CERN COURIER

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Physics monitor

Around the Laboratories

Cover photograph: A portion of the Cherenkov counter of an experiment by a Columbia/Fermilab/Massachusetts/Mexico collaboration working at the Brookhaven AGS. The overall detector is highly segmented and is designed to cope with several million interactions per second. After its work is through at Brookhaven, the detector is scheduled to be moved to Fermilab (Photo Brookhaven).

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Physics monitor

Together at the conference dinner for the recent Workshop on Proton-Antiproton Collider Physics at the University of Berne were (right to left) Carlo Rubbia, leader of the UA1 experiment at the CERN Collider, Pierre Darriulat, spokesman of the UA2 experiment at CERN, and Alvin Tollestrup, spokesman of the Collider Detector Facility, now being assembled at Fermilab. At the Berne meeting, both UA1 and UA2 were able to report indications of possible new physics, beyond the standard 'electroweak' theory. Tollestrup's turn will come in a few years, when Fermilab's Tevatron collider produces its first physics.

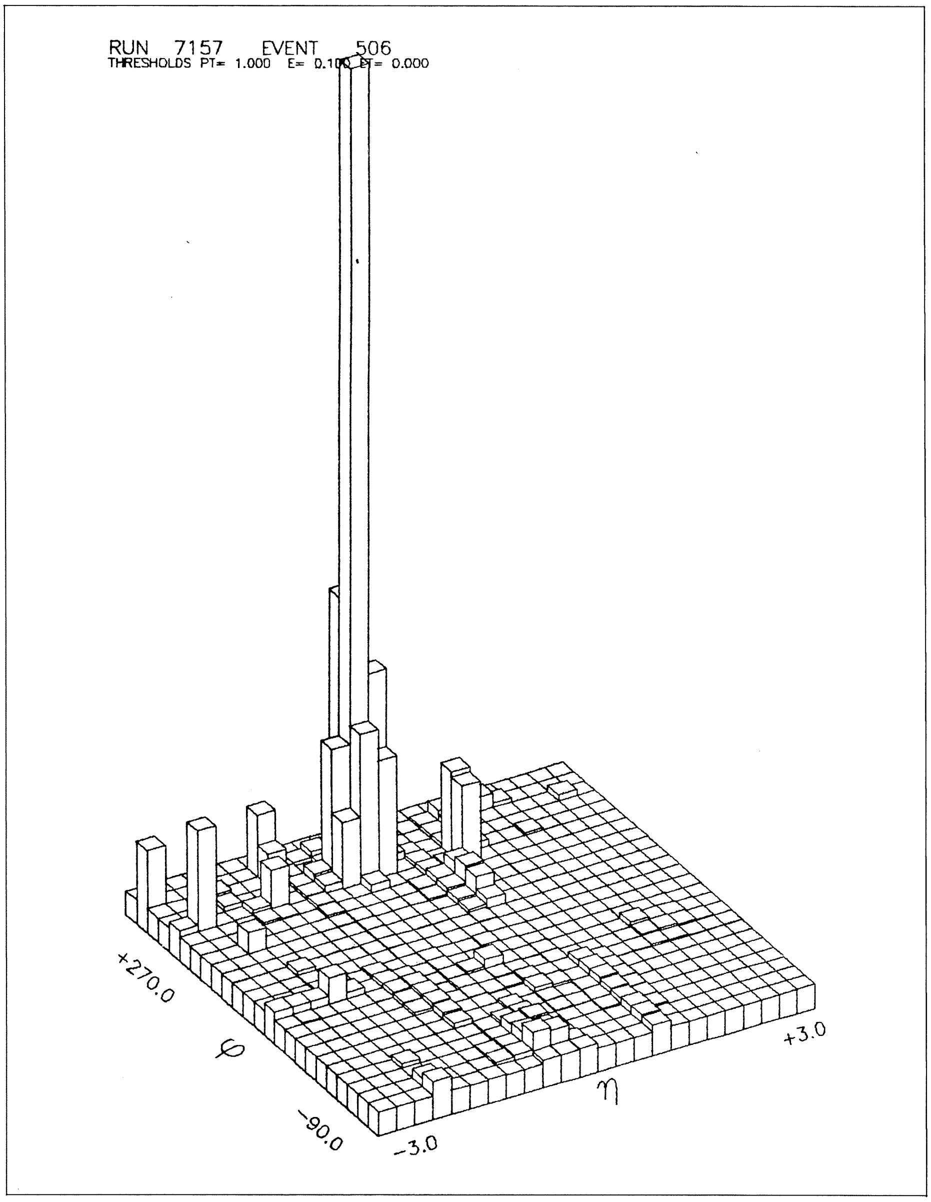
Hints of new physics?

The physics from colliding 270 GeV proton and antiproton beams in the CERN Super Proton Synchrotron continues to be in the spotlight. Although the Collider has been silent since the historic run from April to July last year which produced the evidence for the Z particle, there is still more than enough accumulated data to keep the physicists from the UA1 and UA2 experiments busy.

Their latest efforts came under scrutiny at the Fourth Topical Workshop on Proton-Antiproton Collider Physics, held at the University of Berne in March. The previous such Workshop, held in Rome last January, provided the run-up to the announcement of the discovery of the W particle, and set the scene for what was to be an eventful year for particle physics.

What else has the Collider found? Already last year, there was a lot of interest in the events seen by UA1 and UA2 in which a Z particle decays into a lepton pair plus an energetic photon. In principle radiative photons are not surprising, but this time the photons were very energetic, and even the handful of events collected by the UA1 and UA2 teams was many times the level predicted by conventional theory.

With the rest of electroweak theory seemingly in such great shape after the W and Z particles had been discovered in the right place, theorists were not slow to pick on these energetic photons as a clue of some



One of the new events recorded at the CERN proton-antiproton collider by the UA1 experiment. A 50 GeV transverse energy hadron jet dominates a relatively quiet background. Not shown is the 63 GeV 'missing energy' indicative of the passage of an invisible neutrino. The total transverse energy exceeds the mass of the W particle (81 GeV), and suggests some new physics.

new unexplained behaviour. Candidate ideas include excited leptons and composite bosons.

Giving the summary talk at the Berne meeting, CERN theorist John Ellis said that while these events were very interesting and were natural bait for new exotic mechanisms, he preferred to wait and see whether the high level of energetic photons will survive the test of more data.

At Berne, Carlo Rubbia gave a breathtaking survey of the latest news from UA1, concluding that 'new phenomena have been observed which cannot be explained in the standard model!'. Among these newer phenomena are the so-called 'Zen' events, producing (at high transverse momentum) a few particles on one side and 'missing energy', suggestive of invisible particles. like neutrinos, on the other. (There is a classic Zen riddle — if clapping is the sound of two hands being brought together, what is the sound made by one hand?) UA1 has produced an intriguing example of a 53 GeV photon (or electromagnetic shower) with 47 GeV of transverse momentum missing on the other side.

This UA1 single photon event is difficult to explain. Confronted with just one event, Ellis preferred to quote Sherlock Holmes' advice to Dr. Watson: 'if more than one unusual event occurs, they should be related.'

What else unusual is there? UA1 also has a few 'monojet' events, where a single high transverse momentum spray of hadrons again has the balancing transverse momentum on the other side missing. There are also candidate events producing several hadron jets plus missing energy.

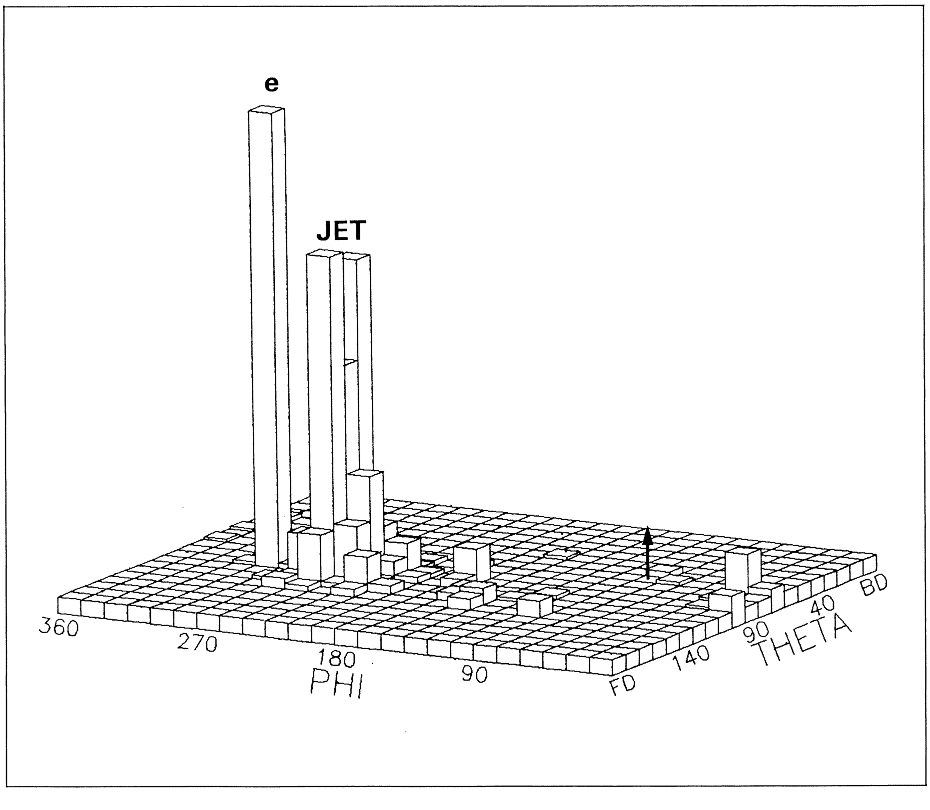
The signature which led to the discovery of the W particle early last year is a high transverse momentum electron accompanied by a neutrino (missing energy). An impressive sample of such electron plus neutrino events has now been accumulated. In addition, the UA2 experiment now has several examples of an electron-neutrino pair accompanied by extremely large transverse energy hadron jets (presented at Berne by André Roussarie). Their energies are too high for W production and the events are difficult to understand in terms of conventional production mechanisms.

An intriguing clue from UA2 comes from the analysis of multi-jet events containing more than two sprays of hadrons, each carrying more than 10 GeV of energy (presented at Berne by John Hansen). These events have a steeply falling exponential spectrum with only a hint of a signal at the mass of the W particle, but there is another possible bump further out, near 150 GeV.

UA1, which analyses muons as well as electrons, has collected about a dozen potentially interesting events with muon pairs accompanied by strange particles.

The initial results from the CERN Collider reported during the 1983 conference season were mainly concerned with conventional ideas. The latest results, while still very preliminary, hint at new and unexpected physics. What it is, only more data will tell, and the experimental teams eagerly await the next Collider run, scheduled to begin in September.

One of the interesting events recorded in high energy proton-antiproton interactions by the UA2 experiment at CERN. The single tower on the left represents an electron carrying 22 GeV of transverse energy. Slightly to the right is the compact spray produced by a hadron jet carrying in total 67 GeV of transverse energy. The arrow shows the position of the 86 GeV 'missing energy' indicative of an invisible neutrino. What caused this interaction?



More antiproton results, this time from low energy

Last year the LEAR Low Energy Antiproton Ring at CERN came into action for the first time, providing physicists with a unique source of highly intense beams of low energy antimatter.

First results from the modest 1983 runs were soon available, such as the elastic scattering of antiprotons off nuclei by a Saclay / Grenoble / Strasbourg / Tel Aviv team (see December 1983 issue, page 416) and the nice new data on antiprotonic atoms from the Basle / Karlsruhe / Stockholm / Strasbourg / Thessaloniki team (see March issue, page 53). This is complemented by interesting precision data from a Munich (Technical University) experiment. The recent Topical Workshop on Proton-Antiproton Collider Physics, held at the University of Berne, provided a showcase for these and other initial LEAR results, presented by Kurt Kilian.

Possible indications of interesting new physics came from the Athens / California (Irvine) / CERN / New Mexico / Penn State/Temple collaboration (PS 183) using a magnetic spectrometer to search for single photons and charged pions released in the annihilation of stopped antiprotons.

Over the years, there has been continual speculation whether these annihilation processes can produce relatively stable states whose quark structure is more complex than the quark-antiquark pair of conventional mesons. The PS 183 team had suggestions of a signal at 1621 MeV from annihilations emitting a single charged pion. Evidence from other LEAR experiments searching for such states is eagerly awaited.

Other LEAR experiments hope to open up the low-lying energy levels of antiprotonic hydrogen, an atom composed of a proton and an antiproton orbiting round each other. This interesting spectroscopy has yet to be studied — if it even exists at all!

The Berne meeting provided an interesting snapshot of the fast developing field of LEAR physics, which encompasses 17 experiments (16 currently installed). The 1983 data naturally takes time to digest, and in many cases it is too early for definite results. In the meantime, LEAR experiments have had another taste of low energy antiprotons.

Putting barium fluoride to work

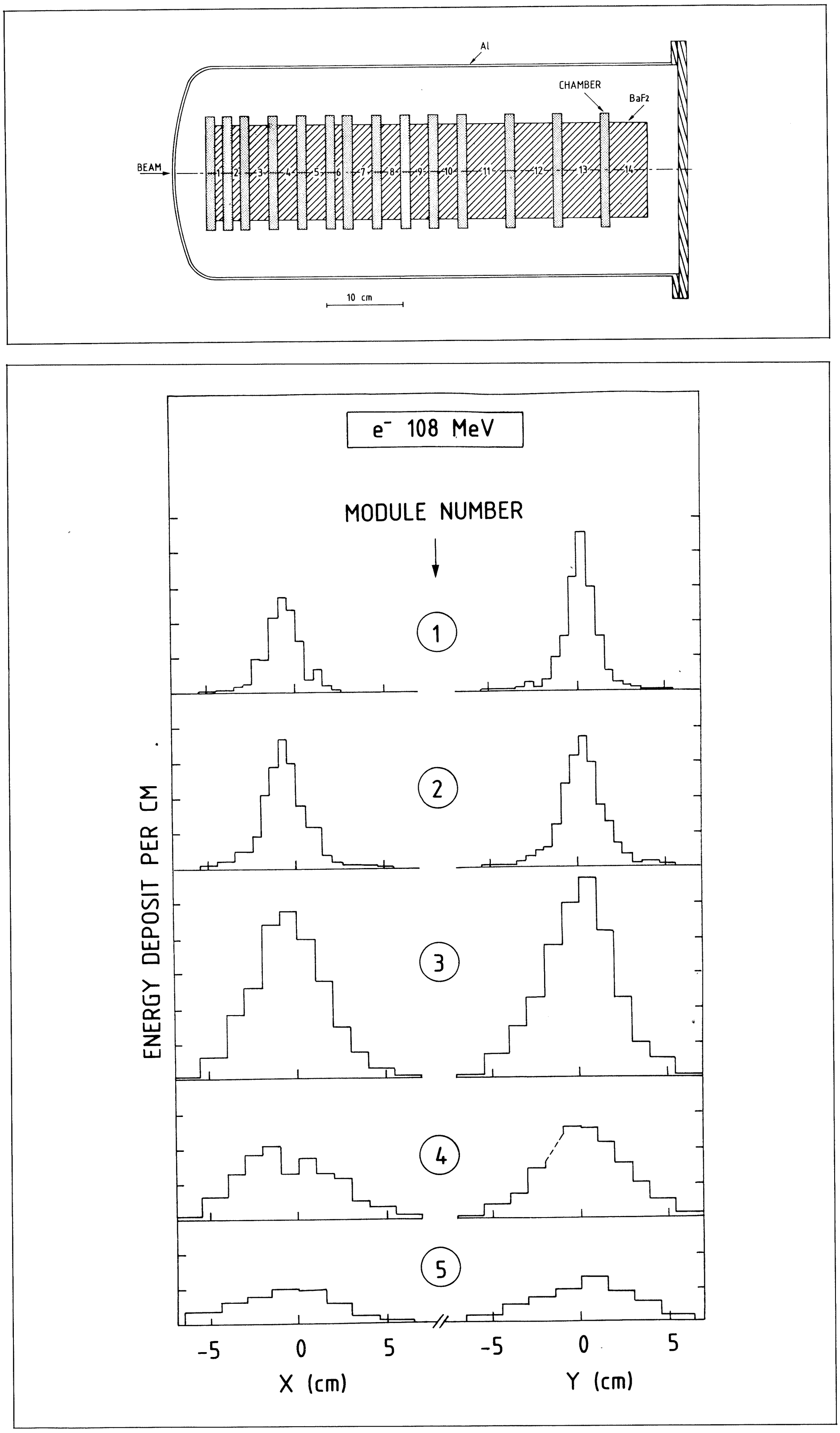
Barium fluoride is being investigated as a possible new scintillator for use in detecting gamma rays (photons). This rugged substance is manufactured from cheap raw materials, and there is a good chance that its price could be substantially reduced. It scintillates in the ultra-violet with a decay constant of only 0.6 ns. Unlike sodium iodide, it is not hygroscopic, and is certainly much cheaper than the bismuth germanate (BGO) now coming into fashion.

At CERN, a highly photosensitive material (tetrakis-dimethylamino-ethylene, or TMAE), monitored by a low pressure wire chamber, has been used to measure the ultra-violet component of a barium fluoride scintillator. Such a detector gives high photoelectron collection efficiency with good timing properties which exploit to the full the fast response of barium fluoride.

These tests used either liquid photocathodes, with the TMAE condensed onto a surface, or with TMAE adsorbed on the cathodes without any cooling. This latter approach, although slightly less sensitive, is easier to handle.

