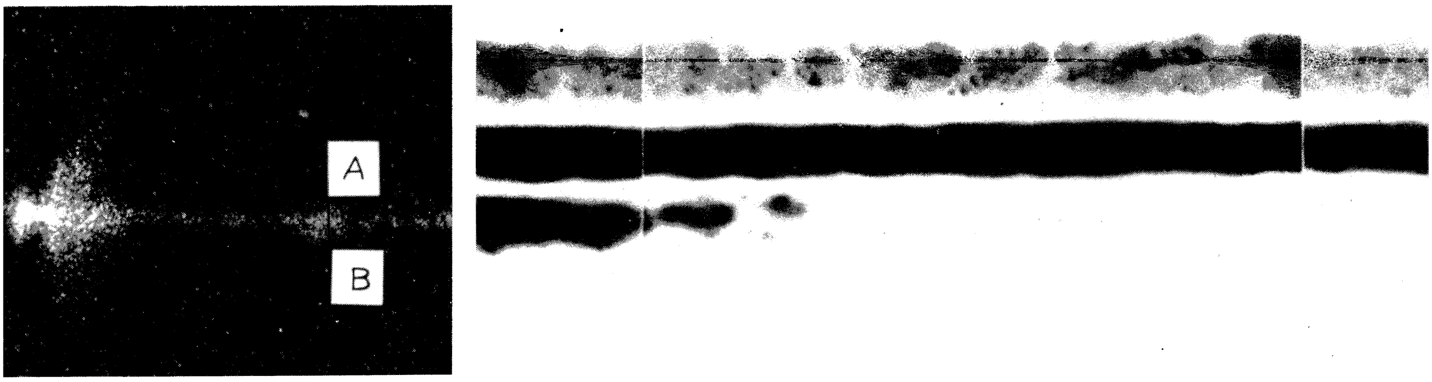
Accelerated beams other than protons are comparatively new on the SC scene, but they have been a success in terms of both machine performance and of the physics programme. About a third of the SC operating time in 1980 was devoted to accelerating ions.

In the following list of SC ion beams, the observed intensities are particularly impressive: 300 MeV/N doubly charged helium-3 with 3 x 10^{12} ions per s, 85 MeV/N singly charged helium-3 with over 10^{13}, 85 MeV/N carbon-12 less four electrons with over 10^{12}, 85 MeV/N nitrogen-15 less five electrons with over 10^{11}. Oxygen and other nitrogen ions have also been accelerated, and beams of neon-20 less six electrons were recently obtained with intensities over 1.5 x 10^{12} on an internal target in a test run. There are plans for further carbon, neon and argon ions in the coming months.

In their energy range, these beam intensities are well in excess of those of other machines, and this, combined with the excellent beam quality, has spurred on the SC experimental programme. The experiments are particularly interesting because they cover the range between research using low energy machines (up to about 10 MeV/N) and the work with relativistic heavy ions in the Berkeley Bevalac (above about 200 MeV/N). This is a transition region between predominantly compound nuclear reactions, which yield information on nuclear structure, and predominantly nucleon reactions, which yield information on the nucleus as a collection of nucleons.

A series of experiments by Orsay groups are using the time-of-flight technique to identify the mass of residual bodies emerging from the nuclear collisions. They are gathering data, as the incident energy is increased, on residual target nuclei after being hit by the ions (the formation of compound nuclei and the subsequent emission of light particles as they 'de-excite') and on deep inelastic effects where fission of the target is observed. Information should emerge about the behaviour of highly excited nuclei which emit light particles (determining the nuclear boiling point). It may also be possible to determine accurately the limits at which the fission process sets in.

The nuclear interaction between copper and 1 GeV carbon-12 has been investigated by a CERN/Marburg/Oslo/Paris team using radiochemical methods. It is found that at these energies, the deposition of energy is determined by the total kinetic energy of the incident particles, as is also observed with higher energy ions. A Berkeley/Corvallis/Studsvik collaboration recently finished data taking in a study of target fragmentation, also using radio-



On the left, a streamer photographed in the chamber of the Max Planck Institute which was analysed to determine the spectral distribution of the emerging light. On the right, the three colour-sensitive layers of the film subsequently developed at the position AB across the track. Only the bottom layer, sensitive to red light, has reacted to the light from the streamer. Thus filters can be used to cut out all other light but red without losing any of the required signal from the streamer (see page 246).

hemical techniques, with carbon ons on tantalum, bismuth and uran-um targets. This experiment was ble to be completed very rapidly as t the required energy of 86 MeV/N, ne ion intensity at the SC was a actor of a thousand up on that of the evalac.

At ISOLDE, results obtained with elium-3 promise well for future iso-ope production, especially after lanned higher beam intensities.

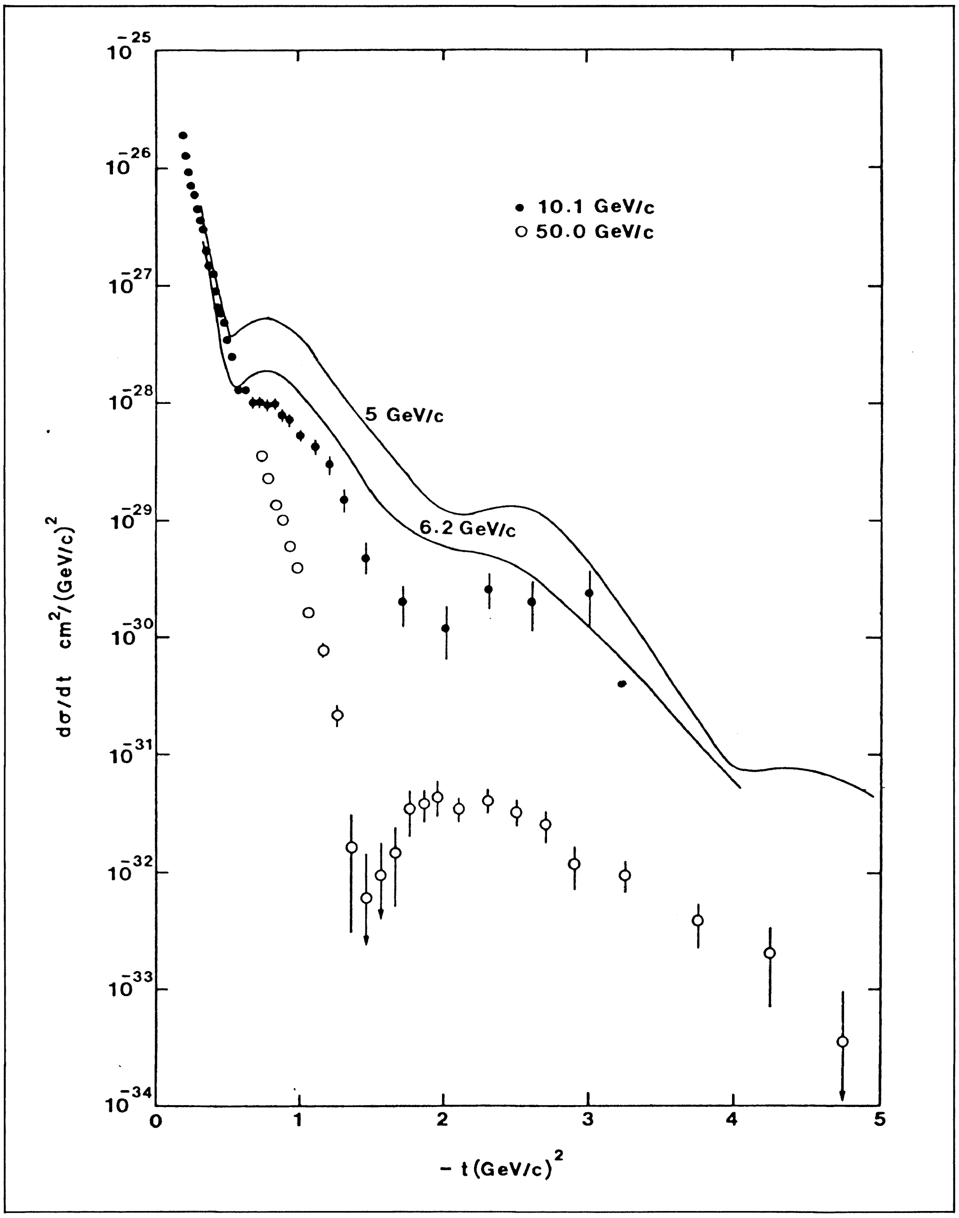
A Bordeaux/Gradignan team is sing an intricate detector to catch ne heavy recoil nucleus from the ollision of ions with heavy targets. he energy of the nuclei is first amped in helium gas before electric elds bring them to a solid state etector. High efficiencies have een demonstrated. The aim is to istinguish between highly excited esidual nuclei far from stability and esidual nuclei with low excitation vhich are nearly stable. The distinc-on may be possible by monitoring he emission of alpha particles from he nuclei. First results indicate that he production of nuclei far from tability (deficient by some twelve eutrons) predominates in the inter-ctions.

A Darmstadt/Heidelberg team is ooking at heavy fragments emerg-ng from the collisions of the ions vith heavy nuclei using a position-ensitive ionization chamber of large rea together with a time-of-flight telescope. The detector can measure energy and angular distribution of the fragments accurately and it is hoped in this way to obtain a better understanding of the concept of nuclear temperature (related to the 'boiling off' of particles).

A CERN/Copenhagen/Grenoble/Lund collaboration is trying to survey the relatively unexplored energy region for nuclear collisions available at the SC, and the 'transition' nature of this region can be seen. Basic information for the nucleus-nucleus interaction comes from elastic scattering measurements. The relative penetration of the two nuclei becomes more important when the incident energy is increased. A large nuclear surface transparency effect is thus observed with these projectiles. Observed characteristic features of projectile fragmentation are target independence, and mean fragment energies determined by beam velocity. However important differences from simple fragmentation behaviour are seen. A low energy component in the energy spectra, increasing rapidly with the angle relative to the beam, indicates a collective energy dissipation mechanism. The energy spectra of light particles have been studied and are found to be very similar for all targets, showing an exponential high energy tail. This cannot be fully explained by either a simple thermal source approach or a simple nucleon-nucleon scattering model. Changing the target has little effect on the spectrum of emerging particles, suggesting that the number of nucleons involved in the collisions remains substantially the same, regardless of the constitution of the total target nucleus. Recently positive pions have been detected emerging from the collisions. This is at energies well below the expected threshold, again suggestive of collective effects.

The success of the SC owes much to the development of an intense ion source of the PIG type. The source is rather small, with chimney diameter of about 10 mm containing a plasma column 2 mm across. Since it feeds a synchro-cyclotron, the source is pulsed (ions are accepted for acceleration for approximately 100 microseconds every 5 milliseconds) which allows the mean power dissipation to be kept down to acceptable limits.

The correct radio-frequency range for the ion to be accelerated is obtained by inserting a piece of transmission line between the dee and the rotating capacitor (rotco). Initially a line suitable for a charge to mass ratio of 2/3 was built, and was later altered to allow a ratio of 1/3. Other values are also possible so that more ions can be accelerated. A new 'universal' line is under con-



The rich structure seen in lower energy proton-antiproton elastic scattering.

struction to allow rapid change between different ion types to extend further the research possibilities with accelerated ions, which have become an important part of the SC programme.

Colour experiments

In these days of copious theoretical papers on the role of colour in quark confinement schemes, the title of 'colour experiments' is designed to lure all high energy physicists to read on. In fact the experiments covered here have been looking at a more conventional kind of colour – the spectrum of light from streamer chamber tracks with a view to optimizing chamber optics and improving picture quality.

The long streamer chambers which will be used to look at proton-antiproton interactions at the SPS by a Bonn / Brussels / Cambridge / CERN / Stockholm team (the UA5 experiment – see June 1980 issue, page 148) will need all the help they can get to pick out the relevant tracks. Their optics are already designed but any knowledge which makes it possible to capture virtually all the streamer light, while reducing light from other sources such as flares, is welcome. For this it is necessary to know the spectrum of light emitted by the streamers so that the cameras can 'see' the streamer light and exclude other light as far as possible. Although streamers look red to the naked eye, a considerable amount of blue light could also be present.

The problem of studying the spectral distribution is not simple because the light from streamers is feeble in intensity, lasts for less than a microsecond and does not appear at the same location in space. One technique would have been to photograph the streamers through a succession of filters. A quicker technique suggested by R. Budde was to photograph using high speed colour film and to see to what extent the different colour-sensitive layers on the film recorded the light. The Kodak and 3M companies helped by taking the necessary thin cuts across the surface of the film to examine the layers separately under a microscope.

Colour film consists of layers sensitive to yellow, red and blue light. In cosmic ray tests on the chamber (from the Max Planck Institute) with the help of R. Meinke, it was found that the light coming from the streamers had virtually no blue or green component (the cyan layer, sensitive to red, was the only one which had recorded light). It therefore looks possible to use a filter to cut out all but the red light so as to eliminate a lot of light from flares without losing anything from the streamers themselves. This will be tried by using a filter which strongly attenuates all light below a wavelength of about 600 nm.

Antiproton spectra

Comparisons of proton and antiproton data are always interesting, and this is one of the major motivations of the new physics programme which recently got under way at the Intersecting Storage Rings (see June issue, page 196).

While the first antiproton physics results from the ISR are eagerly awaited, new antiproton data, this time from a fixed target experiment, show some marked effects in the proton-antiproton elastic scattering spectrum at 50 GeV. Previous experiments have uncovered structure in the spectra at even lower energies. Such rich structure is not seen in proton-proton elastic scattering until about 150 GeV.

The experiment, by an Annecy / ERN / Copenhagen / Genova / slo / University College London ollaboration, measures hadron-halron elastic scattering over a wide ange of incident particle momenum and momentum transfer, using high intensity (2 x 10^7 particles per ulse) unseparated secondary beam om the 400 GeV Super Proton ynchrotron.

Antiprotons account for about two er cent of this beam, and are idenified by a differential Cherenkov ounter. The scattered particles are letected in a double arm spectroneter. The experiment measures roton-antiproton elastic scattering t higher energies and larger momntum transfers than previous fixed arget experiments.

