CERN COURIER

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Around the Laboratories

Cover photograph: The 12 kilometre Mont-Blanc road tunnel linking France and Italy through the Alps. In a side gallery, an experiment by a CERN / Frascati / Milan / Turin collaboration will look for signs of proton decay and other new phenomena. The implications of this and other new physics experiments are described by S.B. Treiman on page 404 in his survey of the current particle physics scene. (Photo Tunnel Routier sous le Mont-Blanc)

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Physics for ISABELLE

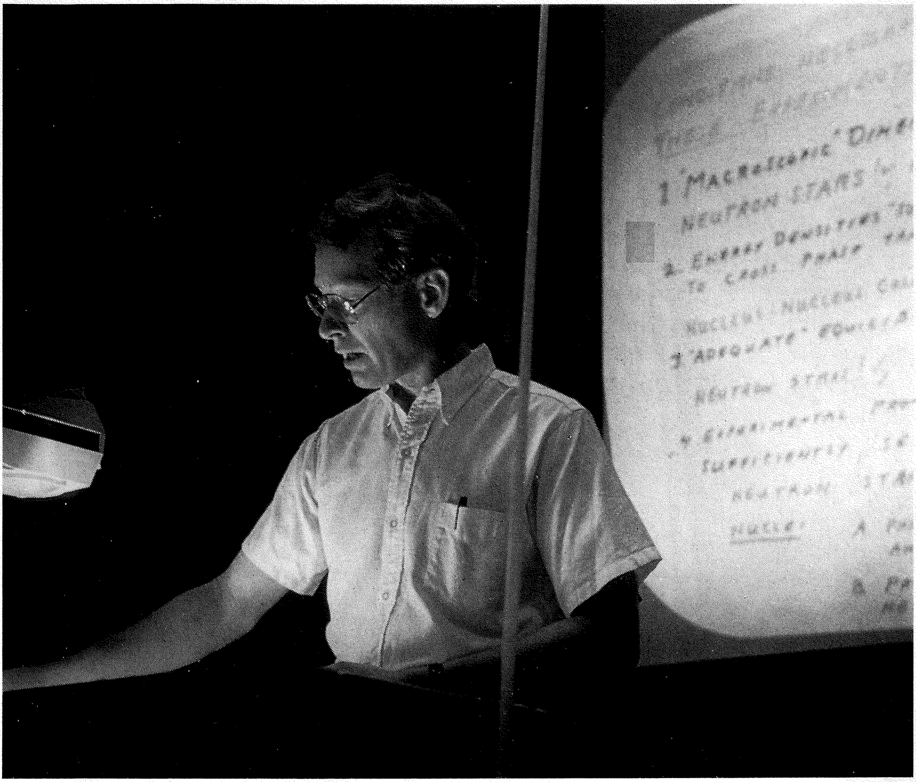
After the recent successes with the new prototype superconducting cable magnets, the future of the ISABELLE 400 GeV proton-proton storage ring project at Brookhaven suddenly looks much brighter (see October issue, page 353). While there is lot of work which remains to be done before the machine becomes operational, it is not too early to look at the physics possibilities which ISABELLE will offer when it turns on, hopefully in 1987.

This physics potential was well covered during this year's ISABELLE Summer Workshop at Brookhaven, which attracted some 250 participants. As well as speculating about new physics, this meeting also got down to some detailed groundwork for experimental areas and detectors.

The wide range of physics opportunities offered by the machine's high design luminosity (in the 10^{32-33} region) is well reflected in the variety of designs for large detectors which are emerging. With many exciting developments afoot in the fields of detectors and data handling, confidence is high that a lot of good physics can be extracted.

Introducing the sessions, workshop co-chairman Nick Samios underlined the attractions of proton-proton machines — high energy and luminosity, dedicated use and a relatively large number of available beam intersection regions. He pointed out the performance of ISABELLE's forerunner proton-proton machine, the CERN Intersecting Storage Rings, which has outstripped all expectations and still improves. On the other hand proton-antiproton colliders, the newcomers to the physics scene, cannot rival proton-proton luminosities, and have to share available beam time with fixed target experiments.

Samios emphasized that the primary physics goal at ISABELLE is the search for the unknown. Rather than describing it as offering a new window on physics, Samios preferred to view ISABELLE as opening a 'barn door', and likened other approaches to 'peepholes'.



Bill Willis puts the case for heavy ion collisions at the recent ISABELLE Workshop at Brookhaven.

ISABELLE's contributions to physics could cover many existing ideas — properties of weak bosons, and exploring the source of symmetry breaking, whether the long-awaited Higgs particles, or 'technicolour' effects. Searches could be made for extremely heavy new quark-antiquark bound states. However the detectors would probably have to adapt to new and possibly unforeseen experimental conditions.

The variety of detector designs were covered in sessions organized by C. Baltay and H. Gordon. LAPDOG is a high resolution spectrometer for electrons, photons and neutral pions envisaged by a Brookhaven / Brown / Columbia / Stony Brook collaboration which has already carried out experimental tests of large arrays of lead-glass counters. A detector design with uranium plates in a dipole field is being prepared by Brookhaven, Columbia and Pennsylvania. A lot of development has already gone into the design of a muon detector incorporating large drift chambers (signal wires 5 m long) by a highly international group with physicists from Europe, Japan and China as well as the US. The aim is to achieve a mass resolution of one per cent at 100 GeV. Another effort involves a toroidal magnet.

From the discussions during the sessions on large detectors, it was concluded that the development of a high precision vertex detector to detect rare particle decays would be useful. Later this year, the ISABELLE management will start to consider a schedule for proposals to occupy the machine's six beam intersection regions.

Sessions on detector research and development were organized by T. Ludlam and W. Carithers with the aim of assessing current detector know-how for ISABELLE's high event rates and the requirement for selective triggers. The usefulness of a detector component would be governed by its ability to select and record useful data using trigger processors, and efforts to improve selectivity at the detector/processor level were deemed important. Calorimeters, the central elements of most of the current detector designs, must have good spatial and energy resolution at relatively low cost. Improved electronics could help with specific problems for wire chambers and drift chambers. Particle identification under ISABELLE conditions has its own special problems. In all, the requirements provide a considerable challenge to detector specialists, both in the adaptation of existing techniques and the eventual use of new methods still at the prototype stage.

In summary, Samios said that the meeting reaffirmed luminosity and energy as ISABELLE's big selling points. Reactions (whatever they might turn out to be) with cross-sections as small as 10^{-35} cm^2 could be investigated. Recalling what had happened elsewhere, Samios pointed out that it is not always the earliest accelerator to turn on which produces the new results. 'It is important to do things right as well as fast', he declared.

In addition to the physics objectives, extensions of the original ISABELLE idea of proton-proton collisions are being put forward. An electron-proton option using 10-20 GeV electrons looks feasible and has stimulated a lot of interest. With more results now coming in from heavy ion collisions, ISABELLE, like the CERN ISR, could eventually find itself being used to collide beams of particles heavier than protons. With these additions, ISABELLE could provide in Samios' view 'the cornerstone' of the US high energy physics programme.

Participants at the Workshop had the chance to see the construction progress for the ISABELLE ring and experimental areas.

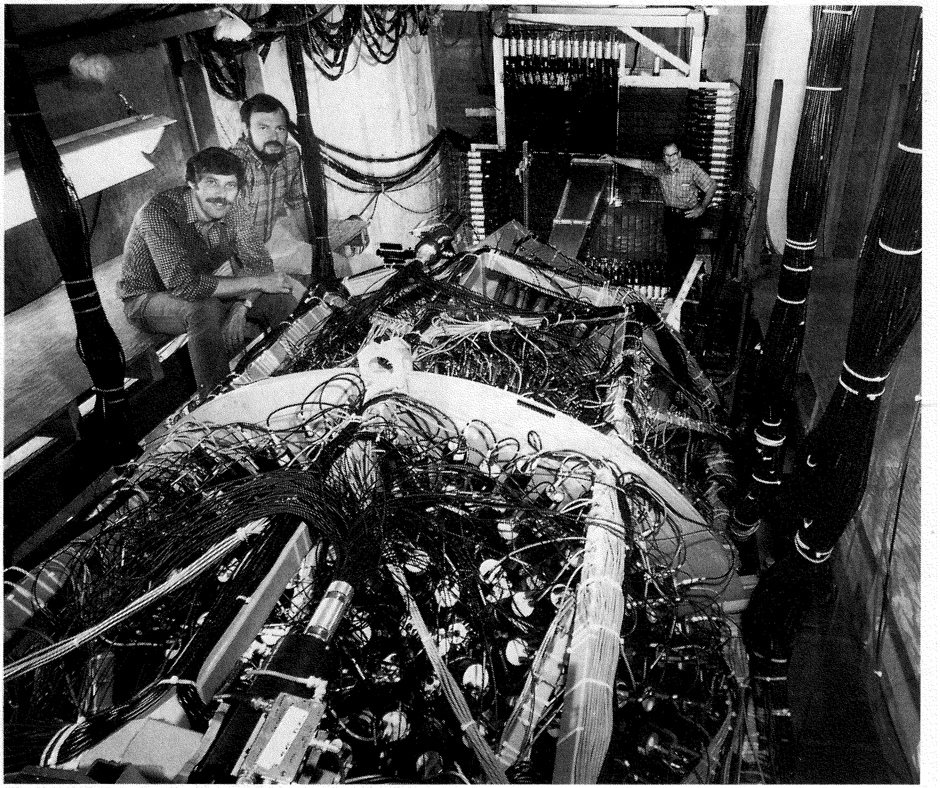
(Photos Brookhaven)

Relativistic heavy ion research at Berkeley

It is a project matching Ernest O. Lawrence's relentless enthusiasm for pioneering science, which he sustained even in the most unpropitious times. It would cost at least $100 million to build at a time when American politicians are slicing budgets at record rates and demanding accountability from Lawrence's legacy of 'big science'. It departs radically from recent studies at high energy accelerators, in which the interactions of six quarks in proton-proton collisions are viewed as complex, and argues instead for collisions between ultra-relativistic uranium nuclei that would involve thousands of quarks and gluons under conditions that hark back to the first few seconds of the Universe.

The project is VENUS (Variable Energy Nuclear Synchrotron), a superconducting collider for relativistic heavy ion research (see December 1979 issue, page 406). It is the most ambitious of several proposed facilities, such as Japan's Numatron, the USSR's TYS at Dubna, and Germany's SIS at GSI, Darmstadt, for extending the energy range for heavy ions beyond the highest available at the Bevalac (2 GeV/amu).

VENUS, with 1 TeV/amu equivalent energy for uranium-uranium collisions, would open the study of nuclear and particle physics to a totally new range of physical conditions, in which the very large energy densities customary in high energy particle collisions would be produced throughout the volume of a large nucleus. According to present expectations, a quark-gluon plasma will be produced. Many-body phenomena involving quarks and gluons are possible. The study of pions, kaons, hyperons, charmed particles, photons and lepton pairs produced under these unusual conditions should enable the transition to this new state of matter to be identified and explored and cast new light on the nature of the strong interaction.