This combination of solid scintillator plus proportional counter (SSPC) combines the photon stopping power of a heavy solid with the versatility of a proportional counter. It has demonstrated good resolution in space, time and energy, and these pioneering developments by Georges Charpak's group at CERN could turn out to be one of the big turning points in detector technology.

At CERN, a 12.5 cm diameter prototype barium fluoride electromagnetic calorimeter has been built



Sketch of a prototype barium fluoride electromagnetic calorimeter built at CERN, containing 14 slabs of fluoride interspersed with low pressure wire chambers. Below, its response, showing its interesting ability to localize electromagnetic showers.

and has given encouraging results in initial tests with low energy electron beams. The detector contains 14 slabs of barium fluoride, representing a total thickness of 20 radiation lengths, interspersed with low pressure (3 millibar) wire chambers containing TMAE as photosensitive material.

With the low energy test beams (100 and 200 MeV), the detector has demonstrated good localization of showers, both longitudinally and transverse to the beam, with quite good energy resolution (within 20% — FWHM — at 200 MeV). Further tests are planned using photon and higher energy beams.

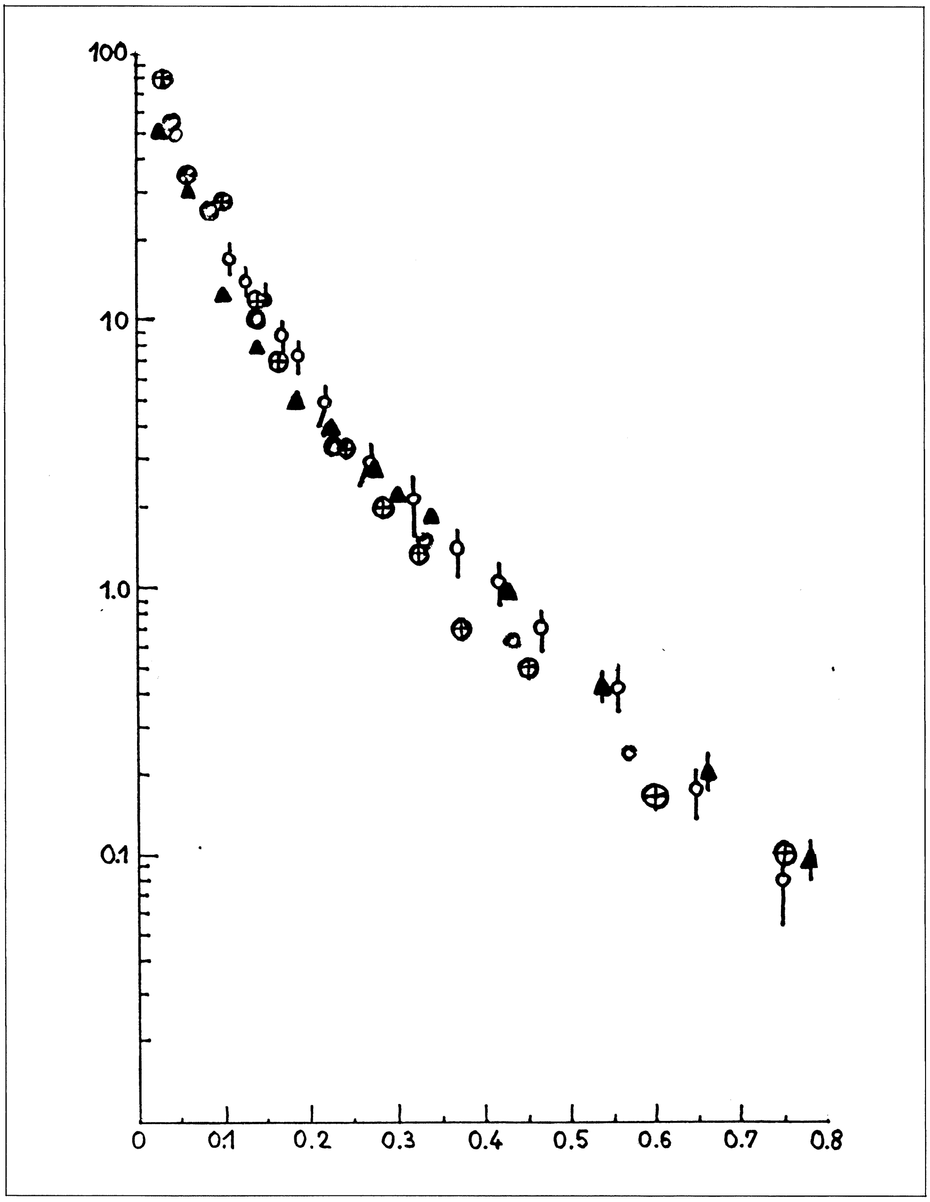
Meanwhile a barium fluoride detector is being built at Strasbourg for experiments at the French GANIL heavy ion Laboratory. In China, barium fluoride has been manufactured at the Artificial Crystal Institute and scientists at Peking are busy measuring the material's properties.

Transverse momentum under the microscope

To a packed CERN auditorium on 1 March, Antonino Zichichi bravely presented a controversial seminar — 'The end of a myth: high transverse momentum physics'.

Back in the late 1960s, electron scattering experiments at SLAC showed that there were small hard scattering centres deep inside the target nucleons. In a tiny percentage of scattering events, the incident electrons penetrated deep inside the nucleons to register direct frontal hits on the tiny constituent particles. In these interactions, particles were observed emerging at large angles (large transverse momentum).

Comparison of hadron production in conventional high transverse momentum proton-antiproton collisions seen by the UA 1 detector at the CERN Collider (crossed circles) with electron-positron annihilations at the DESY PETRA ring (TASSO experiment), and low transverse momentum events at the CERN ISR (triangles), suitably analysed to take into account the 'leading particle effect' due to the uninteracting constituents. (The horizontal scale is a measure of the relative longitudinal momentum carried by the hadron jets.) The agreement looks impressive.



It was a rerun of Rutherford's classic 1911 alpha particle scattering experiment which demonstrated the existence of the nuclear atom. In Rutherford's experiment, a few particles, instead of brushing by their targets, had slammed straight into the nucleus and were observed coming out backwards. The significance of the discovery is enshrined in Rutherford's classic remark — 'It was as though you had fired a fifteen-inch shell at a piece of tissue paper and it had bounced back and hit you.'

While these recoiling particles signalled that small nuclei were hidden deep inside atoms, the discovery did not mean to say that every collision with a nucleus produced a sharply recoiling particle.

In modern particle physics, high transverse momentum is conventionally used as a criterion for selecting out collisions involving hadron constituents. In his seminar, Zichichi examined this privileged role currently enjoyed by high transverse momentum physics. Is the low transverse momentum behaviour really not interesting?

The answer, in his view, requires a careful look at the kinematics of scattering processes involving composite particles. Zichichi's idea is to introduce kinematics which take into account the 'leading particle effect' — the particle constituents which are swept on with the collision and do not interact directly. The idea is to naturally take care of the kinematics of non-interacting constituents and isolate the effective energy and momentum available for the production of new particles.

Zichichi used data collected by his group (Bologna / CERN / Frascati) at the Split Field Magnet in the CERN Intersecting Storage Rings studying proton-proton and proton-antiproton scattering. In these interactions, the colliding particles produce relatively tightly confined sprays ('jets') of hadrons. But he also demonstrated that the technique is equally valid for all interactions involving hadrons, whether the interactions are strong, electromagnetic or weak.

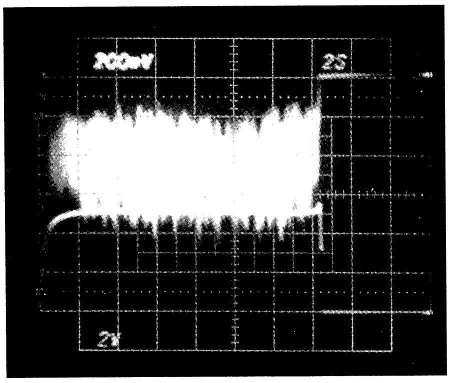
In the framework of the new kinematics, the observed behaviour in the jets of produced particles shows a remarkable similarity, no matter what the scattering process, and not just for 'high transverse momentum'.

As Zichichi points out, the analysis of electron-positron annihilation (pointlike particles with no inner constituents) does not require automatic recourse to wide angle scattering to isolate events of interest.

'Why look for events in places where there are few of them?' asks Zichichi. 'Isn't it better to look where there are plenty of events? Certainly it's cheaper!'

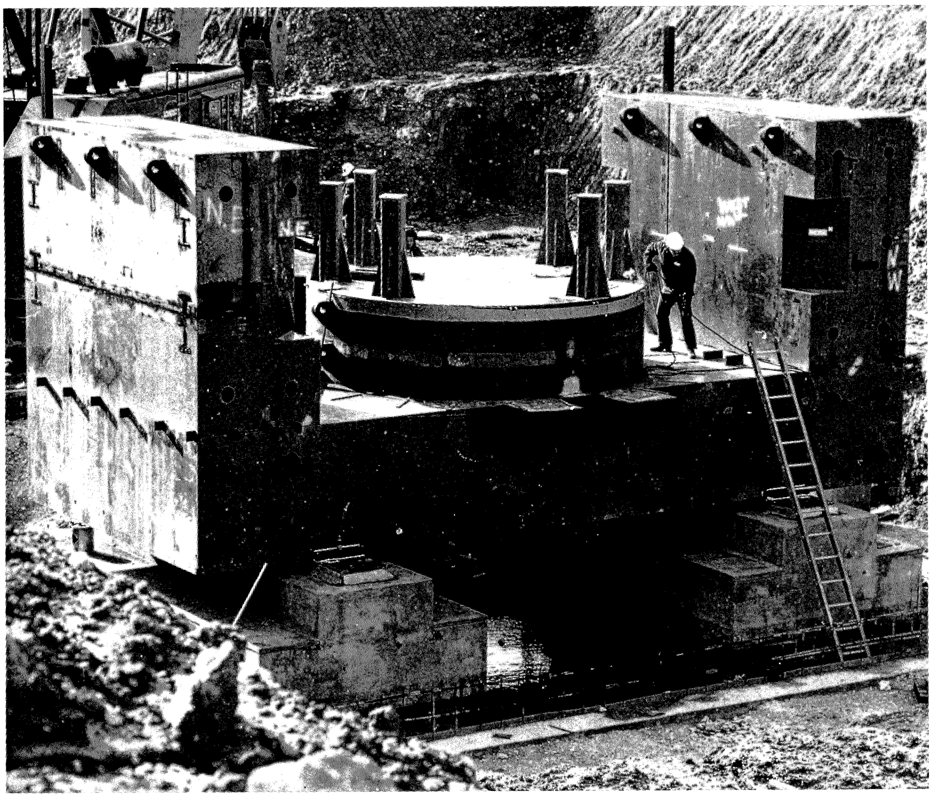
Around the Laboratories

One of the characteristic features of the Fermilab Tevatron is its long spill, extending over some 15 seconds. This makes for good duty factors.



The famous Chicago cyclotron being reassembled for its fourth incarnation. Originally built by Fermi and his colleagues, it was converted to a conventional spectrometer magnet at Fermilab and then made superconducting. Now it will become one of the principal elements in a spectrometer for muon physics. The muon beam and the building to house the spectrometer are still to come.

(Photo Fermilab)



FERMILAB Energy Doubler goes to 800 GeV

The Fermilab Energy Saver/Doubler operated at 800 GeV for the first time on 15 February. The accelerator was ramped to the new energy, twice the normal operating energy of the Fermilab accelerator system.

The accelerator ran smoothly at the new energy for eight hours. Other tests have shown that both the Right Bend external beamline to the Proton Area and the Left Bend line to the Meson Area can operate at 800 GeV.

With the start of the experimental programme at 800 GeV, Fermilab becomes the highest energy fixed target Laboratory in the world. An official dedication ceremony for the new superconducting machine took place on 28 April.

Tevatron experiments start up

The first phase of the Tevatron experimental programme has now been operational for several months. During this period the slow extracted beam, the completely reworked switchyard and many of the Tevatron primary target systems have been brought into operation. Most important, the Tevatron high energy physics programme has started. By early this year the superconducting accelerator was operating smoothly enough so that it had become mostly an accelerator rather than a superconducting test bed.

Still to come are the construction and commissioning of the new secondary beamlines. These consist of the Wide Band Photon Beam in the Proton Area, the Muon and Prompt Neutrino Beams in the Neutrino Area and the Meson Area Pion and Polarized Proton Beams. Many of the components that will be needed for construction of these beams have already been started and plans for the associated civil construction projects are far advanced (see September 1983 issue, pages 251-3).

Some work is already under way, but a great deal of additional civil construction is scheduled to provide housing for the new beam facilities and experiments.

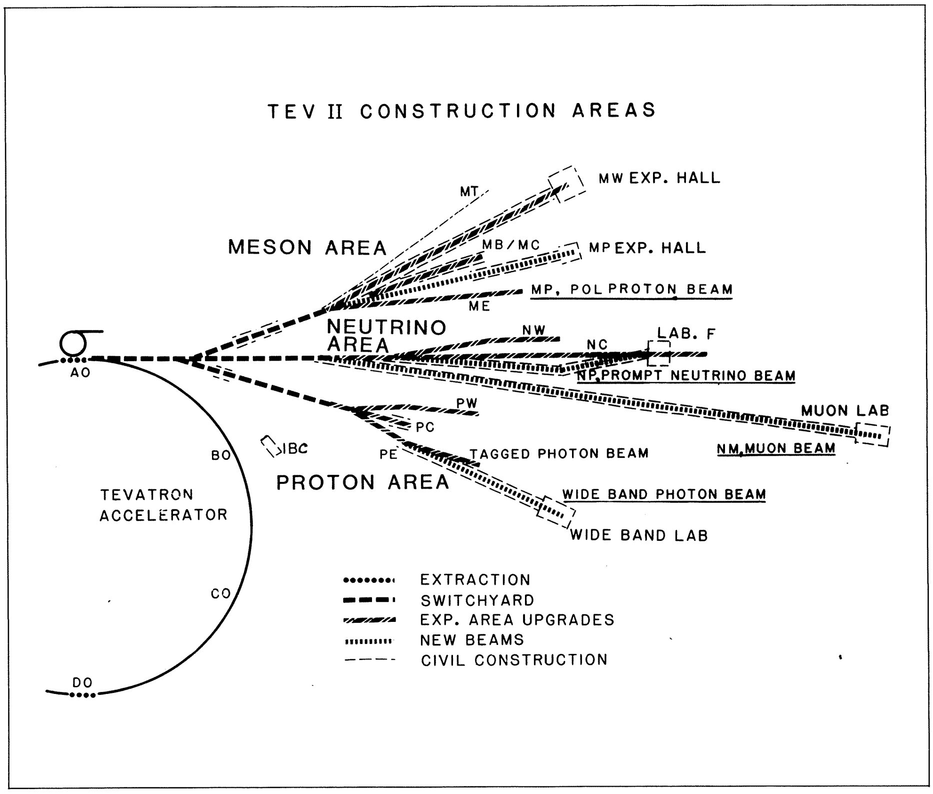
The rapid and successful operation of the superconducting Tevatron accelerator and its associated extraction and switchyard systems bode well for the success of the entire fixed target physics programme. So far, it has been impressive to see how the goals of both the project and the entire fixed target programme have been met.

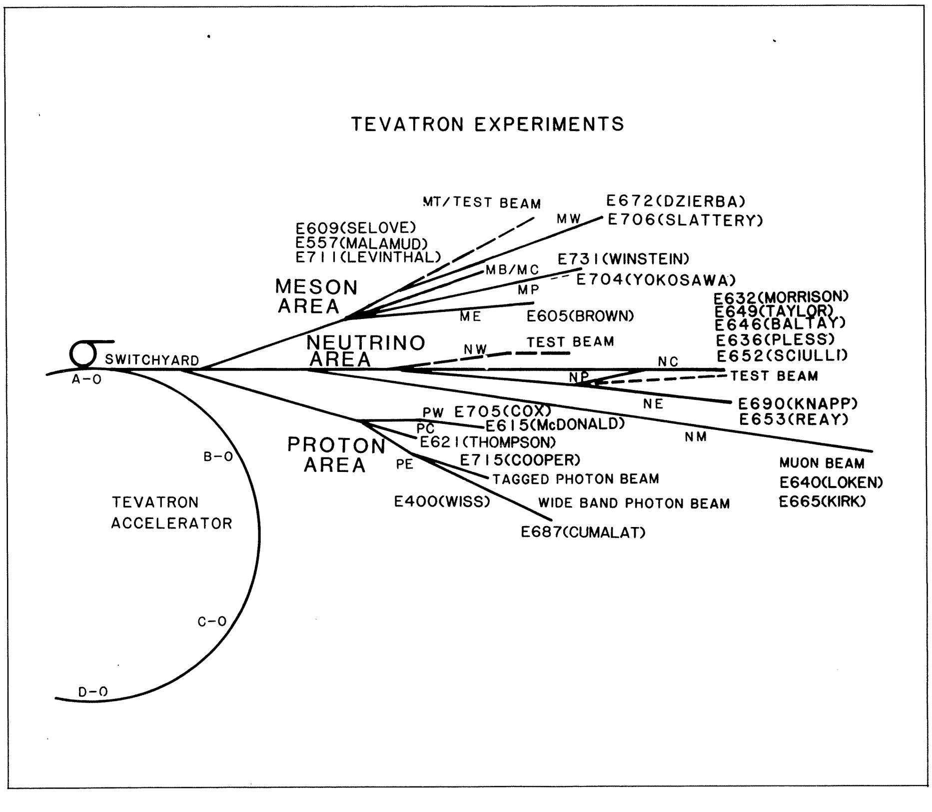
An outstanding feature of the Tevatron is the long spill, characteristically fifteen seconds. This has led to a much better duty factor for experiments.