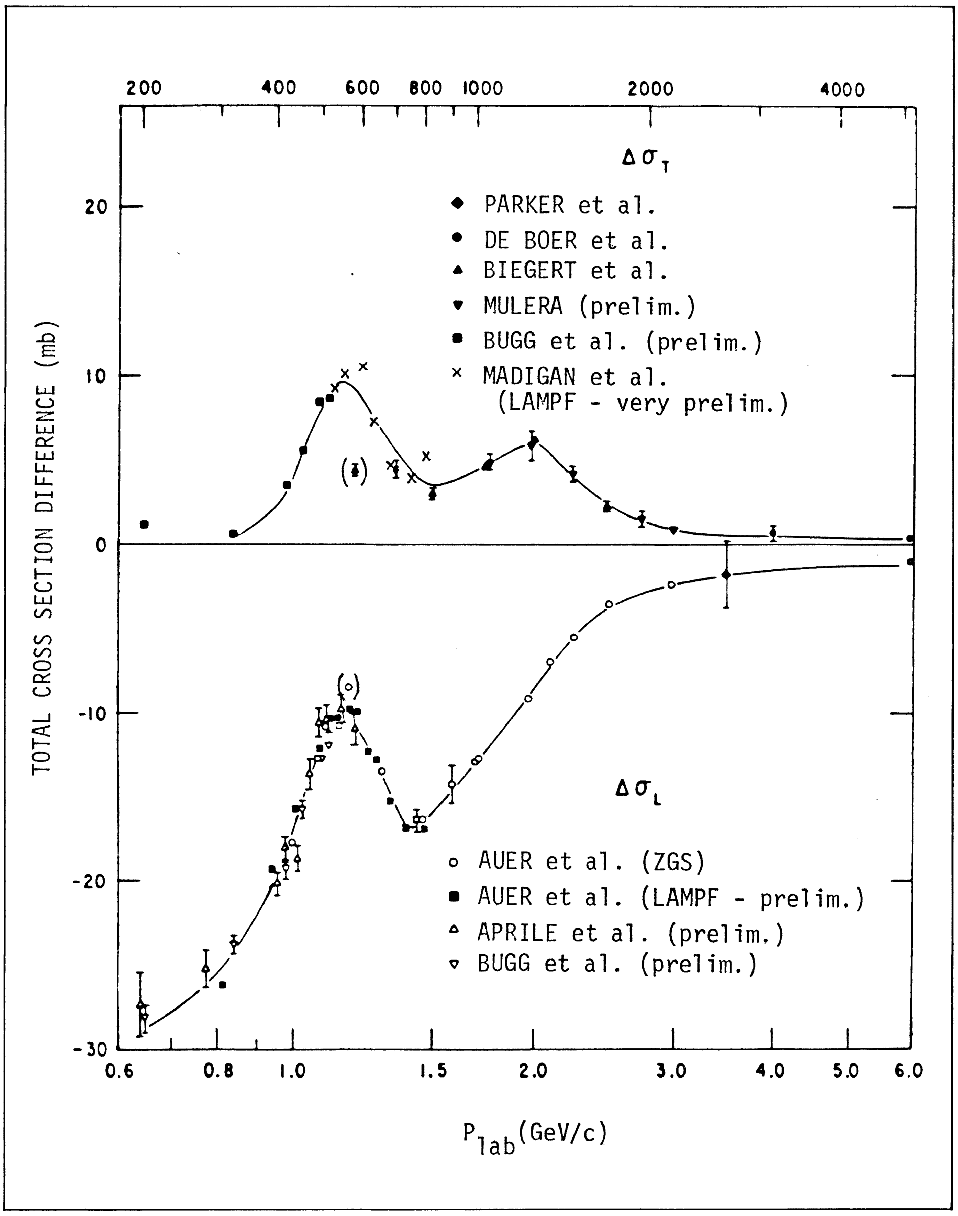
Proton-antiproton elastic scatterng spectra at lower energies have a lefinite shoulder near a squared nomentum transfer of about 0.5 eV^2. This is not seen with 50 GeV ntiprotons, however a very sharp lip is seen at a squared momentum ransfer of 1.5 GeV^2. A similar dip is een in proton-proton elastic scatering above an energy of 150 GeV, nd the 50 GeV proton-antiproton lastic spectrum is curiously like the roton-proton scattering seen in the ntersecting Storage Rings at an ffective beam momentum of 1064 eV.

Already interesting, these lower nergy antiproton results could nake for some intriguing comparions with the higher energy results o come from the ISR and the PS.

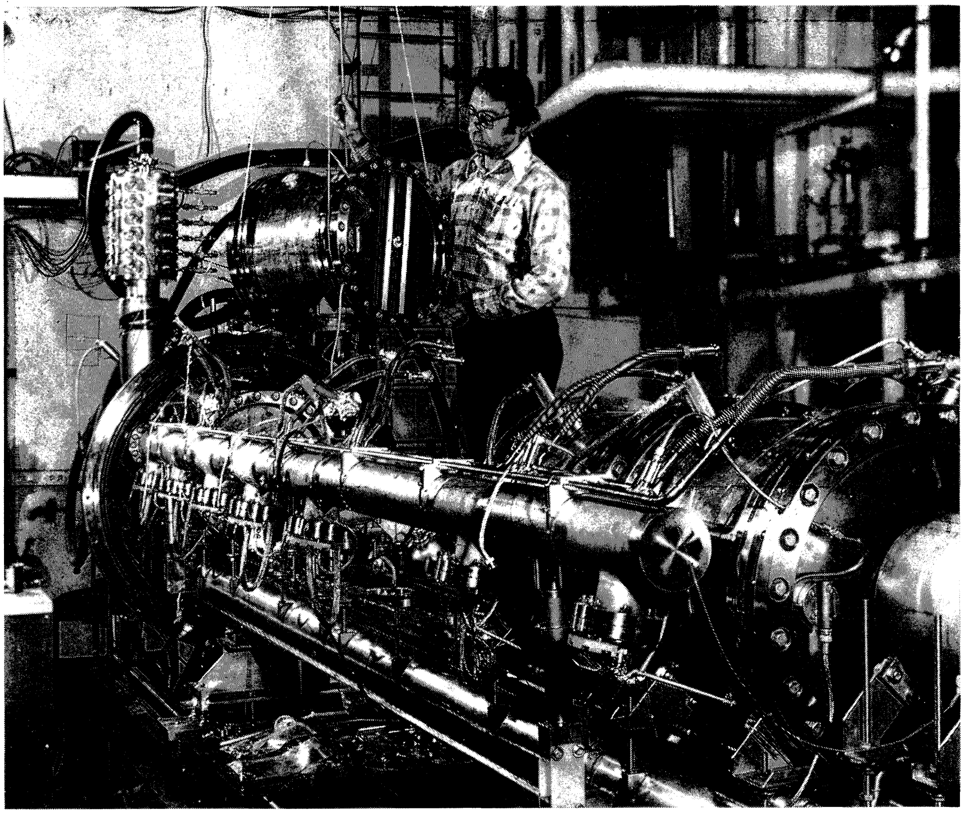
LOS ALAMOS Spin-dependent cross-sections

For years nucleon-nucleon cross-sections appeared to be featureless at medium energies, in marked contrast to the rich structure of meson-nucleon cross-sections. This picture began to change in the late 1970s when spin-dependent cross-section measurements became possible. Since then, new developments in this area have received attention in at least eight separate articles in the COURIER.

The most basic experiments involve measurements of total cross-sections in definite spin states and require both polarized beams and polarized targets. The natural configurations contain spins that are parallel and antiparallel in the direc-



xperimental values of the proton-proton otal cross-section differences in the ransverse (above) and longitudinal (below) irections. The lines shown are to guide the ye. Errors on the very preliminary LAMPF oints have not been accurately computed, ut are roughly 1 mb either way. The old rgonne data points in parentheses at 1.2 eV are probably incorrect because of beam epolarization.



One of the superconducting accelerator sections being made ready for installation in the heavy ion linac at Argonne. Ralph Benaroya is mounting a high-beta resonator of which there are six in the section. This whole assembly slots into a cryostat. The final section of the linac was installed at the end of May.

(Photo Argonne)

tions along and transverse to the beam axis. A clean and direct measurement of the parallel-antiparallel cross-section difference is ensured by simply reversing the polarization of the beam. In so doing, the contribution to the interaction rate by unpolarized particles is effectively removed (an important feature since this contribution is typically much larger than the interaction rate with free polarized target protons).

The cross-section difference measurements since 1975 have shown unexpected structure. The term 'dibaryon resonances' was coined but not universally accepted due mainly to the uncertainty of the partial wave analysis and the difficulty in picturing a two-baryon system in the simple quark model. Furthermore, the evidence was based partly upon data points taken below the normal operating range of the Argonne Zero Gradient Synchrotron (see September 1980 issue, page 252).

Fortunately, part of the energy region of interest is accessible at the meson factories and two of the most active collaborations went to LAMPF at Los Alamos in the summer of 1980 to pursue these experiments. Since the polarized targets required for studying longitudinal and transverse polarization are significantly different, an Argonne/New Mexico State/Los Alamos group carried out the longitudinal measurements, while a Rice/Houston/Los Alamos collaboration did the transverse measurements.

Working alongside each other in the LAMPF nucleon area, both groups benefitted from the dual-energy option that provided the full range of beam energies between 319 and 800 MeV in thirteen steps. The operating mode simultaneously delivers a negative hydrogen ion beam at a different energy from the 600 microamp, 800 MeV proton beam in the meson area. A spin-precession system, employing stripping to vary the ion g-factor, made it possible to deliver longitudinal polarization to one experiment and transverse polarization to the other.

The previous experimental situation was summarized at last year's polarization conferences at Santa Fe (August) and Lausanne (September). With the analysis of the new LAMPF data partially completed, H. Spinka (Argonne) presented the most recent results at a LAMPF Workshop in January.

The emerging picture is convincing : there are large spin-spin effects, as much as 50 per cent of the total cross-section in this energy range, and there is marked structure at about 1.2 GeV, which is largely hidden in the spin-averaged total cross-section.

Using the two well-developed approaches of phase shift analyses and meson exchange dynamical models, the interpretation of the data is not clear. The connection is often made between the cross-section and partial wave phase shifts following the resonance criterion of loops in the Argand diagram. However, to be usefully determined, the phase shift solutions require measurements of at least some other spin-correlation and spin-transfer parameters over an angular range. Some of this data was reported recently and a more definite resolution of the phase shift analyses may be expected soon. However the question remains of inelasticities and energy dependence in the phase-shift parametrization.

A standard dynamical approach fits the data with meson exchange diagrams. These models may reproduce loops on the Argand diagrams without introducing resonances in the direct channel. It is not universally agreed that direct channel dibaryon resonances need to be added to the dynamical models to fit all the data.

Finally, there is the intriguing question as to whether the two-nucleon system can illuminate the quark picture of matter. Theoretical models will have to provide better fits to the present data coming from polarized beams at meson factories before any definite statements can be made.

ARGONNE
Superconducting linac completed

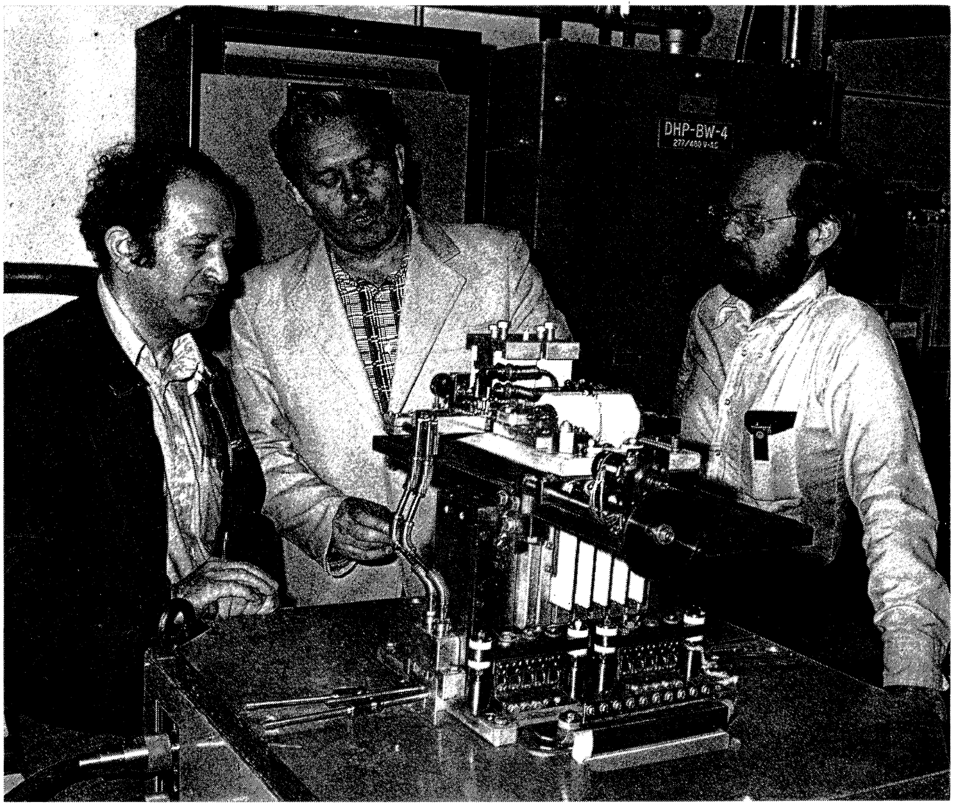
At the end of May the final section of a superconducting linac was installed at Argonne. The linac serves to boost the energies of heavy ions emerging from a 9 MV tandem Van de Graaff and has been one of the most successful applications of superconductivity in r.f. accelerator cavities.

The linac has four tanks, installed at the rhythm of one a year for the past four years, which should eventually permit a total of 29 MV of further acceleration. The tanks contain 24 independently phased split ring niobium resonators consisting f three-gap structures operating at 97 MHz. Each has an inner drift tube of pure niobium and a housing of sheet niobium and are cooled to 4.8 K by liquid helium.

The split-ring idea was promoted by Ken Shepard and his colleagues at CalTech in 1974 and taken up in the linac project under Lowell Bollinger. They aimed to achieve an accelerating gradient of 4.25 MV/m and the measurements with the first three tanks in place (prior to the recent completion of the installation) has given a total accelerating voltage of 13.5 MV. The usual operating gradient is 3 MV/m.

The three tanks have operated reliably for many thousands of hours. The anticipated problem of vibration of the resonators has been encountered but is not troublesome. Operation of the linac has proved very flexible and the modular character of the system which enables rapid changes in output beam energy has greatly helped the physics programme. The quality of the emerging beam has retained, or even improved, the traditional excellent characteristics of beams from tandem machines.

The linac has provided a useful extension to the range of nuclear physics which can be done. It has also proved an encouraging testing ground both for the superconducting technology and for the appropriateness of the technology for bigger accelerators.



Left to right, Carlos Hojvat (Fermilab), Gregory Silvestrov (Novosibirsk) and Jim MacLachlan (Fermilab) examine one of the lithium lenses built at Novosibirsk for the Fermilab antiproton source.

(Photo Fermilab)

FERMILAB/ NOVOSIBIRSK
Lithium lens

Members of Fermilab's antiproton source group welcomed the arrival in late April of a one ton crate from their collaborators at the Novosibirsk Institute for Nuclear Physics. The packet contained two lithium lenses of the type developed at Novosibirsk for focusing an 80 GeV proton beam onto an antiproton production target. A lithium lens is basically a cylindrical conductor that can be pulsed to high currents. The charged particle beam moves through the cylinder axially and the current produces an azimuthal magnetic field with a constant gradient. Lithium, with a low atomic number, is used to minimize multiple scattering. The lenses received at Fermilab are 0.5 cm in diameter and 10 cm long and can be pulsed 15 times a second with a 125 kA pulse to give a maximum field of 10 T. While lithium lenses share with magnetic horns the virtues of axially symmetric focusing and high gradient, they have the important advantage for use in beams of small emittance that there is no neck or inactive region at the centre of the beam. The lenses will undergo further tests at Fermilab to study production targetry and to evaluate their role in the antiproton source for the Tevatron I proton-antiproton project.

The lenses are a product of more than two years of the collaboration between Novosibirsk and Fermilab which was outlined in a July 1979 agreement between A.N. Skrinsky of INP and R.R. Wilson, then Director of Fermilab. It is part of the broader Tevatron I project that also includes Argonne National Laboratory, the Lawrence Berkeley Laboratory, and

Left to right, Phil Livdahl, Doug Pewitt, Bill Wallenmeyer and Harold Hanson, together at the annual Fermilab users meeting, discuss doubler magnet production. These magnets are being produced at Fermilab at the rate of one a day (and not one a week as reported in our May issue, page 146). At the users meeting, both Pewitt, a high energy physicist and Acting Director of Energy Research at the US Deparment of Energy, and Hanson, staff Executive Director of the Committee for Science and Technology in the US House of Representatives, covered some of the issues of funding for high energy research in the US.