A new detector in operation at the Berkeley Bevalac to study nuclear reactions. Called the 'Plastic Ball', it covers a full solid angle. 6 m downstream (rear) is the 'Plastic Wall' to pick up the most forward reaction products.

(Photo LBL)

LBL at CERN

The prospect of this pioneering research is tantalizing. LBL scientists, impatient to have a first glimpse of these new areas of physics before VENUS is completed, have also proposed using light ions in CERN's machines. One collaboration with GSI Darmstadt was proposed to build an ion source to produce carbon, oxygen or neon ions in the CERN Proton Synchrotron and to extend Bevalac-type experiments to energies several times higher.

In another collaboration, LBL joined with Los Alamos to propose a new linear accelerator for experiments at the CERN Intersecting Storage Rings using ions in the mass range up to argon or calcium. While the huge detectors at the ISR, designed for proton-proton collisions, will be strained up to, and perhaps even beyond, their limits to deal with the large multiplicities of secondary particles from nucleus-nucleus collisions, this programme could give a first indication of the physics to be opened up by VENUS.

Meanwhile, back at the Bevalac

A new chapter in this field is being opened at the Bevalac with the installation and initial operation of two major detector systems (HISS and the Plastic Ball/Plastic Wall). In addition, a project to extend the mass range of available heavy ions to uranium and to increase the intensity of lighter ions is scheduled for completion early next year.

The Heavy Ion Spectrometer System (HISS) follows the high energy physics tradition of recycling accelerators, since much of its 475 metric ton steel yoke is the old Michigan Cyclotron magnet. HISS has a 2 m diameter, 1 m gap 3 T magnetic field, together with a highly adaptable detector system that can be arranged in many different ways to suit the experimenter. It is planned to reconstruct the effective mass of correlated groups of fragments with an accuracy of about 1 MeV. This should be useful not only in searches for exotic phenomena but also in extending conventional nuclear physics studies.

The Plastic Ball/Plastic Wall (a GSI/LBL collaboration) is designed to cover 96 per cent of the total solid angle into which reaction products can be emitted. The Plastic Ball is a spherical array of 815 pyramidal scintillator detectors, each with its own electronics to identify and measure charged particles with energies up to about 200 MeV/amu. The Plastic Wall is placed 6 m downstream from the Ball, to detect particles within a few degrees of the beam and to identify them by their time of flight from the Ball. Like HISS, the Plastic Ball/Plastic Wall is designed for the study of extremely complex events and is provided with dedicated computers to cope with the torrent of information from such experiments.

The uranium beams project involved the installation of a third injector at the SuperHILAC (the injector for the Bevatron in the Bevalac scheme) comprising a new ion source plus a 750 kV Cockcroft-Walton and a Wideroe pre-accelerator needed to boost the velocity of uranium ions high enough for acceptance by the SuperHILAC's first tank. Experiments have been run with light ions from the new injector, and preliminary tests with gold ions look encouraging.

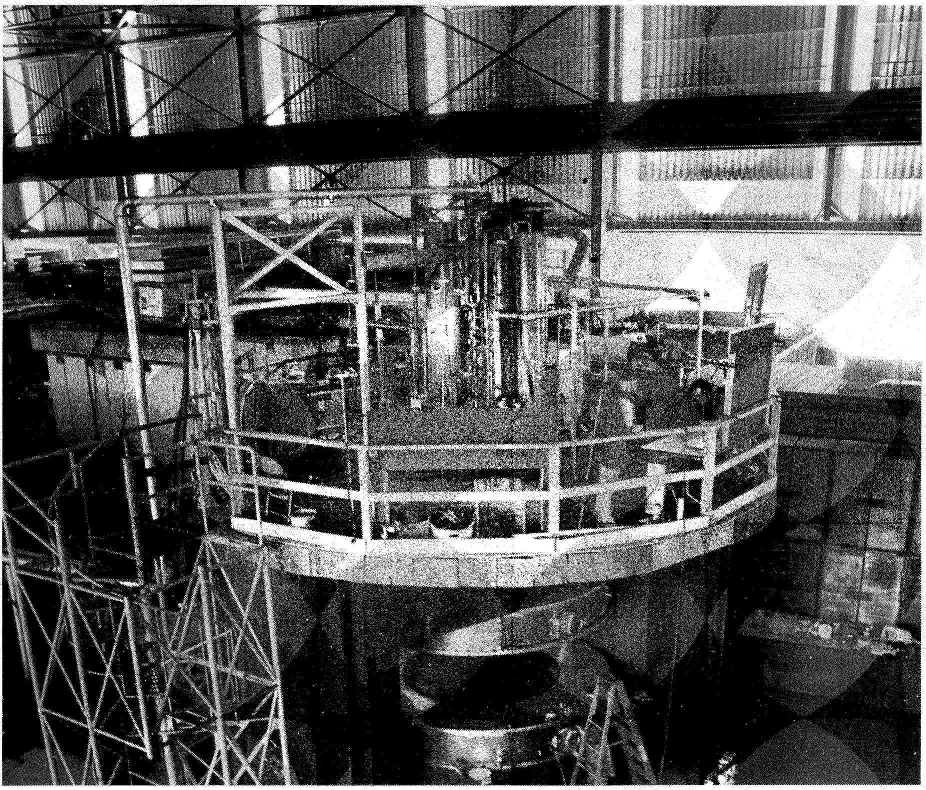
Work began in July to install a triple-walled cold-bore liner in the Bevatron to minimize losses from charge-exchange interactions by lowering the vacuum from 10^{-6} to 10^{-10} torr. The boxlike device, approximately 1 foot by 4 foot, is a cryopump that works by freezing out residual gas molecules on the cold surfaces of its two inner liners. This cold-bore design — which does not call for the precision assembly of printed circuit board and other common materials — eliminated costly attention to fabrication, quality control and technician training that a conventional all-metal ultrahigh vacuum liner would have demanded. The improved vacuum will allow uranium beams to be accelerated to an energy of 1.1 GeV/amu, extending the available mass range of projectiles above the presently available iron ions.

What justifies such enthusiasm for the future? When the Bevalac started, critics said that nothing could be learned because of the complexity of the interactions — it would be impossible to measure interactions in which hundreds of secondary particles were produced. They also said that, theoretically, such events would reflect only triviality since at these energies the nuclei would be almost transparent to each other and physics would consist only of nucleon-nucleon collisions confused by the Fermi motion of the nucleons within the nuclei.

On the other hand, enthusiasts pointed to exciting possibilities for new forms of nuclear matter, especially density isomers and pion condensates. After several years of experiments the critics have been confounded, the enthusiasts have been taught caution and international interest in this kind of research has intensified.

The most encouraging result from the Bevalac, and Dubna's

The heart of the new detector at the Bevalac, the Heavy Ion Spectrometer System (HISS), is this superconducting magnet which produces a 3 T field in a relatively large volume (2 m diameter, 1 m gap).



Installation of the cold-bore liner now under way at the Bevatron to achieve a vacuum of 10^{-10} torr so as to minimize losses from charge exchange interactions. The improved vacuum will allow uranium beams for the SuperHILAC to be accelerated to an energy of 1.1 GeV/amu, and thus extend the available mass range of projectiles beyond iron ions.

(Photos LBL)

Synchrophasotron, is that things are simpler than anyone had a right to expect. There is a clear distinction between participant and spectator parts of the interacting nuclei. In each collision, the two nuclei (seen by an observer looking in the beam direction) partially eclipse each other. The overlapping, or participant, regions fuse to become a hot fireball which spits out pions, kaons, and lambdas in proportions that correspond to temperatures of more than 100 MeV. The noninteracting, or spectator, region of each nucleus is left looking like a nucleus with a piece bitten out of it. The decay fragments of the spectators continue primarily in the beam direction (projectile fragments) or remain nearly at rest in the laboratory (target fragments).

It is possible (by using trigger detectors downstream from the target which are sensitive to the projectile fragments, or by multiplicity detectors sensitive to the breakup particles from the fireball) to select events with given impact parameters. Impact parameter has thus been added to the variables under control, in addition to target mass, projectile mass and bombarding energy. The interactions which have target and projectile of equal mass and an impact parameter of zero (head-on collisions) are particularly interesting because many theories then take on an especially simple form.

The major conclusions drawn so far are:

— Head-on collisions of equal mass nuclei frequently lead to complete disintegration of both target and projectile, together with emission of about twenty pions.

— In collisions of light nuclei with lead or uranium, it appears to be possible to absorb all the projectile energy into the target nucleus. The uranium nucleus is thus not only opaque to the projectile but capable of bringing it completely to rest, prior to subsequent breakup of the whole ensemble.

— Coulomb effects can be very important. For example near projectile velocity, the Coulomb interaction between the projectile fragments and produced pions enhances the negative to positive ratio to 50 to 1, even for a projectile as light as neon. For light nuclei incident on uranium the dominant breakup mode in the projectile fragmentation region is due to electromagnetic effects.

— No evidence has been seen as yet for such exotic phenomena as density isomers or pion condensates, but the signatures for such effects have been defined much more precisely as a result of the interplay between theory and experiment.

