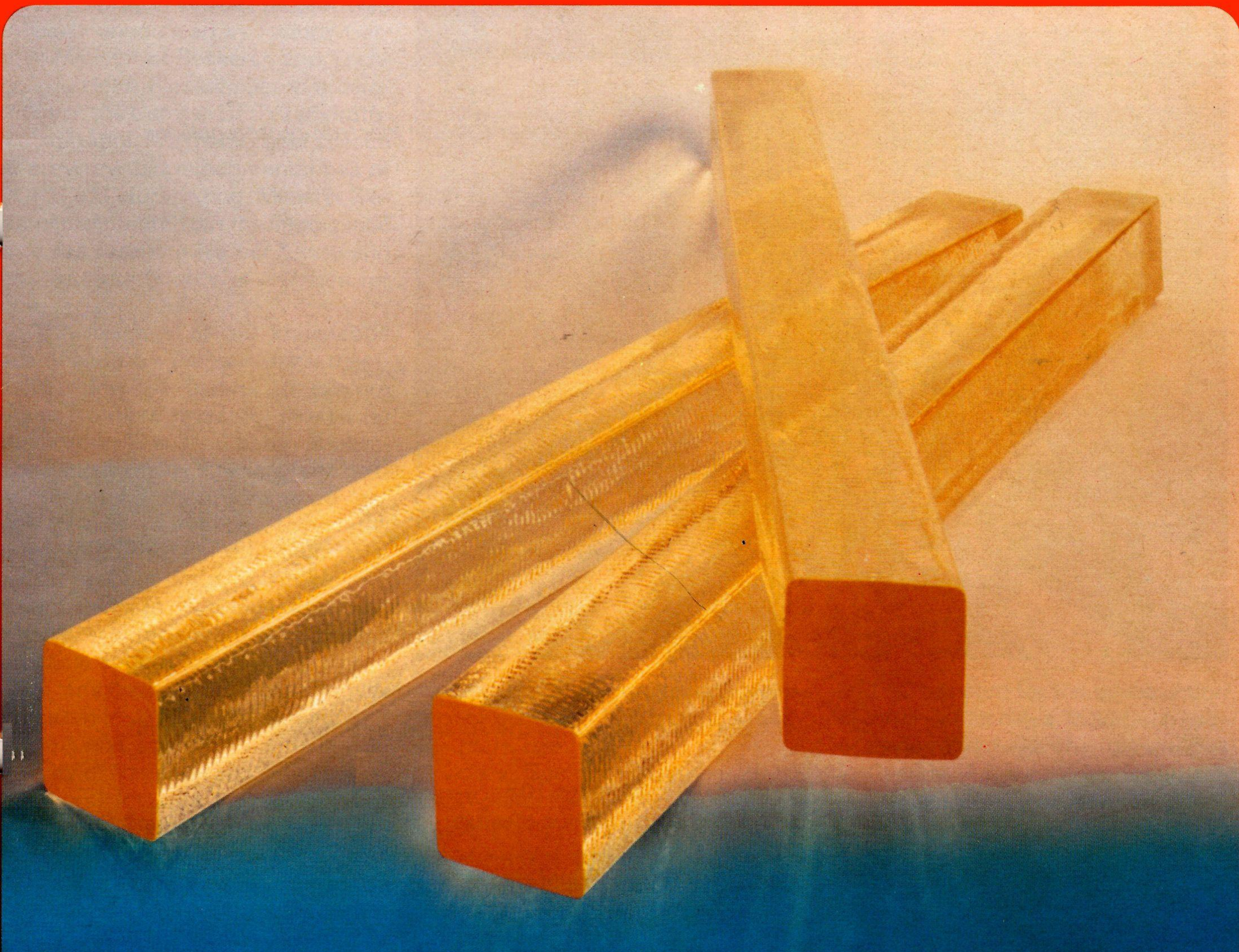
CERN COURIER

International Journal of High Energy Physics



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International Journal of the High Energy Physics Community

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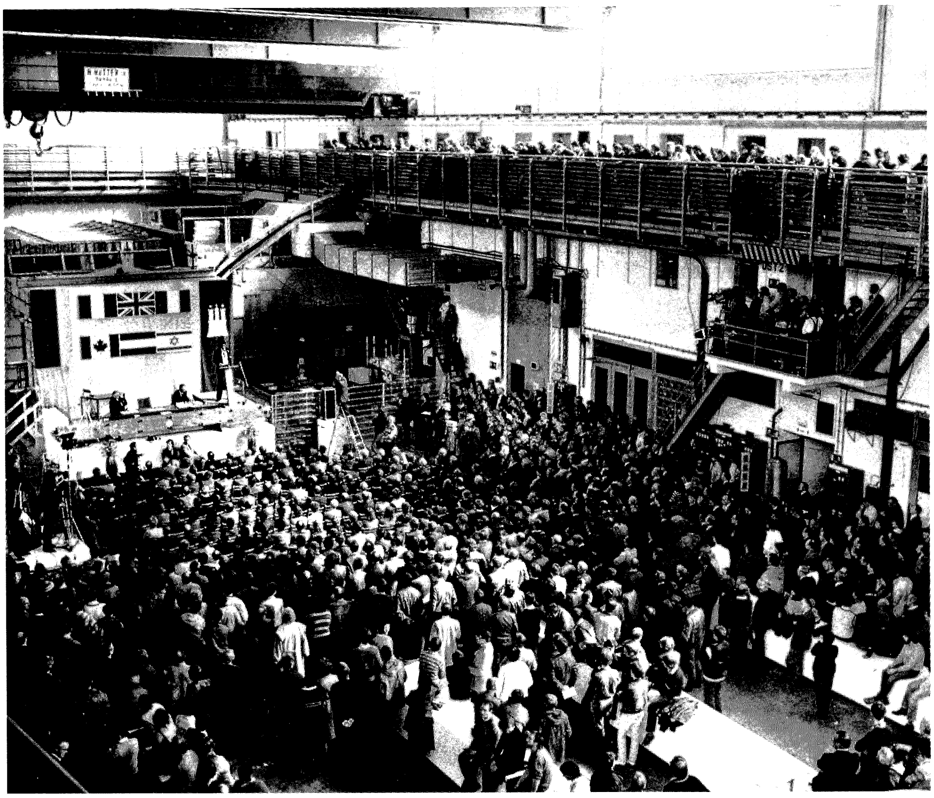
VOLUME 24 N° 5 JUNE 1984

Cover photograph: Not gold, but extruded lead-glass bars for an experiment to study the production of single photons at Stanford's PEP electron-positron ring (Photo Stanford Linear Accelerator Center).

HERA's welcome

The crowded experimental hall of the DORIS electron-positron ring at the German DESY Laboratory on 6 April for the ceremony to mark the official approval of the big new HERA electron-proton collider.

(Photos J. Schmidt, DESY)



The final approval of the big HERA electron-proton collider project was officially announced by Federal German Minister of Research and Technology Heinz Riesenhuber in a ceremony at the German DESY Laboratory on 6 April. In a memorable speech in the crowded experimental hall of the DORIS storage ring, Minister Riesenhuber pointed out the importance of basic research for our future and the absolute priority of freedom for science.

'The frontiers of our knowledge are defined by the scientists themselves and the means to explore these frontiers must be chosen by them too. The search for applications should never interfere with basic research. Preprogrammed research only reproduces the status quo; it should be the 'unknown' which fascinates the scientists and drives them to new investigations, and never some eventually expected practical applications.'

He emphasized the technological importance of the HERA project and the general consensus obtained in the city of Hamburg and in the neighbourhood for its construction. The international participation was also stressed; the technological and scientific contributions from the countries taking part in the project will benefit all of them. 'Once scientific and technological progress has been achieved, once it is shown that something works, then a lot of people find applications and new horizons open up.'

Senator for Science and Research of the City of Hamburg Hansjoerg Sinn, an old friend of DESY and enthusiastic supporter of HERA, pointed out the scientific importance of the work done at DESY and the economic spin-off, particularly for the Hamburg region. Sinn also reminded the audience of the pioneering work of Willibald Jentschke, who came to Hamburg to discuss accelerator projects for the first time exactly 30 years ago.

Volker Soergel, chairman of the DESY directorate, began the proceedings by welcoming the many distinguished guests and thanking the political authorities. He emphasized, among other things, the importance of the Pinkau committee which had advised the Federal Government and took into account many points of view within the scientific community. This was also pointed out by the other speakers. It is a general policy of the German Federal Government to ask scientists for advice on their own projects.

One very important document signed during the ceremony at DESY was the contract between the City of Hamburg and the Federal Government on HERA funding. The city of Hamburg will bear 20 per cent of the costs on the civil engineering side, and 10 per cent for the construction of the new machines. In addition Laboratories and research organizations in Canada, France, Israel, Italy, the Netherlands and the United Kingdom have declared their intention to make significant contributions, mainly in the form of HERA components to be developed and built in collaboration with home industry.

The total investments for HERA will be of the order of 950 Million DM (equivalent to the originally quoted figure of 654 MDM in December 1980). About 30 per cent of the funding will go in building the 6.3 km tunnel and the four experimental halls, 23 per cent will go into the electron ring and 47 per cent for the superconducting proton ring.

In the budget plans of the Federal Government and of the City of Hamburg, a total of 282 MDM have been allocated for HERA for the next three years. Of this, over 50 MDM can be

The HERA project is funded by the Federal German Government and the City of Hamburg. Here Federal Minister of Research and Technology Heinz Reisenhuber, right, and Hamburg Senator for Science and Research Hansjoerg Sinn sign the official HERA agreement.

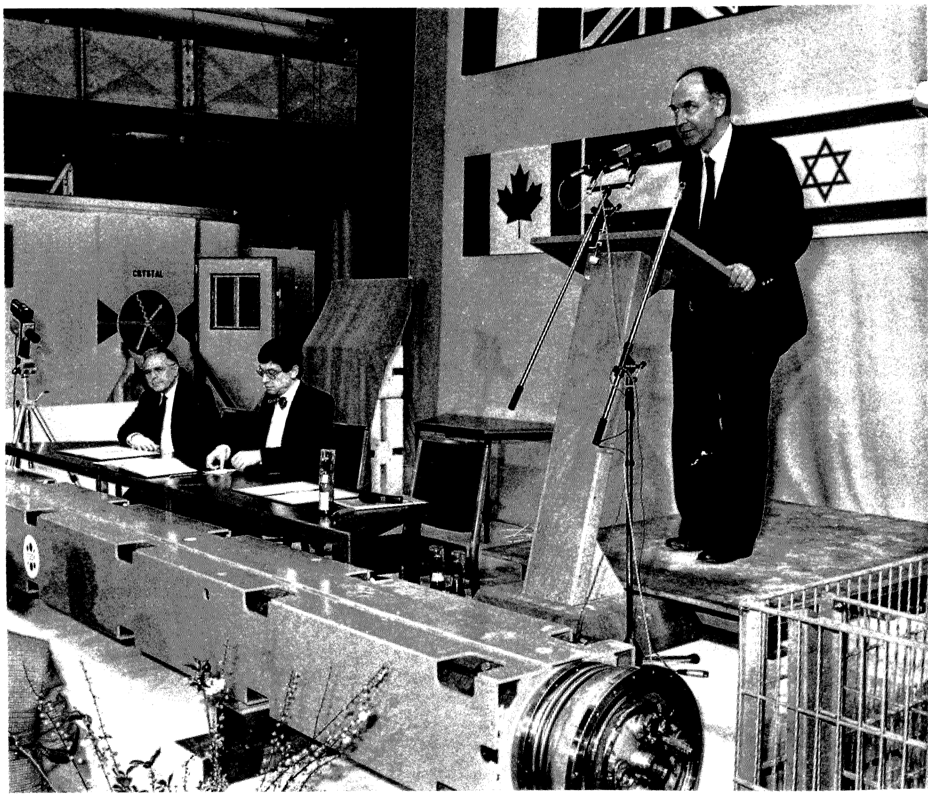
spent this year, boosting the total budget of DESY from last year's figure of 142 MDM to nearly 195 MDM this year.

After the signature of the financial agreement, congratulations were expressed by Chairman of the DESY Scientific Council Klaus Luebbelsmeyer (Technical University of Aachen), by European Committee for Future Accelerators chairman Jean Sacton (Free University of Brussels) and by Hans Wolfgang Levi, Chairman of the association of the 13 major German research institutes of which DESY is a member.

The work on HERA will now accelerate. The tunnel and experimental halls should be finished by the end of 1987, the electron ring about 4 months later and the proton ring in the middle of 1989. Digging for the first experimental hall has already started, since most of the administrative tasks, including tenders, have been completed.

In the meantime the first full size superconducting HERA dipole magnet, wound and mounted at DESY and fully equipped with cryostat and all required connections, at its first cooldown reached a current of 6000 A without a single quench, about 8 per cent more than the current required for 820 GeV protons. A forced quench at 6060 A did not cause any damage.

The two dipole approaches followed so far (warm and cold iron, see March issue, page 52) have each shown good features and thinking is converging towards a hybrid model which may include advantages of both prototypes. Considerable simplification and economy may also be



DESY Director Volker Soergel welcomed the many distinguished guests to the HERA ceremony. Behind him were the flags of the countries (Canada, France, Israel, Italy, the Netherlands and the United Kingdom) which have pledged significant HERA contributions.

obtained by making the magnets 9 metres long (instead of the original 6 metres). Final decisions on these magnets are scheduled to be taken in summer 1985.

The electron and proton injection systems, including the new synchrotrons DESY-II (for electrons) and DESY-III (for protons — see May issue, page 151) will then be progressing. The HERA electron ring will use part of the r.f. system currently installed in the PETRA electron-positron ring, including power supplies and cavities. The bending magnets are of very simple design and require only 1850 gauss for the 30 GeV electrons.