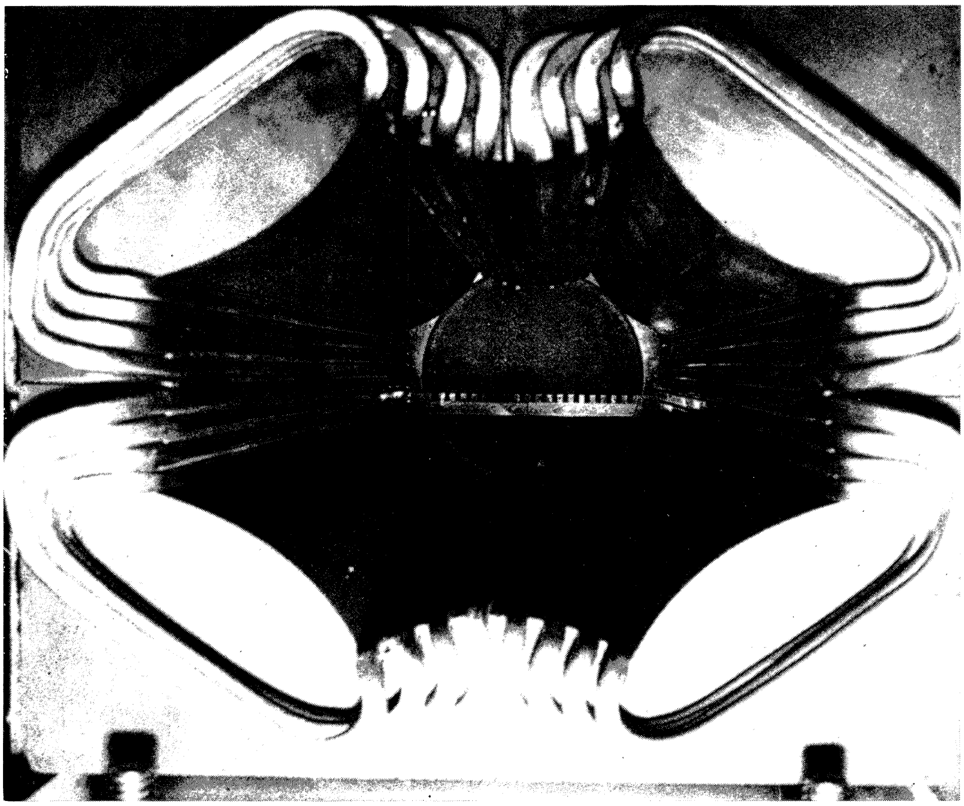
(Photo Fermilab)

the University of Wisconsin. Each institution is responsible for particular elements of the project scheduled for operation in 1984.

Under the terms of the Directors' agreement, visits of scientists between the two Laboratories were approved for general coordination of effort and for joint work on electron cooling and targetry for antiproton production. Gilbert Nicholls and Judith Nicholls of Fermilab worked on the lenses in Novosibirsk in 1979 followed by James MacLachlan in 1980. Gregory Silvestrov, leader of the group at INP developing the lens, has been to Fermilab twice. David Cline of the University of Wisconsin has made several trips to coordinate activities and expedite the shipment.

BROOKHAVEN
Pulsed quads for polarized beam

The main difficulty in accelerating polarized protons in a strong focusing machine like the AGS Alternating Gradient Synchrotron at Brookhaven is the existence of depolarizing resonances. At certain resonant energies the strong horizontal magnetic fields, which keep the beam focused, can flip the protons' spins and depolarize the beam. The trick used at the Argonne ZGS, where much of the pioneering work on high energy polarized proton beams was done, was to jump through these resonances using pulsed quadrupole magnets which rapidly changed the beam orbit. The resulting sudden

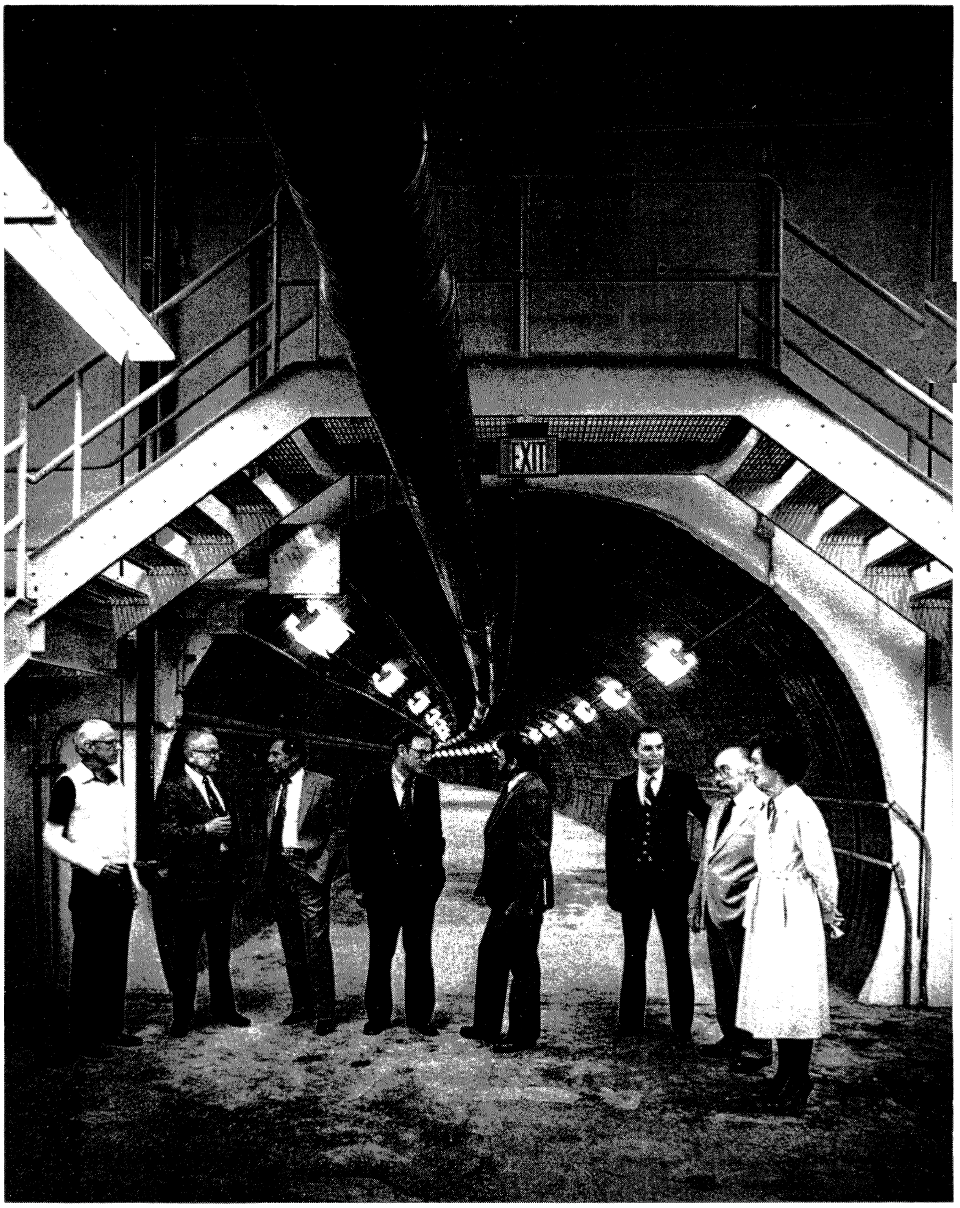


The Michigan pulsed quadrupole for the Brookhaven AGS polarized beam. The hyperbolic ferrite poles and coils form a very symmetric pattern. The AGS polarized protons will pass through 12 of these quads in order to 'jump' the depolarized resonances.

(Photo Brookhaven)

Representatives of the construction contractors and leaders of the ISABELLE project inspect the newly completed magnet enclosure at Brookhaven. The magnet enclosure will not be a continuous ring until all six of the ISABELLE experimental areas are complete.

(Photo Brookhaven)



change in the vertical betatron oscillations destroyed the resonant condition until the beam was safely above the resonant energy and the quads could be turned off.

Unfortunately the depolarizing resonances at the strong focusing AGS are about ten times worse than those encountered at the weak focusing ZGS. For years most people hought that it would be 'almost impossible' to accelerate polarized protons in the strong focusing machines of Brookhaven, CERN and Fermilab. However, the untimely demise of the ZGS led polarized proton enthusiasts to reexamine the problem. The Ann Arbor Workshop concluded that the problem might only be very difficult rather than impossible (see December 1977 issue, page 418). After much soul-searching and discussion, a plan was approved to accelerate polarized protons to 26 GeV in the AGS, using the same resonance jumping trick (see May 1980 issue, page 104). The accelerator modification project was undertaken by an Argonne / rookhaven / Michigan / Rice / Yale collaboration.

Much more powerful pulsed quadrupoles will be needed than those at the ZGS which required only two quads with 15 microsecond rise times. The AGS will need twelve quads with rise times of 2 microseconds or less. Dipole 'kicker' magnets had been built with microsecond rise times, but never such fast quadrupoles.

Quadrupoles have carefully shaped hyperbolic pole tips to give the required field; however iron or even iron laminate cannot be used at these rise times because of the eddy currents. The polarized beam group decided to use ferrite because of its successful use in kicker magnets. However there are problems : ferrite is quite expensive (about $50/pound), it is much too hard to cut with steel tools, and it is a very fragile ceramic. The first problem was solved by acquiring 1.7 tons of ferrite from the surplus r.f. cavity of the ZGS. For machining the hyperbolic poles, the Michigan group, led by A.D. Krisch, obtained a computer-controlled milling machine. The Michigan instrument makers then acquired a collection of diamond tool-bits to cut ferrite and built a special flooding system (which resembles an aquarium) to keep the ferrite from overheating and cracking during the machining. Special hyperbolic copper coils were also produced to minimize eddy currents during the fast rise time.

It all worked smoothly. The first prototype quadrupole has been tested with a 15 kV, 3000 A supply also built at Michigan with ZGS spare parts by the same Michigan /

Argonne / Brookhaven team. The quad exceeded specifications with a rise time of only 1.6 microseconds. It also passed the test of being an almost perfectly linear quadrupole during this fast rise period.

The Michigan people have now geared up a production line for a dozen pulsed quads plus a few spares. The ferrite poles are about 70 per cent finished and the coil winding operation is well under way. Much of the work is being done by students, both graduate and undergraduate, and the entire job should be finished in a few months time, almost a year ahead of schedule and almost a factor of two below the original cost estimate of $ 450 000.

FRASCATI/CERN
Streamer tubes in particle detectors

The study of the details of ionization in gases and their subsequent applications in particle detectors were initiated particularly by the group of Georges Charpak at CERN where multiwire proportional chambers and drift chambers were invented in 1968. There have been many surprises which have not been in line with the 'folklore' on gas discharges which had grown up from the work earlier this century.

Recent work on conditions which produce 'self-quenching streamers' has rapidly found application in detection systems. The developments at Fermilab were reported in our May issue (page 152) but they were not the first of their kind. We believe the first application of the technique was at Frascati by the group of E. Iarocci. In 1978 a 330 tube array was built for use on the Adone storage ring. Also since 1979, 8000 tubes based on this work have been built at Orsay for photon and muon detectors.

The Frascati group passed information on their experience with streamer tubes to the CHARM collaboration (CERN/Hamburg/Amsterdam/Rome/Moscow) carrying out neutrino experiments on the SPS at CERN. Since 1979 the collaboration has added a very large streamer tube system to their 'fine-grained' calorimetric detector of marble plates, proportional drift tubes and scintillators so as to improve the spatial resolution when measuring hadronic and electromagnetic showers.

The added system consists of 20 000 streamer tubes each 3 m long with a 50 micron central anode wire. The tubes are arranged in planes of 256 oriented at right angles to the proportional drift tubes across the beam direction so that the signals from the two types of tube together give both coordinates of the traversing charged particles. Each streamer tube is only 9 mm across and thus particle trajectories are located with good accuracy.

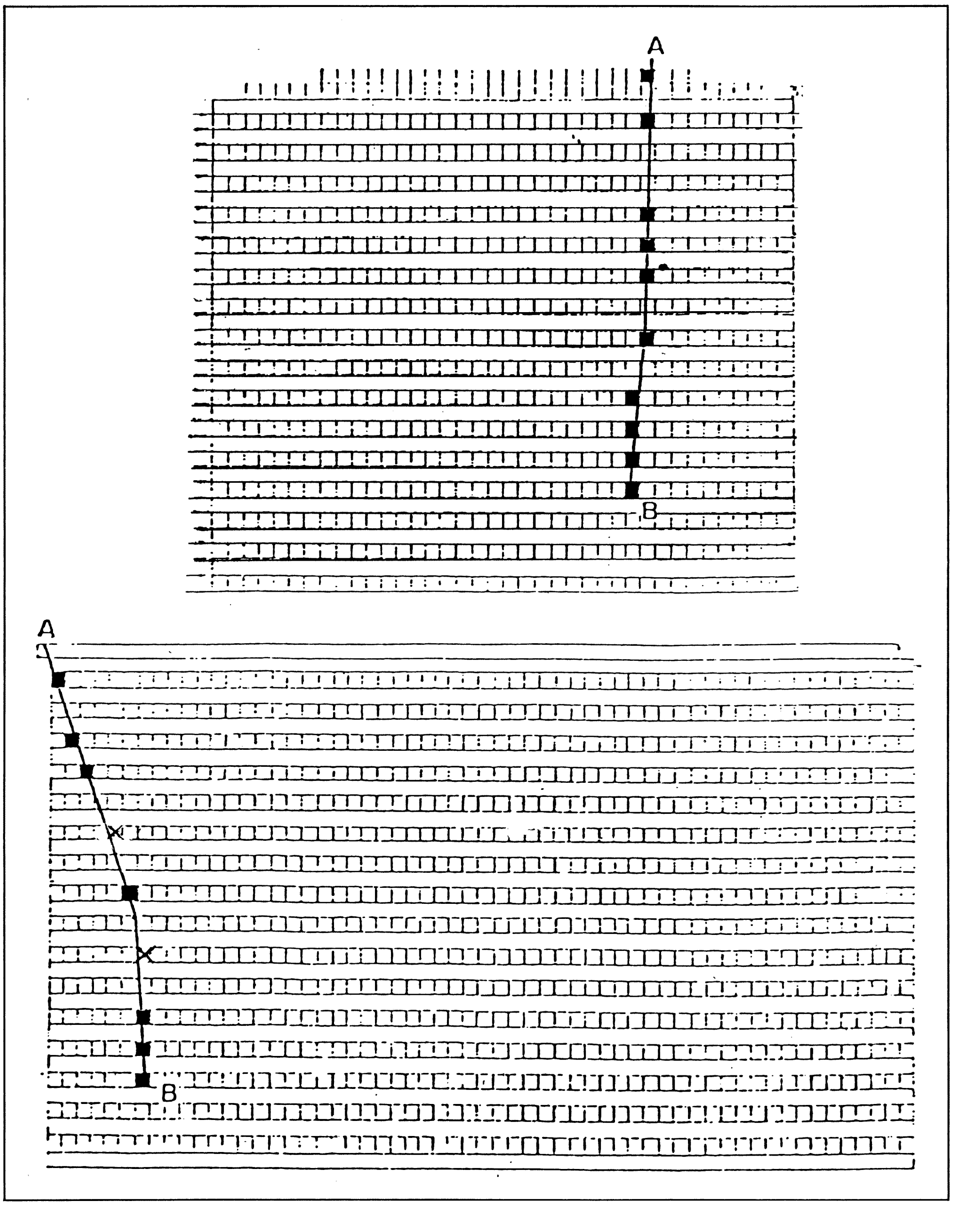
An advantage of the limited streamer mode is that the streamer tubes are not very sensitive to the operating conditions. Performance is about the same over some 500 V around 3.8 kV and over some 20 per cent variation in the gas mixture. The resulting signals from the streamers produced in the tubes traversed by particles have a mean output voltage of around 15 mV so that the subsequent electronics are simple and inexpensive. The tubes are continuously sensitive to the arrival of particles apart from a 'dead-time' of less than 100 microseconds in the few millimeter streamer region.