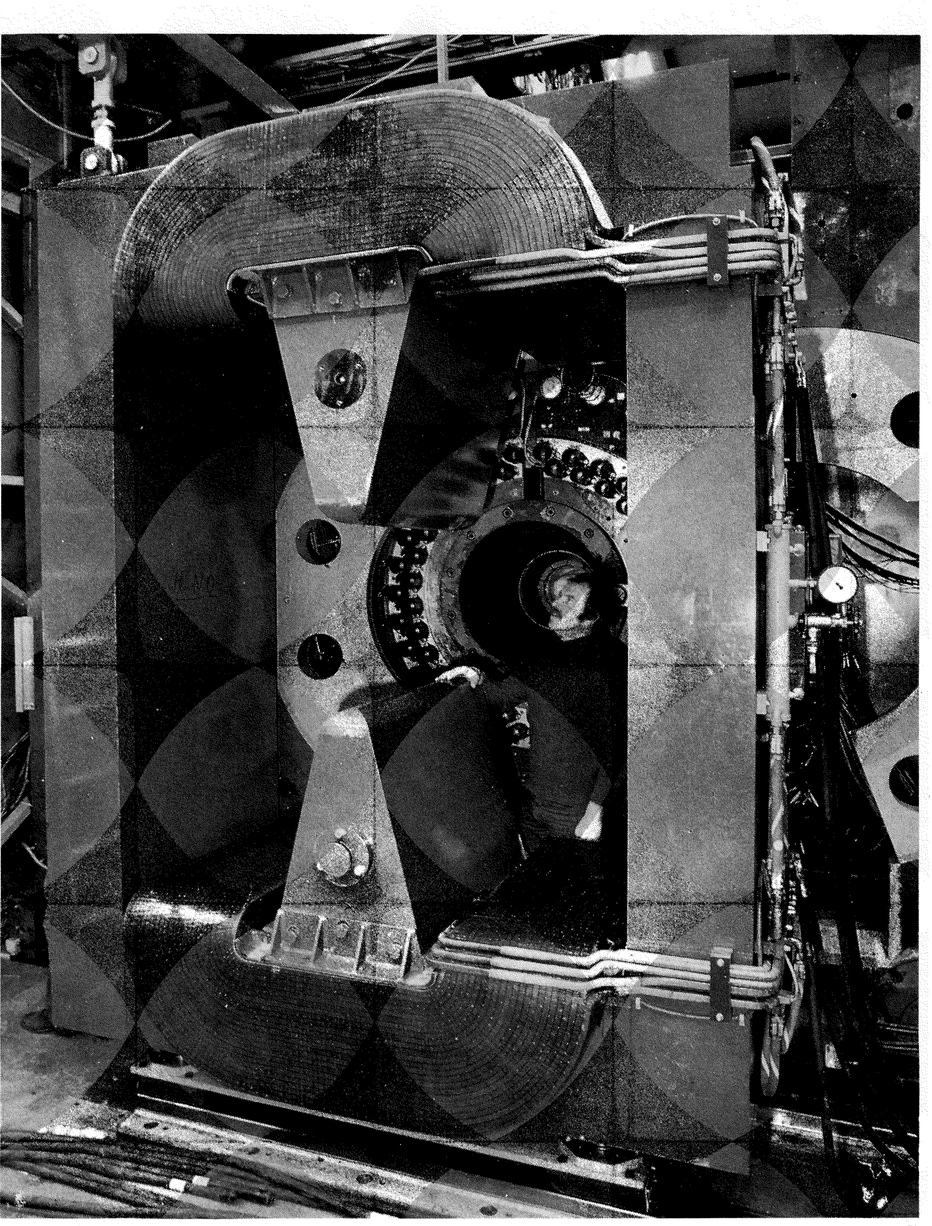
However last year a phenomenon was observed that, if confirmed by independent evidence, may be stranger than either density isomers or pion condensates. A team from LBL, Canada, and the University of Marburg studied collisions of 1.8 GeV/amu iron ions in emulsions. They observed that some nuclear fragments near the beam direction have unusual properties — six per cent of them have about ten times the normal propensity for further interactions with emulsion nuclei. Furthermore, fragments from these secondary interactions include an even higher percentage with anomalous behaviour.

The phenomenon was observed for a wide range of nuclei and it is assumed that the fragments have some new behaviour. Could it be a new quark configuration of nuclei?

Lawrence would have relished this mystery. Asked what he would find with one of his planned cyclotrons, Lawrence one responded 'if I knew the answer, I wouldn't have to build it'. Further experiments on this topic will have first priority with the upgraded Bevalac next year.

(This article was prepared in the Nuclear Science and the Accelerator and Fusion Research Divisions at the Lawrence Berkeley Laboratory. See also the story on page 402 describing medical uses for heavy ion beams.)

Around the Laboratories



A view of one of the two new 80-ton septum magnets of PLUTO. It analyses the momentum of charged particles emitted at angles between 5 and 15 degrees to the beam.

(Photo DESY)

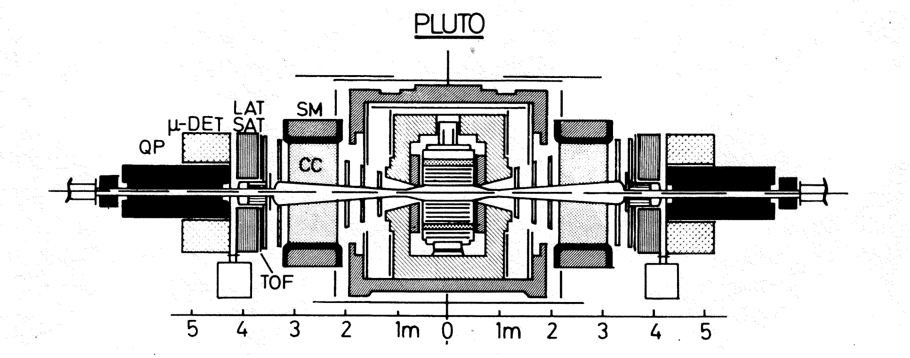
DESY
PLUTO returns

On 9 September 1981 the PLUTO detector was reinstalled in the north-east hall of the PETRA electron-positron storage ring. It took the place occupied since January 1980 by the CELLO detector.

PLUTO is now a very different detector to the one which ran at PETRA in 1978/79. The two forward-backward spectrometers have been substantially improved. Only the central part of the detector with its solenoid magnet, wire chambers and shower counters has not been changed. In the two cones around the beam axis, new magnetic spectrometers have been added to analyse the momenta of charged particles emitted at angles between 5 and 15 degrees. The trajectories are determined by drift chambers and additional information is provided by Cherenkov and time-of-flight counters. The shower counters already used during the 1979 PETRA runs to monitor luminosity and to identify electrons were reinstalled and can cover angles down to 1.4 degrees. Behind them, big drift chambers and iron absorbers identify muons.

Better particle detection at small angles will substantially improve the analysis of photon-photon reactions, a field of research which becomes particularly interesting at the higher PETRA energies.

In the type of event analysed for these studies, the incident electron and positron radiate virtual photons. Measurements of the scattered particles give the kinematics of the two



PLUTO, 1981 version, with upgraded forward spectrometers, consisting of analysing "septum" magnet (SM), drift chambers, Cherenkov counters (CC) and "small" and "large" angle tagging shower counters (SAT and LAT). The long quadrupoles (QP) are part of the mini beta focusing system of the PETRA ring.

photons which collided at the interaction point.

A particularly interesting situation arises when only one of the scattered particles is detected. Since all directions down to 1.4 degrees are covered by shower counters able to recognize electrons, the second particle must have escaped at an even smaller angle (practically through the beam pipe). For such small angles, the emitted photon is 'nearly real' and this type of reaction can be used to probe the hadronic properties of the free photon. Most particles produced in photon-photon collisions are emitted (in the laboratory) at small angles, due to the high speed of the centre of mass of the two-photon system and are detected in the two new spectrometers.

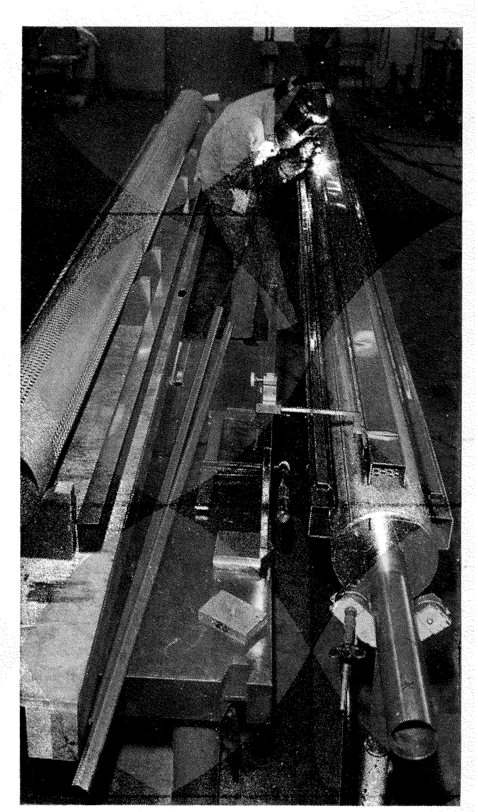
Previous photon-photon results from PLUTO clearly confirmed that the photon behaves like a vector (rho) meson. In terms of the quark model this means that the photon can transform itself into bound quark-antiquark pairs (mesons), as described by the 'Vector Meson Dominance Model' VDM. However when a nearly real photon interacts with a highly virtual one, a new type of reaction appears to be dominant in which the photon dissociates into a pair of 'free' quarks.

A first sample of such photon-photon events (with low statistics) was analysed by the PLUTO group and has been presented at recent conferences (see October issue, page 350). The appropriate cross-section can be well explained by quantum chromodynamics provided that the coupling constant for strong interactions is correctly chosen. The background of other processes (VDM type) is small and calculable. These two-photon reactions provide an excellent means of investigating the strong forces acting between quarks. Unlike most other quark reactions, they are directly accessible by quantum chromodynamics calculations and provide an excellent test-bed for the theory.

(PLUTO is an Aachen / Bergen / Glasgow / Hamburg / Heidelberg / Maryland / Rome / Siegen / Tel-Aviv / Wuppertal collaboration.)

Crystal Ball for DESY

The Crystal Ball detector is to be moved from its present home at the SPEAR electron-positron ring at SLAC and installed in the new DORIS-II ring at DESY. Crystal Ball is a non-magnetic detector containing a segmented array of sodium iodide crystals surrounding the interaction region, giving good gamma ray coverage. At SPEAR, it has already done sterling work on charm and charmonium physics, and the hope is that at the revamped DORIS ring it will make substantial contributions to the spectroscopy of hidden beauty particles, including the upsilons. The Caltech / Carnegie-Mellon / Cracow / DESY / Erlangen / Florence / Hamburg / Harvard / Nijmegen / Princeton / SLAC / Stanford / Würzburg collaboration now using the Crystal Ball envisages a seven-week run at SPEAR to take data in the J/psi region before ceasing operation on 21 December. The detector will then be shipped to Europe in time for the start of operations at DORIS-II next summer.