The slow resonant extraction system is central to the Tevatron experimental programme. Critical to the extraction success was the development of greatly improved wire septa for splitting off the extracted beam with minimal losses.

Once the beam leaves the acceler-

Fermilab Tevatron construction areas, and, below, the layout of the experiments using the new beams. The experimental programme should be fully operational next year.





ator, it passes into the Tevatron switchyard area where electrostatic splits divide the beam into multiple primary beams feeding production targets. The largest project in the Tevatron switchyard was the superconducting right bend to the Proton Area. This project, completed during the 1983 shutdown, uses two strings of superconducting Energy Saver dipoles. After passing through the superconducting right bend, the Proton Area primary beam is again split into three, subsequently targeted independently for the P-East, P-Centre, and P-West beams.

At a later stage the P-East beam will pass through yet another electrostatic split, allowing photon beams to be used simultaneously in the Tagged Photon Laboratory and in the new Wide Band Neutral Beam. The primary beam transport for all parts of the Proton Area are now complete except for the two-way split to the Wide Band target. The Wide Band split will be installed during the summer shutdown.

The primary beam to the Meson Area passes through the superconducting left bend which was installed several years ago. Once through the left bend the beam is split into three parts, as in the Proton area. The three primary beams pass through the old Meson target box and are focussed on new targets in the former Meson Detector Building, now known as the Meson Target Building.

Work in the Neutrino switchyard area has been relatively low key so far, but there will soon be a significant increase in activity with the installation of an electrostatic split and a superconducting bend that will split off primary beam to the new muon production target. Construction of components for the muon split is presently underway and equipment will be installed during the summer.

Several months after the start-up of the Energy Doubler, the Tevatron experimental programme is already well under way. February saw the last 400 GeV running with the Energy Saver before raising the energy to 700 GeV or greater.

Major experiments are in progress or complete in all three areas. E-715 (Chicago / Elmhurst / Fermilab / Iowa State / Iowa / Leningrad / Yale) has successfully carried off a precision measurement of the polarized sigma minus beta decay. A second 400 GeV experiment, E-609 (Argonne / Fermilab / Lehigh / Pennsylvania / Rice / Wisconsin) has been completed in the Meson Laboratory. This collaboration has been studying the structure of high transverse momentum interactions involving low energy jets using a large segmented calorimeter array.

Elsewhere in the Meson Laboratory, E-605 (CERN / Columbia / Saclay / Fermilab / Kyoto / KEK / Stony Brook / Washington) is well under way. Its goal is to study lepton and hadron production for both single particles and pairs at very high transverse momentum.

E-615 (Chicago / Fermilab / Iowa State / Princeton) is operating another large acceptance magnetic spectrometer in the Proton-West high intensity pion beam to study high mass muon pair production.

A third magnetic spectrometer is gathering data in the Proton-East neutron beam. The goal in this experiment (E-400 — Colorado / Fermilab / Illinois / Milan / Pavia) is to study the production of charm particles by neutrons.

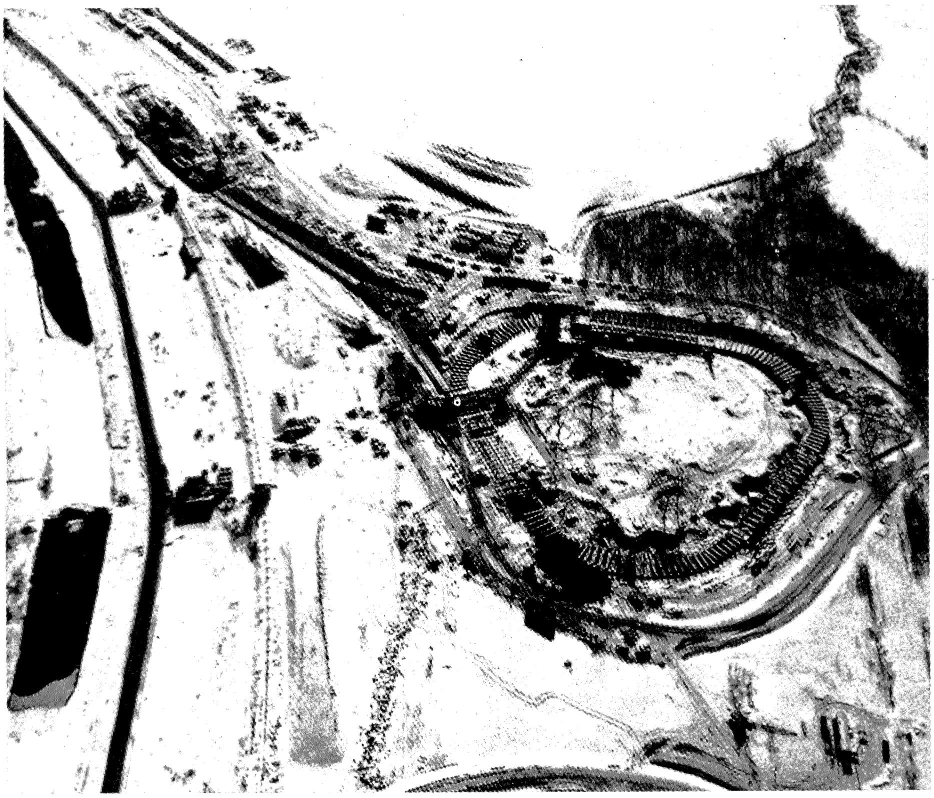
While these experiments gathered their data, several others were preparing for spring running. E-557 (Arizona / Caltech / Fermilab / Florida State / George Mason / Illinois-Chicago / Indiana / Serpukhov / Maryland / Rutgers) was tuning the Multi Particle Spectrometer Facility in the Meson Laboratory with muons.

An ambitious measurement of the CP violation parameter for three-pion decays started in March in the Proton Laboratory. E-621 (Michigan / Minnesota / Rutgers / Wisconsin) will measure the CP violation parameter by observing the interference between different neutral kaon decays to three pions near the production target.

Many of the Tevatron experiments for the upcoming running periods are now into serious preparation. At the same time detector design and development is well under way for the new colliding detector facility at DO (see next story). Construction for the Collider Detector Facility at BO (see January/February issue, page 11) is also producing modules which must be calibrated and proof tested. All of this has led to heavy demand for two test beams — N-West and M-Bottom. A number of interesting new detector ideas are being tried in the process.

Currently, the areas of maximum activity in the Tevatron Project involve construction of new experimental halls for the new particle beams. Lab F is now complete. Experiment E-745 (Brown / Fermilab / Indiana / Beijing / MIT / Oak Ridge / Seton Hall / Tennessee / Tohoku) is installing equipment, the largest item being a large heavy-liquid bubble chamber with holographic optics. The bubble chamber and its associated spectrometer will later be used for an experiment to study production of tau leptons and other phenomena in the Prompt Neutrino Beam.

Two new experimental halls are also under construction. These are the new Muon Laboratory and the Wide Band Experimental Hall. Both of these buildings are major struc-



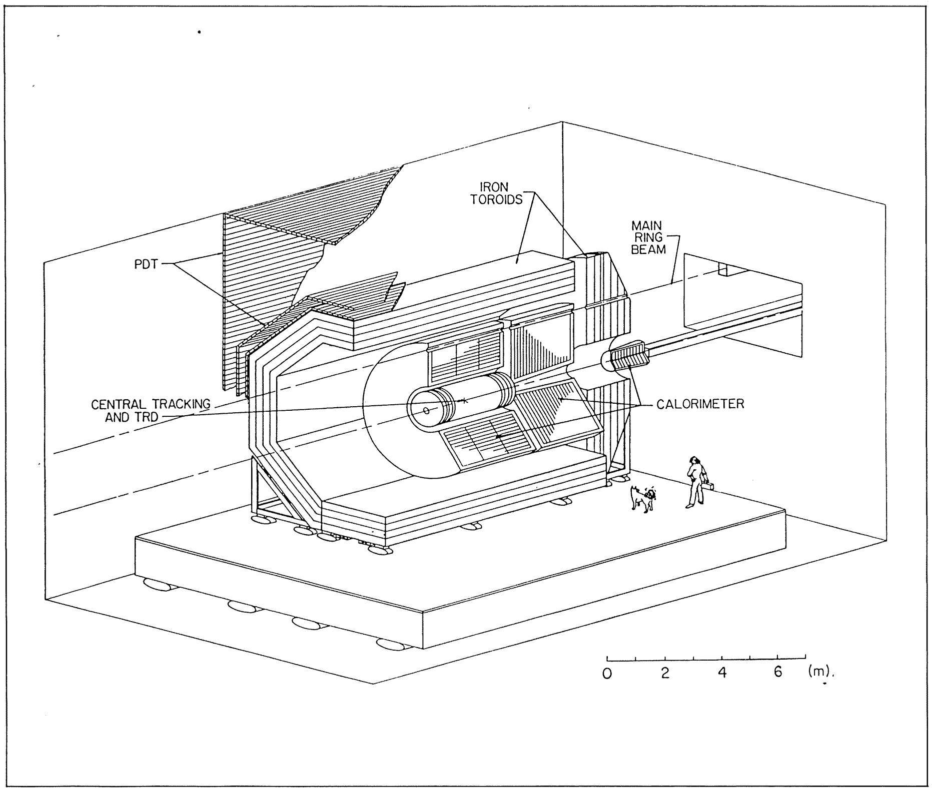
Construction under way in the snow for the Fermilab antiproton source. Note the distinctive triangular shape of the new 'ring'. The Main Ring is visible on the left and the Booster just appears at the bottom of the photograph. For explanation, see November 1983 issue, pages 380-2.

(Photo Fermilab)

tures that will each house two experiments in tandem. Construction is hoped to be complete later this year in order to allow installation of apparatus to be used in testing and shakedown runs for experiments E-640 (Berkeley / Fermilab / Princeton), E-665 (San Diego / CERN / Fermilab / Freiburg / Harvard / Maryland / MIT / Munich / Cracow / Washington / Wuppertal / Yale), and E-687 (Colorado / Fermilab / Frascati / Illinois / Milan / Northwestern / Notre Dame).

Two more large experimental halls are planned for construction in the Meson Area. These will house the polarized proton experiment E-704 (Argonne / Berkeley / Fermilab / KEK / Kyoto / LAPP / Northwestern / Rice / Saclay / Serpukhov / Trieste), and a new multiparticle hadron spectrometer for experiment E-672 (Caltech / Fermilab / Florida State / George Mason / Illinois-Chicago / Indiana / Maryland), and E-706 (Fermilab / Michigan State / Minnesota / Northeastern / Pittsburgh / Rochester). A smaller building is under construction in the Meson Area to house E-731 (Chicago / Fermilab / Princeton / Saclay), a sophisticated study of CP violation.

When it all comes together next year, the Tevatron physics programme will be fully deployed. From hyperons to muons, from neutrinos to antiprotons, from pions to photons, the Fermilab community can look forward to a rich and productive decade of physics with the highest energy fixed target particle beams in the world.



A simplified cutaway view of the D0 detector for the proton-antiproton collider at the Fermilab Tevatron. The muon and calorimeter systems will in fact be symmetrical on both sides. The design complements the CDF detector being assembled at the B0 region.

The D0 detector

Planning has now crystallized for a powerful new detector to be located at the D0 intersection region in the Fermilab proton-antiproton collider. This experiment will complement the CDF detector at B0 (see January/February issue, pages 11-15).

The Fermilab Program Advisory Committee approved this new detector last June, based upon criteria drawn from several earlier proposals. Subsequently a design report and cost estimate have been prepared by a collaboration of over seventy physicists from Arizona, Brookhaven, Brown, Columbia, Fermilab, Florida State, Maryland, Michigan State, Northwestern, Pennsylvania, Stony Brook and Virginia Polytechnic. Paul Grannis is serving as project manager.

The design of the detector has been shaped by several considerations: the results from the CERN Collider on W, Z, and jet production; the capabilities of the CDF detector; the proposed upgrades for the CERN UA1 and UA2 detectors; and the physics potential of the electron-positron machines under construction. The detector stresses excellent identification and energy measurement for leptons (both electrons and muons) and the best available energy and angle resolutions for jets. These goals are set by the expectation of new physics accessible at the Tevatron, involving high transverse momentum leptons and jets and large missing transverse momentum due to neutrinos or new non-interacting particles. Very fine segmentation is dictated for the calorimetry for short-distance collisions because large multiplicities and particle clusterings are expected. The ability to identify leptons even when embedded in jets is highly desirable; control of the errors on missing transverse momentum requires complete angular coverage down to about one degree from the beams.

There are several ways to probe for new physics. Precision tests of the properties of W and Z particles might reveal new effects. High transverse momentum particle and jet production can test the dynamics of quarks and gluons at small distances. Searches for new phenomena at large masses may be rewarded.

At large transverse momentum, the set of observable particles effectively reduces to four: jets, electrons, muons, and photons. In addition, neutrinos and other non-interacting particles can be inferred by the existence of large missing transverse momentum. The measure of a detector for hadron colliders then boils down to how well it handles each of these.

The detector proposed for the Fermilab D0 intersection region includes a central track detector out to a radius of 70 cm; liquid-argon calorimetry covering the full angular range (outside one degree from the beam) and a muon detector consisting of three magnetized iron toroids with a set of proportional drift tubes inside and outside the iron.

In the design configuration, the central detector has three compartments; a cylindrical large-angle detector and two small-angle end detectors. Each compartment has eight gaps of drift chamber planes near the intersection region and sixteen gaps just before the calorimetry. Delay lines near the sense wires give the coordinate along the wire direction to within 2 mm and provide space-point hit information. The region between the drift gaps is occupied by a transition radiation detector (TRD) built from four modules of radiator followed by a xenon-filled wire chamber for X-ray detection. The TRD is important for electron identification in a detector with no central magnetic field. It is expected to yield a factor of about 50 in rejecting hadrons, independent of the rejection power of the calorimetry. The region inside the inner drift module is reserved for a mini-vertex detector.

The calorimetry contains three types of devices. The central calorimeter is a polygonal approximation to a cylinder, covering the polar angle range from 45 to 135 degrees. Two end-calorimeters extend the coverage down to 5 degrees from the beams. Coverage is completed with a pair of plug calorimeters, retracted as far as possible along the exit beamlines, which measure down to 1 degree. The absorber medium in the calorimeter is a mixture of uranium and non-compensating metal (copper or steel).

The longitudinal subdivision of the calorimetry readout will have four electromagnetic sections and typically three hadronic sections. Transverse segmentation is arranged in projective towers. Hadronic section segmentation is typically four times coarser than the electromagnetic towers. The total number of calorimeter-readout tower segments is about 50 000.

The muon detection system is built around iron toroidal magnets in the central region and both end regions. The toroids fulfil two functions; they bend the muons, giving a 20 per cent momentum measurement, and they absorb the remnants of hadronic showers. Muon tracking comes from sets of proportional drift tubes before and after the iron. The goal of the muon system is identification and momentum measurement of muons out to the maximum observable transverse momentum. The muon detection capability will be excellent owing to the large solid angle coverage and thick muon shield. The muon measurement is expected to be possible even when the muon is in the midst of a hadron jet.

Eliminating the central magnetic field in the D0 detector provides calorimetry and lepton measurements which will strongly complement the CDF detector. The D0 calorimetry should be about twice as good as CDF for measuring jet energies and missing transverse momentum.

Electron identification should be excellent. The performance of the calorimetry will be boosted by the transition radiation detector, which also offers the possibility of tagging electrons close to the axis of jets. Photon detection, while not possible unambiguously, is aided by the combination of fine transverse segmentation and depth subdivisions.

Overall, the new D0 detector will be well suited to a wide range of physics. The recent results from the CERN Collider have shown how fruitful the study of high energy hadron collisions can be, and the D0 detector will be well equipped to play a central role in continuing this exploration out into a higher energy range.

STANFORD
Putting your money on electrons

Earlier this year, Stanford Linac Director 'Pief' Panofsky gave his final traditional 'State of SLAC' address before he hands over the Laboratory Directorship to Burt Richter on 1 September. In his talk, he was able to report that the President's budget for fiscal 1985 proposes a generous funding increase, most of which is earmarked for the construction of the new Stanford Linear Collider (SLC), scheduled to become operational early in 1987, if not before (see April issue, page 98).

Stanford Linac Director 'Pief' Panofsky — 'we can look forward to a secure future for the rest of this decade.'

'The President's budget gives us the good news that construction of the SLC can go ahead full steam, paced only by our ability here at SLAC to do the work and by the tractability of the very difficult technical problems that have to be solved as we proceed to build this challenging machine,' said Panofsky.

'Our operating activities will continue to be constrained by fiscal pressures; if the President's budget does not get cut in the Congress, the situation will not be worse than it is today. Equipment money shows an increase, but definitely not enough to live up to our obligations to construct competitive detector systems for the use of the SLC on a reasonable time scale. As far as SLAC's staff level is concerned, I predict a small growth to match our total obligations during the coming year.

SLAC has now grown from its initial configuration using just two beams to a 'three-ring circus' involving many beams, and exploiting SPEAR, PEP, and soon the SLC, all three to collide electrons and positrons.