With the final approval, Gustav-Adolf Voss and Bjoern Wiik have been nominated project leaders. Gus Voss becomes responsible for civil engineering, the electron ring and the injection channels between PETRA and HERA. Wiik takes over the superconducting proton ring, including its refrigeration system, and the proton injection system (including a new proton linac, the conversion of the existing electron synchrotron into the DESY-III proton machine, and the modifications required on PETRA).

At DESY, further HERA news will be published in the new HERA Bulletin.

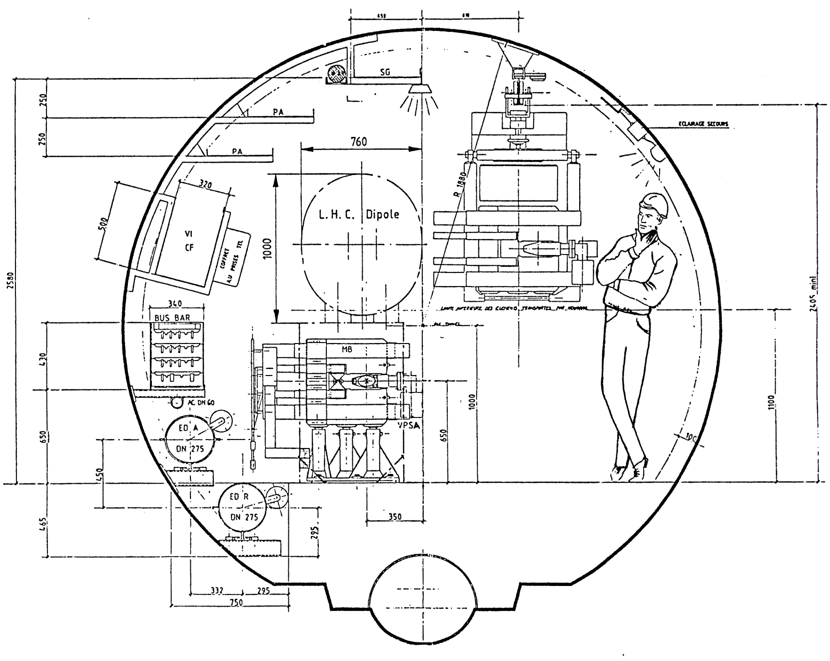
Large Hadron Collider workshop

CERN is at present building the LEP electron-positron collider and preparing for its exploitation up to the highest energy now foreseeable. The physics case for LEP now appears even stronger than in 1978-79 when workshops and meetings organized by the European Committee for Future Accelerators (ECFA) and CERN demonstrated the widespread support and enthusiasm of the European high energy physics community for the project and led to its approval in 1981.

Now the impressive results of the CERN proton-antiproton collider, with the discovery of the W and Z weak intermediate bosons and the clear emergence of hadronic jets, have confirmed the most optimistic statements earlier advanced for LEP physics.

The installation of a hadron collider in the LEP tunnel, using superconducting magnets, has always been foreseen by ECFA and CERN as the natural long term extension of the CERN facilities beyond LEP. Indeed, such considerations were kept in mind when the radius and size of the LEP tunnel were decided. The recent successes of the CERN Collider now give confidence that such a collider would be an ideal machine to explore physics in the few TeV range at the particle constituent (quarks and gluons) level. The present enthusiasm for the Superconducting Super Collider (SSC) in the US reflects the impressive potential of such machines.

Although the installation of such a hadron collider in the LEP tunnel might appear still a long way off (LEP is scheduled for initial operation in 1988), it was still an opportune moment for ECFA, in collaboration with CERN, to organize a 'Workshop on the Feasibility of a Hadron Collider in the LEP Tunnel' from 21-27 March.



Sketch of a cross-section of the 27 kilometre circumference tunnel for the LEP electron-positron collider, now being built at CERN. On the floor are the LEP magnets, with above, the space available for the Large Hadron Collider (LHC) superconducting magnets. On the right is the monorail transport system. Although LHC would not come before the middle of the next decade, the construction of LEP requires LHC thinking to be coordinated well in advance.

At the CERN Large Hadron Collider Workshop, Herman Grunder of Berkeley reported progress on US planning for the 20 TeV Superconducting Super Collider (SSC).

The first four days of detailed work were held in Lausanne, at the kind invitation of the University, and were followed by two days of summary talks and discussion at CERN.

The Workshop was initiated particularly by the then ECFA Chairman John Mulvey in keeping with ECFA's role in stimulating and coordinating plans for future particle physics facilities in Europe. The Workshop was timed to enable CERN to communicate present ideas on long term prospects to an ICFA (International Committee for Future Accelerators) Seminar held in Tokyo from 15-19 May and entitled 'Perspectives in High Energy Physics'.

In his opening address at the Workshop Summary Session, CERN Director General Herwig Schopper emphasized that CERN's top priorities remain the completion of LEP Phase I (to achieve electron-positron collisions up to 50 GeV per beam), followed by Phase II (taking the beam energies to around 100 GeV). Thus the Large Hadron Collider (LHC) means looking as far ahead as the middle of the next decade.

Nevertheless, LHC would have to use the infrastructure permitted by LEP. Present ECFA Chairman Jean Sacton emphasized what LEP and CERN would offer. Besides the LEP tunnel itself, the PS and SPS provide excellent proton (and antiproton) injectors. In particular, with the experience of the Intersecting Storage Rings (ISR) and the proton-antiproton Collider under its belt, CERN can claim unique experience and expertise with bunched beam hadron colliders. The European particle physics community is also well aware of the competition from the SSC in the US breathing down its neck.

Giorgio Brianti summed up the outcome of the LHC machine studies so far. After confirming that the LEP tunnel would indeed be suitable for such a machine the next conclusion was that construction moreover need not interfere significantly with LEP operation, given the foreseen LEP operating schedule. Four excavated colliding beam regions are still vacant, although this may not still be the case by the time of LEP Phase II.

To be competitive, LHC has to push for the highest possible energies given its fixed tunnel circumfer-

US plans

The US particle physics community is pushing for a 20 TeV Superconducting Super Collider (SSC), and progress was reported at the CERN Large Hadron Collider Workshop by Herman Grunder of Berkeley.

The US Department of Energy, via the US Laboratory Directors, launched the preparation of a 'Reference Design' under Maury Tigner with an Advisory Group under Paul Reardon. This design aims to demonstrate the feasibility of an SSC (but not to fix the design parameters) and to indicate the 'ball park' machine cost within 30 per cent.

The SSC circumference could be up to four times that of LEP, depending on the selected magnet design, with colliding proton beams, six collision regions and 1 TeV injection. Three magnet designs, all based on niobium-titanium superconductor, are under study — 3 T two-in-one superferric magnet based in Texas, 5 T one-in-one 'no iron' magnet, based in Fermilab, and 6.5 T two-in-one magnet based in Berkeley and Brookhaven.

The Reference Design is going to the Department of Energy via the Laboratory Directors, and is scheduled to be with the Energy Secretary in June. In August it is hoped that the decision can be taken to start Phase I of the project, foreseen as a three-year period of research and development to produce the detailed design. The Director for this stage of the project would be proposed by the Universities' Research Association, present operators of Fermilab, who were selected as 'prime contractor' for the SSC because of their wide representation amongst the universities and research centres involved in the US particle physics programme. Construction of Phase II would follow the completion of the detailed design, at an anticipated cost of over two thousand million dollars.

ence. Thus the competitivity lives or dies with the development of high field superconducting magnets. The long gestation period of LHC fits in with the research and development required for 10 T magnets (probably niobium-tin), which would permit 10 TeV colliding beams. The keen interest in having such magnets extends into the thermonuclear fusion field, and development collaborations in the US, Japan and Europe look feasible.

There are two main options — either to build a single ring and have proton-antiproton colliding beams, as in the CERN SPS Super Proton Synchrotron and scheduled for Fermilab's Tevatron, or to build two rings and have colliding proton beams. Two considerations turned the thinking firmly towards the second option. The first is the advantage of the higher luminosity (up to 10^{33} per cm^2 per s) of proton-proton collisions. The second is the complications in separating the multi-bunch proton and antiproton beams outside the collision regions, which would require cumbersome separators. These considerations outweigh the intrinsic economy of having protons and antiprotons circulating in the same ring. At the Workshop, designs were presented of two-in-one magnets in single cryostats with the two proton beam channels less than 20 cm apart.

At such high energies, there are aspects of machine operation which need special attention. For example — the enormous stored energy in the beams means that the beam-abort system would have to cope with 60 MJ, the vacuum chamber design has to take account of synchrotron radiation heating, the refrigeration system has to distribute liquid helium over tens of kilometres and be able to cope with several superconducting magnet quenches at a time. The growing experience at the Fermilab Tevatron, where the world's first superconducting synchrotron has come so impressively into operation, would provide important input into design decisions.

Preceding the workshop, studies of machine design, magnets and cryogenics had been (and continue to be) underway at CERN, with periodic meetings to review progress. This work was summarized at Lausanne, including a panel discussion on superconducting magnet design and technology.

On the experimental side, eight working groups had been set up: Jets (convener P. Jenni), Electron and photon detection (P. Bloch), Muon detection (W. Bartel), Tracking chambers (A. Wagner), Vertex detection (G. Bellini), Triggering (J. Garvey), Data acquisition (D. Linglin) and Forward physics (G. Matthiae). There was also a great deal of input from theorists, and the Lausanne theory talks were also attended by many experimentalists.

The reports of these working groups provided much valuable input, and several general conclusions emerged. The highest energy would be a valuable asset but there is no actual threshold known now. The key point is to have at least 10 TeV collision energy in order to have typically at least one TeV at the hadron constituent level. There is also a trade-off between energy and luminosity, a gain in luminosity for a loss in energy and vice versa.

According to present wisdom, differences between proton-proton and proton-antiproton reactions would be in most cases too small to be detectable. Information from proton collisions should hence be adequate.

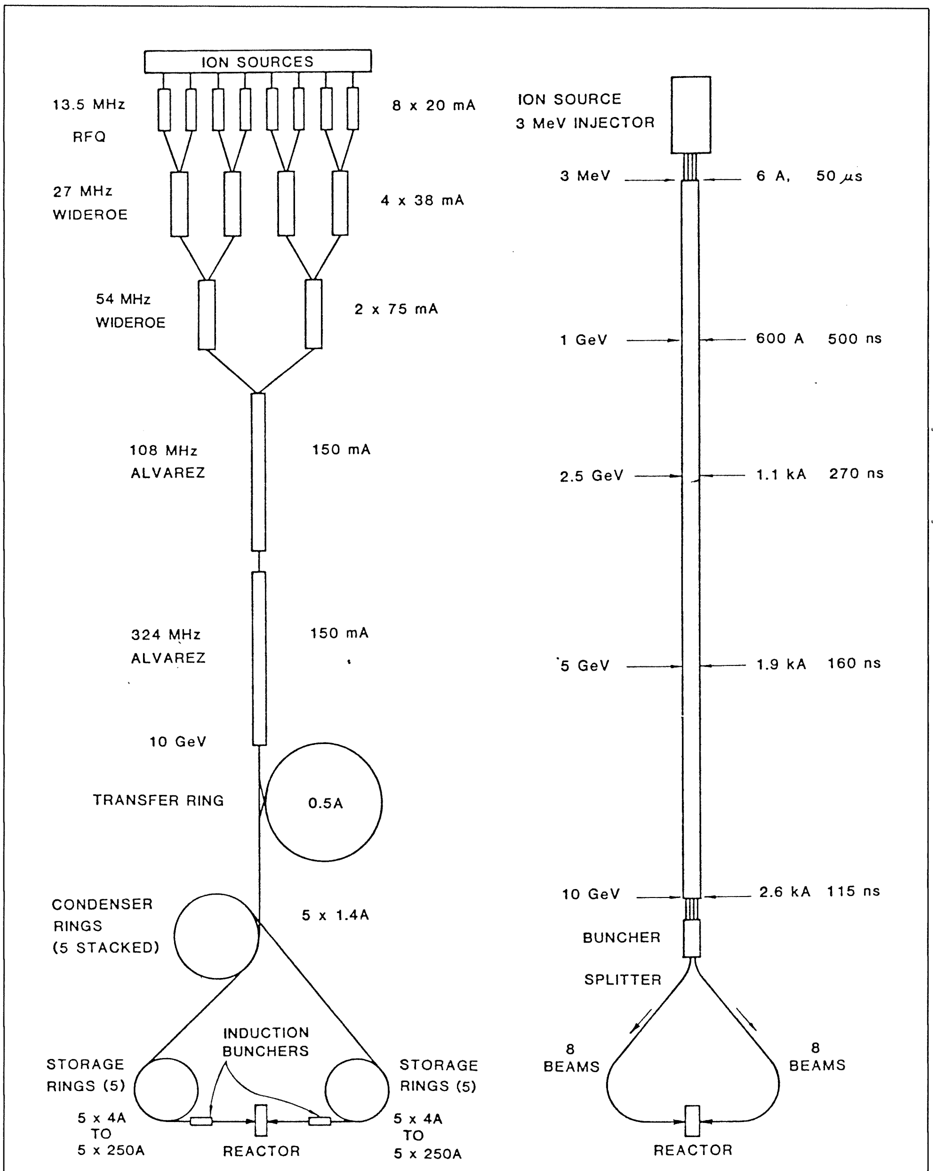
Production rates for hitherto unknown objects are 'expected' to decrease quickly with the mass of these objects, so that here high luminosity would be an advantage. Multibunched beams were envisaged with 3564 bunches per ring, giving 25 ns between bunches and an average of one interaction per bunch crossing. Much thought is going into particle detector performance and there is confidence that the high luminosities could be handled.

Another attractive possibility with both proton and electron rings in the same LEP tunnel is the provision of high energy electron-proton collisions 'for free'.