An even larger system of 43 000 streamer tubes has been under construction since 1980 by a CERN/Frascati/Milan/Torino collaboration for the proton decay search in the Mont Blanc tunnel. This 3.5 m cubic set-up has a calorimeter consisting of 134 iron plates 1 cm thick interleaved with 1 cm tubes. These tubes have a further unusual feature deriving from the early Adone detector – they are plastic (PVC) tubes, made conductive by means of a graphite coating. This graphite cathode has high resistivity which makes the tubes transparent to pulsed fields and allows the use of simple external pick-up electrodes to localize the streamers. Bidimensional track localization in a single tube layer is achieved by the use of two strip (1 cm x 3.5 m) arrays, parallel and orthogonal to the wires, to pick up induced pulses from the streamers inside the graphite cathode tubes.

In this detector for the Mont Blanc experiment the wires do not supply direct readout but are simply connected to the high voltage. The total number of readout strips is about 80 000, for a total sensitive area of 3400 m^2. Inexpensive readout electronics (developed by LeCroy) is connected directly to the end of the strips.

A test calorimeter (1 x 1 x 3.5 m, 15 tons) has been assembled with 3000 tubes and 6000 strips and recently exposed to electron, pion and gamma beams so as to prepare for proton decay identification and neutrino background rejection.

Physics monitor



Two views of one of three candidate proton decay events seen in the 6 x 4 x 4 m honeycomb detector of a Japan/India collaboration operating 2.3 km underground in the Kolar goldfields, India. The cells of the 100 ton honeycomb are 10 cm square. However all three events have a track which reaches (or emanates from) the edge of the detector, possibly due to a particle entering from outside. A more reliable proton decay signal would have all its tracks ending inside the detector volume.

Hunting the unstable proton

Growing confidence in the new unification theories of physics has motivated many physicists to hunt for proton decay and other new phenomena. To search for these rare events, detectors have to be mounted deep below the surface of the earth to screen off unwanted background due to energetic cosmic ray particles. So many projects are now being developed that in several years time it will probably be true to say that at any time of the day, somewhere in the world a physicist will be working deep underground at one of these new experiments.

While these large new underground experiments are being prepared in the US, in Europe and in Japan, first candidate proton decay events have been reported by a Japan/India collaboration (see June issue, page 196).

These events have been seen in a new detector 2300 m underground in the Kolar goldfields 100 km north of Bangalore in South India. The Tata Institute / Osaka / Tokyo collaboration's experiment is scheduled to continue for several years, during which time it is hoped that the 140 ton detector will be able to catch a good sample of proton decays, provided the mean lifetime is not too much in excess of the 10^{31} years or so predicted by theory.

Underground physics at the Kolar goldfields in fact dates back some twenty years, well before ideas of unstable protons ever became current. An earlier detector, containing neon flash tubes interspersed with iron, produced some unexplained events in several years of running. However cosmic ray background was still troublesome, and it was decided to build the latest detector for installation several hundred metres deeper.

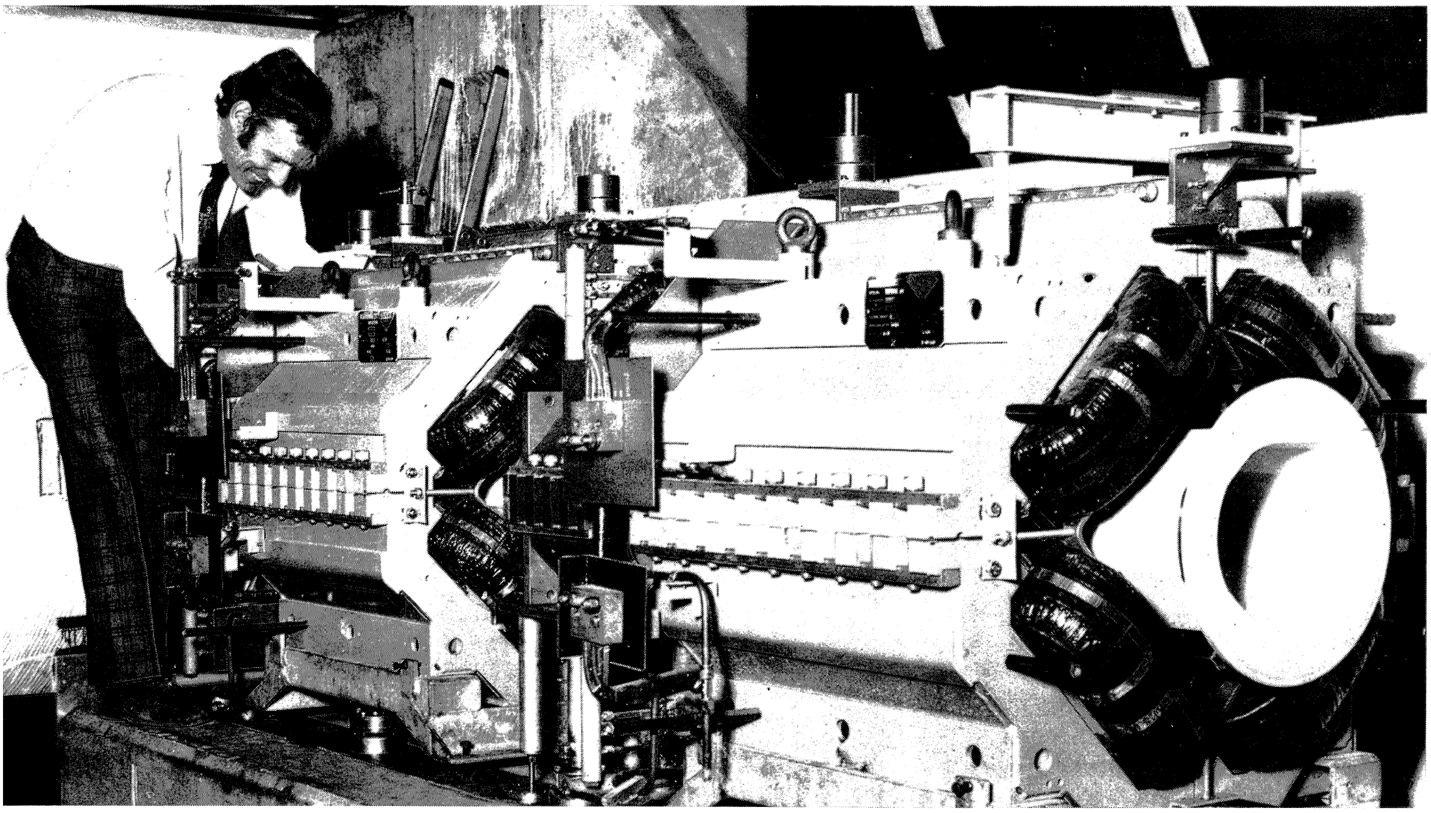
This apparatus contains 100 tons of iron in the form of pipes either 4 or 6 m long and 10 cm square, together with an additional 40 tons of iron shielding. Containing a total of 1650 proportional counters, the detector elements are stacked into a pile 6 m long, 4 m wide and 4 m high, with its sides against the rock face and with readout providing a full three-dimensional picture of interactions.

Even at this great depth, over 200 vertical muon tracks were registered in 131 days. Additional isotropic muon events come from neutrino interactions in the vicinity, producing secondary muons.

Of the three candidate proton decay events, two have two tracks almost back-to-back, and the third has three tracks. Unlike high energy particles, some of these tracks do

Scheduled to be the most intense of the neutron sources presently under construction is the Rutherford Laboratory's Spallation Neutron Source. These quadrupoles for the SNS are ready for installation in the machine, which is being built in the hall which previously housed the Nimrod proton synchrotron.

(Photo Rutherford)



not register in consecutive layers of the detector, and are attributed to low energy electrons or photons. Unfortunately in all three cases, one of the tracks reaches the edge of the detector. This could mean that the events are due to particles entering the detector from outside, rather than proton decay within the detector volume.

If attributed to proton decay, these three events indicate a proton lifetime of the order of 10^{30} years, in line with the current theoretical prediction. However much more evidence is required before the idea of an unstable proton becomes an established fact.

Neutron sources galore

The first large accelerator-based facility for research with neutron beams came into action on 7 May at Argonne. It is appropriate that this achievement happens at Argonne which, since 1974, has been one of the pioneers of neutron research at accelerators with an eye on the higher fluxes of thermal and epithermal neutrons which these facilities can provide.

Argonne's new Intense Pulsed Neutron Source (IPNS-I) uses some of the components of the retired Zero Gradient Synchrotron. A 50 MeV negative hydrogen ion linac feeds a rapid cycling synchrotron of 7 m radius (initially foreseen as the ZGS booster) where the ions are stripped down to protons. The protons are accelerated to 500 MeV, and the planned beam intensity is 8 microamps distributed in 30 pulses per second (which is useful for time-of-flight experiments). These protons are directed onto two heavy metal targets to produce neutrons by spallation.

Argonne previously operated two prototypes (known as ZING – ZGS Intense Neutron Generator), providing good experience for a varied and interesting ongoing experimental programme. Several diffractometers have been developed (powder, single crystal, small angle, crystal analyser and chopper diffractometers). They will be used in the study of crystals in powder form, of biological molecules and of semiconductors. It should be possible to look at the density states of electronic excitations in superconductors. A precision experiment is being prepared to measure the neutron dipole moment. A Radiation Effects Facility will be set up to investigate neutron damage to reactor components at low neutron temperatures and it will also be possible to investigate some neutron damage effects likely to be experienced in components of fusion reactors.

The potential importance of the research with neutron beams was recognized in the USA in a report prepared for the Department of Energy by a panel headed by W. Brinkman. It called for a national programme with annual financial support at the level of some $20 million compared to the $14 million which had been scheduled. The increased funding was intended to cover operation of research reactors at Brookhaven and Oak Ridge and the bringing into operation of two accelerator-based facilities at Argonne and Los Alamos. Argonne hopes that some intermediate funding level will keep research at IPNS-I alive for the next five years by which time a more advanced facility would be appropriate (ideas for IPNS-II are already proposed).

Meanwhile at Los Alamos a proton storage ring (PSR) is being built at the LAMPF 800 MeV linear accelerator to add to the research possibilities at the Weapons Neutron Research (WNR) facility. This can presently take some 10 microamps ut the PSR is expected to increase this to near 100 microamps in 1985. At the TRIUMF and SIN meson factories, neutrons are drawn from beamstops for experiments with modest neutron intensities.

In Japan some of the spare protons from the KEK 500 MeV booster synchrotron have been used for neutron research since 1980. This programme was promoted particularly by Tohoku University. The present available beam of about 1.5 microamps in 15 pulses per second is being improved.

The world's biggest neutron source presently under construction is the Spallation Neutron Source (SNS) at Rutherford in the UK (see May 1976 issue, page 170). The aim is 200 microamps average current with 50 pulses per second in a rapid-cycling proton synchrotron being built in the hall which formerly housed the Nimrod 7 GeV proton synchrotron. Components of the new machine are arriving at the Laboratory and it is hoped to have first beams in 1984.

A still more ambitious project is the SNQ (Spallations-Neutronenquelle) planned by a Jülich/Karlsruhe collaboration (see October 1980 issue, page 299). It is based on a 1.1 GeV linac which could be supplemented by a compresssor ring. As reported in the June issue (page 210), the project received backing in principle from the Pinkau Committee which looked at large projects in the Federal Republic of Germany.

People and things

New director for TRIUMF

On 1 July, Erich Vogt became the fourth Director of the TRIUMF Laboratory, succeeding J.B. Warren, J.R. Richardson and J.T. Sample. With its policy of rotating directorships, TRIUMF can now claim two-thirds of all the 'meson factory' directors ever appointed.

Erich Vogt was a leading member of the group which proposed and built TRIUMF and served as Associate Director from 1968-73. Since 1975 he has been Vice-President of the University of British Columbia, but in spite of this handicap has continued to supervise graduate students and to co-edit 'Advances in Nuclear Physics'. He also served as Chairman of the Science Council of British Columbia and as President of the Canadian Association of Physicists. He is assisted at TRIUMF by five Division Heads ; D. Axen (Science), E.W. Blackmore (Experimental Facilities), M.K. Craddock (Accelerator Research), G. Dutto (Cyclotron) and B.D. Pate (Applied Programme).

Jack Sample's five-year term has seen both the facility and the experimental programme come into full operation, with sizable increases in budget, staff and buildings. The annual average current has been increased fifty-fold, with regular 100 microamp operation. Many new beamlines and facilities have been built (under Karl Erdman), while a number of applied projects have been successfully inaugurated (under Brian Pate).

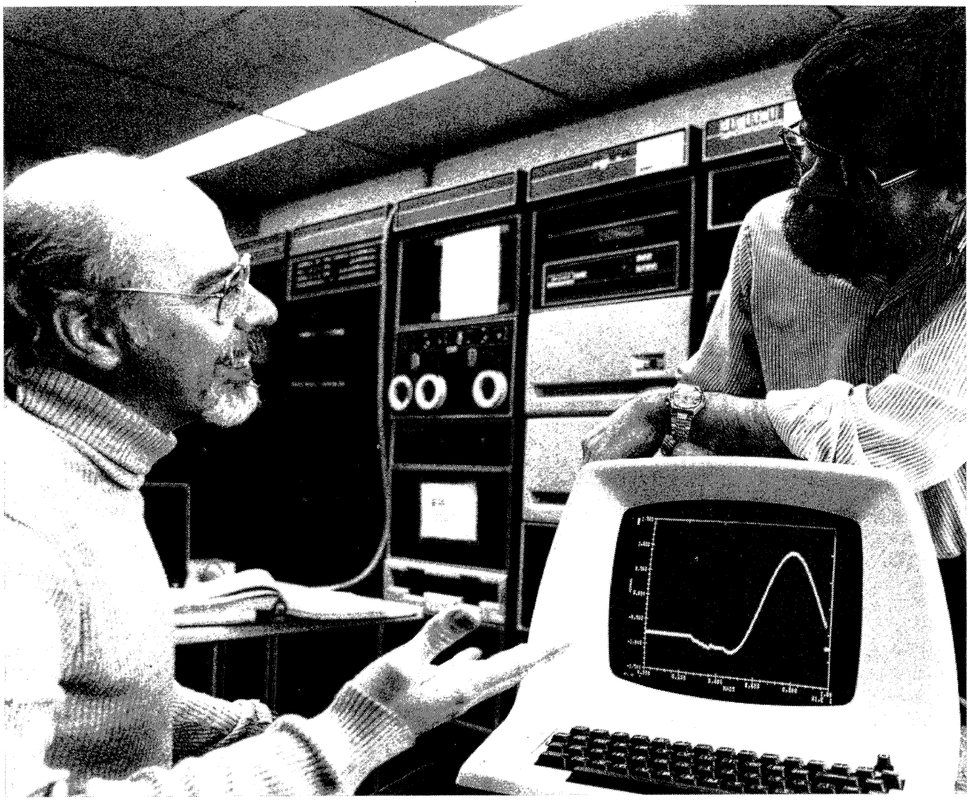
Erich Vogt

MULTI

Over the last several years a new 'language', MULTI, has made a major hit at Fermilab. MULTI is a program that can flexibly handle inter-

Fritz Bartlett (left) and Dave Ritchie with a typical display given by MULTI, the on-line program now widely used at Fermilab.