How has this dramatic change come about? I believe that the basic reason is that our initial hunch that the future of high energy physics would be deeply intertwined with the use of electron beams has proven to be correct. When SLAC was started there was general acquiescence to the idea of building a very large electron accelerator on the part of the scientific community, but there was not much enthusiasm. Through the mid-1960s the mainstream of high energy physics followed the development of proton accelerators.

The decade of the 1970s turned out to be the golden years of high energy physics using what we call 'lepton' beams — electrons, muons and neutrinos. The work was paced by electron accelerators and colliders, both at SLAC and at the DESY laboratory in Germany; proton accelerators made some of their biggest contributions through the use of secondary neutrino and muon beams.

There are good physical reasons why this happened. Leptons are not affected by the strong or nuclear force that holds the nucleus of the atom together; instead, leptons interact through electromagnetism and to a lesser extent through the weak interaction. Thus when leptons collide with nuclei, one is exploring unknown structures with relatively well known forces, and the resulting events are easier to understand than when protons with their complex internal structures collide with other protons. To go even further, when electrons collide with positrons they can annihilate into a single 'quantum' of pure electromagnetic energy, which then materializes into any of those particle states that can be cre-

Getting ready for Linear Collider

Early in February, the Stanford Linear Collider (SLC) passed a major milestone by accelerating a damped beam of 10^{10} electrons one-third of the way down the main two-mile linac. The invariant emittance, which is a measure of how finely the beam can be focused was 3×10^{-5} metre-radians and 5×10^{-5} metre-radians in the horizontal and vertical planes respectively.

The combination of intensity and emittance determines the luminosity which can be obtained by colliding two such beams. These emittances would yield a luminosity of approximately 10^{29} cm^{-2} sec^{-1} at the final focus of the collider.

These experiments required many of the components of the linac control system for the collider. The beam from the high intensity electron gun was accelerated to 950 MeV and injected into the damping ring. The damped beam was ejected from the ring 32 milliseconds later, reduced in length from one-half centimetre to one millimetre in a special bunch compressor, and reinjected into the main linac. At the monitoring station one-third of the way down, the beam (at an energy of 6.5 GeV) passed through a toroid, which measured the intensity, and onto a screen.

Work under way at Stanford for the new SLC linear collider, with (bottom right) excavation of an access ramp for tunnelling equipment. Centre is the flat roof of the experimental hall housing the MAC detector at the PEP electron-positron ring.

(Photo Stanford)

ated under the applicable rules. The events that result from this process exhibit new physics with remarkable clarity.

Largely as a result of this 'golden age of leptons' of the 1970s, we now understand the fundamental building blocks of Nature much better than before. The world as we know it today is made up of leptons, on the one hand, and quarks which are the carriers of the strong interaction and the building blocks of nuclei, on the other. We now know that protons and neutrons are each composed of three quarks, and that the forces among these quarks are carried by objects known as gluons which have characteristics that give rise to the known properties of the strong interaction.

Most of this was initially uncovered through lepton experiments and has been confirmed by the behaviour of protons, neutrons, and other particles; SLAC has played a truly crucial role in achieving this great leap in understanding. The key to this role has been the technical achievements made by SLAC in building and using its accelerators and colliders.

The question now facing us is for how long this role of electron machines will continue into the future. We know that the SLC in the United States and the LEP machine in Europe will advance the energy of electron-positron colliders to 100 GeV centre-of-mass collision energy, and eventually beyond that value at LEP. But what will happen thereafter, perhaps in the mid-1990s?

The energy of proton machines promises to be advanced by the mid-eighties to a collision energy of 2000 GeV, building on the recent successes at Fermilab in bringing a large superconducting proton synchrotron into operation. The 270 GeV per beam proton-antiproton collider at CERN has been a great success; it has provided the first direct conclusive evidence that the carriers of the weak interaction actually exist — a great achievement indeed.

Does this mean that the pendulum will swing back again? Will the dominance of the high energy physics world that moved from proton machines in the '60s to lepton physics in the '70s swing back to proton machines in the '80s? We cannot be sure.

The essential simplicity and analysability of the events produced by electron colliders will continue to provide an enormous advantage to experimenters using those machines. At the same time, the energies that can be reached with proton machines will continue to outstrip the energies attainable with electron machines at comparable cost, at least for the time being.

However even this last remark must be tempered. Since protons are complex objects consisting of quarks and gluons, the energy of each of the colliding protons is divided among these elementary constituents. Therefore the energy available to generate truly new phenomena is really that carried by the individual elementary constituents; these carry on the average only one-sixth or so of the energy of the proton. Thus the 2000 GeV collision energy attainable at Fermilab by the mid-'80s translates into an equivalent collision energy for electrons of about 300 GeV, which is still above the energy limit attainable by LEP and the SLC, but not by much!

For these and other reasons the results of electron machines and proton machines will continue to be complementary in the future, with no such thing as a single 'best machine.'

The dominant reason why electron

machines — in spite of the inherent simplicity of the physics they produce — have not thus far matched the reach into the unknown projected for proton machines is simply one of technology and of cost. We can extrapolate the established technologies of proton machines into the future to energies of perhaps as high as 20 TeV (20 000 GeV) of proton energy per beam. A comparable advance for an electron machine requires development of new technology for which the SLC will point the way, but which has not as yet been demonstrated.

Thus the next logical step for the US high energy physics programme is the proposed superconducting supercollider (SSC), which is envisaged as a colliding beam proton-proton machine with each beam having an energy of 20 000 GeV. If the current hopes of the community materialize, such a machine will operate by the middle of the '90s.

This hope can only be realized if this new machine can be built as a truly national effort — that is, an effort to which all Laboratories in the US contribute, including SLAC. Thus while operation of PEP and SPEAR and the construction of the SLC now comprise and will continue to comprise the large bulk of our work, we are already beginning to be involved, albeit to a very small extent, in the planning process for this very large proton machine.

Nevertheless, it is not at all clear that electron machines will also not be able to attain the same or an even larger reach of discovery as is now planned for proton machines. But we simply do not know today how to do this at a cost that appears affordable. No one can be sure now whether this cost disadvantage of electrons vs. protons will continue indefinitely, or whether progress in technology will erase or reverse it.

Using the new linear collider technique opened up by the SLC, there are several possible approaches towards building better and cheaper very high energy electron colliders. As construction of the SLC approaches completion, we will dedicate an increasing fraction of our work towards exploring these new technologies that may carry us beyond the SLC.

If the SLC, in addition to making valuable contributions in terms of its own physics programme, also leads to an exciting and supportable proposal for a large-scale electron-positron collider, then this avenue should and will certainly be pursued.

Whether it could be pursued on the SLAC site, or whether exploitation of such a machine would require more space than can reasonably be made available locally, I simply do not know. Neither do I know whether such a large linear collider would be best pursued as a national or as an international high energy physics programme.

In other words, in parallel with SLAC's increasing participation in the national programme for the SSC we will at the same time explore the opportunities for making a high energy linear electron-positron collider a competitive or even superior machine in the long run.

All of these issues relate, of course, to the question. What is the long-range future of SLAC? I would be uncomfortable in facing that question today if it were not for the fact that the very same question has been asked of me ever since the founding of this Laboratory.

It has always been true that the future programme of SLAC was relatively well-defined for a large fraction of the decade ahead, but beyond that little or nothing could be said. The situation is the same today.

We can look towards a secure future for the rest of this decade and perhaps somewhat beyond. What happens after that depends on our ability to exploit new ideas and initiatives. The director of SLAC after 1 September is a past master in this respect.'

**** The HERA electron-proton collider at the German DESY Laboratory has been approved, and construction starts immediately.***

DESY
I, II, III . . .

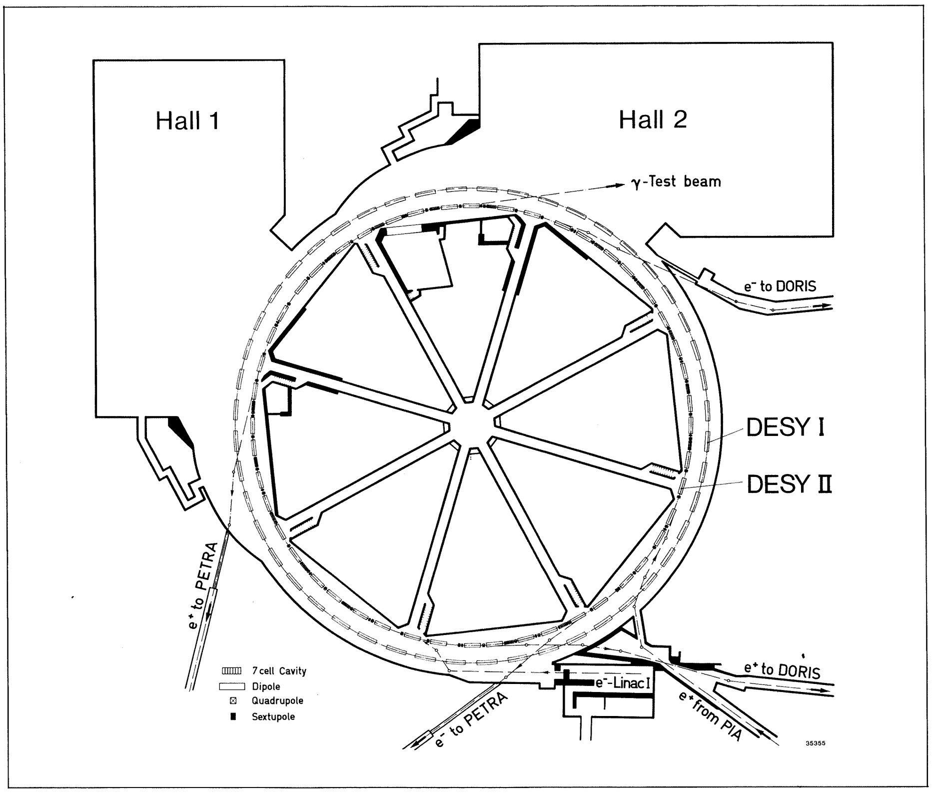
Back in February 1964, the electron synchrotron then called in short 'DESY' came into operation in Hamburg with a beam energy of 5 GeV, a world record at that time. It is still running now, twenty years later, as a 7 GeV injector of electrons and positrons for the storage rings DORIS-II and PETRA. It is also providing several test beams in the old experimental halls, but its days of providing beams for high energy physics experiments are over.

For the new projects at the DESY Laboratory, including the HERA storage rings, the old synchrotron is to be rebuilt for continued working as an injector, but this time for protons. For electrons, the machine group of DESY is building a new synchrotron which will be placed in the same tunnel. This will allow the new injector to be brought into operation without any undue interruptions for DORIS-II and PETRA.

The new electron synchrotron, called DESY-II, will be of the separated-function type and will reach a maximum energy of 9.2 GeV. The magnets will be placed inside those of the present synchrotron.

A prototype bending magnet for the new machine has already arrived and is under test. DESY-II will work with a repetition rate of 12.5 instead of the 50 cycles per second used so far. Therefore a stainless steel vacuum chamber (0.3 mm walls) can

The new DESY-II synchrotron for electrons and positrons, inside the old DESY-I, which will be later rebuilt as DESY-III for a new lease of life injecting protons into the new HERA ring via PETRA.



be used in place of the ceramic one needed for the old synchrotron.

The installation of components will take place in a four-month shutdown starting this November. Injection and acceleration tests up to 1 GeV with a provisional dipole power supply will follow, while the faithful old DESY-I will continue to feed the storage rings with electrons and positrons.

In a second shutdown in the winter of 1985/1986, all injection and ejection channels of DESY-II will be connected and full magnet and r.f. power will be switched from DESY-I to DESY-II.

All this programme is being carried out within the normal DESY budget and will cost about 15 million DM.

After the second shutdown, the old synchrotron will enjoy a well-earned rest while being prepared and partially rebuilt for proton injection into HERA. Called DESY-III, this 'new' machine will use the DESY-I bending magnets which are of the combined function type and, with the addition of new quadrupoles and some optical manipulations, increase the transition energy to a value higher than that required for proton injection into PETRA and from there to HERA.

CERN

More protons for antiprotons

Now that the CERN antiproton project has shown itself such a scientific success, the quest is on to squeeze more antiprotons into the big SPS ring. Thus at the end of last year, CERN Council approved the antiproton improvement programme (see January/February issue, page 23). This includes the construction of a new Antiproton Collector (ACOL) to capture more antiprotons for subsequent stacking in the Antiproton Accumulator (AA), where the precious particles are stored before being sent into the SPS ring.

As well as the ACOL ring (which will surround the AA ring in the existing AA hall), improvements are being implemented and other ideas studied all the way down the line.

The antiprotons are formed when proton beams strike a target, and one way to get more antiprotons is simply to have more protons hitting the target. However the AA (and later ACOL) can only accept single turn injection. As the AA's circumference is only a quarter that of the PS, the proton beam in the PS can only fill a fraction of the machine's circumference before being ejected towards the antiproton production target.

The PS is fed in turn by the four ring Booster, and experts have been looking at various schemes to concentrate the PS beam (which normally consists of 20 bunches) by playing tricks with the ejection and recombination of the beams from the four Booster rings.

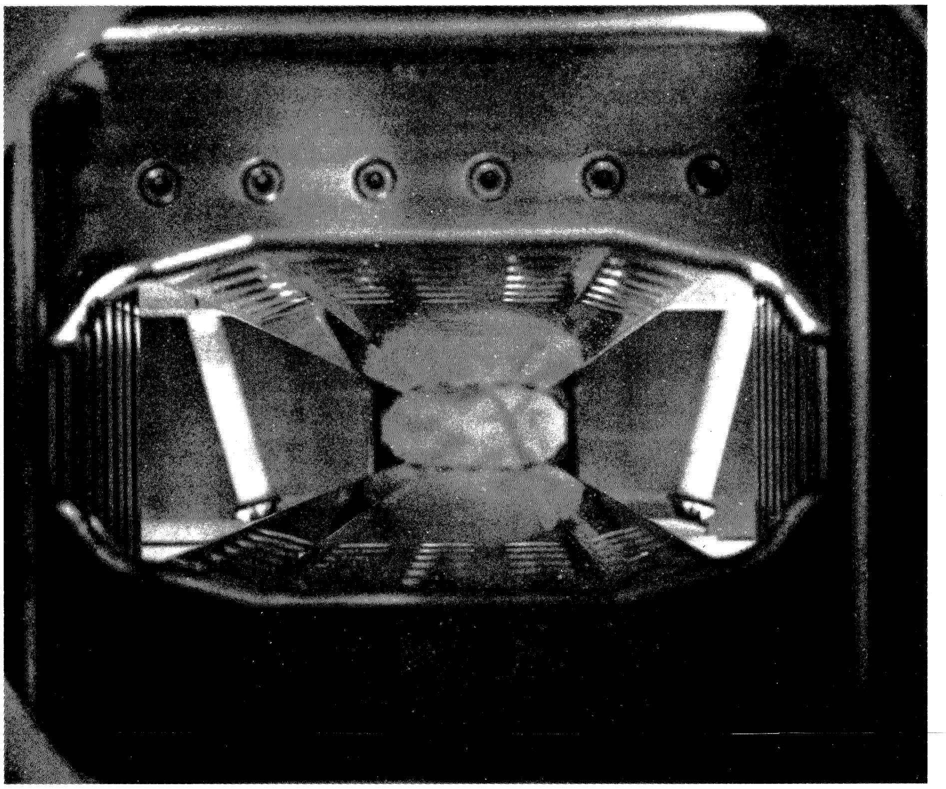
One scheme already tried is to vertically superimpose bunches from two rings in pairs (ring 3 with 2, and 4 with 1). Unfortunately the increase of the vertical size of the recombined beams led to beam losses and limited the intensities available this way. Thus for normal antiproton operation at present, beams from only two Booster rings are used.

The new scheme proposed by George Nassibian uses an r.f. (8 MHz) dipole to control the vertical recombination of the beams and enable successive bunches to be interleaved. This unusual dipole, designed, built and tested all within a year, is a resonator with horizontal magnetic field and sinusoidal vertical deflection (4 mrad in either direction).

In initial tests, it successfully recombined high intensity beams from rings 2 and 3 (each about 7×10^{12} protons per pulse). The necessary ejection gymnastics were accomplished very smoothly. The PS now has the problem of capturing and accelerating this intense recombined beam, so that the AA can benefit from the 80% increase in the level of injected beam intensity.

This form of recombination has been considered before for handling linac beams in inertial fusion studies, but it is thought that this is the first time beams have actually been recombined in this way.