No attempt was made at the Workshop to arrive at even a tentative cost estimate for LHC in the LEP tunnel. The project has only been under consideration for a few months and a great deal of further study is needed. However as Carlo Rubbia emphasized in his concluding remarks — the feasibility of the LHC has been demonstrated, a good physics case has been outlined and CERN is able to promise a great deal when future perspectives in high energy physics are discussed.

Heavy ion fusion revisited

The two schemes which remain under study as 'drivers' to achieve controlled thermonuclear fusion via heavy ion bombardment of deuterium-tritium pellets. On the left, radio-frequency linacs and storage rings produce the high energy, high intensity bombarding ion beams. On the right, an induction linac, accelerating several beams simultaneously, produces the required beams.



Enthusiasm for the heavy ion route to thermonuclear fusion has had its ups and downs since it first flourished in 1976. Now it seems to be on the way up, judging by the discussions at the 'Heavy Ion Accelerators and their Applications to Inertial Fusion' Symposium held at the Institute for Nuclear Study in Tokyo in January. (We are grateful to Helmut Reich for communicating information from this Symposium.)

The basic idea is to bombard deuterium-tritium pellets with intense beams of high energy heavy ions so as to compress the pellets to the point where fusion occurs (and ultimately, of course, to use the energy liberated in the deuterium-tritium reaction to produce electricity). Despite the fiendish complications involved in achieving this objective, there are those who advocate this technique as being more likely to achieve controlled thermonuclear fusion for power reactors than any other currently under investigation (including the conventional magnetic confinement technique studied, for example, at the Tokamak Fusion Test Reactor at Princeton in the US and the Joint European Torus at Culham in the UK).

To set the scale of the complications — the heavy ion beam energy would need to be in the region of 10 GeV and have an intensity of some 30 kA, bombarding the fuel pellets from both directions. Information on appropriate pellet design has become more open than it was some years ago, but a lot of thorough work on the physics of these target pellets remains to be done (stopping power, effect of pre-heating, energy transport parameters, possible instabilities, etc.).

To provide the necessary ion beams, two schemes (usually known as 'drivers') remain under study, and all synchrotron schemes have been dropped after it was realized that high currents and lower energies are inappropriate.

One driver uses conventional technologies, although aimed at limits yet to be achieved. It has a cascade of r.f. linacs progressively funnelling ions from many sources into a single beam as the energy is increased. Storage rings subsequently get the beam to the right intensity and the right form for bombarding the pellets. This is the scheme under study predominantly in Japan and in the Federal Republic of Germany.

Work on ion sources to produce intense beams and on radio-frequency quadrupoles for the linac inputs is quite well advanced. At the Tokyo Institute for Nuclear Study, a small storage ring, TARN (Test Accumulation Ring for NUMATRON — a heavy ion project), and LITL (Lithium Ion Test Linac) are being used for beam studies. A larger (25 m diameter) version, TARN II, is proposed to extend the ion energies to 450 MeV per nucleon to investigate such aspects as multiturn injection at high currents, beam bunching and instabilities, and the possibilities of beam cooling. The Japanese have also prepared a conceptual design known as HIBLIC (Heavy Ion Beam and Lithium Curtain). It has 16 ion sources for singly charged ions of lead 208 and radio-frequency quadrupoles preceding the linac cascade. Alvarez linacs complete acceleration to 15 GeV prior to bunchers and storage rings.

In Germany, a six-year research and development programme began in 1979, based at the GSI Laboratory, Darmstadt (the home of the UNILAC heavy ion linac), Garching, Karlsruhe, and the Max Planck Institute of Quantum Optics, together with several universities (including Wisconsin). They have also prepared a conceptual design know as HIBALL with eight bismuth ion sources, linacs and storage rings finishing up with 10 GeV, 2.5 kA pulses being fired at the pellets. There are plans to extend the work beyond the present programme (1985–90) with a storage ring at Darmstadt and with target experiments.

Before leaving the r.f. linac scheme for the driver of a fusion reactor, it is worth mentioning the work at Westinghouse in the US, where the thinking has been carried all the way through to the eventual electrical power generator. Other studies at the Rutherford Appleton Laboratory in the UK have shown that their Spallation Neutron Source, shortly to come into operation, will be useful (operating in storage ring mode) for some important simulation studies on heavy ion beam dynamics.

The second driver scheme under study is based on the use of linear induction accelerators (where the accelerating field gradients are provided by changing the flux in cores around the beam) has been successfully used in electron acceleration but not yet for heavy ions other than in single modules. The scheme has received most attention at Berkeley in the US and the requirements for a full-scale driver have been sketched out. Four 3 MeV ion beams are envisaged at the linac input and the output is some 3 kA of ions at an energy of about 10 GeV. There are plans for a 'High Temperature Experiment' by the end of the decade with 6.5 A sodium ion beams taken down 500 m of induction linac to an energy of 125 MeV. Amongst the main preparatory studies, cores of the new Metglas material are being tested.

There was one new idea from Al Maschke presented at the Symposium under the name 'momentum rich beams'. It suggests trying to achieve the necessary energy transfer to the deuterium-tritium pellets, not by energy deposition, as the ions are brought to a halt in the pellets, but simply by momentum transfer on collision. The need is then for a beam of neutral particles of total mass over one milligram (for example 1 MV, 100 kA caesium beams) transferring some 25 per cent of their energy on collision.

The Symposium showed that the interest in pursuing the concepts of heavy ion drivers for fusion is still very much alive and a number of research programmes will contribute more information in the coming years. Schemes to reach the stage of a High Temperature Experiment, where ion interactions in a hot plasma can be confined, are on the table in Germany, Japan and the US.

Around the Laboratories

CERN
UA1 gets a refit

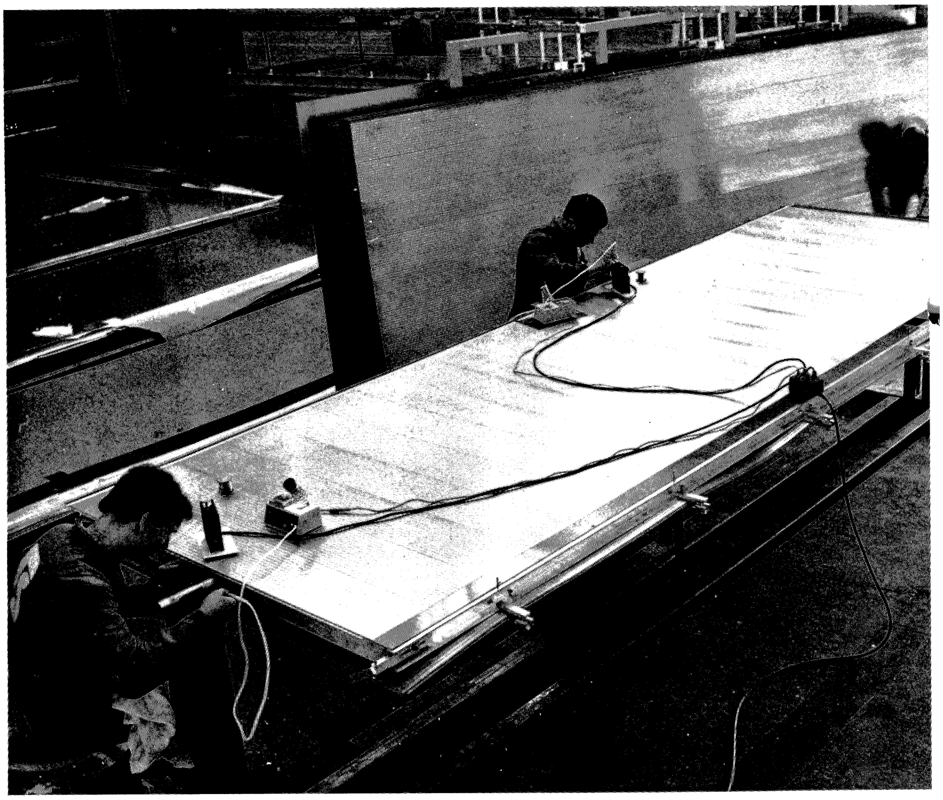
Although still basking in the glory of last year's epic discoveries of the W and Z particles, and with recent indications of still more interesting physics to come (see May issue, page 139), the design concepts behind the big UA1 detector at the SPS proton-antiproton Collider are nevertheless six years old.

Since it recorded its first events back in 1981, the mammoth detector has operated to its design specifications and schedules, and most of the physics goals foreseen in the initial design are now science history.

However techniques at the SPS proton-antiproton Collider have evolved over the years, and with the Antiproton Improvement Programme now approved (see January/February issue, page 23), substantial increases in the proton-antiproton collision rate can be expected over the next few years. The detector itself is looking towards new physics. Thus the UA1 team has embarked on an ambitious improvement programme, the first phase of which is scheduled to be ready for this year's Collider run which begins in September.

Assembly at CERN of the new muon chambers which will be added to the giant UA1 detector at the CERN proton-antiproton collider for the next run, scheduled to begin in September.

(Photo CERN 687.4.84)



These initial improvements include the outer muon shielding and detection system, the inner 'microvertex' detector and new data acquisition electronics and triggering.

The UA1 detector consists of a central cylindrical tracking chamber, surrounded in turn by modules which measure the deposition of electromagnetic energy and hadronic energy, and finally the outer detector to pick up the penetrating muons which traverse the rest of the apparatus.

To improve the efficiency of muon detection in the outer arrays of drift chambers, more iron shielding and instrumentation is being added. This is particularly important in the forward and backward sections of the detector, where the muon counters are hit much more frequently than those around the sides. With the existing muon detection system, there was a risk that these counters would be swamped if (as is hoped) the proton-antiproton collision rate in the forthcoming runs went much above the level achieved in 1983.

The extra shielding being installed in the forward and backward sections of the detector amounts to some 800 tons of iron, on average 1.2 m thick. More iron has been added around the sides. This shielding will be magnetized and interspersed with special streamer ('Iarocci') chambers to track the particles as they traverse the outer slabs of the detector, and to link back with tracks picked up in the central detector.

Another new feature of UA1, 1984 style, will be the microvertex detector embedded inside the central calorimeter, surrounding the beam pipe. This is designed to achieve the fine resolution (some 40 microns) required to pick up the small 'offsets' from the main interaction vertices due to the production and decay of short-lived particles.

The beam pipe inside will be of beryllium to minimize secondary interactions. The microvertex detector is 85 cm long, has inner and outer radii 25 and 80 mm, and is fitted with 256 sense wires. With this in place, the UA1 team hopes to be able to uncover signs of the long awaited sixth ('top') quark, which has failed to show itself conclusively so far.

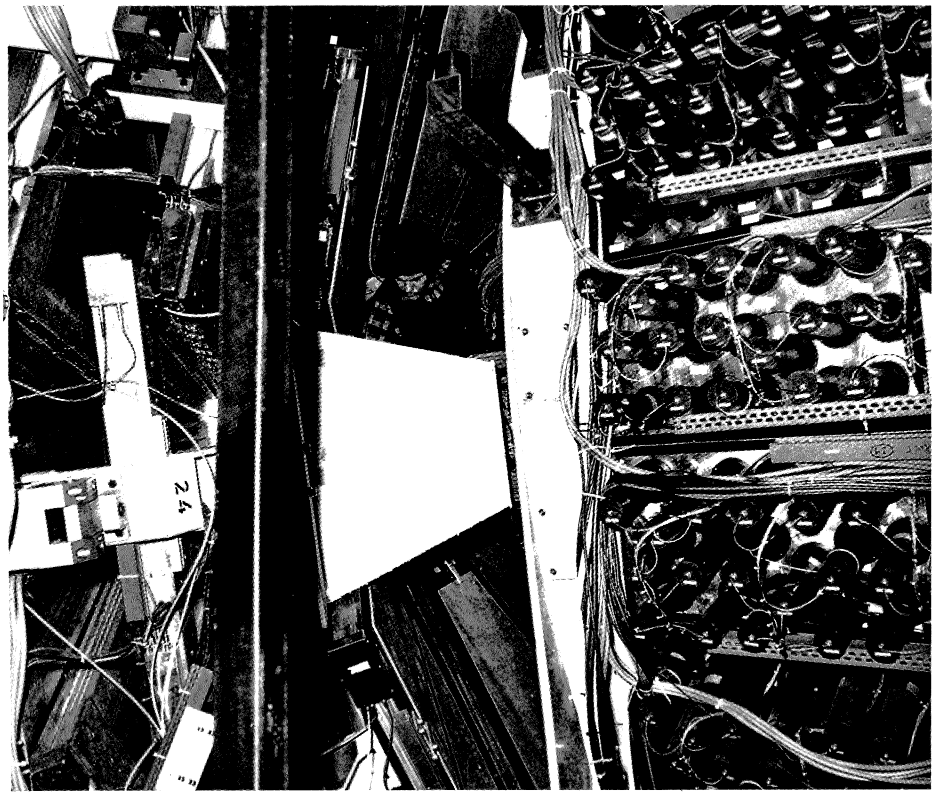
It is in the domain of electronics and data handling that the rapid development of modern technology really shows itself, and UA1 is no exception. One of the outstanding features of the original UA1 design was the brilliant data acquisition and triggering system which coped splendidly with the vast volumes of accumulated data, providing fast on-line selection to enable the W and Z particle samples to be isolated in record time (see April 1983 issue, page 82).

Here again, if the proton-antiproton collision rates improve significantly, then the unmodified electronics would become saturated by signals. To avoid this, the available memory space in the fast digitizing electronics of the central detector has been increased and the already fast analog to digital conversion has been speeded up. In this way the 'deadtime' of the central detector digitization (before the data handling electronics is ready for the next event) is reduced from 35 msec to less than four microsec. This 'double buffering' conversion was a major hardware and software enterprise.

In addition, extra triggers have been provided (these now cover electrons, particle jets and total transverse energy in the calorimeters together with improved selection of muons) at an initial level, while the complement of 168 E emulators for fast on-line event selection has been considerably increased. These processors played a valuable role in the

A model of the RICH (Ring Imaging Cherenkov Counter) installed in one of the endcap sectors of the UA2 detector at the CERN proton-antiproton collider. Later this year, the RICH will be for real.