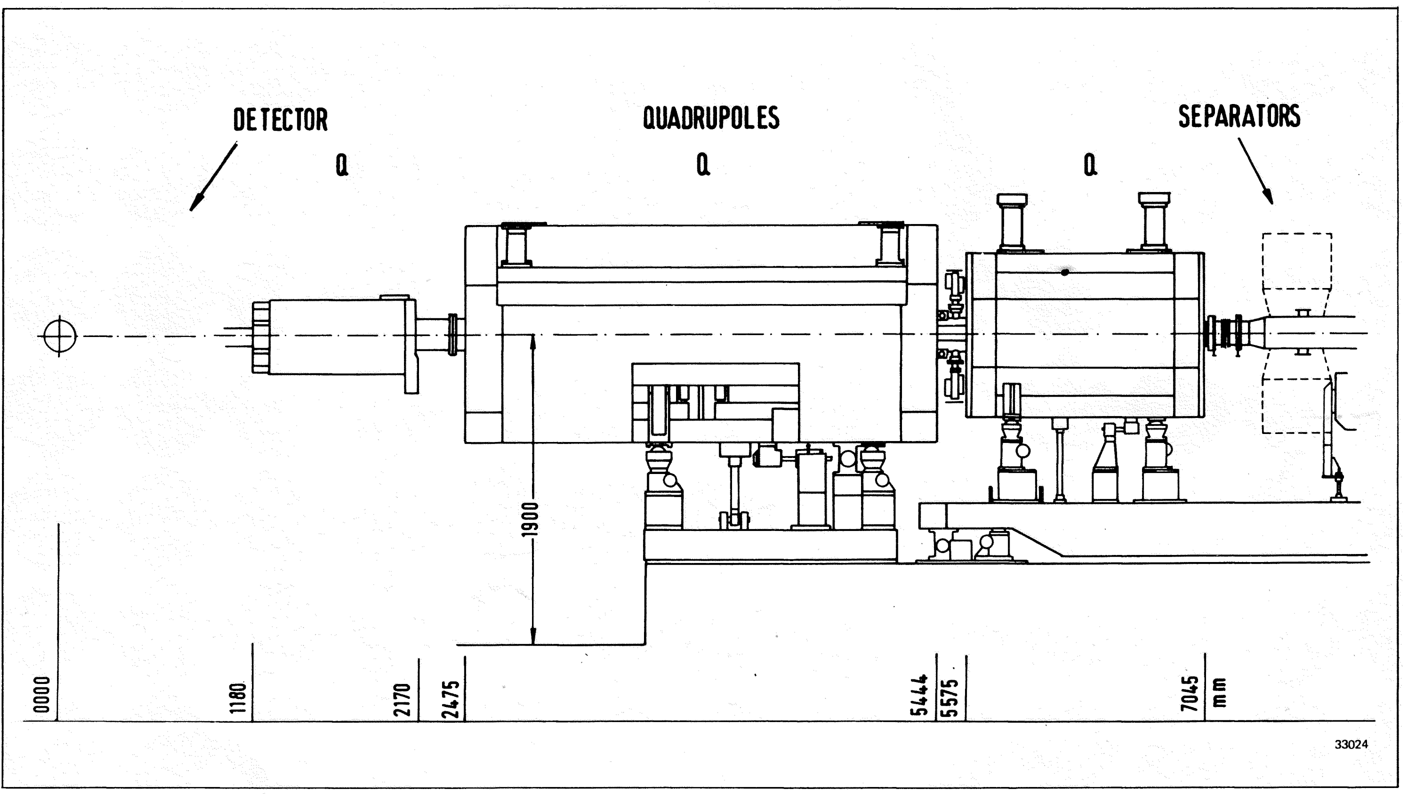
Work in progress on the new smooth vacuum pipe to be installed in the mini beta quadrupoles of DORIS-II. The four long boxes seen on the outside of the chamber will house distributed pumps.

(Photo DESY)

DORIS—II new storage ring in an old tunnel

Starting on 2 November, the two existing rings used for storing electrons and positrons in the DORIS machine will be dismantled and rebuilt as 'DORIS—II' with a single ring. The main objectives are to improve the luminosity by an order of magnitude, to increase the beam energy to 5.6 GeV in order to cover more of the beauty region and to halve power consumption — an important economic issue. The extra 5 million DM needed for this project eventually will be recouped by the electricity savings, estimated at about 2 million DM per year.

In the 10 GeV total energy region, DORIS—II will be able to span the upsilon (hidden beauty) mesons, like the CESR storage ring at Cornell.



A section of the mini beta quadrupoles to be installed at the revamped DORIS-II electron-positron ring at DESY. The two interaction regions will be occupied by the new ARGUS detector, now being assembled, and the Crystal Ball from SLAC.

Two big collaborations are preparing to start data taking at DORIS–II next summer. One uses the new ARGUS universal detector, which is being assembled at DESY. It will take the place previously occupied by LENA (and before by PLUTO) at DORIS. The second is the well-known Crystal Ball detector from SPEAR which will be shipped to Europe and replace DASP–2 in the DORIS ring. These two groups will cover an interesting physics programme.

To achieve higher luminosity with DORIS–II, a kind of mini beta scheme, similar to the one applied at PETRA (see July/August issue, page 237) has been prepared. New quadrupoles, to be placed just 1.18 m from the interaction points, are already waiting to be installed. They will provide vertical focusing, while the old pairs of big quadrupoles on each side of the interaction region will be used in their original position for horizontal focusing. In addition, another quadrupole will be placed behind each of them, providing further vertical focusing. Thus four triplets of quadrupoles will give the required mini beta beam waist. The calculated new luminosity is a factor of ten higher than the present one.

The accumulated luminosity over a period of time will profit from a new injection scheme. The injection channels will be rebuilt to allow injection at any required DORIS–II operating energy up to 5.6 GeV. Electrostatic beam separators will avoid beam-beam interactions at injection time (there are no such separators at present). New kicker magnets with shorter pulses, provided by new generators and new septum magnets, will also improve the injection process. In addition to all these new devices, a new vacuum chamber will replace the quite complicated old one. The new stainless steel pipe is smaller in diameter and much smoother inside, where unwanted high frequency resonant 'cavities' must be avoided. Further optimization of the beam will be made possible by the installation of position monitors, similar to those successfully used at PETRA. Thus the new design of the beam pipe includes many developments made in the ten years since the original DORIS ring was built.

In 1978 during the hunt for the upsilon particles, the DORIS beam energy was pushed just over 5 GeV. Most of the magnet yokes are well into the saturation region at such energies and a further field increase is not possible. Now the magnets are being dismantled and rebuilt using shims to reduce the gap from 78 to 60 mm. Horizontal width will be somewhat smaller, so that the magnetic field can be increased to attain 5.6 GeV beam energy without significant saturation effects. Some iron will be added to the return yokes to double the space left for coils. In this space the coils from the dismantled second DORIS ring will be added. Power consumption will thus be reduced to about 30 per cent of its original value. New shimming of the quadrupoles will reduce their power consumption to only 22 per cent of the present value. The high frequency system will use more power when 5.6 GeV operation is required and the overall consumption is expected to be reduced by half. A further reduction is expected when the five-cell PETRA–type cavities used at present are replaced by the newly developed seven-cell ones.

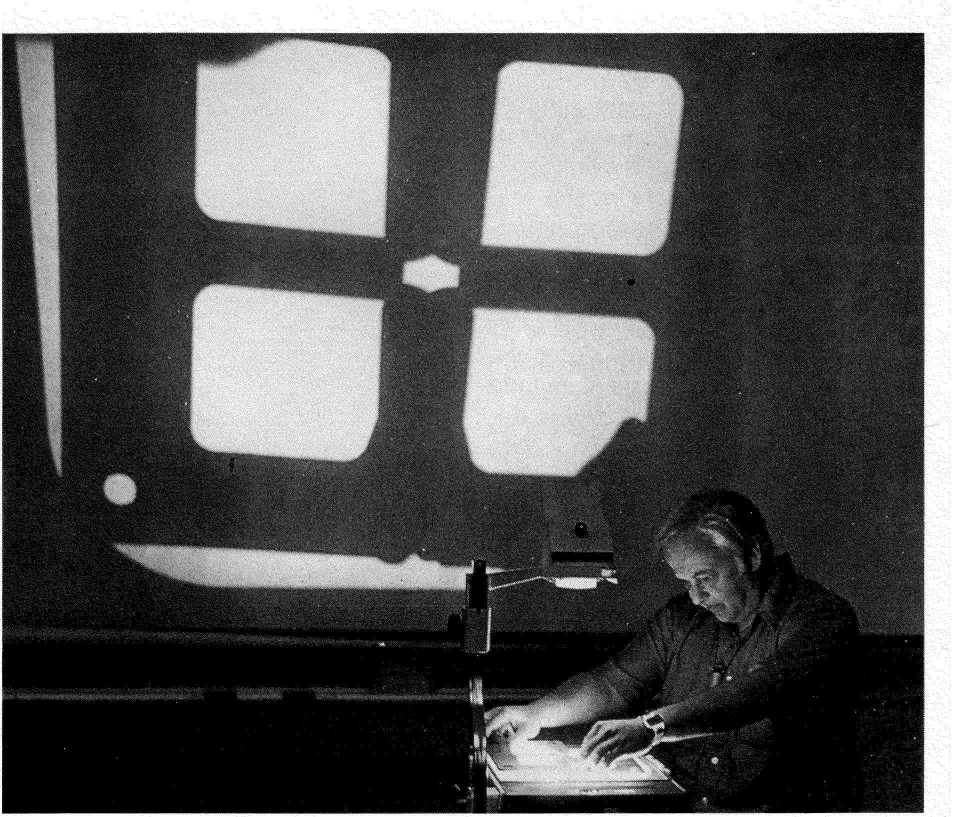
The DORIS–II ring will be at the same height as the previous upper DORIS ring and the synchrotron radiation research (using some 25 channels) will not be affected. The old lower ring will be replaced by dummy supports. The vertical beam deflection feature used in DORIS will remain. This lowers the two interaction points (now 200 instead of 400 mm) with respect to the rest of the orbit and reduces background in the two high energy experiments. The detectors can be shielded from the background, which is mainly contained in the higher orbit plane.

The DORIS–II project is under the direction of Klaus Wille, who is also the author of most of the proposed modifications. The time schedule is extremely tough and it will require a major effort to finish everything by May, when ARGUS, Crystal Ball and the many synchrotron radiation users will be anxious to exploit the new improved beams.

Already DORIS has proved to be a highly cost-effective physics investment and DORIS-II will surely add to the impressive list of discoveries made at DESY.

At the recent Linear Collider Workshop at SLAC, Burt Richter displays some of the magnet laminations for the proposed machine. These magnets could be so small that Richter is seen placing actual lamination designs on the overhead projector.

(Photo Joe Faust)



STANFORD
Linear collider physics

Over a hundred physicists met at SLAC in the summer to review physics opportunities for the proposed SLAC Linear Collider – SLC. In this project, high energy electron-positron collisions would be achieved by accelerating electrons and positrons to 50 GeV in the (improved) linac and bending the beams round to collide – once only.

At the meeting, Burt Richter first reviewed current SLAC machine developments and future plans. A new sector of the main linac has been tested. Bunches of more than 10^{11} electrons have been injected and their acceleration studied. The plan now is to equip more of the linac, and to construct the damping ring needed to store the positrons for the SLC. This ring is scheduled to be ready for testing next October, and to feed the linac early in 1983. One useful by-product will be a ten-fold increase in the positron current for the PEP electron-positron storage ring.

On the physics side, Chris Llewellyn–Smith described the more and the less orthodox physics expected at 100 GeV. Standard physics covers electroweak and quantum chromodynamics predictions, with question marks over Higgs particles, quark confinement, further quarks and leptons, and evidence for possible larger unification schemes. Less conventional ideas include technicolour, composite bosons and quarks, and supersymmetry.