(From K. Schindl)



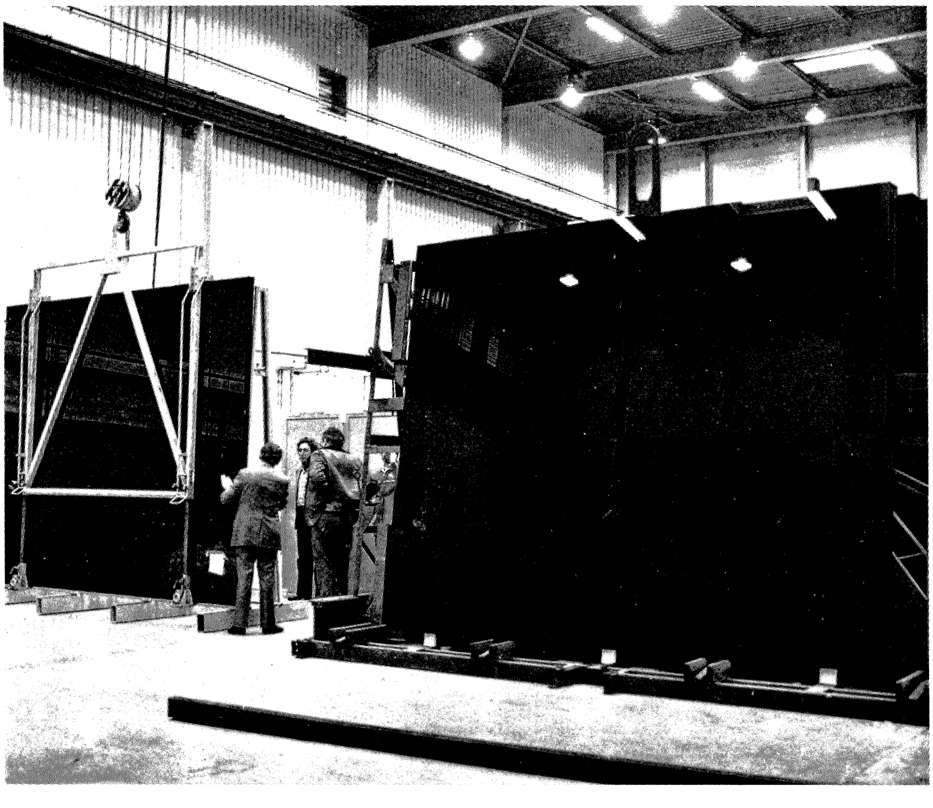
View of the 8 MHz beam deflecting magnet installed in the transfer line between the CERN Booster and Proton Synchrotron to interleave successive bunches from the Booster's four rings.

(Photo CERN 791.11.83)

CHARM II

The scattering of (muon-type) neutrinos by electrons was first observed in the Gargamelle heavy liquid bubble chamber in 1973, and provided the first evidence for the neutral current of the weak interaction. For the first time, weakly interacting particles (leptons) were seen to interact without having their electric charges shuffled around, as predicted by the electroweak theory.

Once the discovery had been made, it opened a new, and very clean, window on particle interactions. Neutrino-electron collisions involve only pointlike particles (to the best of our knowledge!), and thus involve a minimum of confusing background effects. Unfortunately they are extremely rare. Only about a hundred such events have been collected in the past ten years. To improve these meagre statistics, new



The glass sheets to form the targets for the new CHARM neutrino experiment arrive at CERN.

(Photo CERN 673.2.84)

detectors are needed. Thus a new project — CHARM II — has been approved for installation in the high energy neutrino beam of the 450 GeV Super Proton Synchrotron. It will provide several thousand neutrino-electron scattering events.

The first CHARM detector, installed immediately downstream of the big WA1 (CERN / Dortmund / Heidelberg / Saclay) neutrino detector, began operation in 1978. Designed to probe the structure of the nucleon as revealed by the neutral current, CHARM I has carried out sterling work over the years, including amassing most of the world stock of neutrino-electron scattering data, studying the structure and coupling strength of the weak neutral current, helping to pin down the Weinberg parameter in the electroweak theory, and extending the search for neutrino oscillations.

(The 'CHARM' acronym comes from the original collaborating institutions — CERN, Hamburg, Amsterdam, Rome and Moscow, conveniently disregarding the conventional alphabetical ordering. For the new project, Amsterdam is replaced by Naples, but the CHARM label still sticks!)

CHARM I combined the features of a hadron calorimeter (measurement of deposited energy) with a fine-grained matrix of scintillation counters and drift tubes, enabling the direction, as well as the energy, of produced showers to be measured. In 1979, a comprehensive system of fine streamer tubes, similar to that adopted for the Mont Blanc proton decay search, was added to further improve the spatial resolution of shower measurements (see July/August 1981 issue, page 252).

Drawing on the CHARM I experience with these streamer tubes, the new detector will be composed of 420 3.7 m square modules, each composed of a 4.8 cm-thick plate of glass covered with a plane of streamer tubes with 1 cm wire spacing. Wire orientation is shifted by 90° in successive modules and position is shifted by half a wire spacing. With analog electronic readout, the centre of a track or vertex can be reconstructed to within 2 mm.

As well as neutral current interactions (elastic scattering of neutrinos and leptons), the detector will also study charged current lepton interactions, chiefly through 'inverse muon decay' — when a muon-type neutrino hits an electron, producing a muon and an electron-type neutrino. The 7 m-long muon spectrometer for CHARM II will use the same toroidal iron magnets used in the WA1 neutrino experiment, complemented by planes of drift chambers. CHARM II is scheduled to begin operations next year.

On the gallery (top right), the new CERN radio-frequency quadrupole is dwarfed by the Cockcroft-Walton machine it replaces. To the left of the RFQ is the housing of the ion source.

(Photo CERN 114.3.84)

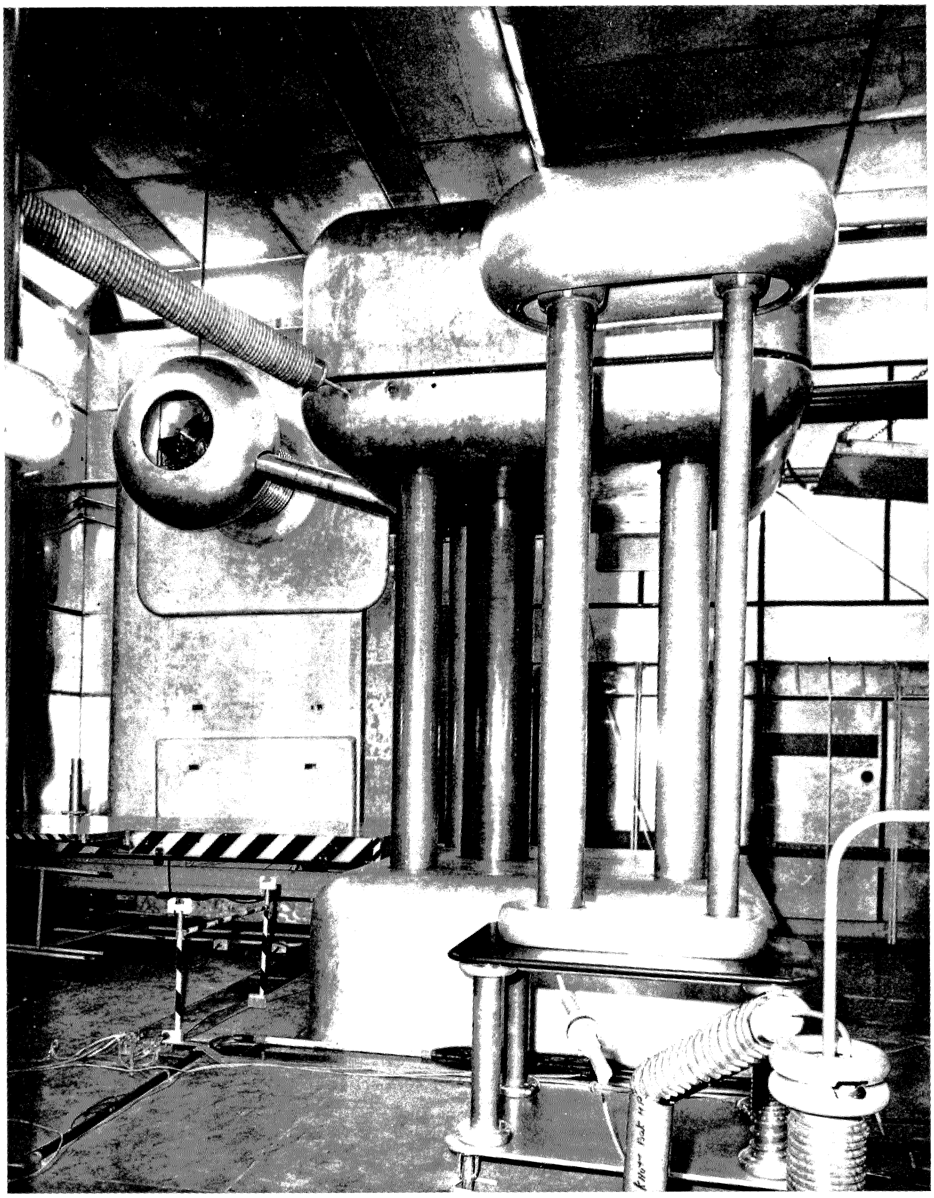
PREACCELERATORS New technique in action

Many Laboratories throughout the world are now using or constructing radio-frequency quadrupoles (RFQs). These are simultaneous r.f. linacs and focusing quadrupoles which provide a new and more effective way of handling the preacceleration, focusing and bunching required for the injection of beam into the downstream linac.

Last month (see page 100) we reported first operation of the RFQ at Brookhaven, and now comes news of RFQs at CERN, Los Alamos and Saclay. (No doubt there are others!) At CERN, the RFQ has provided its 80 mA design current, which was subsequently accelerated in the linac (Linac 1) to provide a test beam for the

The traditional Cockcroft-Walton preaccelerator at CERN's Linac 1. Such machines are fast becoming museum pieces.

(Photo CERN 127.3.74)



LEAR Low Energy Antiproton Ring.

This novel type of accelerator will go on to play a vital role in providing beams of heavy ions for acceleration in the complex of CERN's machines (see July/August 1983 issue, page 223).

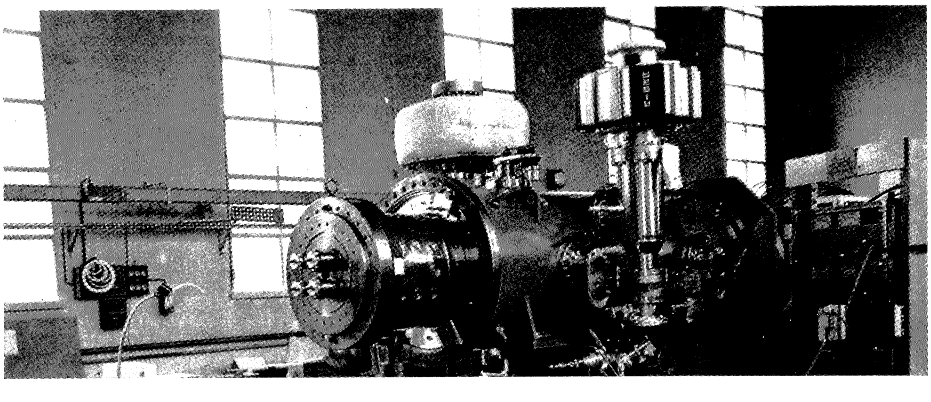
At Los Alamos one 2 MeV RFQ has approached its design power level, while a second is being developed for the Fusion Materials Irradiation Test Project at Hanford.

At the French Saturne machine at Saclay, an RFQ has been commissioned, working with the Cryebis source of totally stripped ions. This will enable the machine to fill out its range of projectile particles, so far restricted to light ions up to helium, but with the important addition of polarized protons and deuterons.

In February, fully stripped nitrogen ions were handled by the RFQ, and by the beginning of March, everything was ready for injection into the linac. After an initial test with alpha particles (same charge to mass ratio), nitrogen ions were accelerated to 250 MeV per nucleon and ejected. Subsequently, the total energy was boosted to 13 GeV (930 MeV per nucleon) without loss.

These tests demonstrated the excellent behaviour of the new preinjector system and the high levels of stability achieved in the main ring, even when handling such delicate beams (10^7 charges and below). Now that the way is clear, proposals for heavy ion experiments will be examined by the Experiments Committee.

For the future, the new Dioné source of completely stripped ions will gain a factor of ten in ion intensity, and will provide ions heavier than the current limit (argon) of Cryebis. In



A view of the radio-frequency quadrupole at the French Saturne machine at Saclay.

(Photo Saclay)

People and things

addition, the MIMAS booster is scheduled for completion in 1986. As well as accelerating very heavy ions, this could push the supply of light ions and polarized particles up by a factor of between 10 and 50.

MUNICH (MPI) / CERN New streamer chamber techniques

Many of the particles now being sought in high energy experiments are so short-lived that even at high energies (when relativity endows them with a longer lifetime), they travel only a fraction of a millimetre before decaying. To record the tracks of such transient particles and measure their lifetimes taxes the ingenuity of experimenters, and many new techniques have been developed to assist in these searches.

One method being worked on by a Munich (Max Planck Institute)/CERN team aims to use a triggerable streamer chamber to select out events of interest, providing a direct visual record of the interaction while eliminating the need to scan 'empty' photographs showing little of interest. They have built a small 50 mm diameter high pressure streamer chamber which has given encouraging results in initial trials.

With neon/helium filling at 20 atm, this chamber has shown itself capable of picking up some 60 streamers per cm, the diameter of each streamer being typically about 60 microns (the streamer diameter of a conventional chamber at atmospheric pressure is about 500 microns). When recording streamers holographically, for example with 13 atm helium/methane filling, streamer width as low as 25 microns has been achieved.

A completely new result from the team is the use of dark field illumination in this small chamber using a dye laser to illuminate the streamers. This technique overcomes the need for resolution-limiting image intensifiers to record the faint streamer light. A simple optical arrangement has already given tracks with good contrast (see photo). If higher pressure (some 25 atm) is applied, the track definition accuracy can be expected to improve to 10 microns because of the high streamer density (about 70 per cm). Even allowing for diffusion, the high resolution is still achieved because there are effectively many position readings along the particle track. This resolution is comparable to that achieved with silicon microstrip detectors.

A laser track recorded in a streamer chamber by a Munich (Max Planck Institute)/CERN team using a dye laser to illuminate the streamers. The track is 25 mm long in 8 atm. helium/methane, and the streamer diameter is about 55 microns.

On people

Arie van Steenbergen steps down as Deputy Chairman of the US National Synchrotron Light Source (NSLS) at Brookhaven to concentrate on accelerator research and development. Stepping in as interim Deputy Chairman is Mark Barton, former chairman of Brookhaven's Accelerator Department and recently head of the Brookhaven Heavy Ion Facility Laboratory Task Force. John McTague remains as head of the NSLS.

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.

PETRA inches higher

The peak energy collision energy in the PETRA electron-positron ring at the German DESY Laboratory continues to be nudged higher. After the 45 GeV 'record' set in December (see January/February issue, page 16), the energy has been taken to 47 GeV. Still no sign of the 'top' particle, however.

Meanwhile the first complete superconducting bending magnet for the proton ring of the approved HERA electron-proton collider attained 6000 A on 23 March, beyond the 5636 A level required for HERA operation, without a quench and on its first cooldown to 4.45 K.

F meson mass

One of the talking points at last summer's conferences was a new measurement of the mass of the F meson by the CLEO group at the CESR electron-positron ring at Cornell, USA. The F meson (which carries both strangeness and charm quantum numbers) was first attributed with a mass of about 2020 MeV, but the CLEO group found instead a value of 1970 MeV (see January/February issue, page 15). This was quickly corroborated by the ARGUS group at the DORIS II electron-positron ring (see December 1983 issue, page 422), and by the TASSO group at the PETRA electron-positron ring, both at the German DESY Laboratory.

Now another F measurement in line with the new value comes from the Amsterdam / Bristol / CERN / Cracow / Munich / Rutherford experiment (NA 11) at the CERN 450 GeV Super Proton Synchrotron. Using a telescope of high resolution silicon microstrip detectors to measure six events, the mass of the F meson comes out as 1975 ± 4 MeV.

The experiment also measures the lifetime of the F meson, giving a value of $(3.2 + 3.0 - 1.3) \times 10^{-13}$ s, which is interesting to compare with the measured lifetimes of charged and neutral D (charmed) mesons.

High Field Workshop

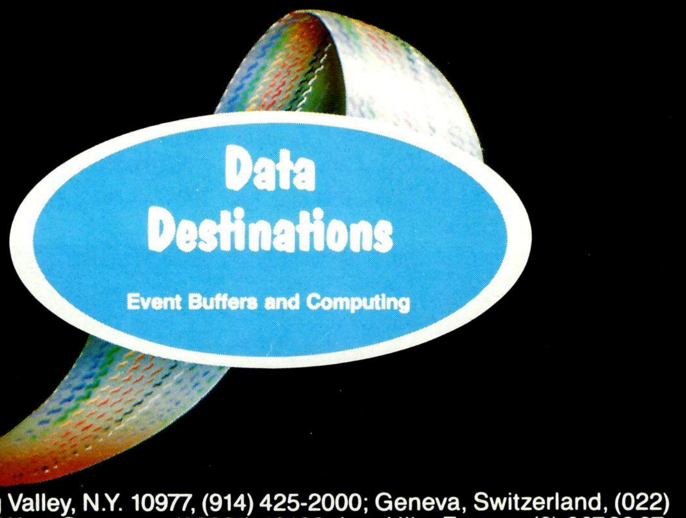
The CERN Accelerator School, the European Committee for Future Accelerators (ECFA) and the Italian INFN are organizing a workshop on the generation of high fields for particle acceleration to very high energies, to be held at Frascati from 25 September to 1 October. Its aim is to stimulate studies of methods for generating high electric fields which could possibly lead to new methods of particle acceleration, and to attract specialists from the areas of plasma and laser physics as well as conventional accelerator physics. Participation will be limited to about 80. For further information, contact P. Bryant, LEP Division, CERN, CH-1211 Geneva 23. The closing date for applications is 1 June.