(Photo CERN 333.2.83)



fast data handling carried out last year in the discoveries of the W and Z particles. The 168 E's algorithms are also being extended to cover jets and missing energy as well as the electron data handled with the initial versions.

The passive CAMAC data collection techniques have been largely replaced by the 'intelligent' VME system under microprocessor control. This will allow for easier incorporation of new triggers, while providing general flexibility and modularity for fast event handling and data formatting. A 'readout supervisor' processor will look after digitization, triggers and input/output, and an 'event manager' processor will take care of event data requests.

Together, these short-term improvements promise to keep the efficiency of the data-handling system in step with the envisaged increases in collision rates. For the longer term, other plans are being prepared, so that after its flying start, UA1 looks assured of a long and distinguished physics career.

UA2 gets RICH

When the run for proton-antiproton collision physics gets underway at the SPS ring in September, one of the new features of the UA2 detector will be a Ring Imaging CHerenkov (RICH) counter in one of the endcap sectors.

In this way, the detector's ability to distinguish electrons of intermediate energy (1-15 GeV) previously achieved using lead/scintillator shower counters alone, should be significantly enhanced in this sector.

The RICH technique is a refinement of the classic Cherenkov counter in which the angle of light emission is determined, giving a precise measurement of particle velocity. The UA2 RICH uses the now commonly-used TMAE as light-sensitive material and a Time Projection Chamber (TPC) to measure the ring of Cherenkov light.

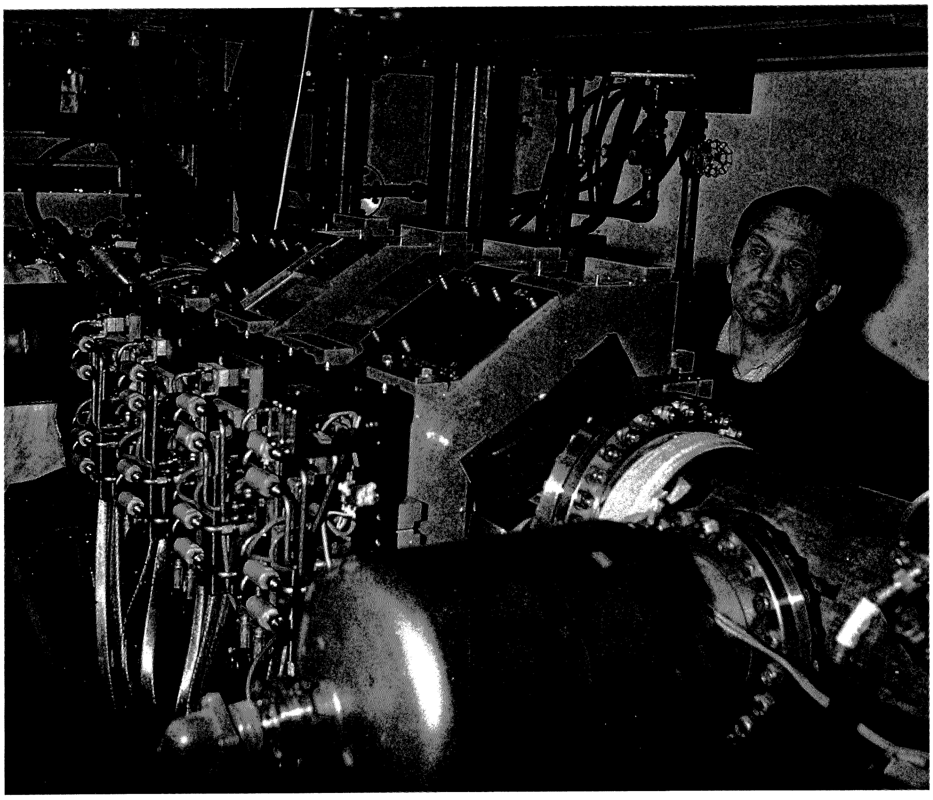
It was built by a CERN / Collège de France / Uppsala team (the 'RICH Group') which is also assisting with a similar, but much larger, high resolution detector for the DELPHI experiment at the LEP electron-positron collider now under construction at CERN.

A wiggler for LEP

In the last few years, so-called 'wiggler' magnets have been extensively used at electron machines to act on the circulating beams and provide more intense sources of synchrotron (electromagnetic) radiation to feed experiments and more recently, to test free electron lasers.

In their simplest form, wigglers consist of a few sections of alternating polarity magnets with relatively high transverse field. While there is no net deflection of the particle beam, the electrons swerve violently to and fro as they pass through, emitting lots of synchrotron radiation as they do so.

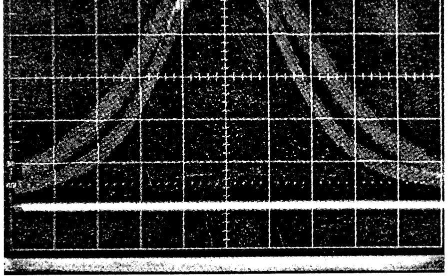
The CERN prototype wiggler magnet installed in the ring of the DCI machine at Orsay for tests with positrons.



However 30 years ago, the idea of the late Ken Robinson was not so much to use this radiation explicitly, but to exploit the resulting damping of the stored electrons to obtain more stable beams in combined function machines. First tests were carried out at the Cambridge (Massachusetts) Electron Accelerator.

Now the wiggler wheel has turned full circle. To enable it to provide compact electron beams for the LEP machine now being built at CERN, the CERN 28 GeV 'proton' synchrotron (PS) is to be equipped with such a magnet, and a prototype was built at CERN last year. The effect on proton beam optics was measured, using an additional (fifth) magnet cycle to simulate the acceleration of electrons and positrons.

At the beginning of this year, the magnet was moved to the DCI electron-positron ring at Orsay in France to measure its ability to damp real beams of electrons. At the end of February, the predicted damping effects were observed by a PS team, working in close collaboration with DCI personnel.



The horizontal profile of a positron beam in the DCI machine at Orsay before and after excitation of the new CERN wiggler magnet, showing the damping achieved. Now that the magnet has shown its paces, three will be installed in the CERN 28 GeV 'proton' synchrotron for damping the electron and positron beams required for the new LEP electron-positron collider.

After the success of these tests, three magnets of this type will be installed over the next two years so that electron and positron beams (provided by the LEP Injector Linacs and the EPA Electron-Positron Accumulator) emerging from the PS will be compact enough for injection into the SPS on the next lap of their journey towards the 27 km LEP main ring.

ELECTRONICS
Fastbus gathers momentum

Fastbus, the new physics data acquisition electronics system, has definitely moved out of the prototype stage into the domain of implementation and application. After initial pilot projects, several major Fastbus applications are either already in action or being assembled. In particular, all the four experiments being prepared for the LEP electron-positron collider now under construction at CERN will have large portions, if not all, of their data acquisition systems based on Fastbus.

The definition of the Fastbus specification was a real international effort, involving task groups both in Europe (ESONE Advanced Systems Study Group) and in the US (NIM Fast Systems Development Group).

To facilitate its entry, starter kits have been provided, comprising power supply and cooling, ancillary logic, CAMAC to Fastbus interface, etc., and some thirty such kits have been issued in Europe. Now commercial manufacturers are offering additional off-the-shelf systems. However there is still a lot of ground to be covered before the system gains acceptance as universal as its CAMAC predecessor.

At the Swiss Institute for Nuclear Research (SIN), a Fastbus system for the SINDRUM experiment (see May issue, page 106), has been taking data since last August. At CERN, the Fastbus pilot project for the European Muon Collaboration experiment (see January/February 1983 issue, page 9) continues to give excellent performance. The CERN / Dortmund / Edinburgh / Orsay / Pisa / Siegen experiment in the North Experimental Area of the 450 GeV proton synchrotron will shortly use new instrumentation, including Fastbus, to make new measurements of the (CP-violating) decays of neutral kaons. The initial (real time) trigger rate is some 5×10^4 per s, which should be reduced to some 300 per s by the Fastbus-based multilevel data acquisition and handling system.

A microprocessor-based general-purpose CAMAC to Fastbus interface has now been developed, and other designs are nearing completion. Crates, power supplies and cooling have been integrated. Stimulated by the demand from the starter kits, considerable effort at CERN has gone into Fastbus software.

However in Europe most Fastbus attention centres on the four gigantic experiments for the LEP machine, each of which has between 100 000 and 200 000 data channels. The ALEPH, DELPHI and L3 experiments have their data acquisition systems committed to Fastbus, while OPAL will use Fastbus for its central detector readout system.

At Fermilab too, a big effort is underway, and prototypes or small production quantities of several modules have been completed. A US / CERN / TRIUMF (Canada) / KEK (Japan) collaboration is working on interface circuitry.

The University of Illinois is particularly involved. Fermilab experiments E400 and E401 (particle search and study of photoproduction in the Proton East Lab) have high speed data acquisition systems using Fastbus elements.

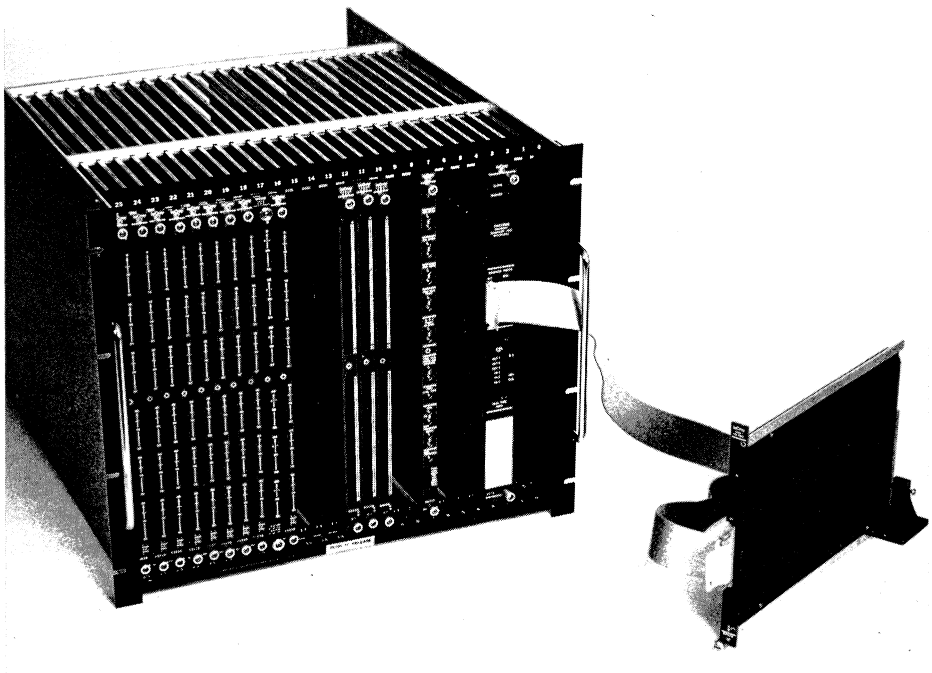
Elsewhere at Fermilab, the CDF detector for the Tevatron proton-antiproton collider has a considerable investment in Fastbus electronics (see January/February issue, page 13). Other experiments supplement home-grown equipment with off-the-shelf Fastbus modules from commercial suppliers.

At Brookhaven, an early prototype Fastbus system has been in operation for several years (see October 1980 issue, page 301), while at the MPS multiparticle spectrometer, a newer Fastbus design has been in operation since 1982, and a replacement is being built.

At Stanford, more hardware is being developed. The first Fastbus application at the Laboratory is the control system for the liquid argon of the Mark II detector, scheduled for installation at the new SLC linear collider. The upgrading of the detector will also include a Fastbus-based data acquisition system.

Other Fastbus applications are afoot at Los Alamos, Berkeley, TRIUMF (Canada), and KEK (Japan). At the giant TRISTAN electron-positron collider now being built at KEK, Fastbus will feature in the accelerator control system and the experiments' data acquisition systems.

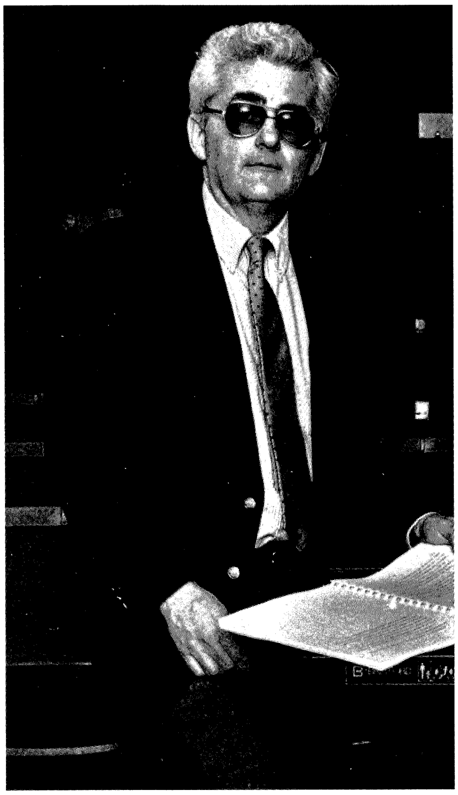
Just as CAMAC, the previous standard physics data acquisition system, went on to be a great success, so hopes are high that Fastbus too will gain widespread recognition and promote interchange of experimental skills and techniques.



A Fastbus crate (left) under the control of a CAMAC module. Fastbus, the new data acquisition electronics system standard for high energy physics experiments, is quickly becoming a way of life.

(Photo Lecroy Research Systems)

Gerry Smith of Penn State was one of the summary speakers at the recent Brookhaven High Energy Discussion Group Meeting. He stressed the rich diversity of the particle physics programme and the importance of pushing for rapid upgrades.