(Photo Fermilab)



active on-line computing from widely differing experimental CAMAC configurations. By now two-thirds of the running experiments at Fermilab are using the system. It is literally true that an on-line system can be put into practical operation over a weekend.

The original MULTI was invented by Fritz Bartlett to satisfy the needs of three widely different CalTech experiments in the early days of Fermilab. This global perspective of on-line computing resulted in a flexible graphics-oriented interactive data analysis package capable of supporting MULTIple data investigations.

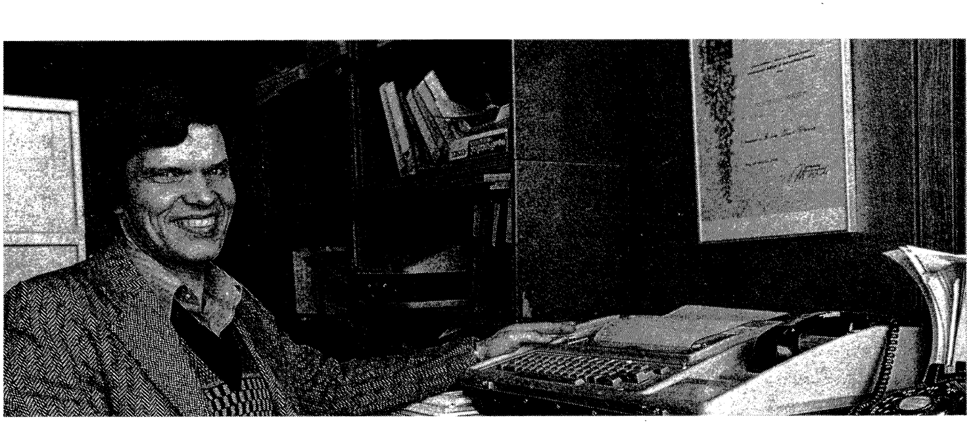
Lou Taff, Dave Ritchie, Liz Quigg, and Terry Lagerlund of the Fermilab Computing Department documented the system. They, along with Dan Curtis, Robert Dosen and Joel Biel also of the Computing Department, together with Bartlett, developed data acquisition modules for the two prevalent operating systems. The result was two varieties of the present package, referred to properly as MULTI/DA. The most popular of these can handle input/output from widely differing CAMAC configurations without any progran ming changes.

The MULTI part of the package serves as the user interface. It has a straightforward language coverin all the features required by a typica operating experiment. BEGINRUN and ENDRUN statements do just as expected. Tape manipulation commands exist along with an extremely flexible histogramming philosophy. An EVALUATE sequence makes it possible to dip into a run in progress and modify the calculation scheme.

Many of the normal trials and tribulations of an on-line program are taken care of automatically by MULTI/DA. Buffers, record lengths, and CAMAC commands are all specified without programming. It is easy to modify these elements in order to tailor the program to a specific experiment. In addition, a series of calls to dummy FORTRAN subroutines are provided so that specialized program additions can be readily integrated into the system.

The wide use of MULTI/DA at Fermilab has resulted in an increasing body of software integrated with the MULTI approach. This is overcoming a long-standing 'Tower of Babel' problem with earlier on-line programs – none seemed to build on, or connect to, prior work.

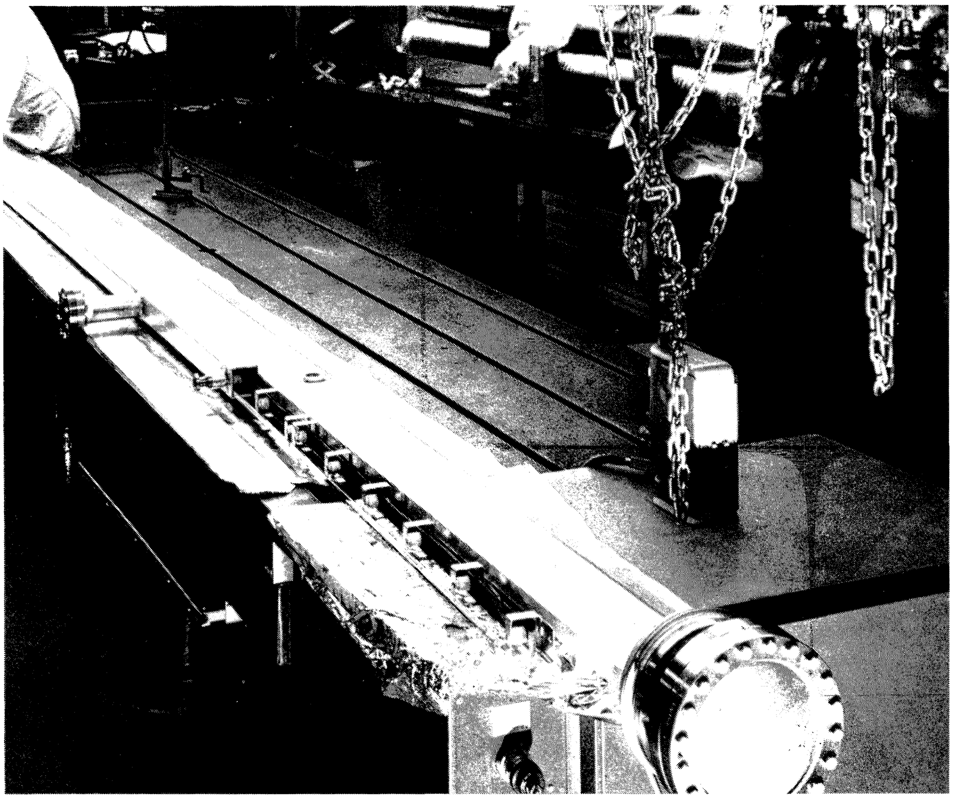
A great deal of the success of MULTI is due to an approach to on-line computing pioneered at Fermi-



Risto Orava, newest Wilson Fellow to be appointed at Fermilab.

lab by Al Brenner, who mandated a basic on-line computer hardware package in the early days of the Laboratory. As a result, each Laboratory-provided installation has a compatible complement of on-line equipment. This hardware philosophy proved to be fertile ground for the development of a universal on-line system.

In addition, MULTI has been modified to run in other environments, such as those handling multiple processors within its framework. At Fermilab, it is being employed to study the parameters involved in the automated cool-down and operation of a test string of Tevatron superconducting magnets. Away from the Laboratory, it is being used at several installations in support of nuclear physics experiments as well as the more customary high energy physics uses.



Insertion of a strip of non-evaporable getter into the pumping channel of a section of beam pipe for the PETRA ring at DESY. Tests with this pumping system achieved encouraging results.

(Photo CERN X519.1.81)

Getting better

The demands of particle accelerator builders frequently stretch modern technology to the full. One notable example is in the field of vacuum technology, where some of the world's largest high vacuum systems have had to be developed during the construction of large accelerators. As well as being large, these projects have their own special requirements. With their vacuum chambers very long but with small cross-section, the vacuum pumps have to be distributed as evenly as possible to ensure prompt removal of molecules released from the surface of the pipe. In electron machines, this has traditionally been achieved using sputter ion pumps which make use of the magnetic fields of the bending magnets.

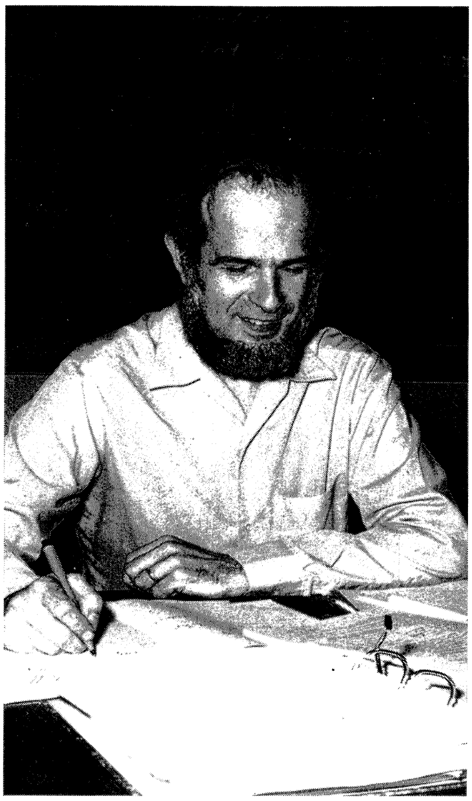
Recently a new possibility has emerged, using the technique of non-evaporable 'getters' - NEG. Getters are substances capable of absorbing gas molecules, so setting up a pumping action. They come in two types, evaporable and non-evaporable. With the better-known evaporable getters, fresh layers of getter material are sublimated to maintain the pumping action. With non-evaporable getters, the material is heated so that the gas compound molecules diffuse into the interior of the material. This ensures a fresh supply of surface getter material to continue the pumping, and provides a means of achieving high vacua where the magnetic fields required for integrated sputter ion pumps are not available.

At CERN, a technique has been developed using a commercially available non-evaporable getter, composed of a zirconium-aluminium alloy, which can be mounted in strip form along a beam pipe. This can achieve pressures in the 10^{-9} torr range within 20 hours, including initial mechanical pumping down from atmospheric pressure, even without taking the precaution of baking the vacuum chamber. In a commendable collaboration between CERN and DESY, the technique has been tried out in a real machine environment. A 6 m length of PETRA vacuum chamber fitted with NEG pump achieved faster results and somewhat lower pressures than the traditional integrated sputter ion pumps installed in the rest of the machine. This encouraging result is of interest for future accelerator projects, like LEP, where the available magnetic fields might be limited.

Electron-proton workshop

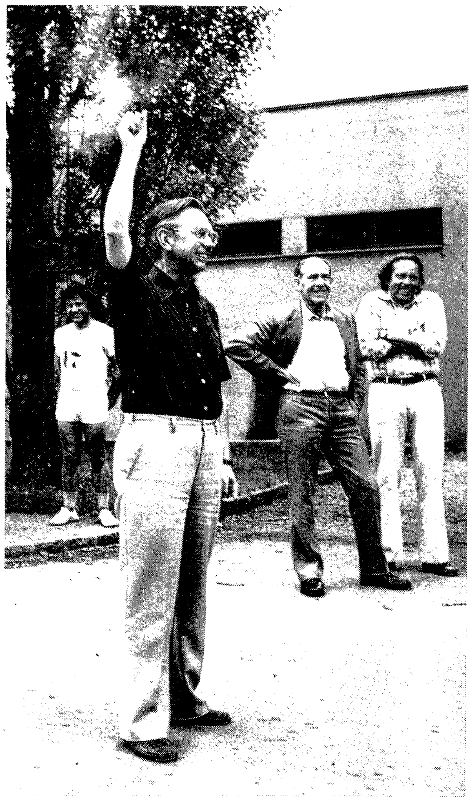
The workshop for electron-proton physics at the proposed HERA machine will take place at the Univer-

Jacques Lefrançois, new chairman of CERN's SPS Experiments Committee, who takes over from Bjorn Wiik.



CERN Director General Herwig Schopper starts the 1981 round-CERN relay race.

(Photo CERN 557.5.81)



sity of Wuppertal (Federal Republic of Germany) on 2-3 October. There will be reviews on the physics potential of electron-proton collisions, on the different electron-proton collider projects, on detectors and on polarization. Further information from Peter von Handel, DESY, Notkestrasse 85, 2000 Hamburg 52, Federal Republic of Germany.

Name change

What was formerly the UK Science Research Council is now known as the Science and Engineering Researcl Council. The name change does not affect the objects of the Council, but does reflect the increasing importance placed on supporting the worl of engineering research departments.

Win for UA1

One of CERN's annual sporting highlights is the 3.9 km relay race around the Meyrin site. The circuit, broken into six legs of 1 km, 800 m, 800 m, 500 m, 500 m and 300 m, is quite hilly and is no mean test. This year some 40 runners lined up at the start, and in what could be interpreted as a portent of things to come, the race was won by the UA1 team (David Dallman, Alan

On 20 May there was an official opening ceremony at a Laboratory complex in Amsterdam including the high energy physic Laboratory, NIKHEF-H. On this occasion CERN set up an exhibition on its research. In the photograph touring the exhibition at NIKHEF are, left to right, A. Pais, Dutch Minister for Education and Science who opened the Laboratories, A. Diddens, Director of NIKHEF-H, I. Mannelli, CERN Research Director and R.F. Heyn, CERN Director of Administration.

(Photo CERN 600.5.81)

Honma, Veikko Karimaki, Ray Frey, Jean Sass and Bill Haynes). Lying fifth at the gruelling uphill finish of the first kilometre, UA1 established a lead by the end of the second leg, and went on to win by an impressive margin. After a somewhat less brilliant performance last year, the team attributes its success to an influx of new blood.

Winners of two very different kinds of beauty contest: Laboratory Director Leon Lederman, co-discoverer of 'hidden beauty' with the upsilon particle, interacts with the shapely Miss Illinois, resplendent in her full Fermilab/upsilon finery.