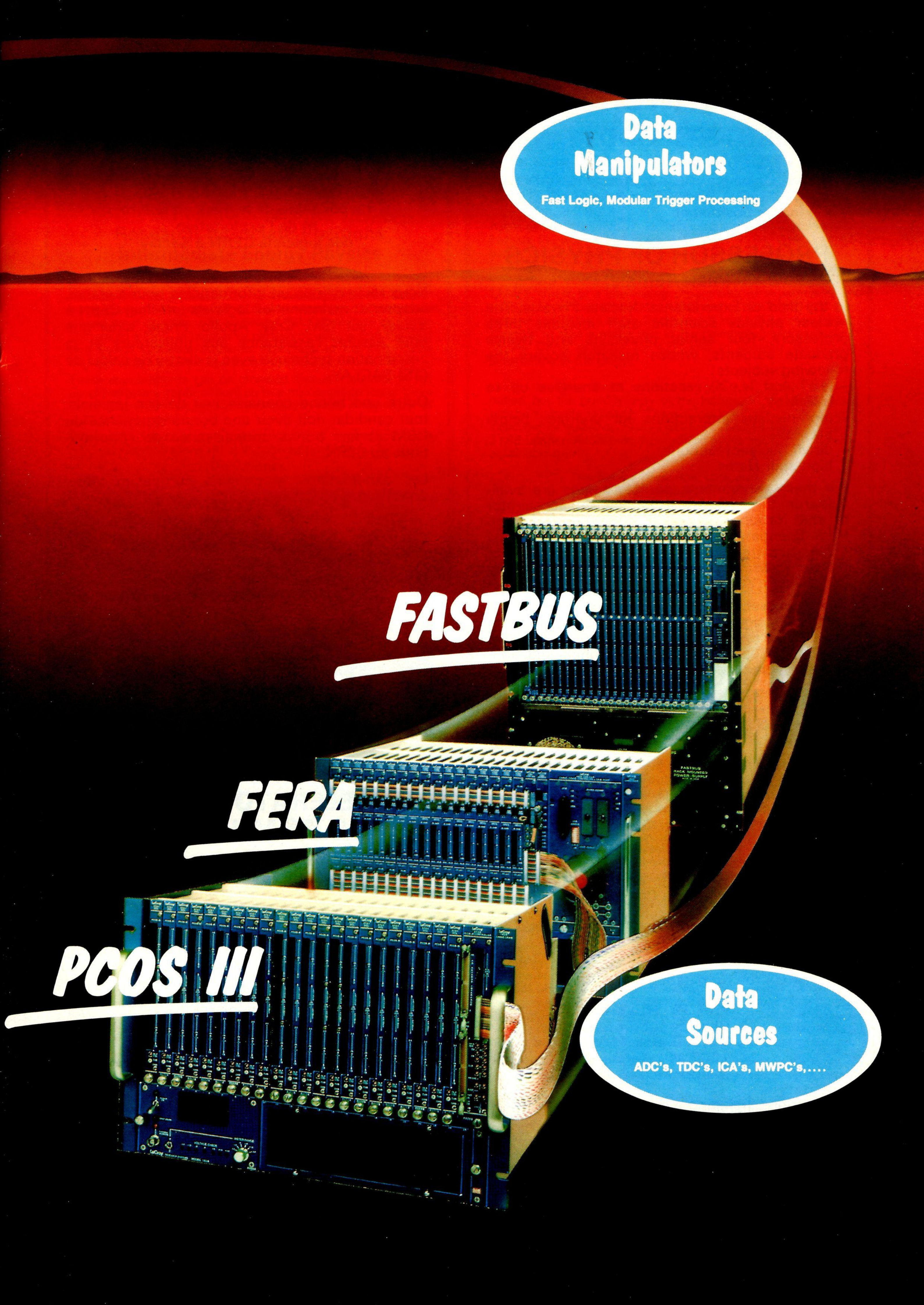
Snowmass

From 23 June to 13 July, a meeting is being organized at Snowmass (Colorado) for the US high energy physics community to help contribute towards the definition of the proposed Superconducting Super Collider (SSC). It will also help inform the community of the progress being made in both identifying and solving the technical problems involved. Further information from Joanne Day, Argonne National Laboratory, Building 362, Argonne, Illinois 60439, USA.

CERN Director General (and former DESY Director) Herwig Schopper (left) visited the DESY Laboratory in Hamburg early in March for a colloquium arranged to mark his 60th birthday. Former professors and students joined his colleagues past and present to add their congratulations and to recall his forty very active years in physics. Here he is greeted by Alexander Hocker (right), who played an important role in the creation of CERN and DESY, watched by a smiling Hans-Otto Wüster.

(Photo DESY)


Data
Destinations
Event Buffers and Computing


Data Manipulators
Fast Logic, Modular Trigger Processing
FASTBUS
FERA
PCOS III
Data Sources
ADC's, TDC's, ICA's, MWPC's,....

vrije universiteit
amsterdam

The Free University (VU) at Amsterdam, Department of Physics and Astronomy, invites applicants for the position of

PROFESSOR OF PHYSICS
(male/female)

in the field of Experimental Nuclear Physics. The nuclear physics scientific staff includes three professors, four senior physicists and twelve graduate students, whose research covers the following subjects:

- (e,e') and (e,e'X) reactions at energies up to 500 MeV,
- pion-nucleus interactions for energies below 50 MeV,
- direct nuclear reactions,
- high-spin states.

For these experiments particle beams are available from the 500 MeV linear electron accelerator of the Nationaal Instituut voor Kernfysica en Hoge-Energiefysica at Amsterdam (in which the VU participates), the K = 160 MeV cyclotron of the Kernfysisch Versneller Instituut at Groningen and the own K = 30 MeV cyclotron.

The successful candidate should be able to contribute significantly to the further development of the research programme especially in the area of nuclear structure studies, including non-nuclear degrees of freedom.

Although emphasis should be given to experiments with electrons, hadronic reactions may also be included. Participation in the teaching programme and administrative duties is expected.

Applicants should have an extensive and internationally recognized experience in experimental nuclear physics, preferably at intermediate energies; they must also have a thorough theoretical background. In addition they should have a good teaching record at undergraduate and graduate level.

Applicants are expected to respect the principles of the Free University as a Christian Institution.

The salary will be according to the Dutch Civil Servants Code.

Further information may be obtained from the chairman of the Nominating Committee,

Prof. Dr. H. Verheul,
Physics Laboratory,
VU, P.O. Box 7161,
1007 MC Amsterdam,
telephone 020 – 548 2469.

Applications including a curriculum vitae, a list of publications and the names and addresses of three references should be addressed, **quoting vacancy reference number 590-0534, before July 1st, 1984 to Vrije Universiteit, Afdeling Personeelszaken, Hoofdgebouw, Kamer 1E, De Boelelaan 1105, 1081 HV Amsterdam.**

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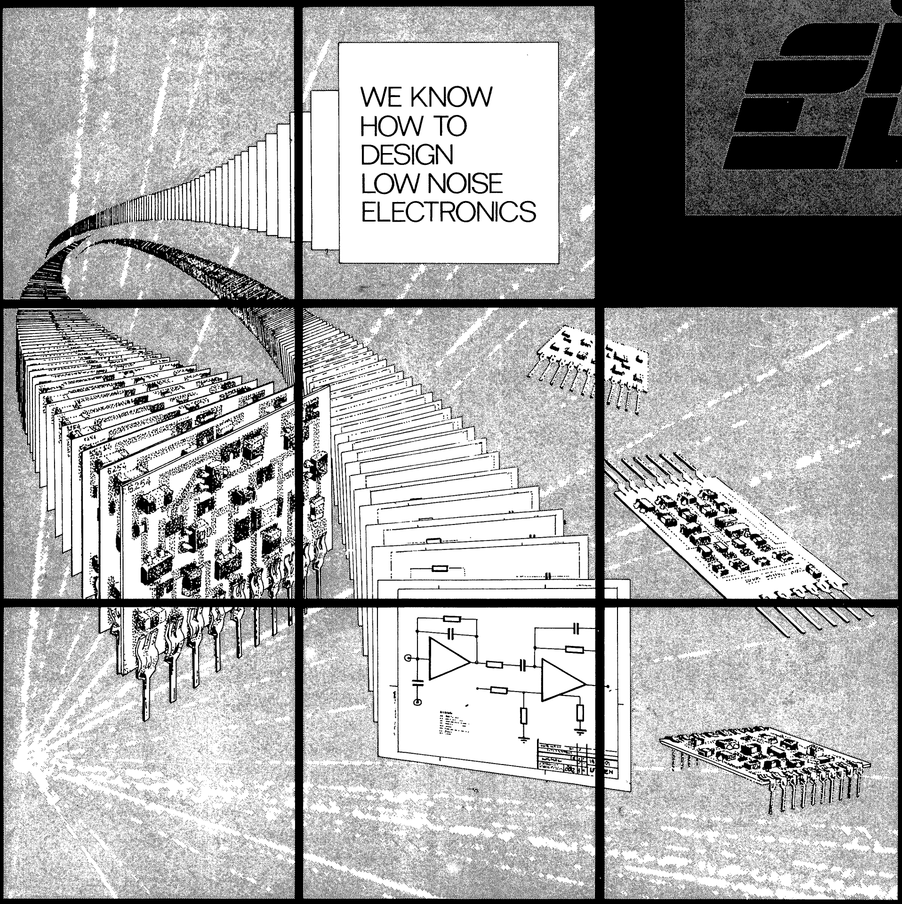
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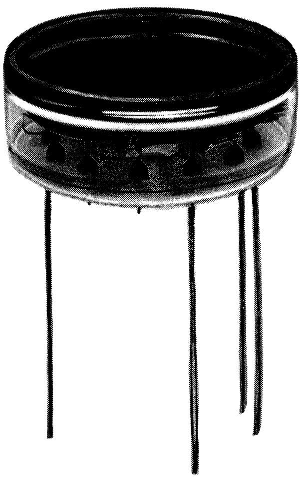

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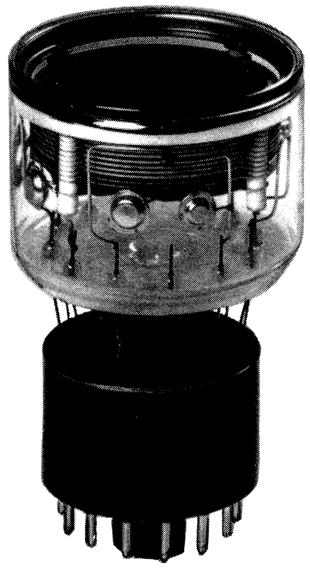

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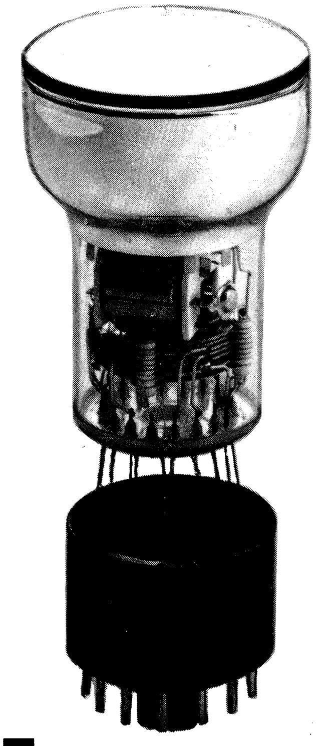

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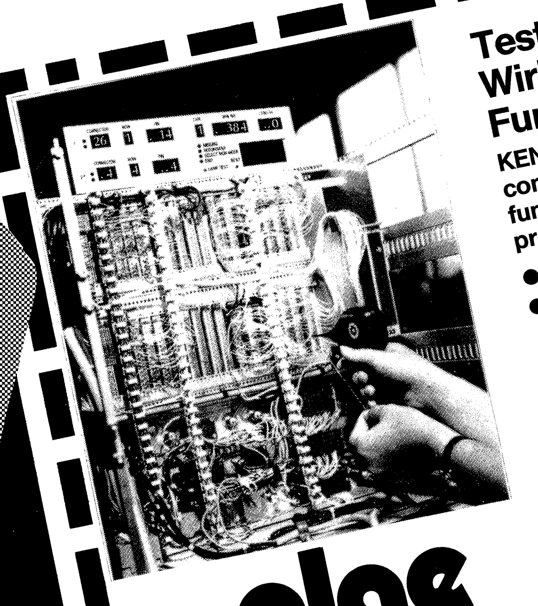

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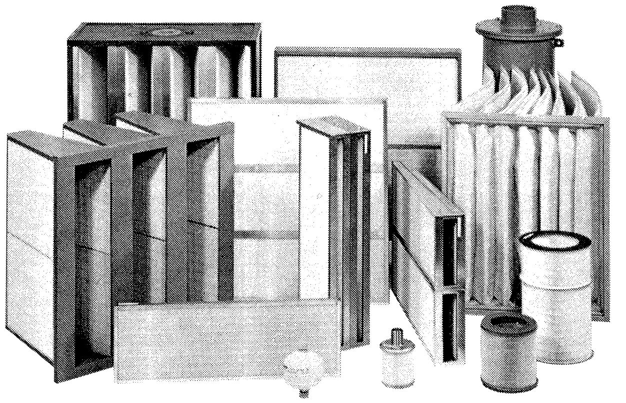

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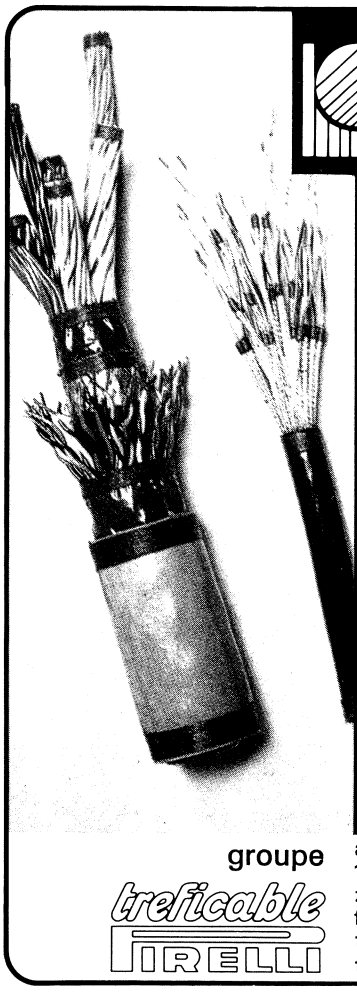

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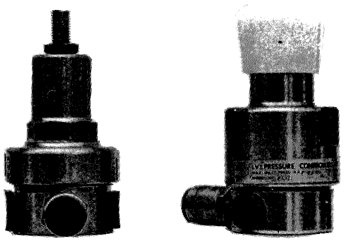

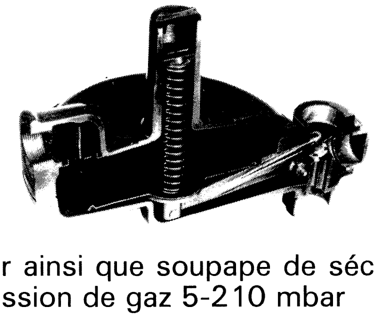

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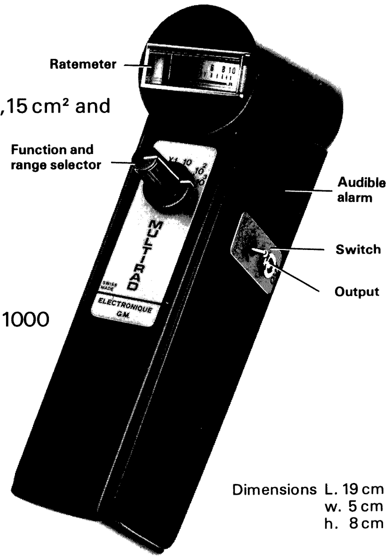

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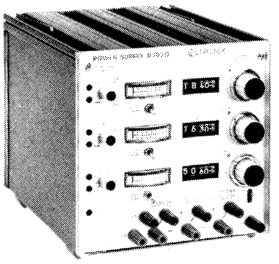

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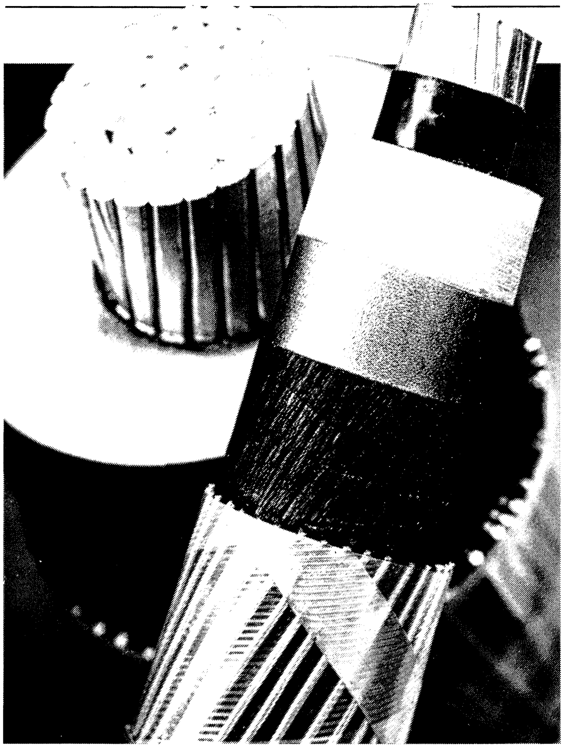

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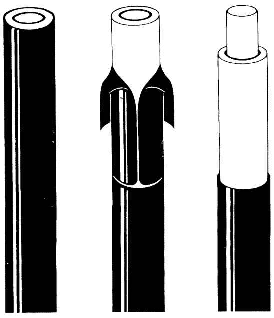