BROOKHAVEN 'Smoking gun'

Already assured of an illustrious history, the twenty-four year-old Alternating Gradient Synchrotron (AGS) at Brookhaven could also have a bright future. With traditional synchrotrons at many Laboratories being pressed into service as injectors for newer, bigger machines, the AGS, now that the plans for Brookhaven's Colliding Beam Accelerator have been shelved, has the opportunity to make additional significant contributions to physics.

However to accomplish this, it is clear that AGS hardware improvements are required, and an 'AGS II Task Force' was recently set up, charged with making recommendations (at high speed) on what needs to be done. These were extensively discussed at a user meeting at Brookhaven at the end of March.

The physics areas identified as being ripe for exploration with a revamped AGS include rare kaon decays, neutrino interactions, muon physics, exotic atoms, dibaryons and hypernuclei. Intense hadron beams and polarized proton beams would be useful in detailed studies of quark-gluon dynamics.

To carry out this programme, the intensity and intrinsic reliability of the AGS would have to be improved. A full energy stretcher ring could smooth out the supply of extracted particles. Further intensity increases (up to 10^{14} protons per s) could be attained with a 2.5 GeV, 10 Hz booster machine. In parallel, many of the existing AGS systems (r.f., vacuum, control,...) would be upgraded. New beamlines would be required and there would be a parallel effort with new detectors.

While the recommendations are seen as 'ambitious', the Task Force recommended that the goals should be attacked 'aggressively', to ensure that the ongoing physics programme at the AGS is in keeping with its splendid tradition.

These recommendations and other Brookhaven activities were reviewed when the Laboratory's particle physics community (High Energy Discussion Group) had its annual meeting at the end of March. Particularly important for the future are beams of heavy ions and polarized protons in the AGS. At the meeting, the polarized proton progress and plans were reviewed by Alan Krisch (see April issue, page 100), while Arthur Schwarzschild covered the project to transfer heavy ions from the tandem to the AGS (see January/February issue, page 17). Meanwhile a Brookhaven heavy ion user group is being formed (contactman is Ole Hansen at Brookhaven).

On the heavy ion front, great progress has been made. New funding has been made available for the construction of the transfer line, and ions up to sulphur with energies of 15 GeV/nucleon are expected by the summer of 1986. Five weeks of heavy ion operation are foreseen for that year, increasing to about ten weeks in subsequent years.

The meeting then turned to the AGS II Task Force recommendations. Paul Reardon underscored the commitment of the Laboratory over the next three years to improving the AGS reliability and duty factor, increasing intensity by adding a 1 GeV (rather than 2.5 GeV) 'El Cheapo' booster, and providing multiple beam operation. Further intensity improvements would come later, plus the stretcher ring.

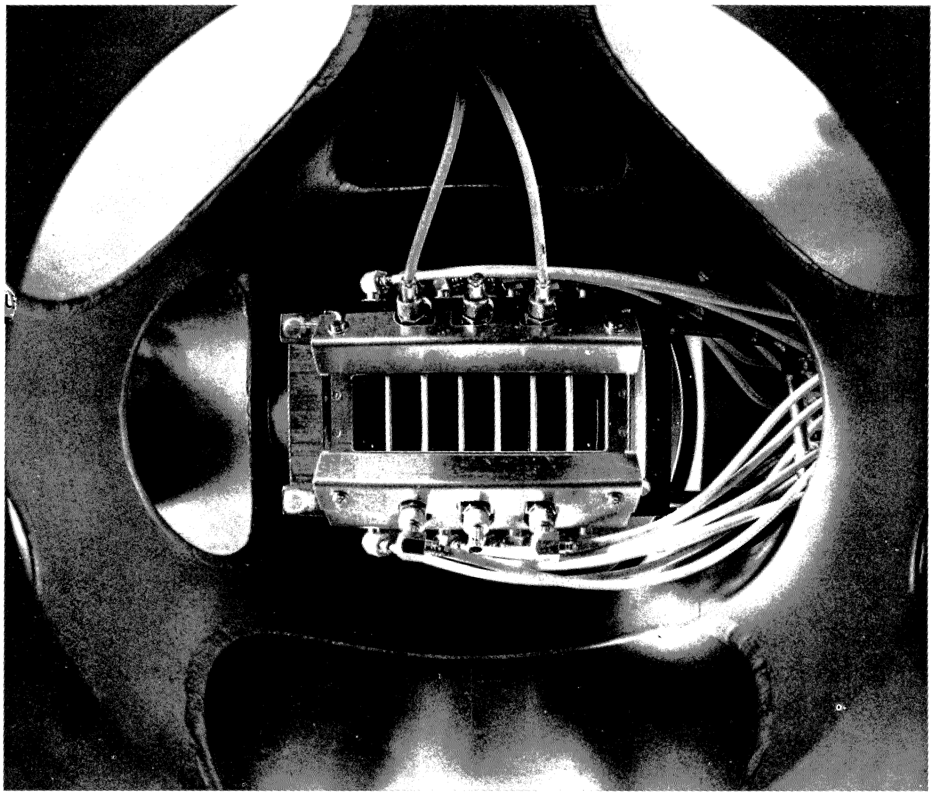
The new booster would serve both the proton and heavy ion programmes and even in an initial upgrade could increase proton intensity fourfold while allowing the acceleration of heavier ions (as far as uranium). With some initial funding next year, the first phase of the booster project could be complete by late 1987.

Laboratory Director Nick Samios covered the global Brookhaven programme, which includes the US National Synchrotron Light Source now coming into operation, a major effort on research and development work for the proposed US Superconducting Super Collider (SSC), the ongoing AGS programme and the Relativistic Heavy Ion Collider (RHIC), which will be proposed this simmer. RHIC would be built in the tunnel cut for the cancelled Isabelle / CBA Collider to provide all kinds of ions at 100 GeV/nucleon and a luminosity of 10^{27} per cm^2 per s. This would require a booster similar to that considered by the AGS Task Force.

Many presentations covered the

This 10 cm detector at GSI (Gesellschaft für Schwerionenforschung) Darmstadt has now identified elements 107, 108 and 109, as well as discovering single proton radioactivity.

(Photo GSI)



physics possibilities at the AGS. Pointing out the machine's potential for new discoveries, John Donoghue observed 'it would be fun to find the smoking gun for 1 TeV physics ten years before the dead bodies are found at the SSC'.

DARMSTADT Element 108

The GSI (Gesellschaft für Schwerionenforschung) Laboratory in Darmstadt has made something of a speciality out of the discovery of new heavy elements. After element 107 in February 1981 and element 109 in August 1982, a group of 14 physicists headed by Gottfried Münzenberg has now seen element 108 (see January/February issue, page 21).

A week before the run for element 108, isotopes of element 106 were investigated, among them the alpha decay products of element 108. Then in a twelve-day run at the end of March, element 108 was formed by fusion of iron 58 projectiles with lead 208. The iron beam was accelerated to 5 MeV per nucleon in the UNILAC machine, sufficient to overcome the Coulomb barrier. With a beam intensity equivalent to 200 nA, three nuclei of element $^{265}108$ were identified. (The compound nucleus $^{266}108$ evaporated one neutron.)

To distribute the heating due to the beam over a larger surface, the lead target was continuously rotated on a wheel, and despite this and additional cooling by carbon layers on both sides of the target, the isotopically pure target had to be changed every two days.

The fusion products carry only about a fifth of the beam velocity and are deflected by a velocity filter into silicon surface barrier detectors. Subsequent analysis pins down the alpha disintegration chain of the new element. Its half-life is approximately two millseconds and the alpha decay energy (for $^{265}108$) is 10.4 MeV. The half-life against spontaneous fission appears to be about an order of magnitude larger than theoretical predictions, hinting at possible new structure effects in nuclei beyond the conventional periodic table.

CONFERENCE Physics in the Alps

One of the annual features of the European particle physics scene is the traditional 'Rencontre de Moriond' organized by G. Tran Thanh Van at Orsay, which for almost twenty years has been attracting a balanced blend of experimentalists and theoreticians to mountain resorts in Haute Savoie (French Alps) in late February/early March.

This year the conference took place at La Plagne-Bellecôte, with the first week given over to electroweak interactions and unified theories. A conference on astrophysics (a more recent arrival to the Moriond series) was held in parallel, covering the composition, spectrum and origin of cosmic rays.

Summarizing the physics results, Gerson Goldhaber was able to cover the physics of the W and Z particles which carry the weak nuclear force, the observation of the F (carrying strangeness and charm) meson at 1970 GeV (see May issue, page 157), and the narrow ksi particle seen at 2200 MeV (see April issue, page 99). These, together with recent estimates of the lifetimes of particles carrying 'beauty' (relatively long — see October 1983 issue, page 312) and the new limits of proton stability given by the big Irvine / Michigan / Brookhaven underground experiment, were considered to be the main results of the year.

Despite much effort, searches for new effects such as 'top' and supersymmetric particles, right-handed weak currents and anomalous muon decays only succeed in pushing back the limits.

A few spectacular events evoked much interest — an unlike sign muon pair plus jets seen at the PETRA electron-positron ring at the German DESY Laboratory, and like sign muon pairs accompanied by strange particles in the UA1 detector at the CERN proton-antiproton Collider. No unambiguous explanation is available, and more statistics are needed before these effects can be explained.

In the area of known phenomena, new data with increased precision is proving very useful. The decays of beauty and charm particles now constrain the parameters of the six-quark model (Kobayashi-Maskawa matrix). New determinations of the electroweak mixing angle come from experiments at the PETRA (DESY, Germany) and PEP (Stanford) electron-positron colliders, and from studies with neutrino, electron, and muon beams. In addition, the measurement of the masses of the W and Z particles by the UA1 and UA2 experiments at the CERN Collider uphold the validity of the electroweak picture.

One place where there was a possible hint of a new effect was in the workshop on neutrino masses and neutrino mixing, with a suggestion from the Annecy / Grenoble team working at the Bugey reactor of neutrino oscillations. The candidate signal is in an area not excluded by previous studies (see March issue, pages 62-3).

One day in the first Moriond week was shared by particle and astrophysicists. The exchange of information and ideas between the two communities was fascinating at a time when the disciplines are focusing on common problems, and suggest a new vision of the physical world.

The second week at Moriond was devoted to the study of new particles, particularly at the SPS Collider and at big electron-positron rings, with special emphasis on the search for massive new states and 'glueballs' (particles containing gluons but no quarks) and heavy flavour spectroscopy. The summary talk at the end of the second week was given by K. Berkelman.

Besides the particle physicists and astrophysicists there were also the biologists, who also have a long-standing tradition of Moriond meetings. Two remarkable moments of this year's meeting were the joint lectures for biologists and physicists — Patricia Simpson on 'How do animals get their form? From a linear genetic code to a three dimensional animal', and Frank Close on 'Cosmic Onions'.

In the characteristic Moriond style, experimentalists and theorists presented and discussed their results and ideas together, providing a fertile ground for debate and for new points of view. These lively discussions are often the place where novel ideas and approaches are born. This year, once again the Moriond participants left the meeting full of fresh ideas and sharing the speakers' enthusiasm for such interesting results.

(From P. Musset and L. Montanet)

Physics monitor

Flowing nuclear matter*

Besides the nuclei (composed of protons and neutrons) of everyday atoms, a different type of nuclear matter is believed to exist in the dense cores of neutron stars and other cosmic exotica.

Such compressed matter would have properties very different to those of ordinary nuclei, and calculations based on hydrodynamical models predict that any blobs of dense matter formed in high energy collisions should take on definite shapes. Instead of scattering off in many different directions, the particles of the colliding nuclei would stick together, and in the subsequent reexpansion, a blob of matter would be deflected sideways.

So far, the only way open for physicists to create such nuclear matter is in the high energy collisions of heavy nuclei (ions). Now in a collaboration between the GSI Darmstadt and Lawrence Berkeley Laboratories, new behaviour has been seen which could be due to compressed nuclear matter.

At the Berkeley Bevalac, calcium and niobium beams were accelerated to 400 MeV/nucleon and the products of these beams hitting calcium or niobium targets analysed in the Plastic Ball / Plastic Wall detector.

This instrument is designed to cover a maximum solid angle. The Plastic Ball is an intriguing spherical array of pyramidal scintillator modules, while the Plastic Wall is placed 6 m downstream to detect particles which emerge a few degrees from the beam. (There are plans for the detector — with a streamer chamber — to come to CERN for use with new heavy ion beams from the 28 GeV

** Similar behaviour has also been seen in a GSI Darmstadt/ Berkeley experiment using a streamer chamber to study pion production. More next month.*

'proton' synchrotron — see July/August 1983 issue, page 223).

In each case, 50 000 events were analysed, and the energy flow calculated for each. Fluctuations due to finite particle effects are a big obstacle in extracting information from such a flow analysis, so the analysis took account of the number of charged particles produced (multiplicity).

With niobium, higher multiplicities show a definite deflection of the energy flow (termed 'side-splash') which moreover increases with multiplicity. No sign of this is seen with the lighter calcium. The extensive modifications to the Bevalac which enabled it to work with heavier ions such as niobium thus seem to have paid dividends.

The definite flow angles detected in the collisions provide a natural reaction plane for each event. In a further analysis, the projections of transverse momentum on this plane are calculated and their angular distributions compared for both calcium and niobium reactions.