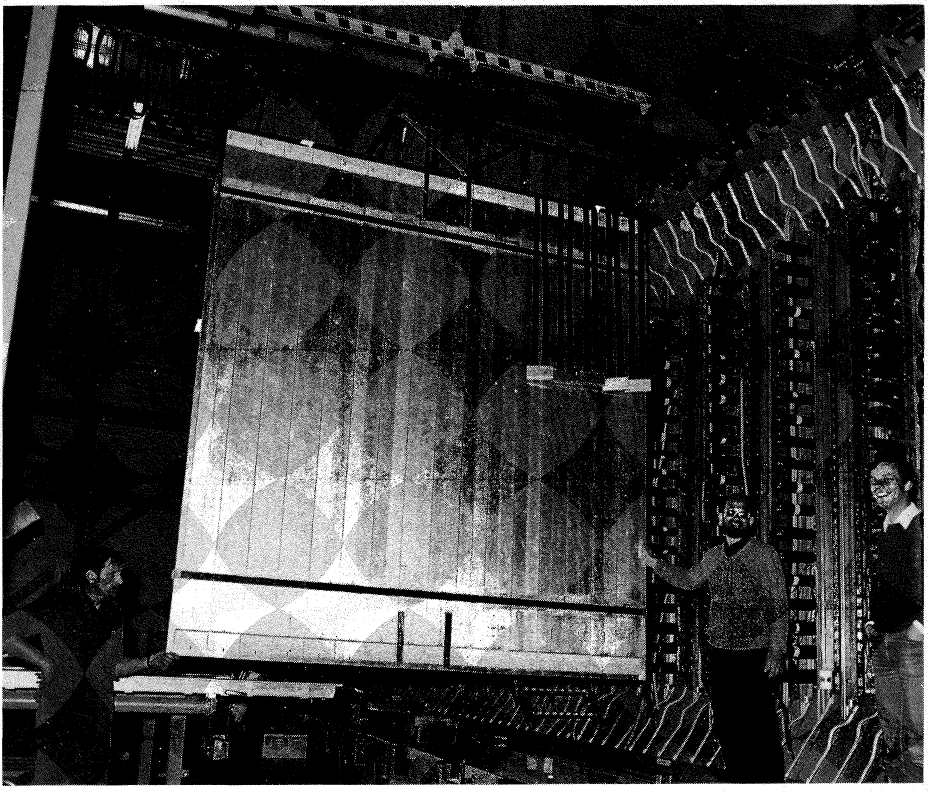
On the detector front, presentations covered current construction techniques, as exemplified by the Fermilab proton-antiproton collider detector design, and new approaches, including new chamber materials, scintillating fibres with avalanche photodiode readout, and multi-electrode silicon detectors.

The SLC Workshop (see June issue, page 199) includes a number of working groups charged with looking into various aspects of the machine's exploitation. The recommendations of the (main) interaction region group should soon appear. Another group is looking at the possibility of using a second detector. Other topics being studied include polarized particles, and possible detector technologies, including data handling requirements. The tracking group is favouring low field, large radius cylindrical drift chambers and secondary vertex detectors matched to the small beam size of the SLC.

The next full meeting of the SLC Workshop is scheduled for 17–19 December.

The detection capabilities of the CHARM neutrino experiment at CERN have been extended by the addition of planes of 256 streamer tubes of cross-section 1 cm^2. This improves the spatial resolution for measuring the showers of particles produced.

(Photo CERN 361.5.80)



CERN
The weak interaction under the microscope

These days, high energy lepton beams (neutrinos, muons or electrons) are frequently used as fine probes of nucleon structure to glean more information about the quark-gluon forces at work inside hadrons. However lepton beams also provide insights into the weak interaction — better understood but still far from being a closed book.

The first experimental observation of a weak interaction through the neutral current came in 1973 when an example was seen in the CERN Gargamelle bubble chamber of the elastic scattering of an antineutrino off an electron.

This was something of an accident, as most neutral current events are in fact due to interactions with nuclear constituents, rather than atomic electrons. However when it comes to analysing the behaviour of the neutral current, the more plentiful collisions involving the complex nuclei of experimental targets are much more difficult to analyse than the scattering of neutrinos off leptons. These reactions provide a very clean way of studying the neutral current.

The world's stock of antineutrino-electron scattering data, previously dominated by bubble chamber results, has received a significant boost from the CHARM (CERN / Hamburg / Amsterdam / Rome / Moscow) experiment using the high energy neutrino beam in the West Experimental Area of the CERN SPS 400 GeV proton synchrotron.

The CHARM detector was specifically designed for neutral current work, combining the features of a traditional hadron calorimeter with a fine-grained matrix of scintillation counters and drift tubes (see July/August issue, page 252). In this way the direction, as well as the energy of the produced shower can be measured. The targets are slabs of marble, which simplifies the isospin analysis and provides a good medium for studying muon polarization.

Neutrino-electron events are expected to be several orders of magnitude rarer than neutrino-nucleon. From a painstaking analysis of some million and a half antineutrino events producing showers with energies larger than 2 GeV, the CHARM experiment carefully sifted out some 70 events which can be attributed specifically to antineutrino-electron scattering.

The corresponding calculated cross-section gives a value for the 'Weinberg angle' — one of the basic parameters of the electroweak theory — which is in agreement with analysis of results from neutrino-hadron collisions. With these latter studies reaching their maximum sensitivity for this kind of work, it looks as though neutrino-electron scattering, together with results from electron-positron annihilation in storage rings (see October issue, page 349), will provide the new precision results needed to probe the electroweak model further.

Despite being more difficult to analyse than purely leptonic interactions, the more abundant neutral current interactions on nucleons still provide useful information. Unlike its charged counterpart, the weak neutral current is not uniquely left-handed. The standard electroweak theory predicts what should happen. The CHARM experiment has provided differential cross-sections for both neutral and charged current interactions which show that the neutral current is well behaved. It couples to strange quarks with the same strength that it couples to the lighter down quarks, and its right/left couplings are as expected.

Upstream of the CHARM experiment in the CERN neutrino beam is the big detector of the CERN / Dortmund / Heidelberg / Saclay collaboration. Charged current neutrino interactions in this calorimeter produce high energy muons, whose subsequent behaviour can be studied by the CHARM apparatus.

The idea is to measure the polarization of the muons and so obtain the spin dependence of the charged current neutrino interactions. At low energies, such as those encountered in nuclear beta decay, the neutrino spins left-handedly. Muons emerging from neutrino interactions should inherit this handedness. While this has been confirmed for lower energy muons, the exact behaviour of weak interactions at much higher energies was less well known.

The kinematical behaviour of the muon polarization, from interactions on nucleon targets, measured by the CHARM experiment provides an acid test of the structure of the weak interactions. Other information comes from the observed levels of inverse muon decay, in which a neutrino hits an electron target and produces a muon, and from reactions giving two opposite sign muons. Together, these results show that the standard picture of charged current weak interactions now holds good from the tiny energies of nuclear beta decay to the GeV range covered in high energy experiments, even under kinematical conditions which favour other spin effects.

These results from the CHARM experiment have been presented recently by F. Büsser at the Hawaii neutrino conference and G. Barbiellini at the Bonn lepton/photon symposium.

Booster still boosting

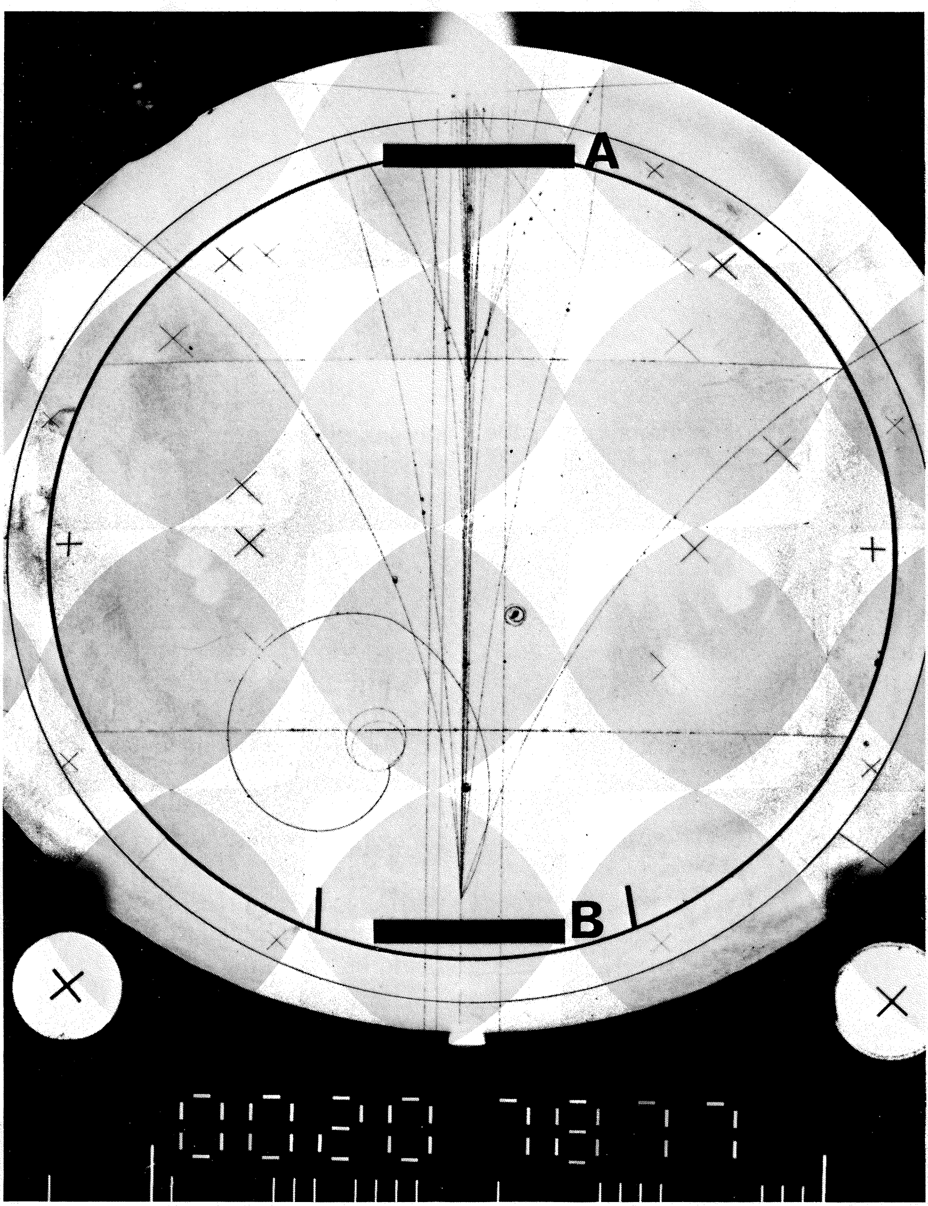
The 22-year old CERN Proton Synchrotron has consistently risen to the new tasks it has been assigned over the years. It is the universal source of particles of many types and in many modes. One of the important factors in this series of successes has been the grafting on of the four-ring 800 MeV booster to the PS injection system. This year, the Booster, aided and abetted by good performance from the linac, has attained new intensity records and has played an important role in providing the right kind of proton bunches for the new antiproton scheme.