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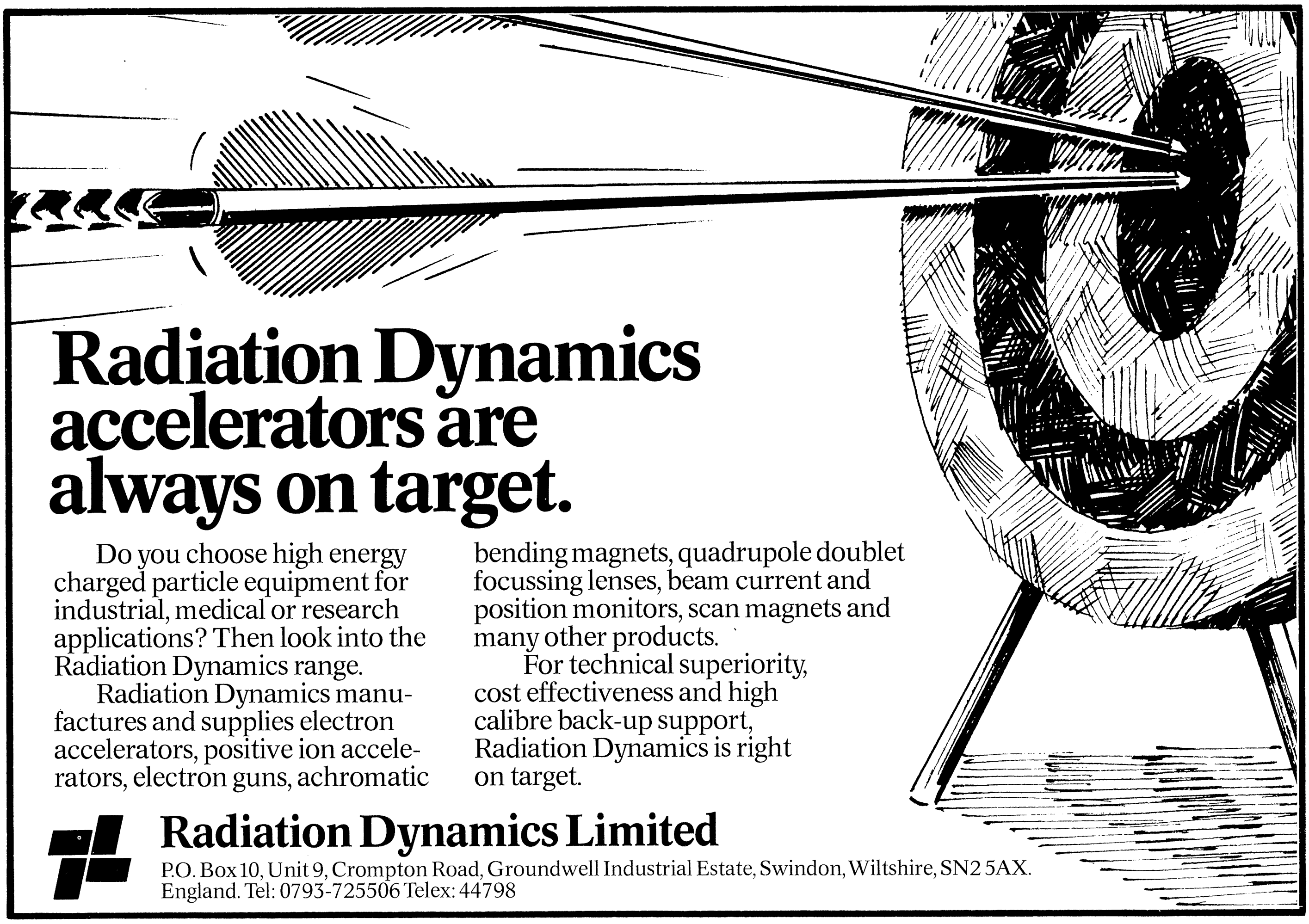

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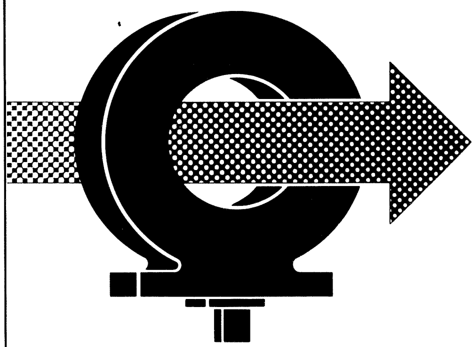

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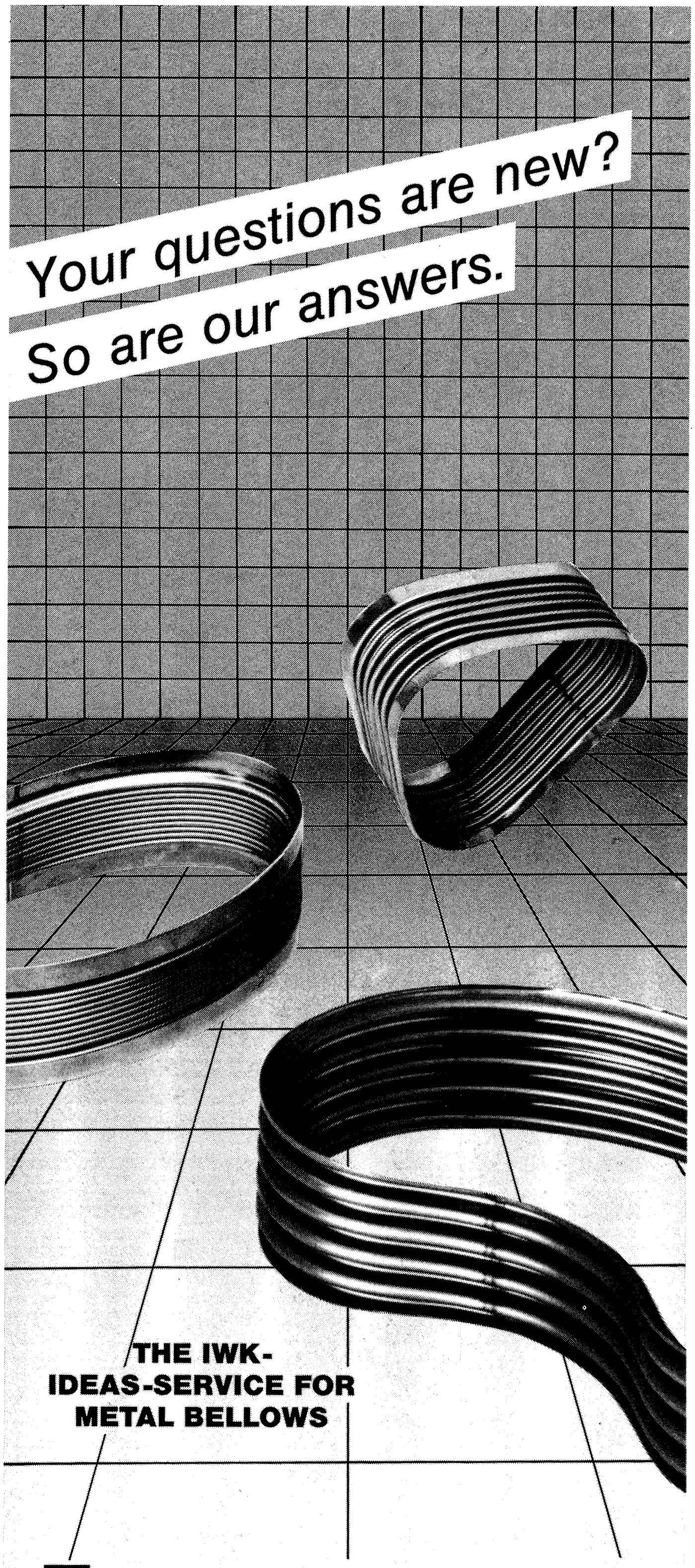
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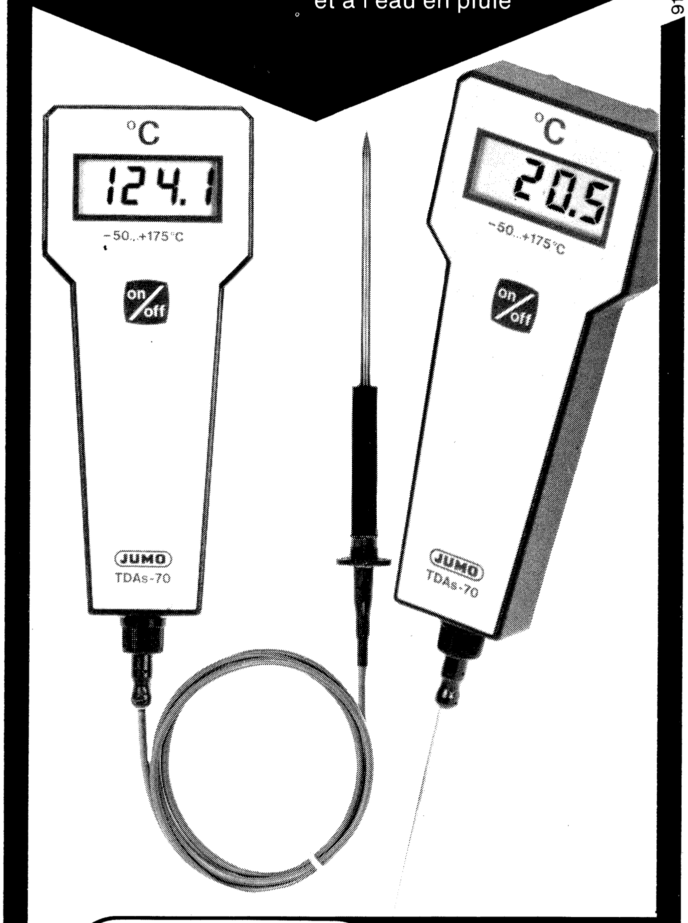
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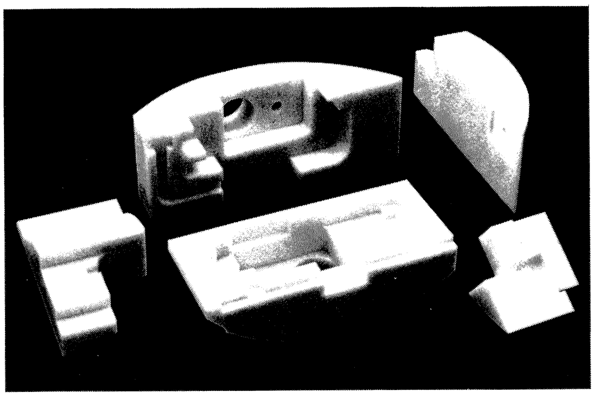

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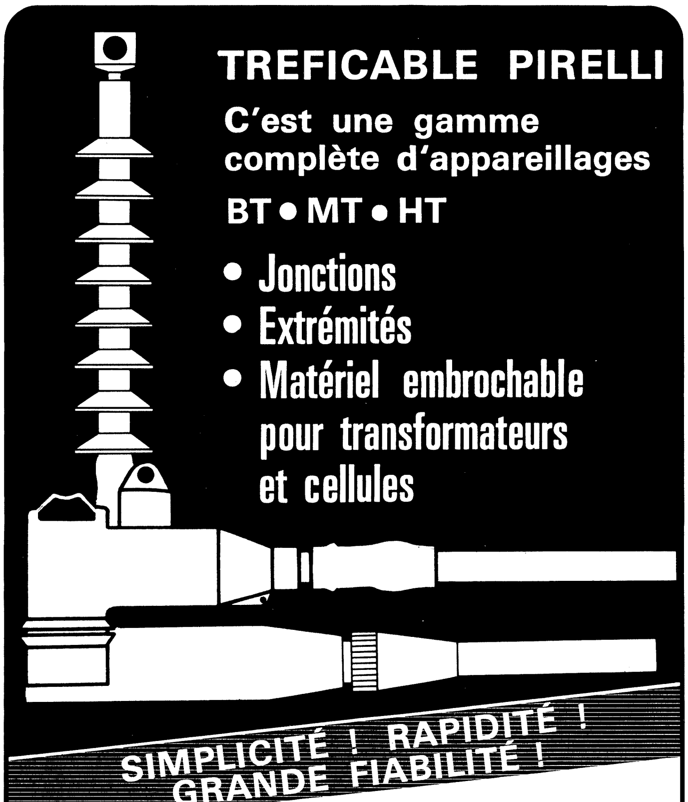

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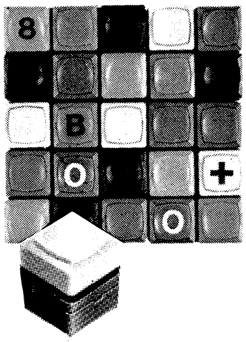
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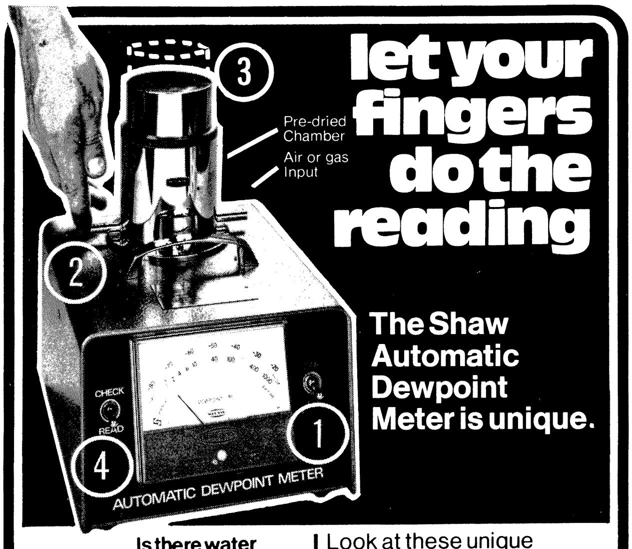
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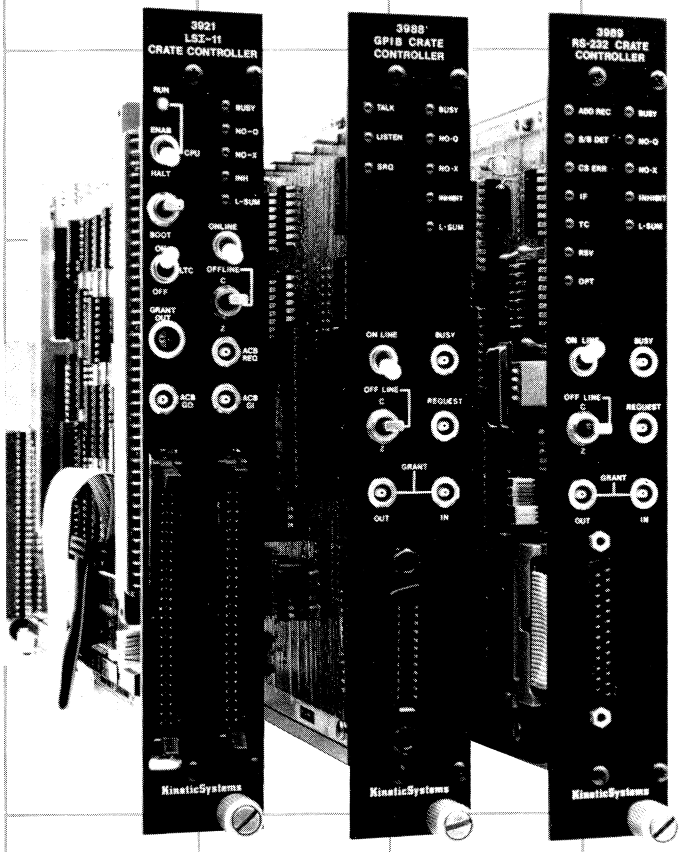

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3921
LSI-11 CRATE CONTROLLER

Houses an LSI-11/2, LSI-11/23, or SBC-11/21 DEC processor for stand-alone or auxiliary controller applications

- Features -

- Combined crate controller and processor
- Full LSI-11 bus compatibility
- 22-bit addressing capability
- Full software support
- Four I/O-mapped registers for all CAMAC operations
- Expandable via front panel LSI-11 bus
- Stand-alone or auxiliary controller
- Real-time clock

3988
GPIB CRATE CONTROLLER

Provides for CAMAC I/O in a GPIB-controlled system

- Features -

- Complete CAMAC/GPIB interface
- Full GPIB (IEEE-488) capability
- Single data transfers
- Q-scan and Q-stop block data transfers
- GPIB service request capability
- Switch-selectable talk/listen address
- Main or auxiliary crate controller
- Auxiliary controller support

3989
RS-232 CRATE CONTROLLER

Allows a CAMAC crate to be driven from a computer serial port, modem, CRT terminal, or other RS-232-compatible device

- Features -

- Computer independent
- Strap-selectable for RS-422
- User-selectable Baud rate and data format
- Main or auxiliary crate controller
- Auxiliary controller support
- Data link control signals
- Multidrop signalling compatibility
- Q-scan and Q-stop block data transfers
- PROM-based software
- Manual crate controller capability

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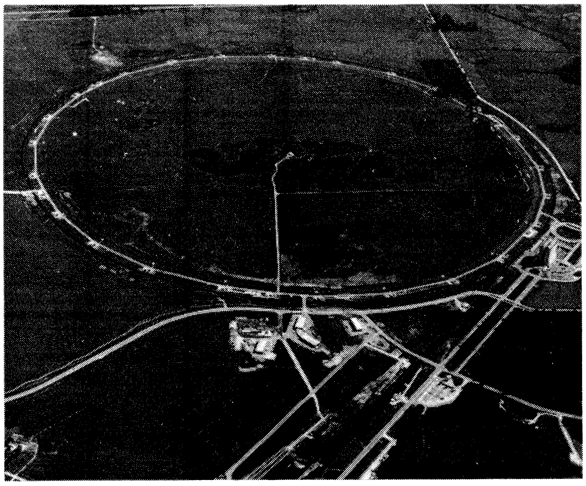