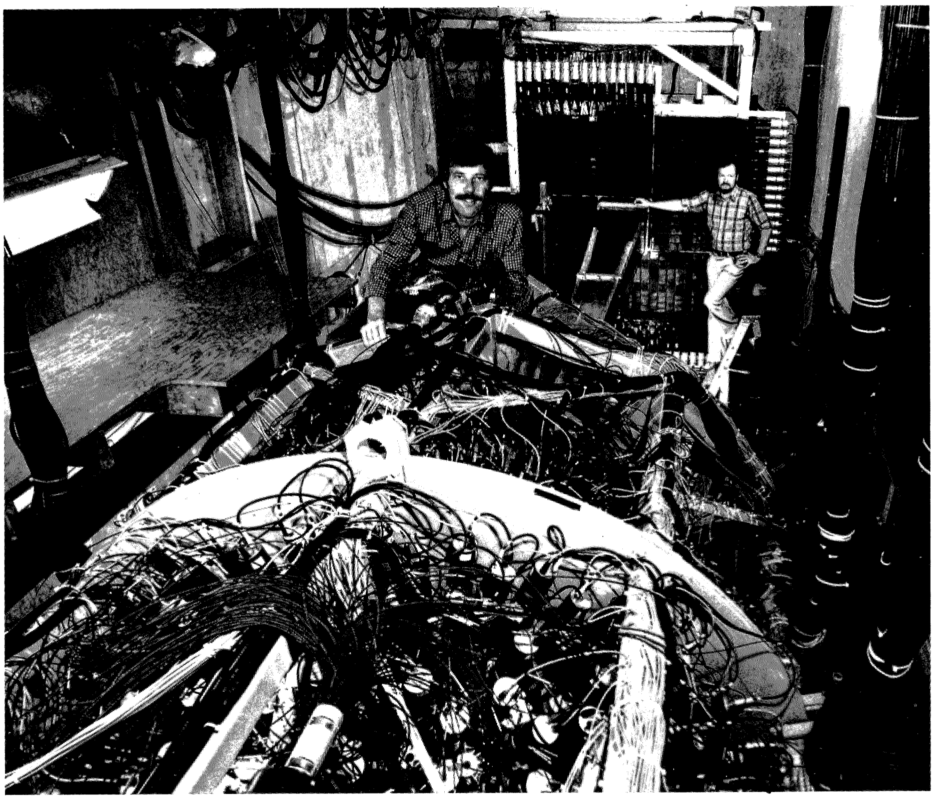
In a conventional scattering model, such an analysis is symmetric about the beam axis, but in the GSI/Berkeley experiment there is a definite asymmetry, with the remnants of the projectiles preferring to come off at an angle ('bounce-off'). This appears to be due to a slowing down of the projectile fragments together with a sideways deflection. Both bounce-off and side-splash occur in the same plane.

Although the new findings are encouraging, not all the predicted behaviour is seen. Comparison with simulations indicates that only about 10 per cent of the total kinetic energy of the collision is contained in the collective nuclear motion, which makes its detection and analysis difficult.

More data has been taken for niobium-niobium and gold-gold collisions at other energies, and results are eagerly awaited.

The 'Plastic Ball' detector used at the Berkeley Bevalac to study the products of heavy ion collisions. In the background is the 'Plastic Wall', which picks up the most forward particles.

(Photo LBL)



Putting cosmic rays to work

How much does the Bolshoi Theatre in Moscow weigh? That question is not as futile as it might sound. When an underground railway line, for instance, is to be built under a large building it is vital to know the pressure that the building exerts on the ground. But how can this be done without knowing the weight of all the building's components and its contents? That's where cosmic ray muons come in. Scientists at the Moscow Institute of Geological Research are putting these extraterrestrial particles to work for very down-to-earth purposes.

Up to the moment they strike the earth's atmosphere, cosmic ray particles have an energy of thousands of millions of electron-volts. Apart from that, the flux is also remarkably stable: its radiation intensity varies by less than a per cent. When the primary radiation passes through the earth's atmosphere it creates a secondary shower of various particles, including muons capable of penetrating several kilometres into the earth's crust. These particles can be used as natural cosmic 'X-rays' for examining rocks and for civil engineering applications.

These measurements are carried out using a muon telescope — several parallel rows of counters recording particles moving in a definite direction. The density of the subject (target) can be very accurately determined from the radiation intensity registered by these counters installed in tunnels underneath the target.

Muon telescopes have already done excellent work during the construction of RATAN-600, the largest radio telescope of the USSR Academy of Sciences. The land under the radio telescope is composed of irregular deposits of rocks, sand, clay and gravel, and the water table was very close to the surface. Thus it was impossible to use conventional methods for assessing the density and condition of the soil under the foundations. It was decided to bore about twenty pits, in each of which a compact muon telescope was lowered to a depth of 10 metres. The invisible particles accurately 'drew' a geological cross-section of the ground.

The same method was used to solve a similar problem when a new underground railway line was being built beneath the Moskva hotel in the Soviet capital. A telescope was installed in a tunnel under the building to record the muon flux passing through. From this data it was possible to determine the density of the building and hence its mass and the pressure it exerted on the ground — a mass of nearly 45 000 tonnes and a pressure of 1.1 kg per square centimetre.

Muons also help to detect cavities in mountain ranges formed when soluble rock such as limestone is worn away by underground water. The recording principle is the same: if there are cavities in the muon telescope's field of vision the particle flux increases immediately. These telescopes are used to monitor systematically the formation of cavities in seams of rock to make sure that it is safe to carry out underground work. Telescopes of this type detected a landslide in a rock seam in the North Caucasus in time to prevent an accident.

The muon telescope can also be used to prospect for minerals. When a mineral (which is generally more dense than the surrounding rock) is 'in the way' of the particles, the counters immediately show a weakening of the flux. The contours of the seam and its volume can therefore be calculated.

Another idea which came up was to use muons to estimate how much water there was in a blanket of snow. Such information is essential to predict avalanches in mountain regions or to estimate water reserves in river basins. Measurements carried out by scientists from the Kharam-Koul Institute of Applied Geophysics in Tadjikistan have shown that a high degree of precision and reliability can be obtained, despite the relatively low density of snow.

Elsewhere, archaeologists are using cosmic rays to try and trace the secret passageways in the Chephren pyramid. Geologists are also pinning great hopes on neutrons for underground exploration. It is known, for instance, that some chemical elements, in particular tungsten, actively absorb slow neutrons. Thus even small deposits of these elements can be detected in rock by a weakening of the particle flux.

Other ideas have been put forward to use neutrino detection to 'X-ray' large areas of the earth's crust.

(Novosti)

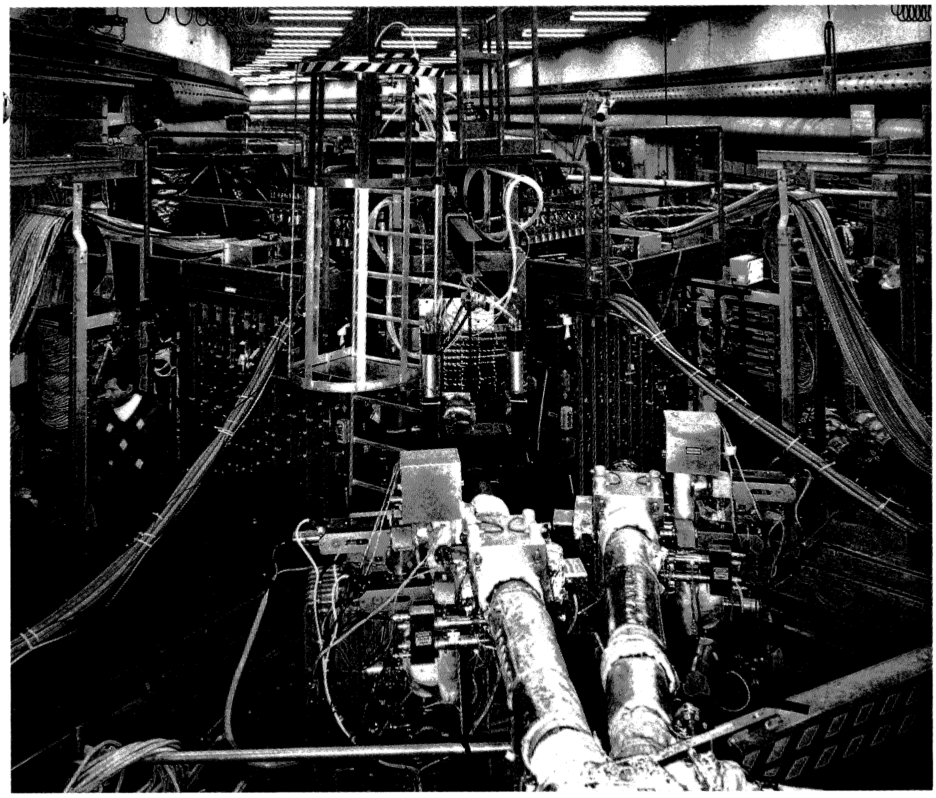
People and things

Piotr Leonidovich Kapitza

With his scientific contributions spanning more than fifty years, physics lost one of its monumental figures when Piotr Kapitza died on 8 April. He was born in Kronstadt, Russia, in 1894, and after initial training as an engineer became a lecturer at the Petrograd (Leningrad) Polytechnical Institute in 1919. However his research career began in earnest when he came to the Cavendish Laboratory, Cambridge, UK, in 1921 to work with Rutherford. The story goes that Rutherford initially told Kapitza he could not take on another research student. However after pointing out that one extra student would change the research staff complement by less than the ten per cent accuracy inherent in Rutherford's own measurements, he was accepted. His early work at Cambridge was on classical nuclear physics, however he soon displayed his strong flair for technical applications, in particular the generation of strong magnetic fields. During his later years at Cambridge, Kapitza also turned to the work in low temperature physics that was to continue for much of his life. In 1933 he was appointed Director of the newly created Mond Laboratory at Cambridge, but the following year he returned to the USSR to become Director of the Institute of Physical Problems of the USSR Academy of Sciences in Moscow. There his work in physics continued to expand, leading to important contributions to cryogenics and to high power electronics. From time to time he turned his attention to interesting topics in basic general physics. In 1978, he shared the Nobel Physics Prize with Arno Penzias and Robert Wil-

On 17 April, the Joint European Torus (JET) nuclear fusion joint undertaking was formally opened at Culham, UK, by Britain's Queen Elizabeth II and France's President François Mitterrand. The two guests of honour are seen here being escorted by JET Council President Jean Teillac, formerly President of CERN Council. Two rows behind the Queen looms the large figure of Hans-Otto Wüster, JET Director and a former member of the CERN Directorate.

(Photo JET Joint Undertaking)



son. In addition, this giant of modern physics was showered with awards from both his native country (the Order of Lenin no less than six times) and abroad, with recognition from the UK, USA, France, Sweden, Belgium, the Netherlands, Yugoslavia, Finland, Czechoslovakia, India, Germany, Denmark...

On people

Louis Michel of the Institut des Hautes Etudes Scientifiques at Bures-sur-Yvette receives the Wigner medal for 1984. This award is made every two years for distinguished contributions to physics using group theory.

Michel is well known for his work in beta decay (the 'Michel parameter') and for the introduction of G-parity. In addition, he has shown great inventiveness in applying abstract mathematical techniques, including group theory, over a wide range of physics.

Previous recipients of the award have been E.P. Wigner and V. Bargmann (1978), I.M. Gel'fand (1980) and Y. Ne'eman (1982).

Louis Rosen, leader of the Medium Energy Physics Division at Los Alamos National Laboratory, has been named vice-chairman of the Nuclear Physics Division of the American Physical Society. Rosen will succeed to the chairmanship in 1985.

Final activity at the CERN Intersecting Storage Rings (ISR). After the end of colliding beam physics last year, the only task left for the ISR was to provide a beam of antiprotons for this Annecy / CERN / Genoa / Lyon / Oslo / Rome / Turin experiment studying charmonium spectroscopy. In the foreground are the two arms of the ISR beampipes, with the one on the right sealed off.

(Photo CERN 116.3.84)

Secretary of State at the Federal German Ministry for Research and Technology Albrecht Probst (centre) being welcomed to CERN by Director General Herwig Schopper (right).

(Photo CERN 329.3.84)

The Second International Workshop on Atomic Physics for Ion Fusion will be held at the Rutherford Appleton Laboratory, UK, from 10-14 September. Further information from J. H. Aram, Building R63, Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire OX11 0QX, UK.

Eta-c at Mark III

In our report of physics from the Mark III detector at Stanford's SPEAR electron-positron ring (April issue, page 99), a few unfortunate errors crept in. The detector has been looking at the radiative decays of J/psi particles, mesons composed of a charmed quark and antiquark. One possible outcome is the eta-c, where the charmed quarks' spins are aligned antiparallel (spin zero), rather than parallel (spin one) as in the J/psi. After laboriously explaining this, the article went on to say that the eta-c's spin was one, 'as expected'. Clearly this was wrong, as we hope alert readers would have spotted. The eta-c really has spin zero and negative parity, as expected! (See March 1981 issue, page 68.)

The Stanford Linear Accelerator Center has become the 67th US National Mechanical Engineering Landmark of the American Society of Mechanical Engineers.

TRIUMF
MESON RESEARCH FACILITY
University of Alberta
Simon Fraser University
University of Victoria
University of British Columbia
Competition No. 446-044

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The Accelerator Research Division at TRIUMF has openings for physicists or engineering physicists with significant experience in the following areas:

– Cyclotron beam dynamics – in support of improved cyclotron performance, particularly towards higher beam intensities, short pulses, separated turn operation and extraction of H^- ions.

– Secondary channel optics – to design and assist in the commissioning and improvement of channels for pions, muons, kaons, neutrinos, etc.

– Synchrotron Design – for beam dynamics, lattice design and hardware design studies of machines dealing with very high intensity beams.

Candidates should have a Ph.D. or equivalent in physics or engineering and at least three years relevant experience in an accelerator laboratory. A good theoretical background is required, together with appropriate experimental abilities. Salary will depend on qualifications and experience.

Please reply in writing by June 30, 1984, outlining qualifications and experience to:

TRIUMF Personnel (Competition No. 446)
Attention: Dr. M. Craddock,
Head, Accelerator Research Division
4004 Wesbrook Mall
Vancouver, B.C. V6T 2A3

We offer equal employment opportunities to qualified male and female applicants.