(Photo Fermilab)

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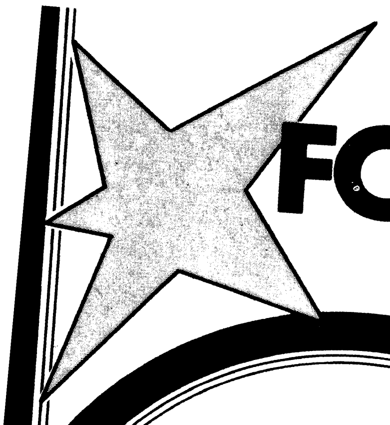

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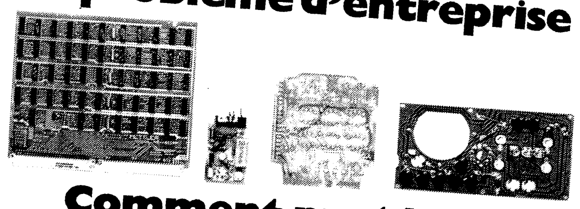

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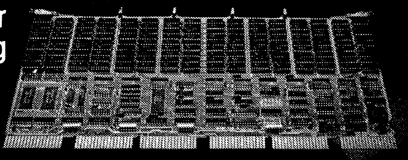

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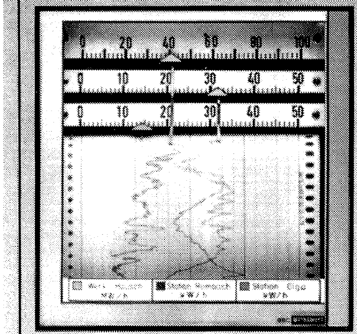

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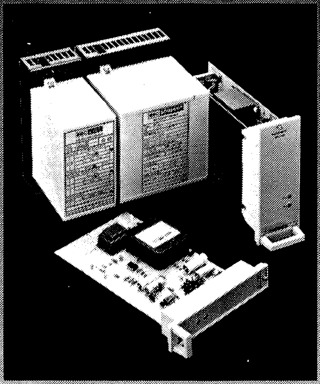

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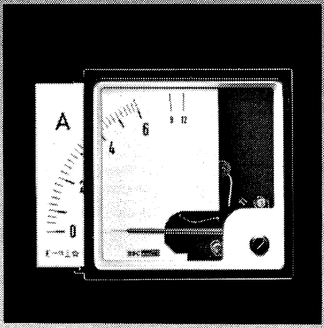

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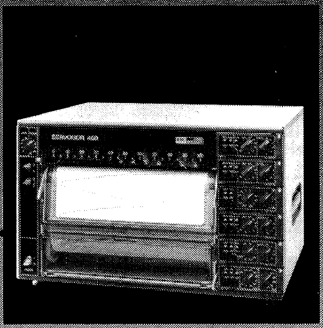

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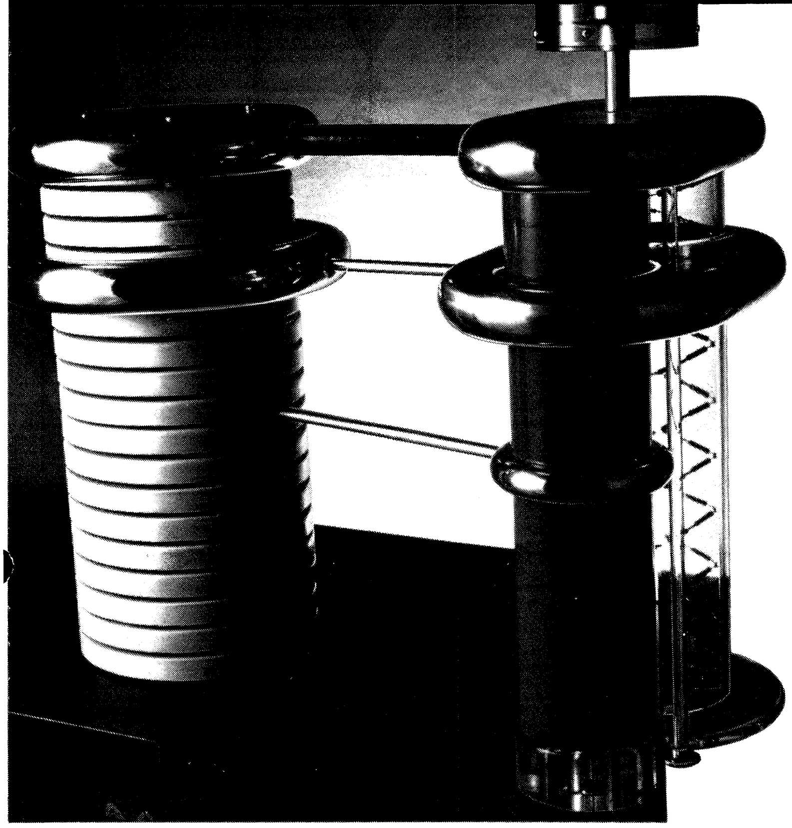

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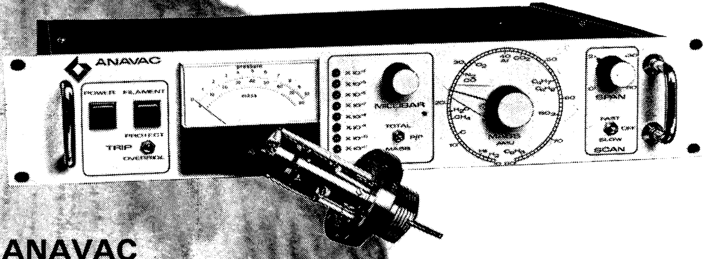

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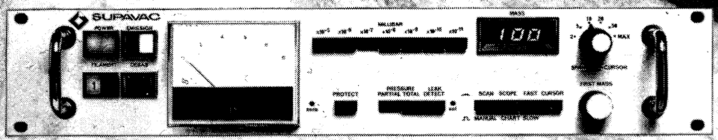

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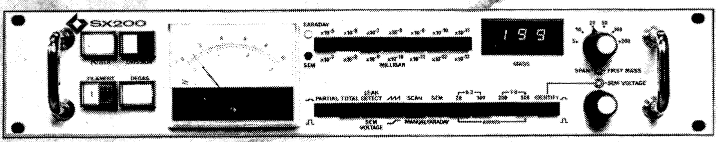

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- DPP16 fitted as standard.
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- Choice of inlets for all applications.
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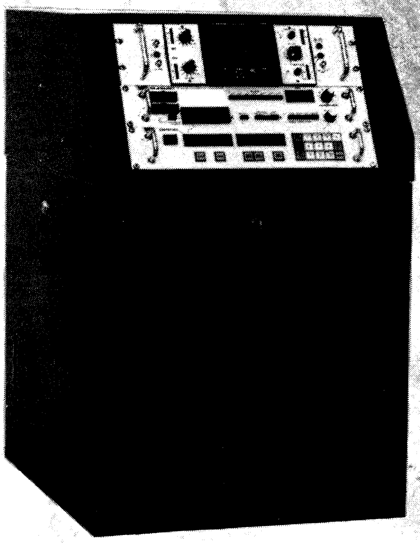

For applications demanding the ultimate in performance, high precision magnetic sector instruments are available. These applications include impurity analysis, accurate mixture analysis and isotope distribution. Computer control and data acquisition systems are available with comprehensive data handling programmes.

For further information contact:

VG Gas Analysis Limited,
Nat Lane, Winsford, Cheshire CW7 3QH.
Telephone: Winsford (06065) 52021 Telex: 668061.

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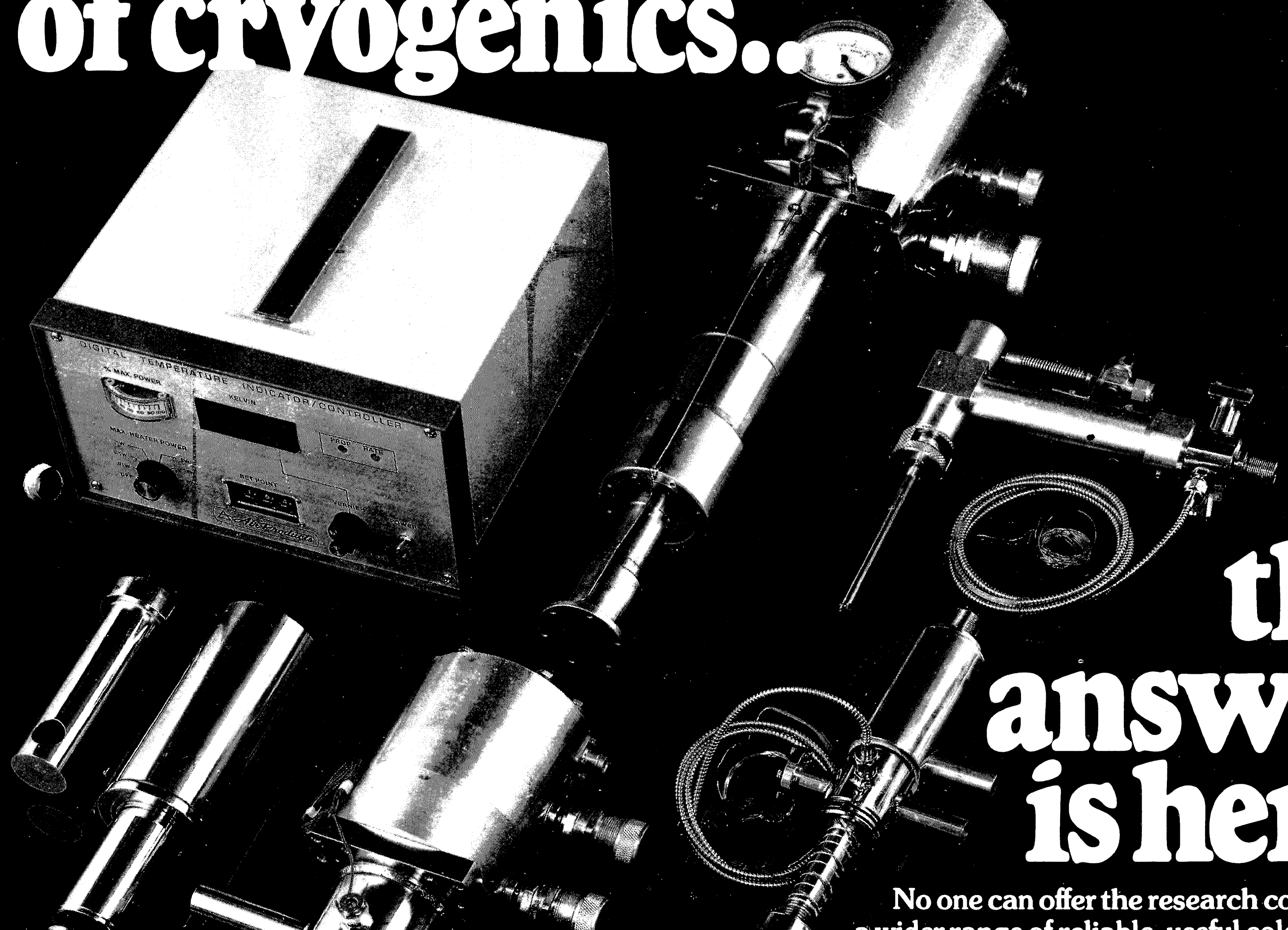

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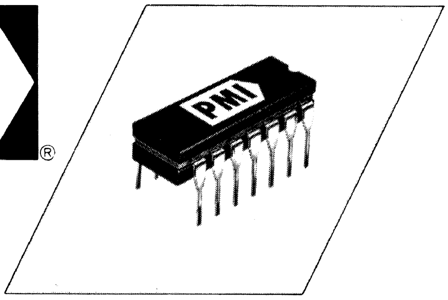
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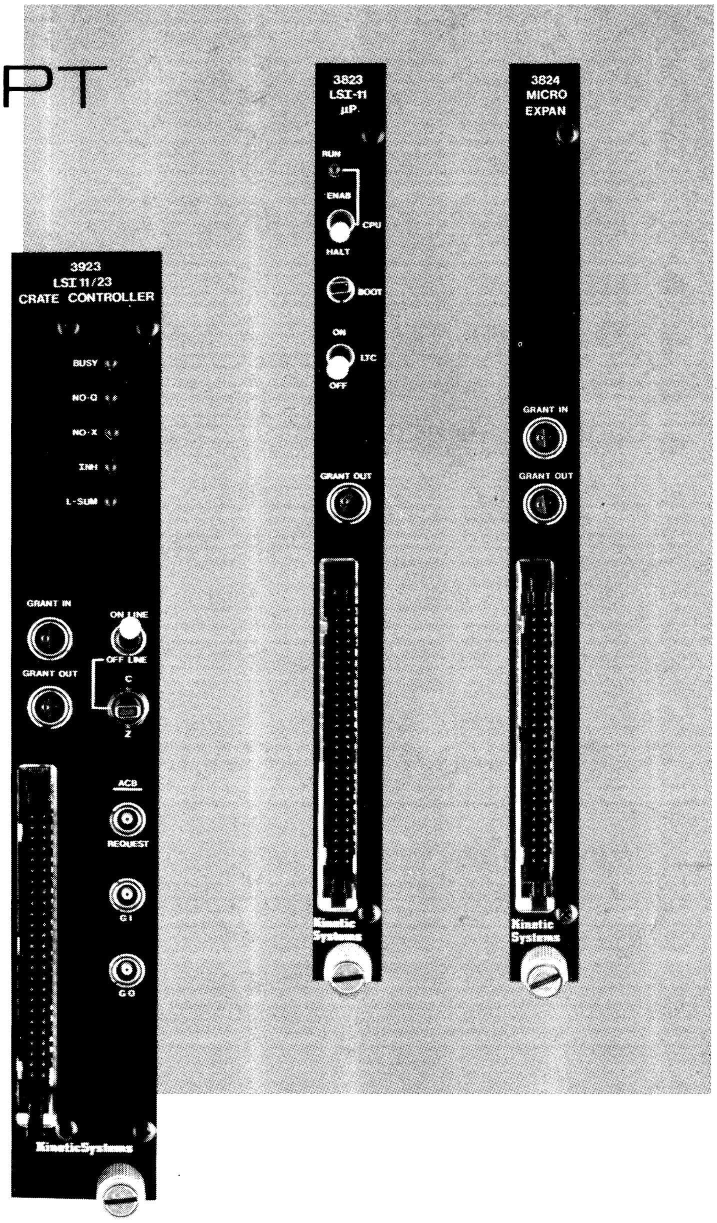
New 8033 CONCEPT gives you the best of two worlds-

CAMAC control and LSI-11 power



Now you can realize all the advantages of a cost-effective, compact LSI-11 microcomputer system within a CAMAC crate. Another total system concept, the 8033 can be used as an autonomous stand-alone system or as an integral part of a CAMAC serial highway. Its applications include laboratory automation, industrial process control, distributed systems, and software development.

The *8033 CONCEPT* offers you a unique I/O-addressable crate controller concept where four registers in the crate controller can be mapped anywhere in the LSI-11's I/O page. This concept eliminates address restraints on the I/O page and permits your application software to take full dvantage of the LSI-11/23's speed.