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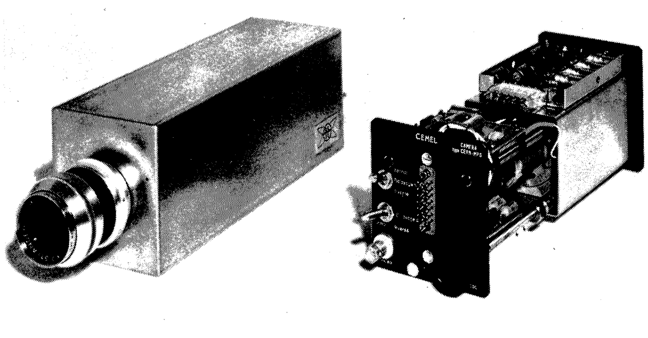

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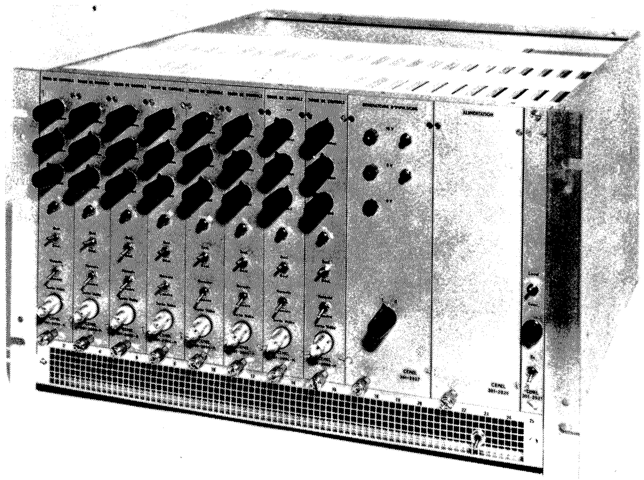

CAMERA CRATE

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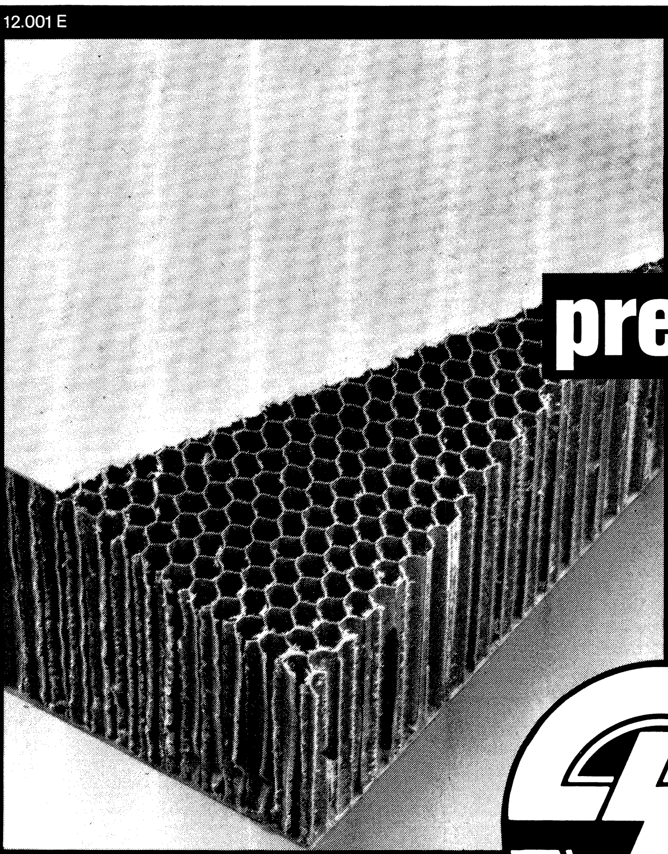

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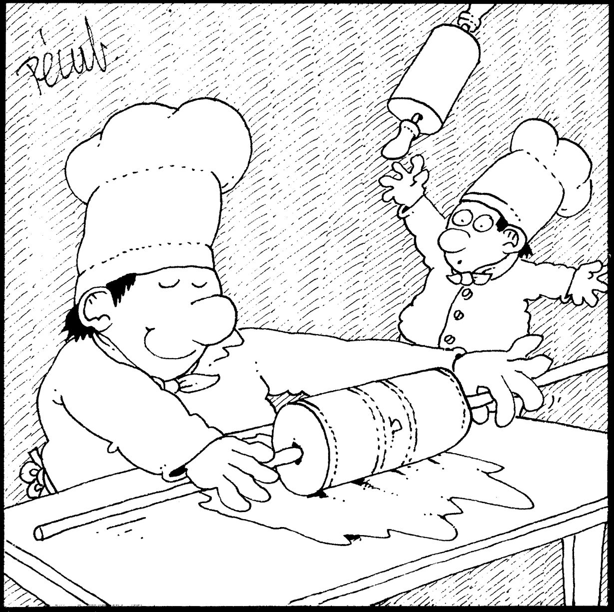

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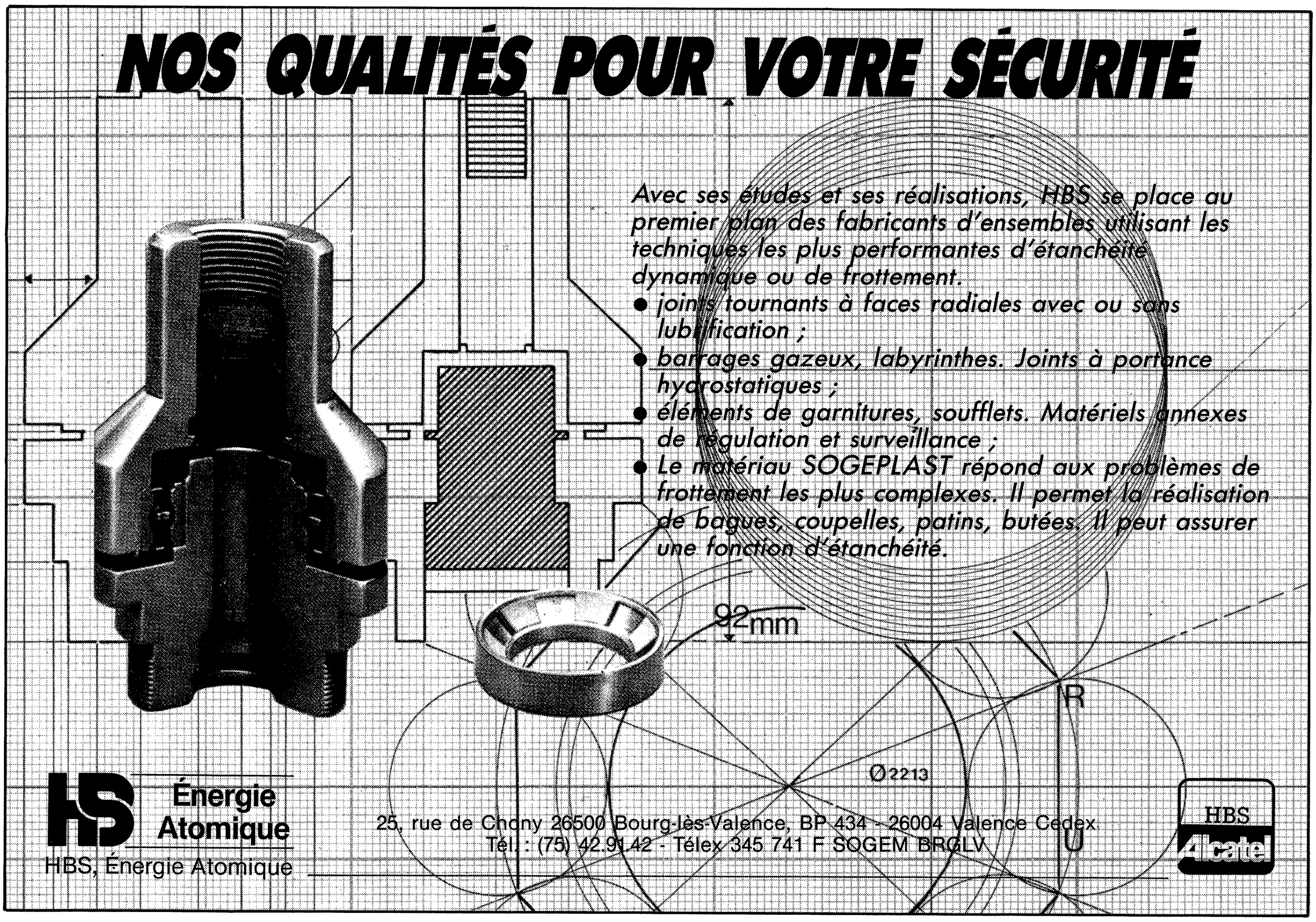
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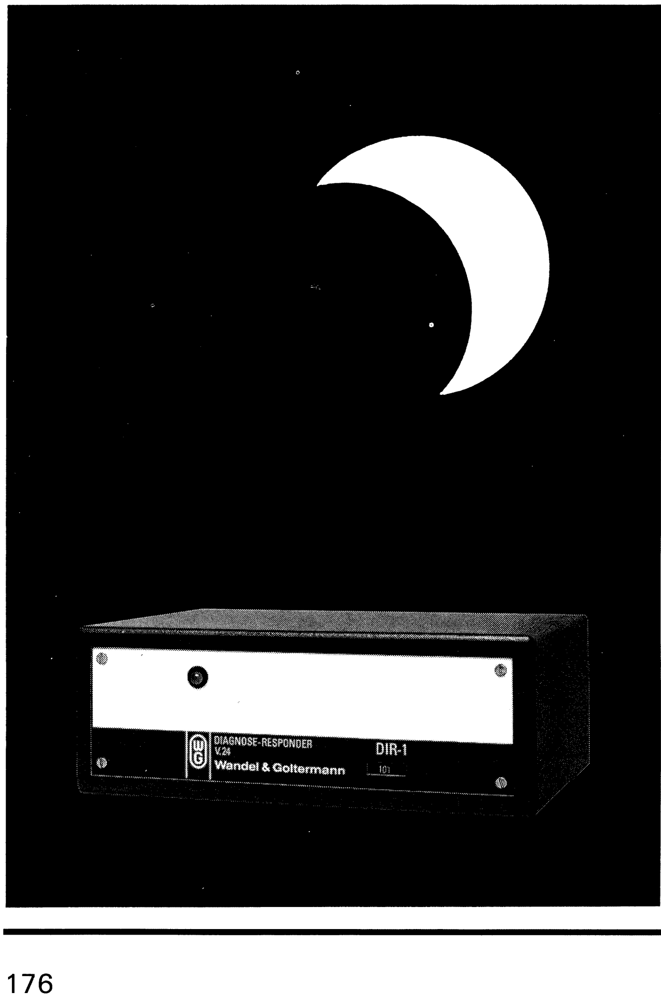
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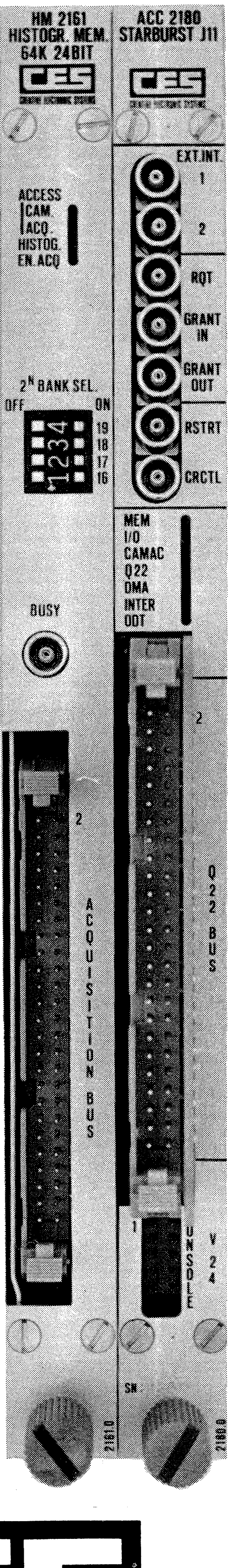

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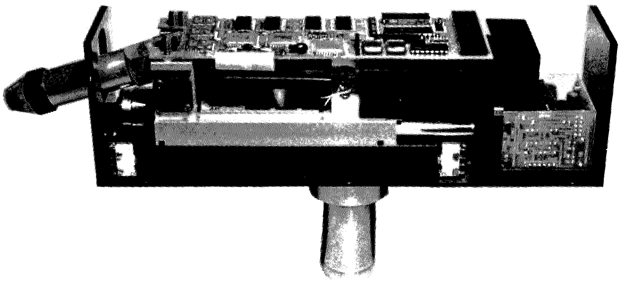

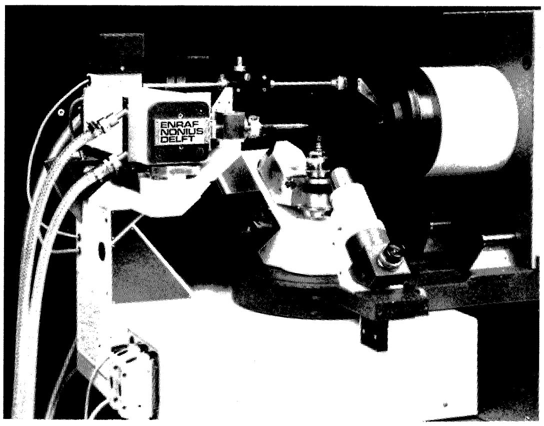
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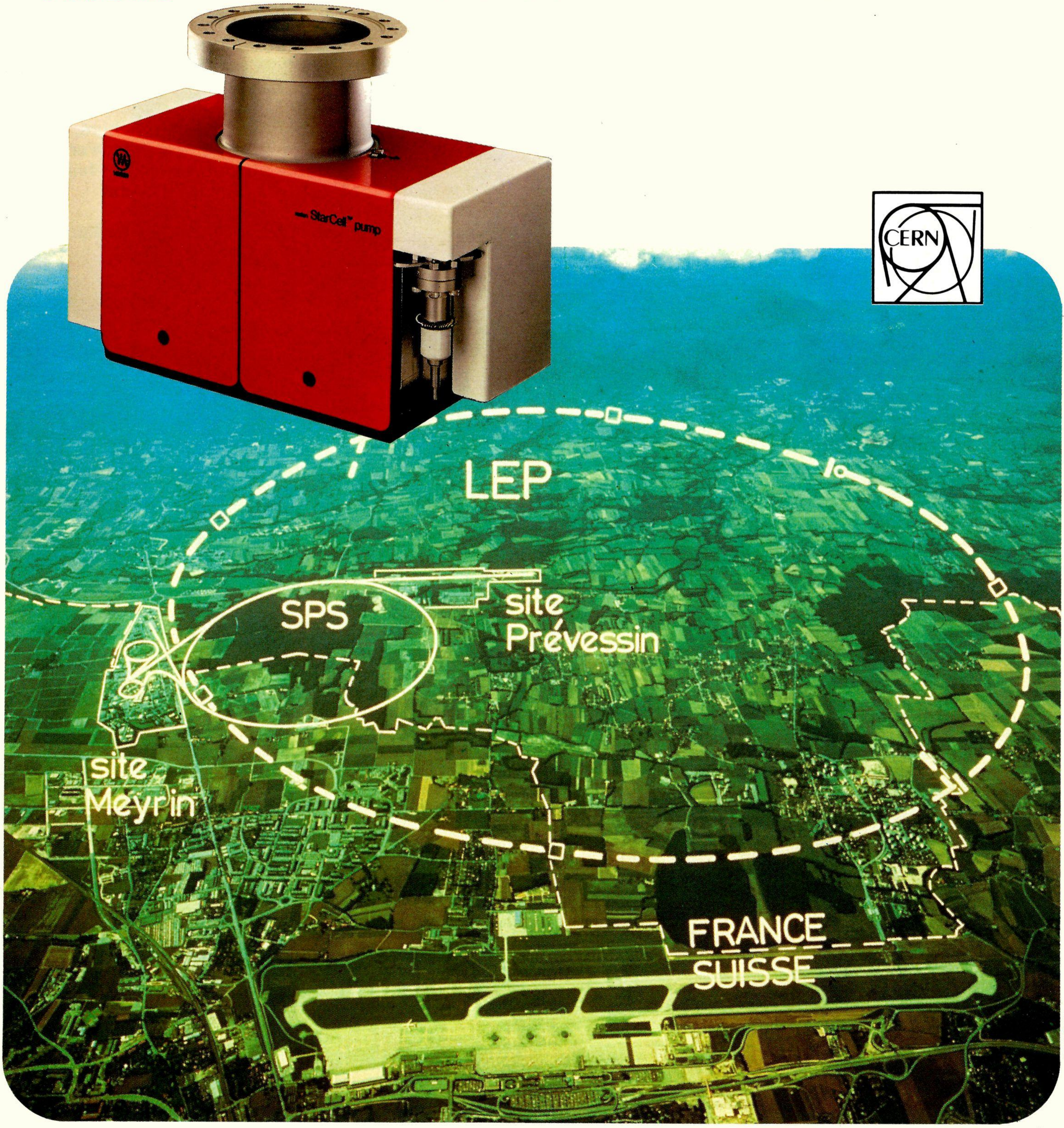

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