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JAMES R. MACDONALD LABORATORY, KANSAS STATE UNIVERSITY

The James R. Macdonald Laboratory at Kansas State University is seeking an engineer or physicist to be in charge of engineering and installation of a superconducting linear accelerator on the laboratory's Tandem. This person will be working directly with the project director on all aspects of the LINAC design, construction and installation. Applicants should have at least three years experience with accelerator design and operation and have demonstrated ability to work effectively with support personnel and other physicists. Cryogenics experience preferred but not required. Salary will depend on qualifications.

To apply, send résumé and three letters of reference to:

Professor Patrick Richard, Director
James R. Macdonald Laboratory
Department of Physics
Kansas State University
Manhattan, KS 66506 USA

The closing date for applications is October 14, 1984, or until position is filled.

Kansas State University is an Equal Opportunity/Affirmative Action Employer.

POSTDOCTORAL OPPORTUNITIES AVAILABLE IN NUCLEAR PHYSICS

The LAWRENCE BERKELEY LABORATORY'S Nuclear Science Division has postdoctoral opportunities in experiment and theory appropriate to the basic research programs involving heavy-ion studies at low, relativistic, and ultra-relativistic energies. These programs are presently carried out at the Laboratory's 88-Inch Cyclotron and Bevalac/SuperHILAC facilities as well as at the CERN SPS. Those candidates with 0-3 years from Ph.D. in Nuclear or High Energy Physics who wish to be considered should provide two copies of a curriculum vitae and publication list, and arrange for three letters of recommendation to be sent to:

LAWRENCE BERKELEY LABORATORY

Lawrence Berkeley Laboratory,
One Cyclotron Road,
Employment Office 90-1042,
Berkeley,
CA 94720.

Please specify Job No A/2830.

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TRIUMF
MESON RESEARCH FACILITY
University of Alberta
Simon Fraser University
University of Victoria
University of British Columbia
Competition No. 449-044

RESEARCH ASSOCIATES-EXPERIMENTAL PARTICLE PHYSICS

The particle physics group at TRIUMF is seeking two postdoctoral research associates to contribute their ideas and talents to an active experimental program. The group's major new project is a measurement of the decay $K \rightarrow \pi\nu\bar{\nu}$ recently approved for running at BNL. Experiments performed at TRIUMF include the ongoing search for muon-electron conversion using the TRIUMF Time Projection Chamber, a new high precision study of the decay $\pi \rightarrow e\nu$ and measurements of other rare processes.

Salary will be commensurate with experience.

Interested candidates should reply to:

TRIUMF Personnel (Competition No. 449)
4004 Wesbrook Mall
Vancouver, B.C. V6T 2A3
or contact D. BRYMAN (604) 228-47 11

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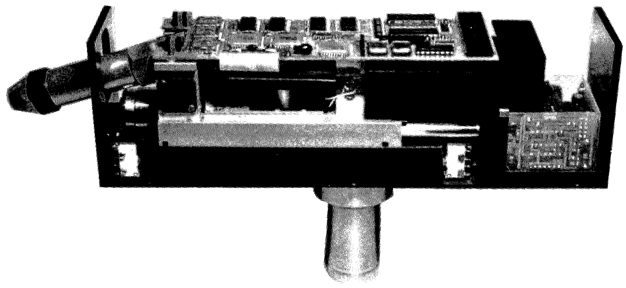

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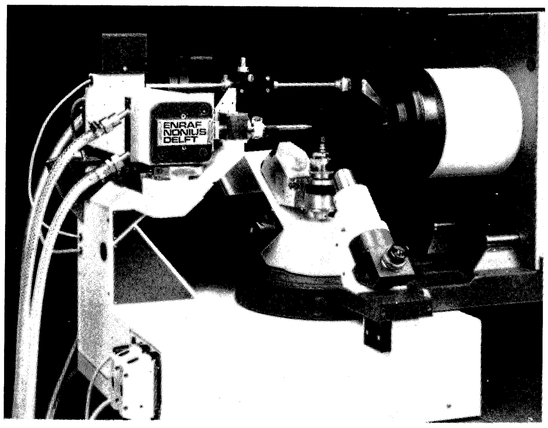

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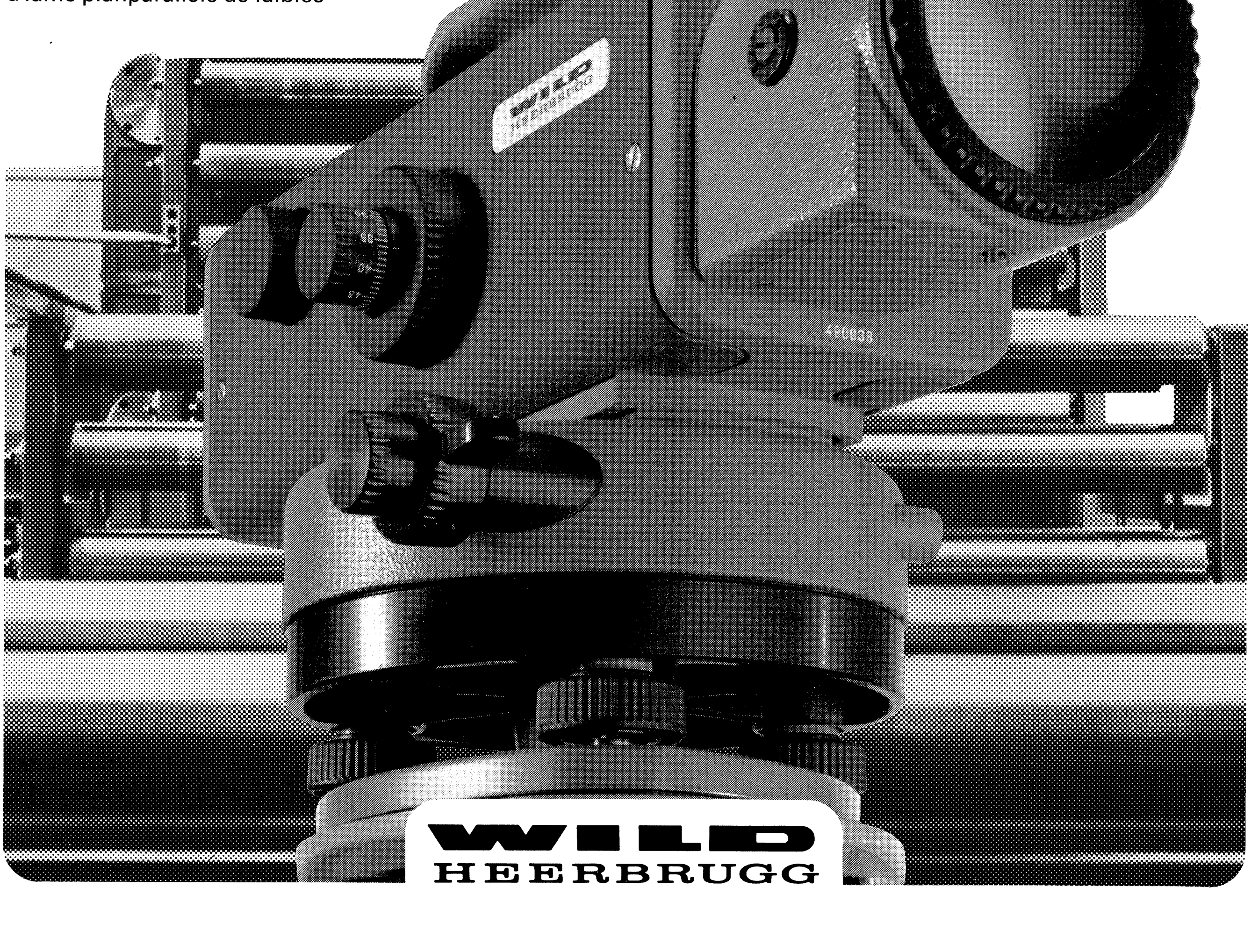

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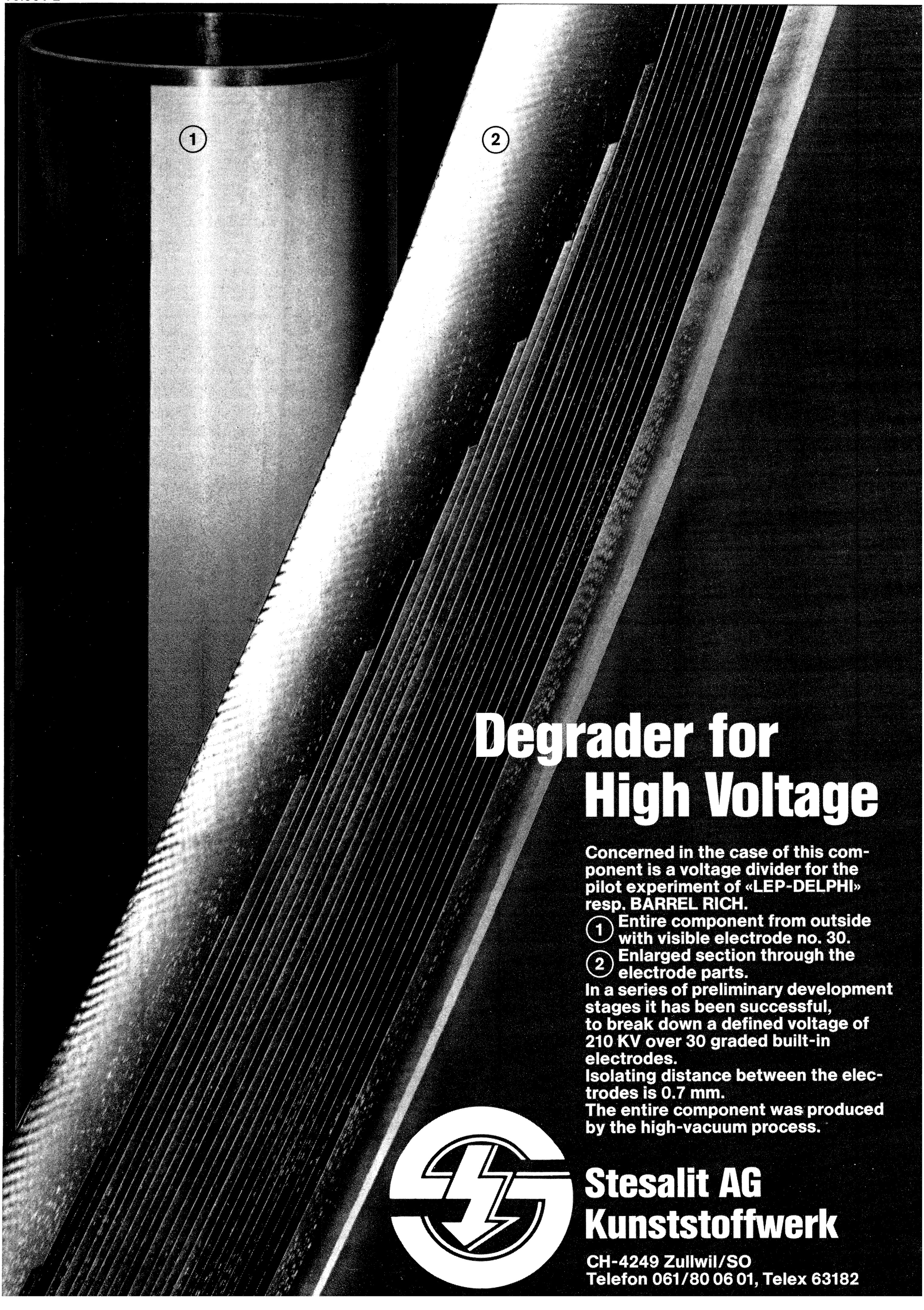
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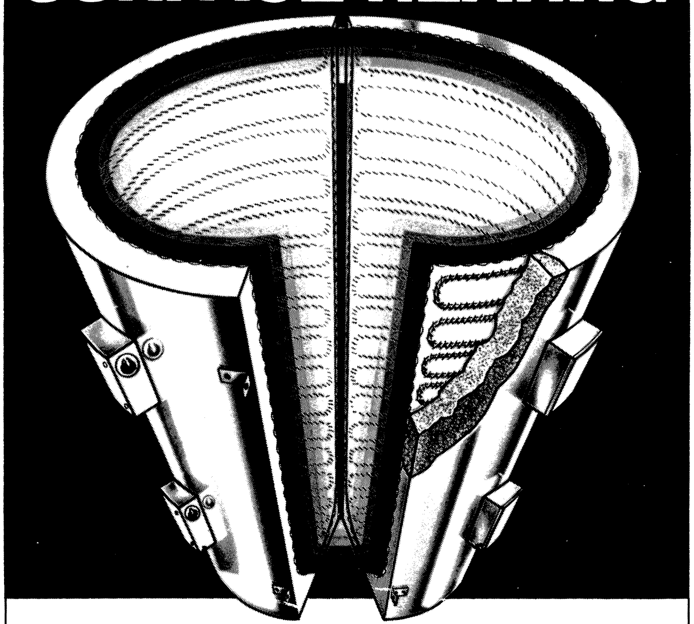

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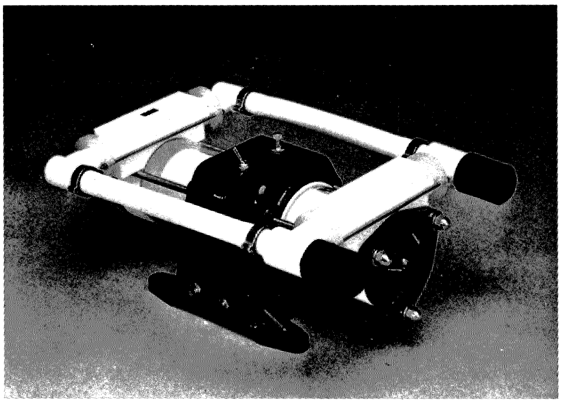