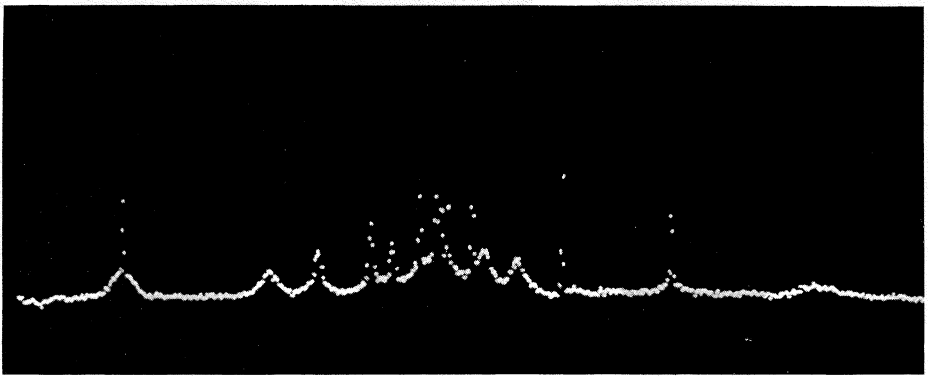
The intensity records followed a programme of improvements which aimed to double the initial design figure of 10^{13} protons per pulse. (The improvements aimed to raise the space charge limit and avoid beam blow-up. They included operation at a different working point, stopband compensation, bunch shaping, and increased acceptances in the rings and the transfer line to the PS.) Beam stability was increased by a feedback damping system and reduced r.f. cavity impedance. Octupoles replacing a Landau damping system reduced the beam size, which also helped the transfer efficiency.

With these manoeuvres completed the Booster reached 2.4×10^{13} earlier this year and exceeded the expectations with such style that it was decided to continue to push for higher intensity. A new goal of 3×10^{13} has now been set. A second harmonic cavity is being installed and a longer beam pulse from the linac is being implemented.

The antiproton project is the main beneficiary of these improvements. Originally, with the lower Booster intensity, it was first necessary to combine (twice) the beams from the rings to give five circulating bunches in the PS and achieve the high proton density required at the antiproton production target (over 10^{13} protons within a quarter of the PS circumference). This beam combination and the subsequent transfer of the oversized beam into the PS lead to unavoidable losses and machine irradiation. With the higher Booster intensity these losses are eliminated because beams from two of the Booster rings suffice for antiproton production.

After extensive modifications of the main Booster power supply, addition of a 6 MVA reactive power compensator and replacement of number of other supplies, a shortened cycle (0.65 s repetition time, 0.32 s rise time) is now possible. An intermediate version (0.84 s repetition time, 0.4 s rise time) will be used at first to achieve energy savings of some 1.5 GWh/year. Another by-product is that the waste heat from the upgraded air-conditioning plant is used for space heating.

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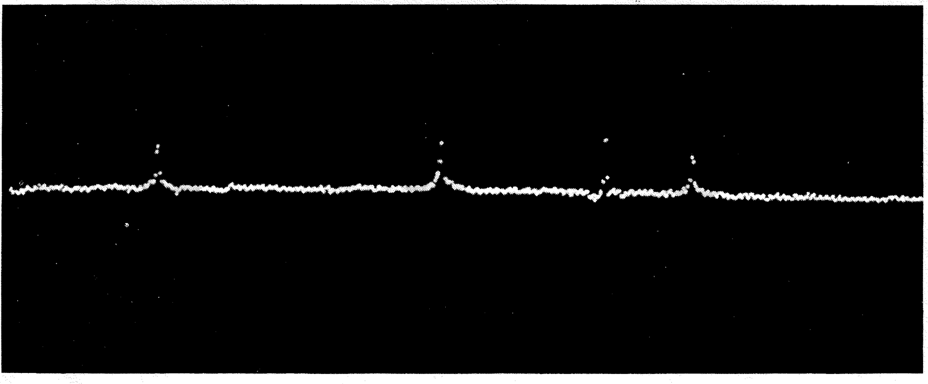
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One of the first batch of 190 000 photographs from the new rapid cycling bubble chamber of the European Hybrid Spectrometer in the North Experimental Area of the CERN SPS. This chamber can make more than 20 expansions per second. In order to veto photographs which would not contain useful events, an Optical Fiducial Volume Trigger has been developed which records on diode arrays the track profiles across the chamber entry (B) and exit (A). These profiles are shown below. The fast ESOP processor then decides whether the event is useful.

BERKELEY
Improving heavy ion therapy

A group at the Lawrence Berkeley Laboratory is developing a new radioactive beam diagnostic technique to optimize the use of accelerated heavy ions in treating cancer patients.

Unlike the stable heavy ion beam actually used for therapy, the radioactive beam gives off radiation which can be visualized and thus the depth that it penetrates can be measured. On the basis of these measurements, radiotherapists can adjust the energy of the therapeutic beam so that its maximal dose is delivered precisely at the depth of the tumour.

For many years, radiotherapists have treated cancer patients with cobalt-60 gamma rays or X-rays. Unfortunately these forms of radiation generally apply greater dosages to normal cells at the surface than to the tumour cells deeper in the body. Heavy ion beams, such as neon, have the advantage that they can deliver a maximal dose to deep-lying tumours because they reach peak intensity (called the Bragg peak) at the end of their range. The challenge is to ensure that the peak coincides with the tumour region, hitting the cells it was meant to destroy. The full potential of heavy ion therapy can only be realized when the Bragg peak can be located.

The radioactive beam technique is feasible only at heavy ion accelerators, like the Bevalac at Berkeley, since its success depends to a great extent on the availability of a fairly intense radioactive beam and on a sensitive detection device. A Positron Emitting Beam Analyzer (PEBA) is used as a detector at Berkeley. It consists of two movable banks, each with 24 sodium iodide crystals. The patient on the therapy couch would be placed between these two banks and the separation distance adjusted according to the location of the tumour.

When the beam stops in the target volume, it emits positrons which convert into gamma rays emerging from the body in opposite directions. These gamma rays are detected by the crystals to locate the stopping region. The radiotherapist then needs only to make a simple scaling correction to adjust the energy of the therapeutic beam to make the stopping region and the tumour coincide.

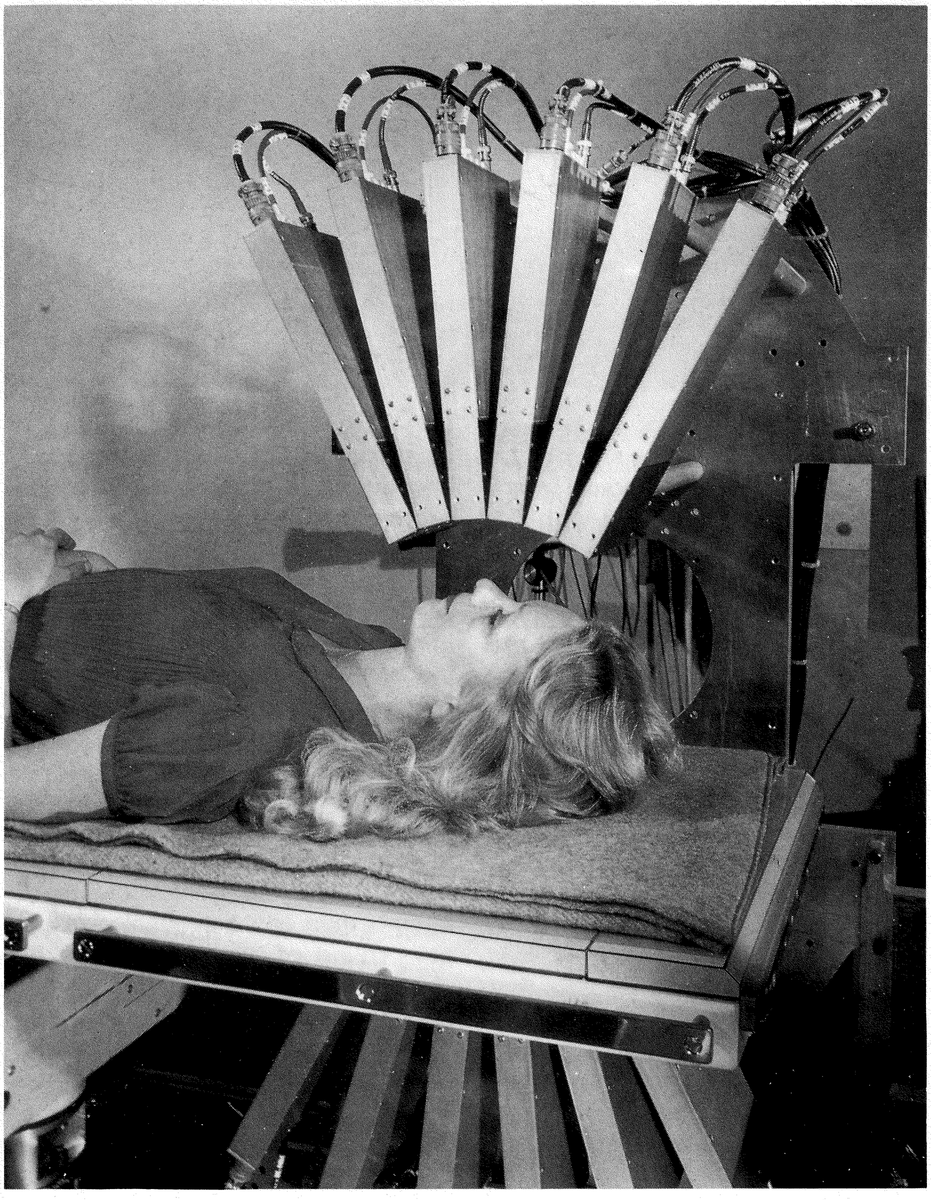
Using materials which simulate the water, fat and bone content of the human body, and using animals, a direct visualization of the beam stopping point has been obtained. The measurements of penetration depths have been accurate to about 1 mm.

Computerized axial tomography (CT) scanners currently used for indirect determination of the beam range may give errors of several millimetres. This is too great when critical structures such as the spinal cord might lie next to a tumour. Such errors may also have severe consequences within the brain.

If the radioactive beam technique becomes routinely available, heavy ion therapy facilities will be able to improve their range estimates. The precision of the technique could also be useful in other areas of nuclear medicine, including a non-invasive method for determining the blood flow rate in a microscopic region.

The development is just beginning but preliminary findings are very encouraging. A PEBA is being adapted for clinical trials.

(This information was provided by A. Chatterjee, J. Scherer, E.L. Alpen, J. Llacer and W. Saunders.)



A Positron Emitting Beam Analyser (PEBA) at Berkeley in position on either side of the therapy couch to locate the depth of penetration of a radioactive beam of heavy ions. The penetration of the ions used for cancer therapy can then be made to coincide with the tumour region. A development programme on this technique is under way at Berkeley.