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8033 CONCEPT system

This LSI-11/23 CAMAC system is an expandable modular device composed of these major components:

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**This unit houses an LSI-11/2 CPU module in our 8032 CONCEPT system.*

concept systems

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SMALL SYSTEMS APPLICATIONS

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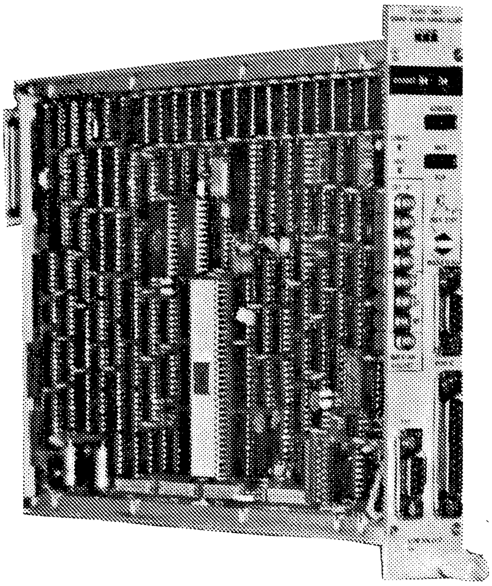

FEATURES

- DOUBLE WIDTH CAMAC UNIT
- POWERFUL 16-BIT MICROPROCESSOR
- 16K - 16-BIT RAM MEMORY
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- EPROM OR FLOPPY DISK RESIDENT PROGRAMS.
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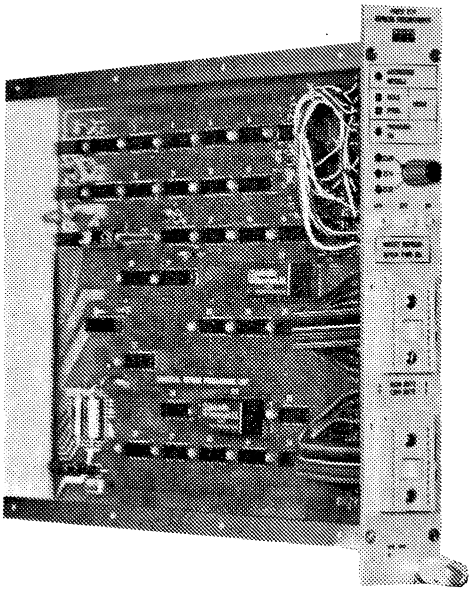
- THE POSSIBILITY OF USING THE NODOL HIGH-LEVEL LANGUAGE

APPLICATIONS OVERLEAF

RP 2114 EPROM PROGRAMMER

ASSOCIATED WITH THE ACC/STACC TYPE DEVICES



FEATURES

- PROGRAMS ALL TYPES OF EPROMS : 2508, 2516 AND 2532
- TWO MEMORIES CAN BE PROGRAMMED SIMULTANEOUSLY
  LOW BYTE
  HIGH BYTE 16 BITS
- WHEN USED WITH THE ACC/STACC TYPE DEVICES, THE RP 2114 SIMPLIFIES THE GENERATION OF SUPPORT SOFTWARE

APPLICATIONS OVERLEAF

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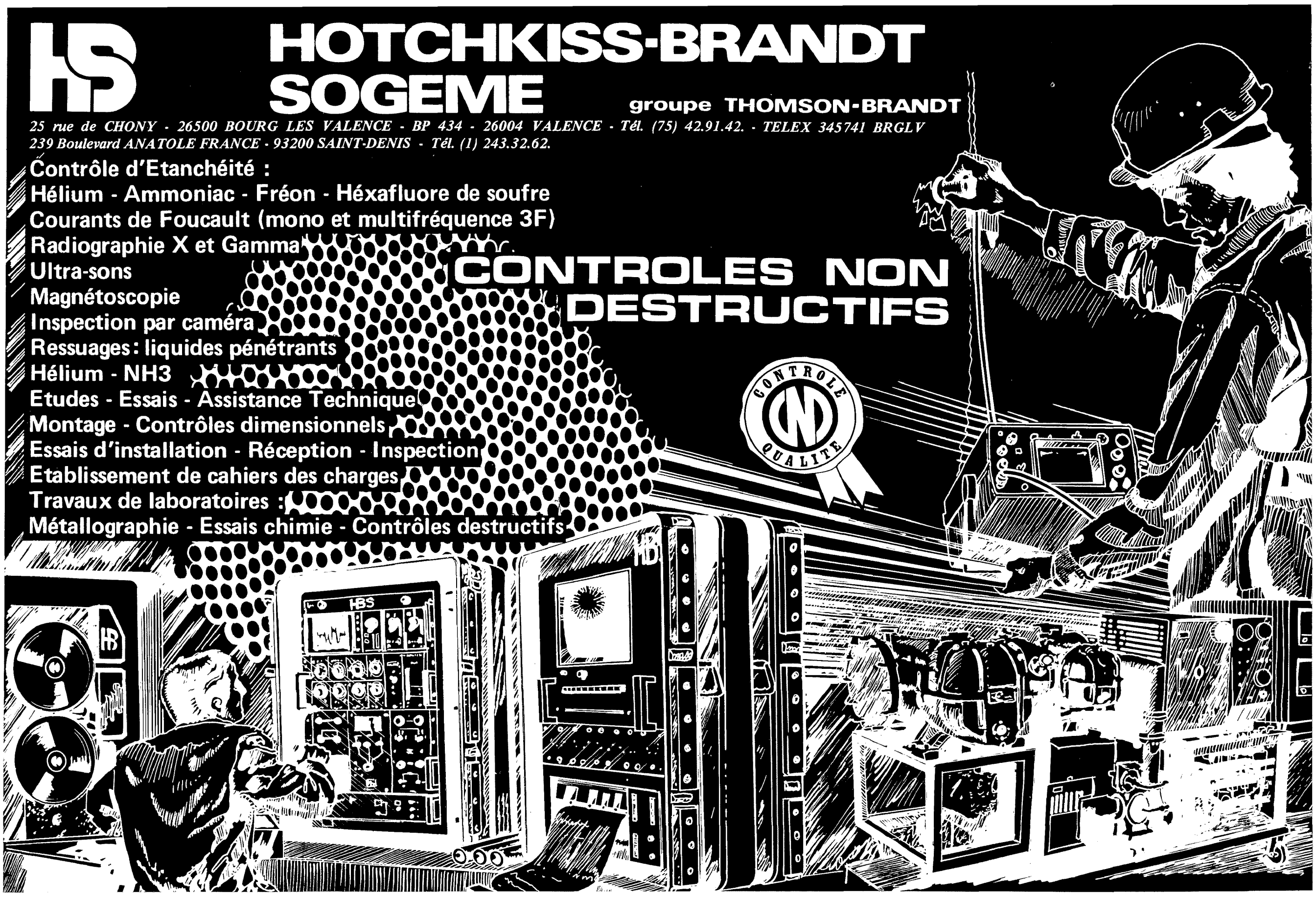

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Travaux de laboratoires :
Métallographie - Essais chimie - Contrôles destructifs

CONTROLES NON DESTRUCTIFS

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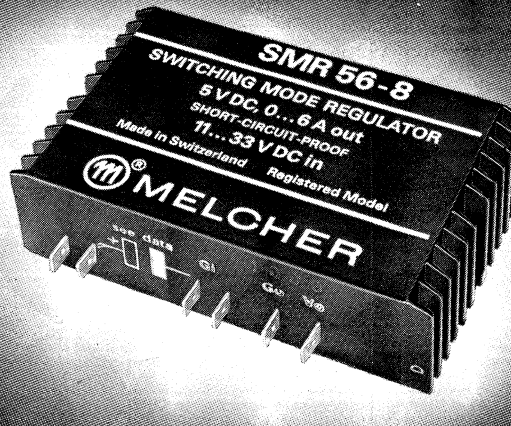

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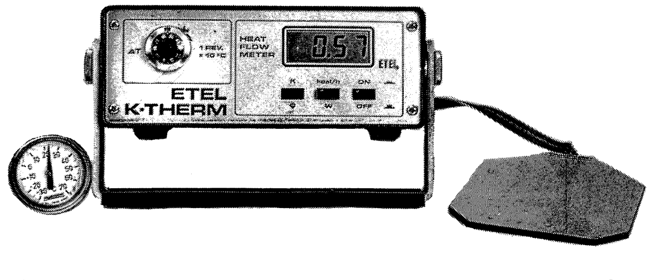

A portable instrument, supplied with a high precision electronic probe, for measuring the flow of heat through walls, insulating materials, etc.

Immediate calculation and display of the k-factor in steady states conditions.

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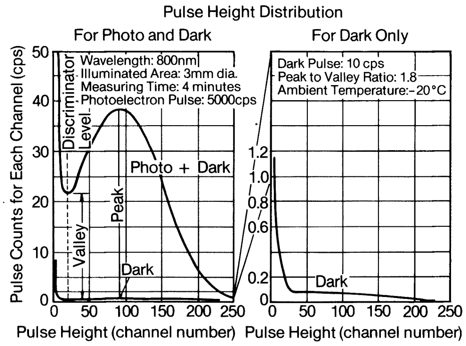
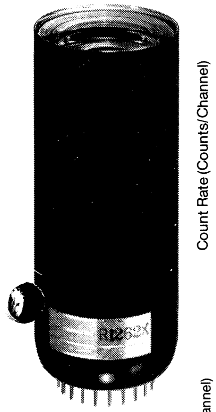
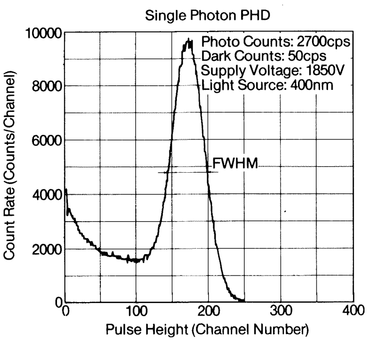
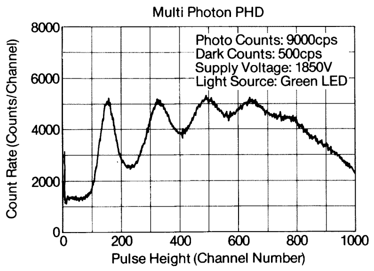
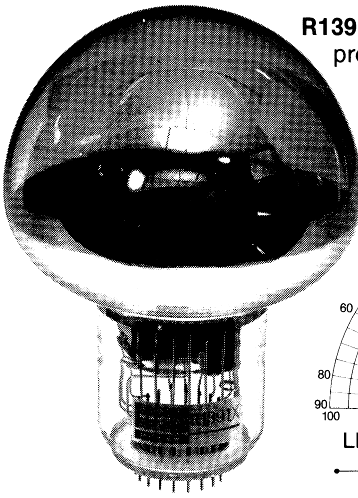
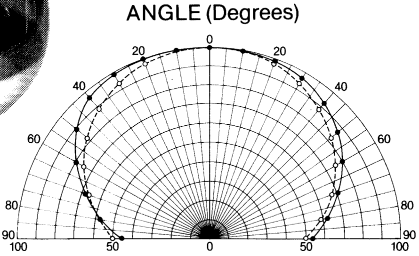

Pulse Height Distribution
For Photo and Dark
For Dark Only
Pulse Counts for Each Channel (cps)
Wavelength: 800nm
Illuminated Area: 3mm dia.
Measuring Time: 4 minutes
Photoelectron Pulse: 5000cps
Discriminator Level
Valley
Peak
Photo + Dark
Dark
Dark Pulse: 10 cps
Peak to Valley Ratio: 1.8
Ambient Temperature: -20°C
0
10
20
30
40
50
0.2
0.6
0.8
1.0
1.2
0 50 100 150 200 250
Pulse Height (channel number)
Pulse Height (channel number)

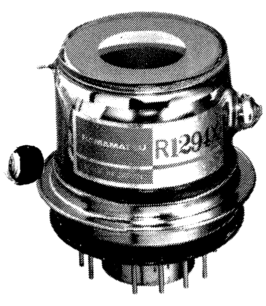


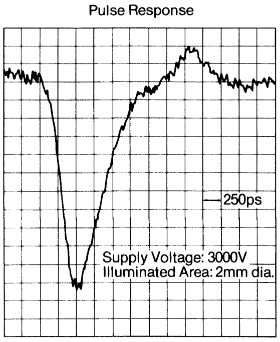

Single Photon PHD
Count Rate (Counts/Channel)
Photo Counts: 2700cps
Dark Counts: 50cps
Supply Voltage: 1850V
Light Source: 400nm
FWHM
0
2000
4000
6000
8000
10000
0 100 200 300 400
Pulse Height (Channel Number)

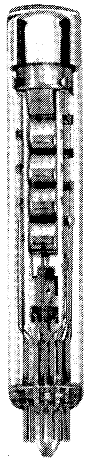

Multi Photon PHD
Count Rate (Counts/Channel)
Photo Counts: 9000cps
Dark Counts: 500cps
Supply Voltage: 1850V
Light Source: Green LED
0
2000
4000
6000
8000
0 200 400 600 800 1000
Pulse Height (Channel Number)




ANGLE (Degrees)
0
20
40
60
80
90
100
50

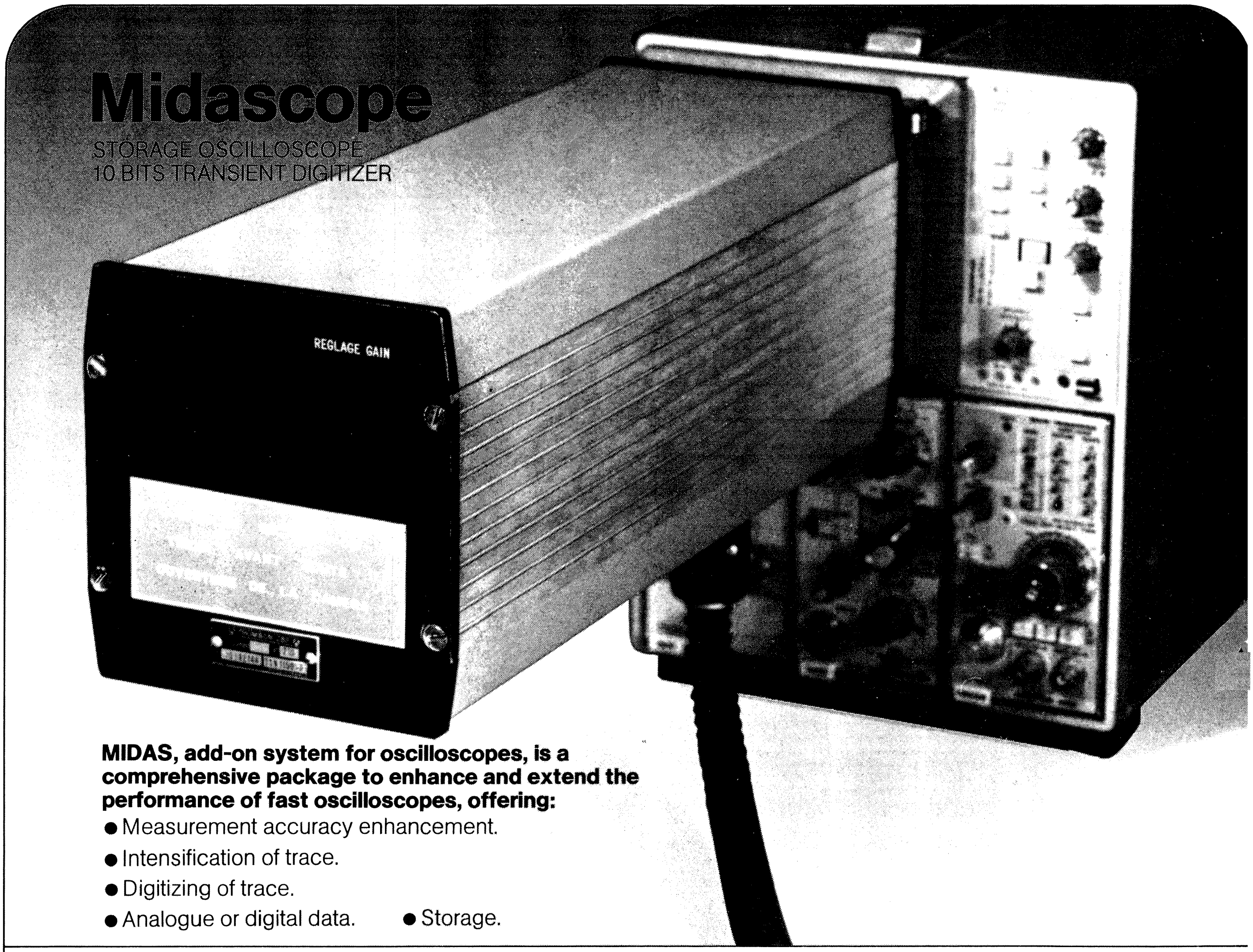



Pulse Response
250ps
Supply Voltage: 3000V
Illuminated Area: 2mm dia.