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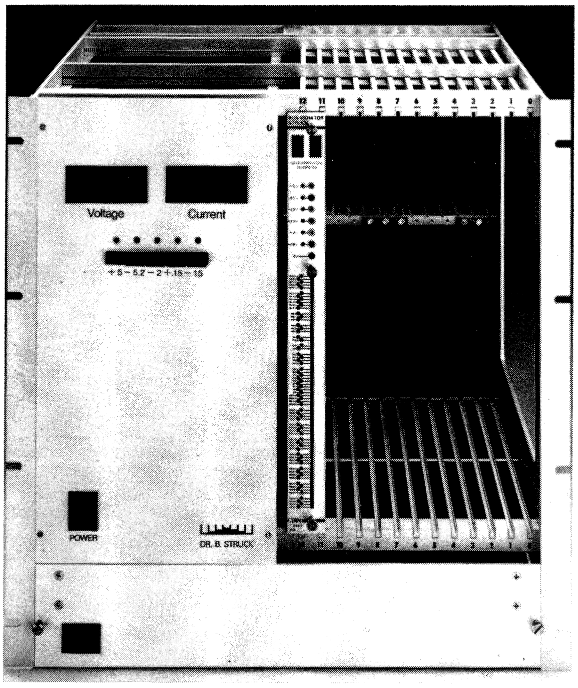

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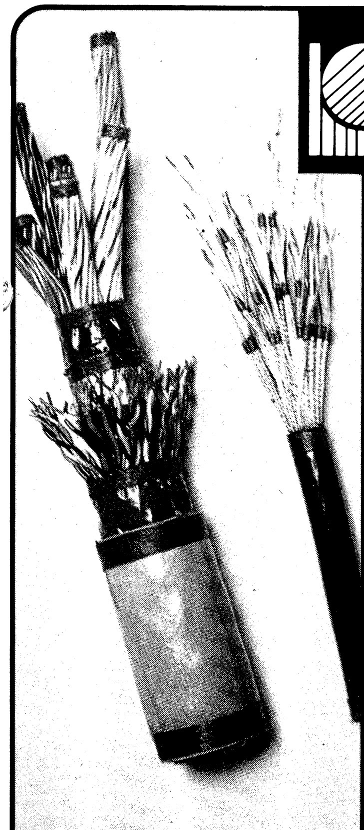

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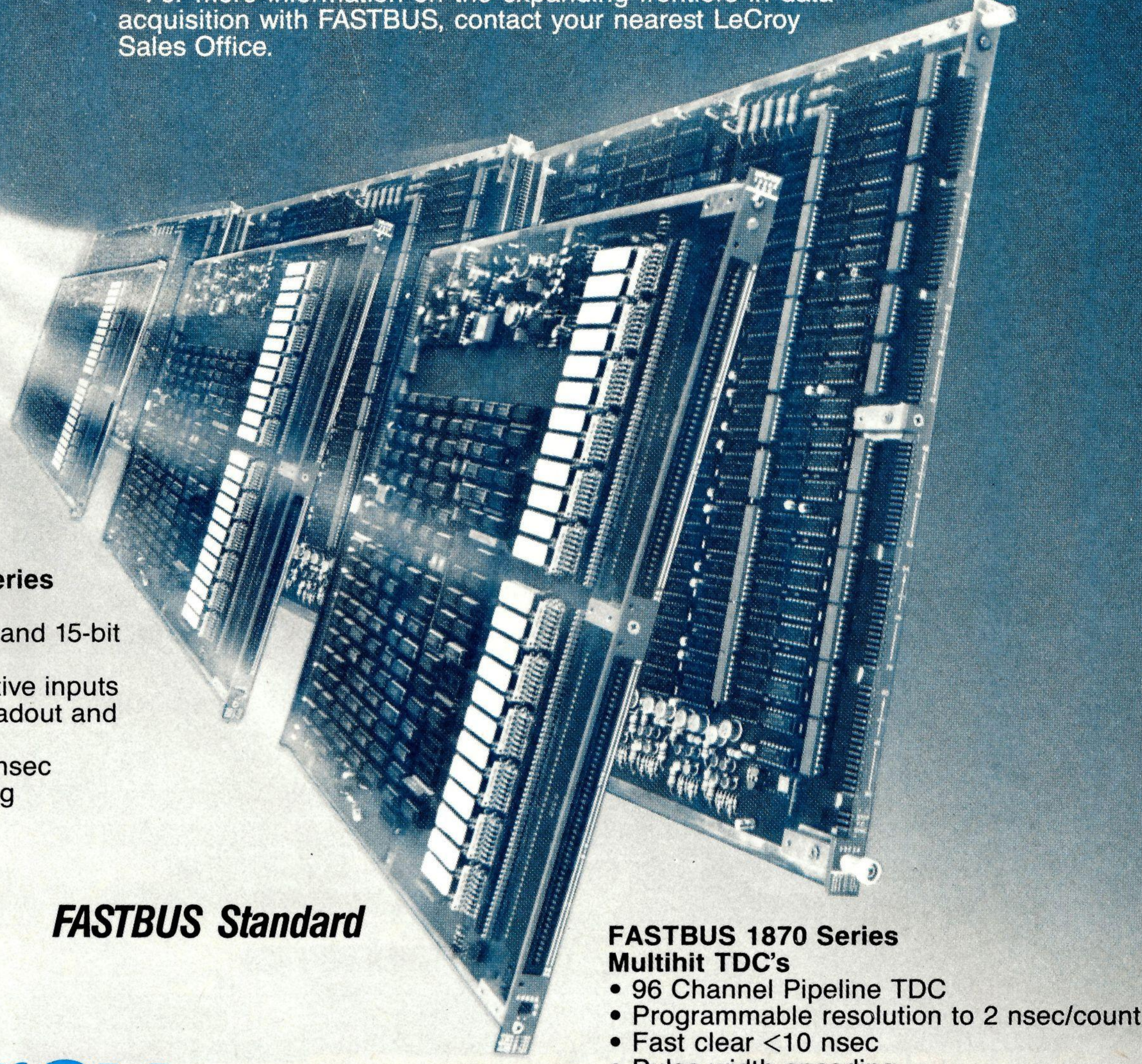

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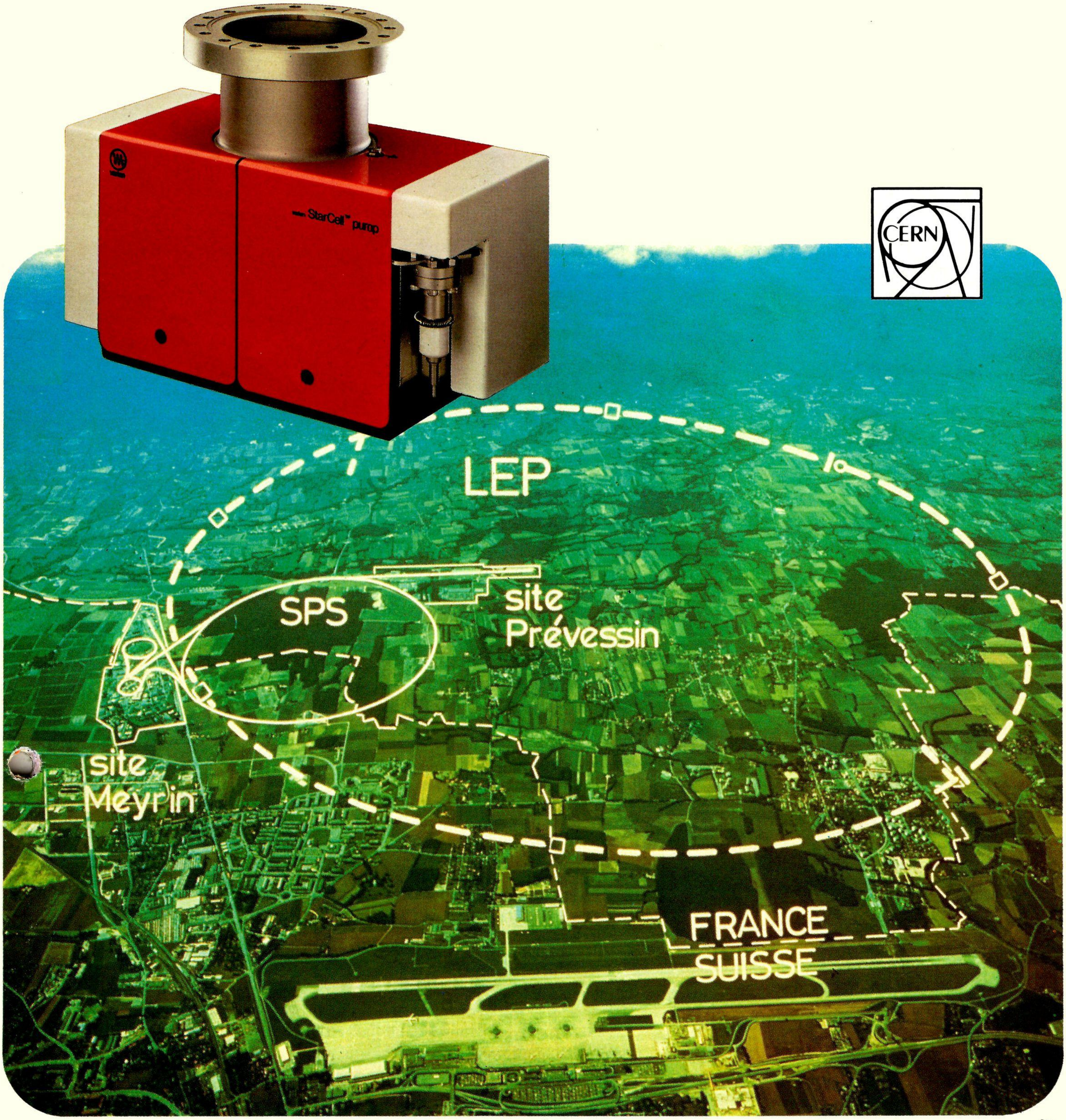

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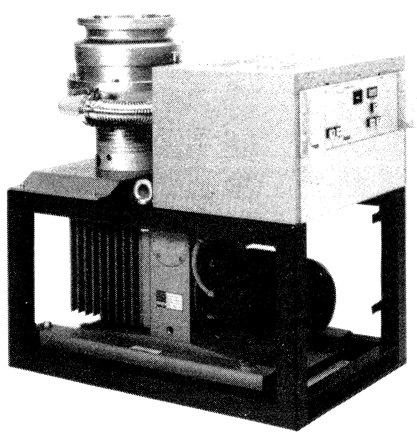

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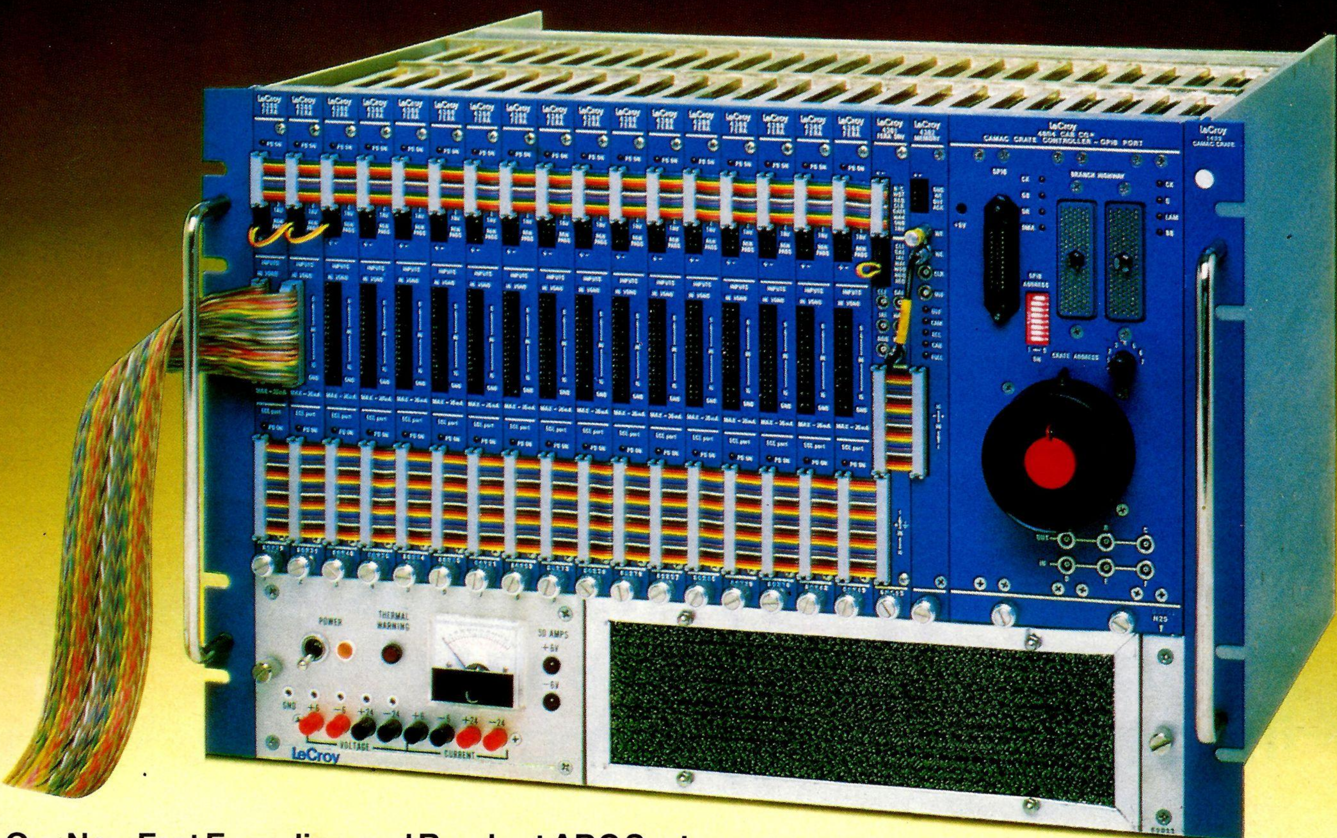


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