(Photo LBL)

Where are we in particle physics?

by S. B. Treiman

The fourth in a series of HEPAP (High Energy Physics Advisory Panel) Subpanels, formed from time to time to review the status of the US high energy physics programme, last year had to confront an unusually wide array of opportunities and problems. The scientific opportunities and challenges are well known. They spring from the prodigious experimental and theoretical strides of the past decade and lay out the case for a new round of accelerator and other facilities — to pursue the critical leads opened up by the recent developments and, as always, to allow for the unexpected.

A number of delicious possibilities, in various stages of definition, were in view: the Stanford Linear Collider for electron-positron physics at 100 GeV centre-of-mass energy; a Cornell conception for an electron-positron collider at a similar energy, based on superconducting r.f. technology; possible electron-proton collider facilities, etc. Nevertheless, the prevailing climate was such as to focus attention mainly on the problems. The problems are also well known — the financial ones, which increasingly constrain the programme and utilization of existing facilities and the technological ones, associated with the large superconducting accelerator projects at Fermilab and Brookhaven.

Now the Saver/Tevatron project at Fermilab seems technologically more surely on course, but there have been magnet problems for ISABELLE at Brookhaven and the national financial picture is more constraining than ever. The situation has perhaps fostered a magnified picture among US physicists of the vigour of the European programme but one also imagines — or hopes — that the hurdles will, in time, be surmounted and that US high energy physics will be able to resume its traditional place.

Technologically on course — installation of superconducting magnets below the Fermilab main ring.

(Photo Fermilab)

The current difficulties seem to be mainly fiscal and technological; there are also problems, shared with Europe, associated with the complex sociology of the large collaborations that are increasingly called for in high energy experimentation. But let me set these things aside and turn instead to another kind of foreboding that has surfaced in certain quarters and that generated a great deal of heated debate among HEPAP members in the off hours.

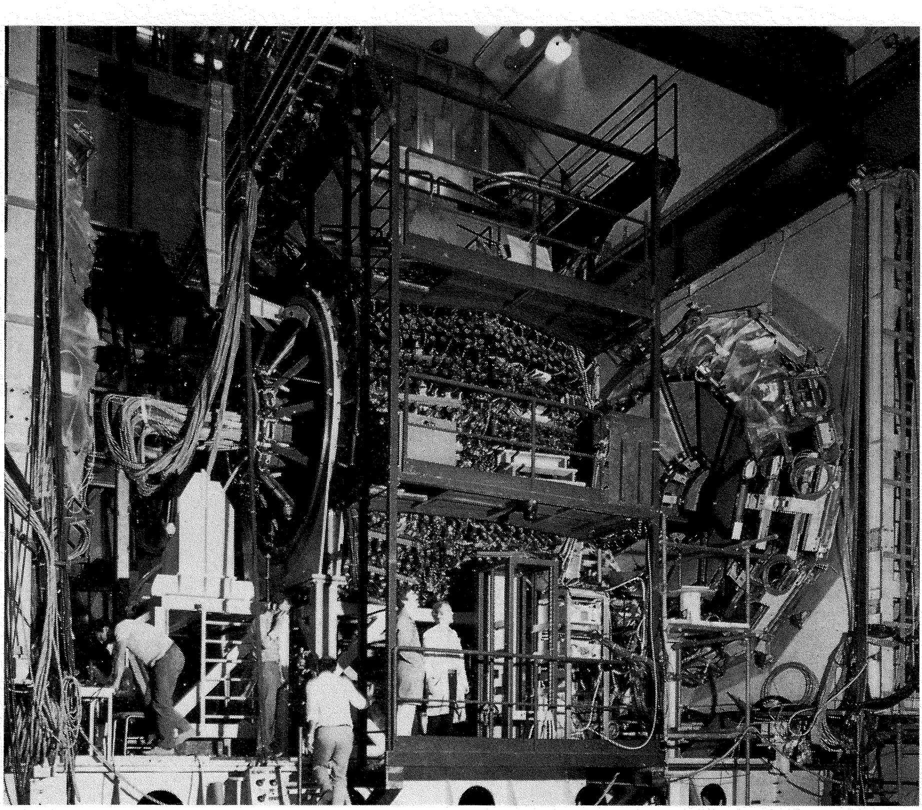
The recent years of particle physics have witnessed enormous progress, culminating in what seem to be very far-reaching synthesis. It is this rising curve of advancement that testifies to the scientific vitality of the field and that makes the case for continuing support. So great is the sense of achievement, however, that one dares to ask whether perhaps we are almost 'there' already. The proposition that we may be almost 'there' is of course risky, if not outrageous, and even the most forward of the proponents of this view qualify it in various ways.

Everyone acknowledges that there are crucial tests to be made and information to be found in the coming round of experimentation; so that, given only the resources needed to exploit the visible scientific opportunities, we surely face very exciting times. Moreover, the proponents acknowledge, even if everything goes as expected, that there will remain much more to be known than can be revealed in the next round of experimentation. Indeed, there are very stirring visions about what may lie out there beyond the immediately foreseeable domains of direct, experimental attack.

The trouble, however, is this: they conceive that these farther reaches

Assembly of the UA2 detector at the CERN proton-antiproton collider — an example of the vigour of the European high energy physics programme.

(Photo CERN 84.9.81)



may lie forever beyond direct experimental investigation and that, for what can be reached, we may already have the basic framework in hand.

The goal of our field is an understanding of the fundamental structure of matter. In discussing our location along the axis of understanding, for present purposes I have in mind our grasp of the fundamental laws, as distinct from a mastery of all the implications of those laws for phenomena. In principle, until one can work out and test a sufficiently wide range of predictions, one can't be sure that the right foundations are in hand. Nevertheless, it is a fact that great syntheses are established and accepted from time to time on the basis of vastly more limited evidence, at least initially, provided that the conjectured theoretical structures look both pretty and consistent. At the start one is not even so fussy about consistency, in view of the possibility of experimental error and/or theoretical refinement.

When the foundations for some domain of science seem to be in hand, what is there left to do within that domain? Well, plenty! There still remain all the rich and varied phenomena themselves and the work of relating the phenomena to the foundations. It is not easy, for example, to get to superconductivity straightaway from Schrödinger's equation, the Pauli principle, and Coulomb's law. For some fields there also arises the possibility of exploiting the new understanding for practical applications. Above all, for those of a certain mentality, there remains the task of making trouble for the established orthodoxy — by searching for indications of its limitations and thereby opening up new fields to be conquered.

For particle physics, throughout much of its modern history, this trouble-making has been especially easy. In the limited domain of electron-photon physics, the great quantitative successes of quantum electrodynamics had convinced most people already by the late 1940s of the correctness of the general notions of relativistic quantum field theory. At about the same time, however, the explosive proliferation of new particle types, with all their complicated interaction chemistry, had set in. This explosion of new phenomena dominated, and theory, at best, could only limp along with partial and ever-shifting insights and rough provisional models.

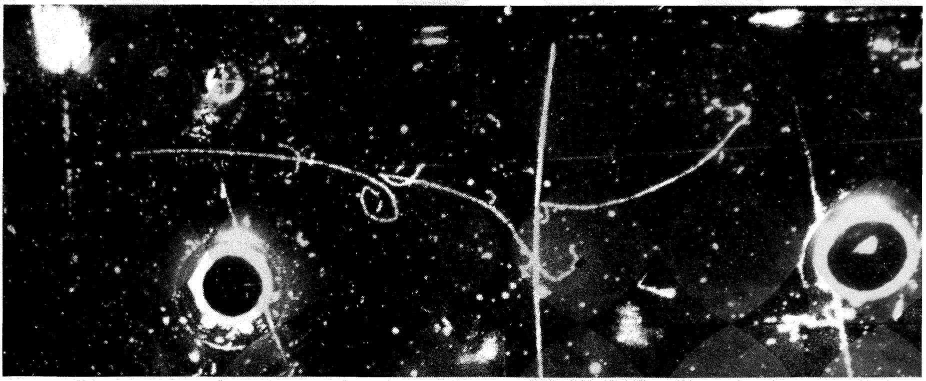
Serious visions of a realistic and fundamental dynamics receded. There was no encompassing orthodoxy to shoot at. To be sure in corners there were some people toying with new dynamical ideas — like spontaneously broken symmetry and non-Abelian gauge theories. The possibilities, to those who could follow the developments, looked very interesting indeed, at least as amusements, but the connections with reality were still obscure.

By the early 1960s the one thing that was clear to most people was that the different hadron species were already far too numerous for any of them to be regarded as fundamental in any reasonable sense; and the idea of a more parsimonious substructure, the quarks, was born, though unaccompanied by a serious and detailed quark dynamics. One could get away with only three quark flavours at the time. The number has since grown ominously to five, with reasonable expectation of at least one more — the 'top' quark.

Then, by the early part of the last decade, the whole outlook for the strong interactions began to change dramatically. At SLAC, then subsequently at CERN and Fermilab, the experimental study of deep inelastic scattering of leptons by nucleons revealed a certain scaling behaviour which suggested that the scattering takes place off point-like constituents in the nucleon — the quarks we now think. The quarks, it appeared, behave as if free in these high momentum transfer transactions. This made for a nice physical picture, embodied in the parton model, but at a deeper field theoretic level, it was hard to understand what was going on. One has to explain why the distorting strong interactions among quarks become effectively unimportant at large momentum transfers, or equivalently, at short distances.

This was an important clue to strong interaction dynamics. It led to the notion of 'asymptotic freedom', the discovery that asymptotic freedom is uniquely peculiar to non-Abelian gauge theories, and then to the widespread focus on Quantum Chromodynamics (QCD), a non-Abelian gauge theory based on the SU 3 colour group that had already begun its development from different origins. A look at current issues of any particle physics research journal shows that QCD now provides an orthodoxy for the strong interactions.

Similarly for the weak interactions, by the late 1960s there was a whole new outlook based on a pulling together of ideas drawn from earlier investigations of dynamical symmetry breaking and, again, on the ideas of non-Abelian gauge theory. The new picture absorbed the phenomenologically successful current-current structure of the weak interactions but, at long last, in a serious and renormalizable framework. It could incorporate the independently-developed notion of charm and had the great merit of predicting testable things — neutral current interactions. Both charm and neutral currents were subsequently discovered and are among the great experimental triumphs of the past decade. Best of all, the new picture unified two hitherto separate classes of interactions, the electromagnetic and the weak.



The discovery of the neutral current at CERN — an example of a testable prediction.

In QCD, for the strong interactions, the various quark flavours all enter on an equal footing apart from their differing mass parameters. The number of different flavour types, and the masses, are external inputs to the theory. The interactions among the quarks are mediated by eight massless gauge bosons — the gluons. For the rest, there is only one additional parameter, a renormalization scale with the dimensions of a mass. The basis of the QCD theory can be written down in one line, thanks to the power of compact notation. But that is of course deceptive. It is a very long way from this one line of formalism to all of the phenomena of the strong interactions and although the theory is very beautiful in the eyes of many beholders, it is also ferociously difficult.