Midascope

STORAGE OSCILLOSCOPE
10 BITS TRANSIENT DIGITIZER



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- Digitizing of trace.
- Analogue or digital data.
- Storage.

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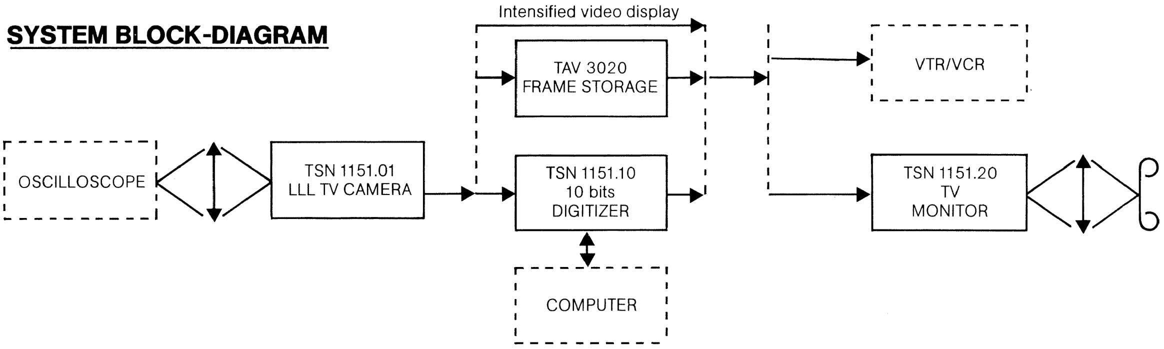

TECHNICAL SPECIFICATION

• **TSN 1151.01**	Low Light Level TV camera with NOCTICON ® tube (SIT tube) Equivalent monitoring sensitivity of 100.000 ASA
• **TSN 1151.10**	Dual beam digitizer 2 x 256 points 10 bits. Computer interface: RS.232.C IEEE.488/75
• **TSN 1151.20**	10 x 13 cm flat-screen TV monitor with POLAROID camera.
• **TAV 3020**	Digital frame store 256 x 256 matrix 6 bits

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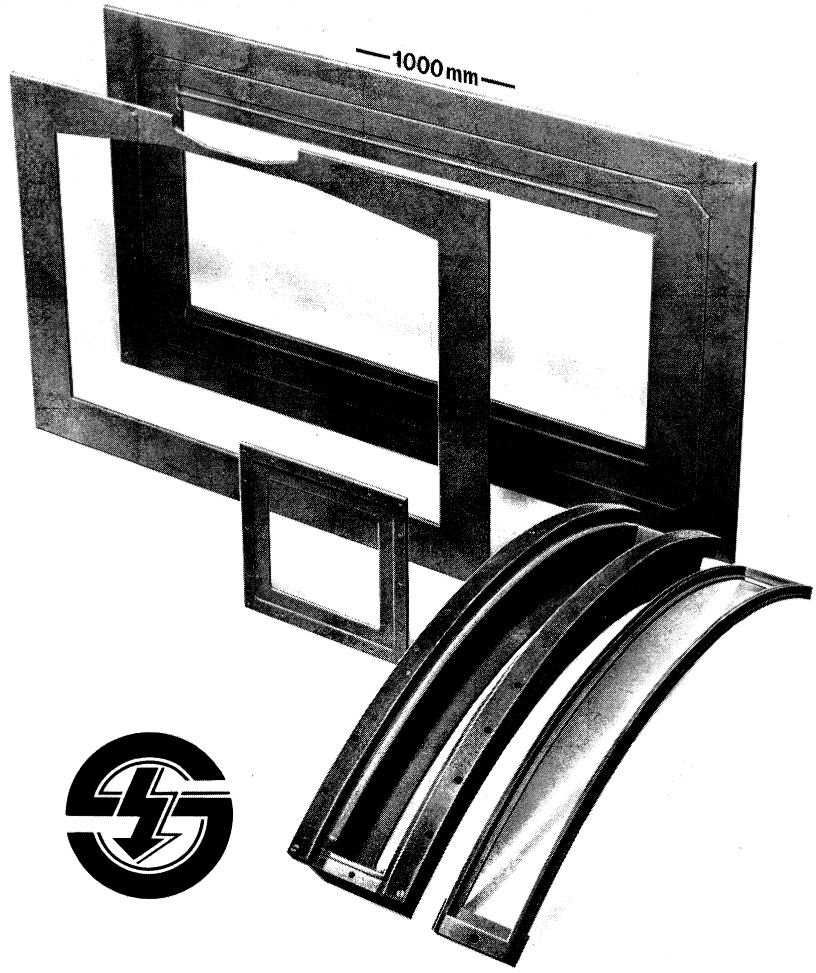
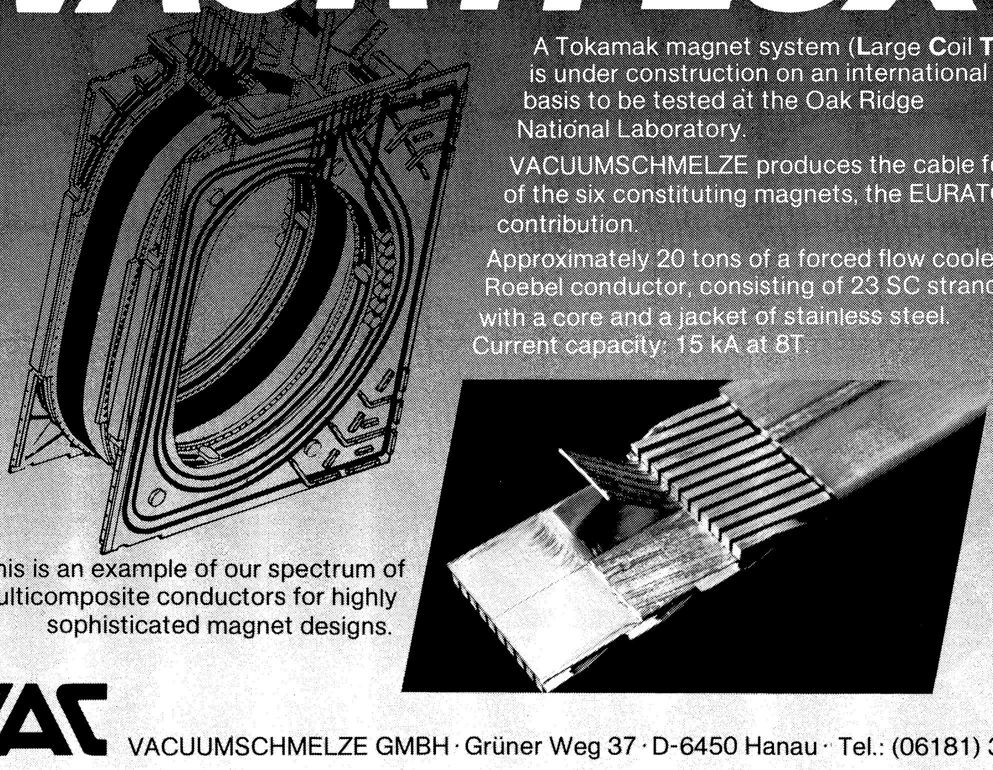
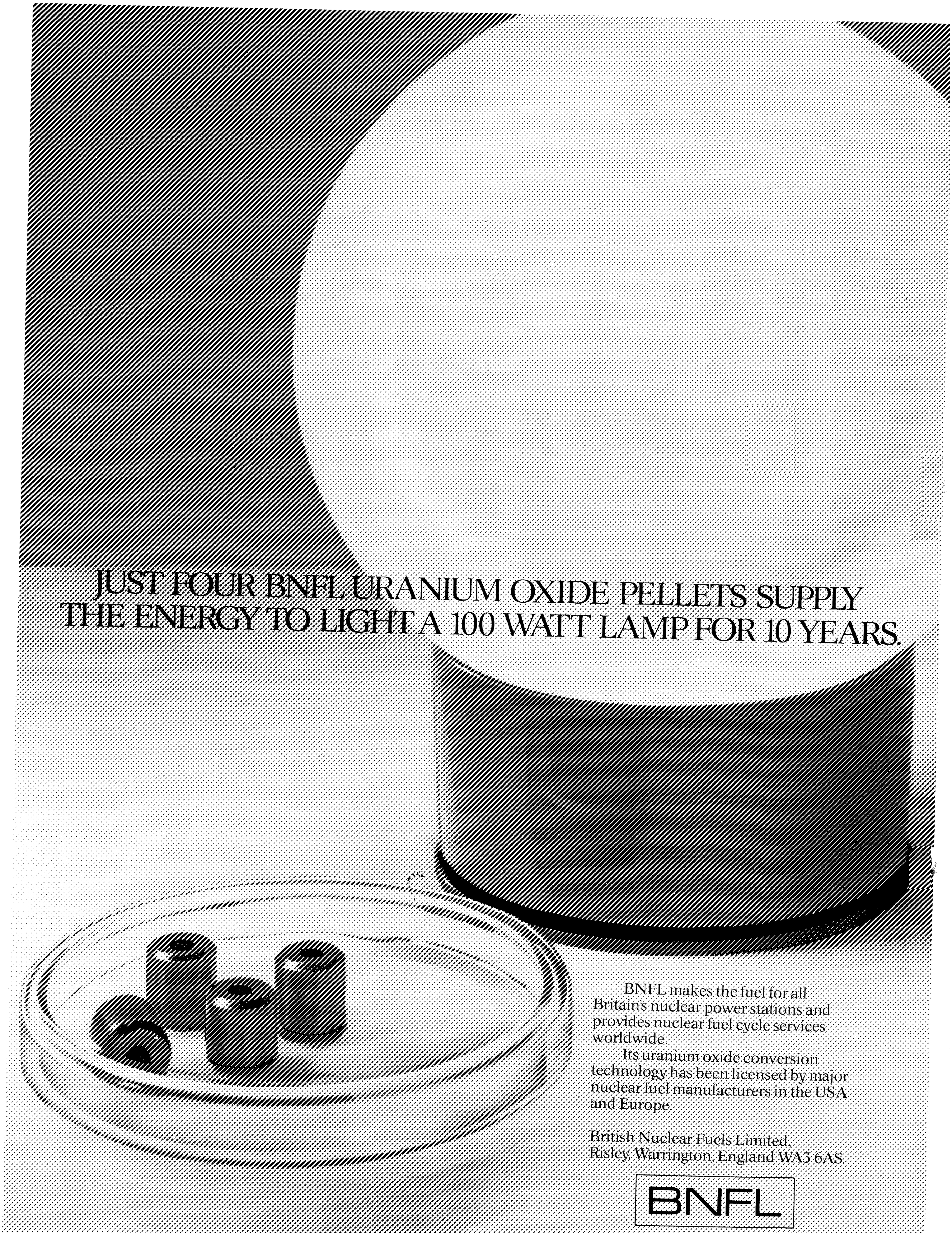

1000 mm





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XP2012	32	bialkali	10	1	1	200	7,2
XP2202	44	bialkali	10	1	1	200	7,4
XP2212	44	bialkali	12	1	1	250	7,5
XP2030	70	bialkali	10VB	0,5	0,8	40*)	7,2
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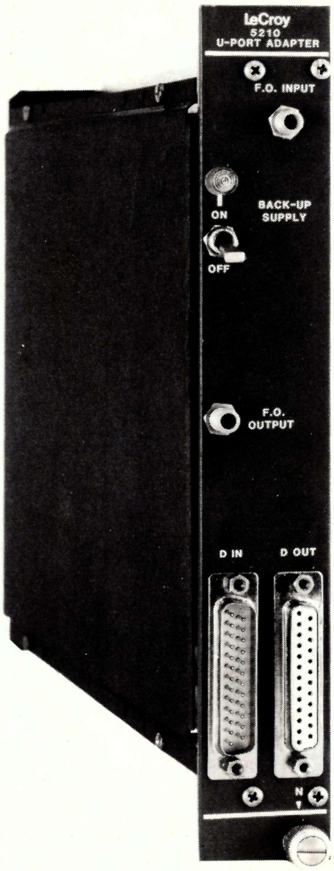
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OFF
F.O. OUTPUT
D IN
D OUT


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ERROR
OFF
LTC
ON
SINGLE STEP
LSI
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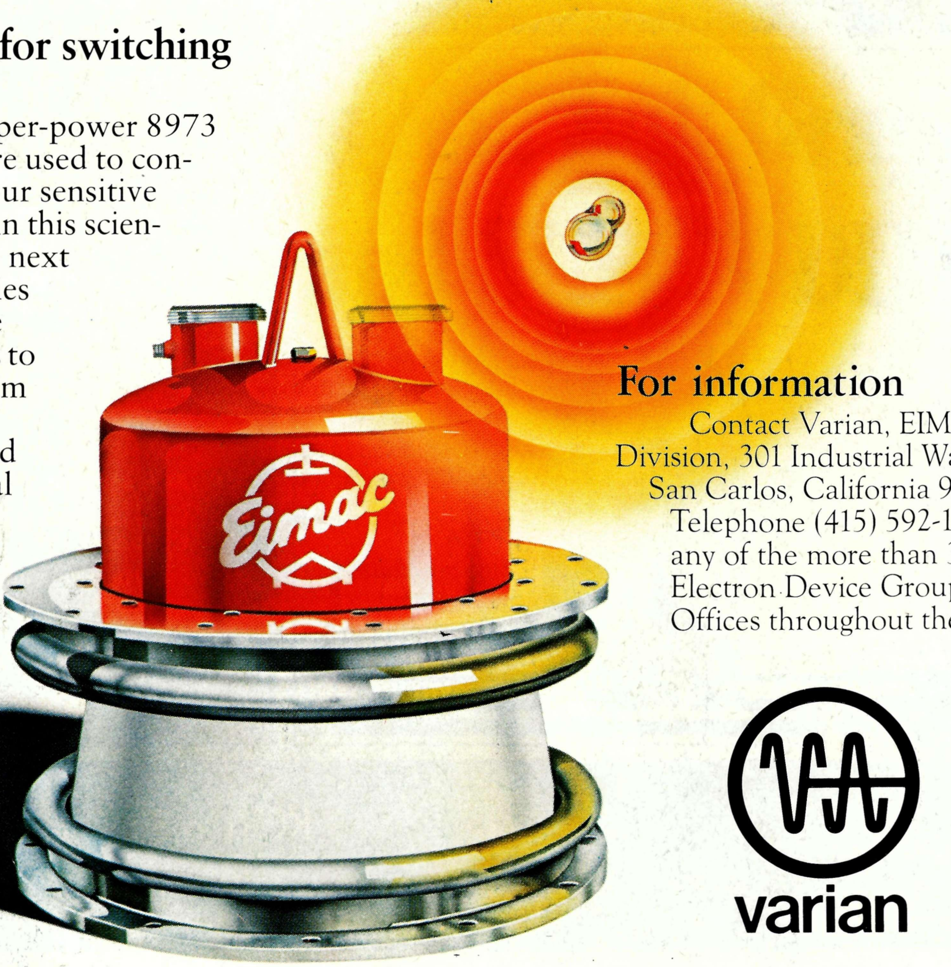
January 1981

EIMAC 8973 provides over one megawatt CW power output at 78 MHz with 14 dB stage gain.



For information

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