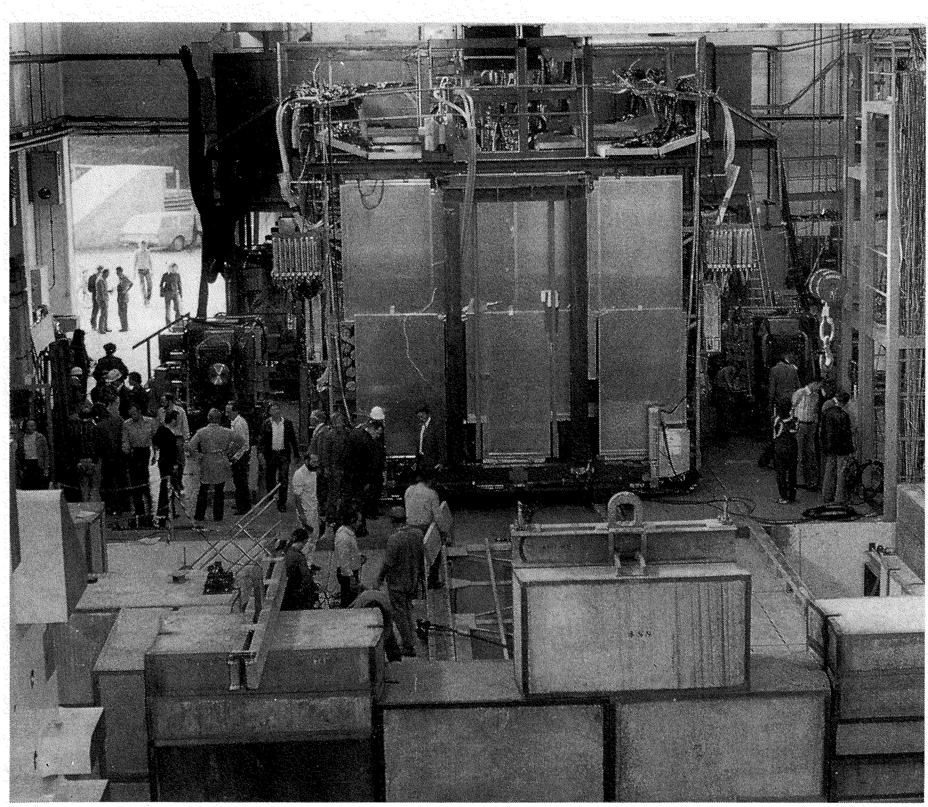
The predictions extracted so far are limited, dealing for the most part with short distance phenomena such as deep inelastic lepton scattering, electron-positron annihilation at high energies and muon pair production in hadron collisions.

Even within these limits, more phenomenological inputs, such as parton distributions, are still needed. Nevertheless, there have been successes and there are as yet no obvious contradictions. One can still be sceptical — the whole thing could be wrong and the successes an accident; or the theory could be generally on the right track but in need of serious modification or extension. It is not unthinkable, however, that QCD is altogether correct for a very wide domain of strong interaction physics. Internally, at least, it looks to be fairly whole and parsimonious. In order to form a reliable opinion, one will need not only a series of crucial experimental probings but also a vast development in the art of extracting the implications of the theory.

For the electromagnetic and weak interactions, one deals with leptons as well as quarks. At its beginnings, the unified electroweak scheme appeared as a rather general framework, leaving open a variety of possible detailed realizations depending on the gauge group, quark and lepton content, etc. This is still the situation; but a simple variant, the so-called standard model has taken hold and seems capable of assimilating all the present data. Here the quarks and leptons enter in families, each family on an equivalent footing. Two families are well established and a third is almost complete, awaiting only the top quark.

The PLUTO detector moves into the PETRA ring in DESY in 1978, where it was able to provide valuable data to test quantum chromodynamics. After having been succeeded by the CELLO experiment, PLUTO is once more in the PETRA ring (see page 396).

(Photo DESY)



Within each family the members enter in characteristically different roles. The electromagnetic forces are of course mediated by photons, the weak ones by charged and neutral vector bosons. The masses of these bosons are rather sharply predicted in the standard model, in terms of already known parameters. The predicted masses lie below 100 GeV and it is one of the exciting objectives for the coming round of experiments to produce, detect, and study these objects — or better yet, to find troubles.

Internally at least QCD looks to be fairly whole and well structured. The standard electroweak model on the other hand looks considerably less whole or in final form. Spontaneous symmetry breaking gives the quarks and leptons their masses, but only in terms of other adjustable parameters. There are additional parameters as well — various mixing angles in the weak currents and the mass and self-coupling strength parameter of a (still undiscovered) scalar Higgs boson that is crucial to the theory in its present form. To many people, this Higgs particle looks somewhat artificial — a kind of provisional stand-in for deeper effects at a more fundamental level. Altogether, although the standard electroweak model seems to serve very well for all the phenomena presently accessible to us, there is a widespread feeling that it is only a part of some more comprehensive structure.

The overall outlook comes close to the ideal for a vigorous science: the proliferating phenomena of decades at last (perhaps) brought into order, at least 'in principle', while at the same time, there is the almost sure indication that we are not yet at the bottom of things — that there is yet more out there beyond to be pursued.

But how far beyond? There already exist visions which are simultaneously breathtaking and foreboding. The weak interactions are so called because the forces are very tiny, at least for the domain of energies that have so far been achieved. Nevertheless electroweak theory unites these disparate interactions in a way that suggests that the effective weak forces grow with energy until the weak and electromagnetic forces become roughly comparable at energies corresponding to the masses of the weak bosons. Then there are the hadronic forces which, at present energies, are stronger still than the others.

Electroweak and QCD theories sit side by side, compatible but separate. Why not join them together in one grand unification picture? According to QCD ideas, the strong forces, loosely speaking, become progressively less strong with increasing energy. On a 'grand unification' picture one can make rough estimates of the characteristic energy where all the interactions, strong and electroweak, become comparable. For the simplest versions, at least, the answer is about 10^{15} GeV. Out there we would encounter all kinds of new physics, new gauge bosons, etc.

In the nearer future, we will get to the 10^3 GeV region, with excitement enough in pursuit of the weak bosons, the elusive Higgs or its dynamical equivalent, the top quark and perhaps still other quarks and leptons. The immediate issue will be whether everything falls in with the standard ideas of QCD and electroweak theory. Even if it does, the standard picture is in part only a framework, whose quark and lepton (and Higgs) content is still open. There will be much to be learned even at the modest 10^3 GeV level.

But one also wants to extend the

foundations and we are certainly not going to build 10^{15} GeV colliders (not even in Europe). Is there any way we can get an indirect glimpse of this new physics at the far lower energies that will be accessible to us? For that matter, is there anything beyond just aesthetics that suggests grand unification? As to the latter question, there is already at least one impressive empirical indication: the simplest grand unification models give a good quantitative explanation of the Weinberg angle, a parameter that is well measured but that is unexplained within the standard electroweak model.

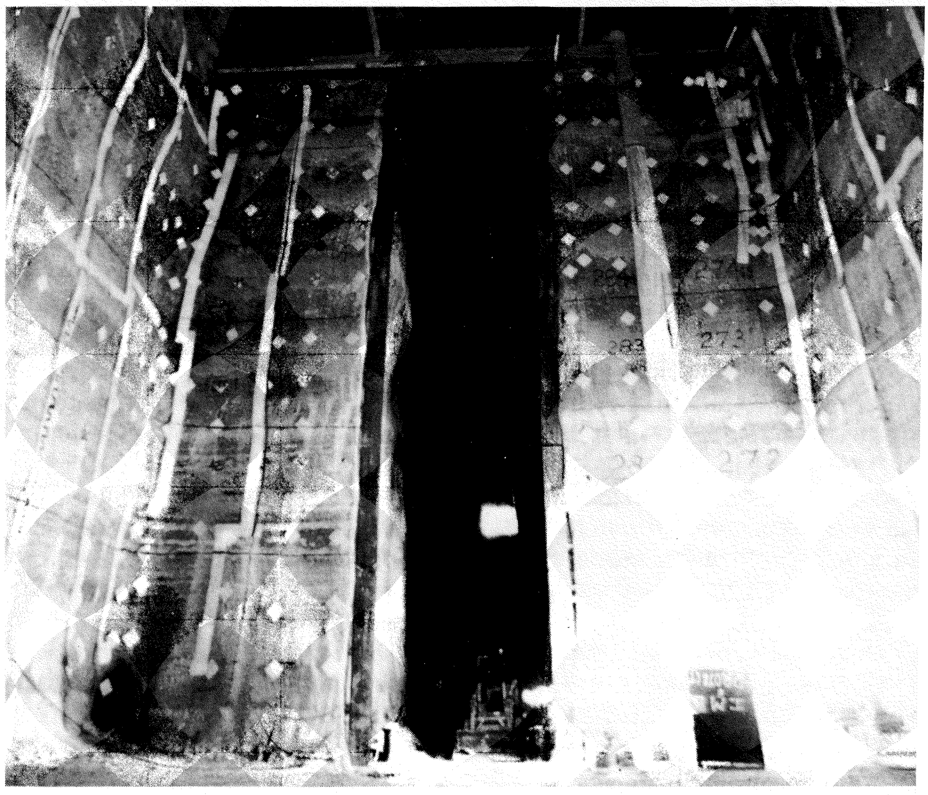
The simplest schemes lead to the expectation of baryon nonconservation and the instability of the proton. The predicted lifetime is about 10^{31} years, give or take perhaps one or two powers of ten. A number of experiments are now under way in search of proton instability. The stakes are obviously very high.

The establishment of non-zero neutrino masses, directly or through observation of neutrino oscillations, may also bear indirectly on the new physics of grand unification. Present evidence is not conclusive. Moreover baryon nonconservation, taken together with the violation of combined charge and parity symmetries, opens up the possibility of dealing with one of the great outstanding problems of cosmology, the asymmetry between matter and antimatter in the content of the universe. The estimates are very crude as many of the dynamical details and parameters are matters of speculation, but the gross order of magnitude looks promising.

Clearly, the idea of grand unification out at 10^{15} GeV opens up vast new vistas. What is foreboding about all of this, however, is the possibility that there is nothing fundamentally new between the imminently accessible 10^3 GeV region and the exciting prospects of 10^{15} GeV. We may still hope to get some indirect glimpses of that new world but the evidence is bound to be limited. This of course will not stop our theoretical brethren from speculating, but without the restraining and guiding influence of data they are sure to run amok. They often do, after all, even when there is data.

There are really two questions. Is there in fact a 'Glashow desert' between 10^3 and 10^{15} GeV? For the vast bulk of the phenomena that will be accessible to us, do we already have the basics in hand with QCD and standard electroweak theory? The HEPAP debaters were divided. The theorists, proud of their recent accomplishments, tended toward the affirmative view; the experimentalists, equally proud, were in general full of scorn.

There is clearly room for caution. I owe the following fragment of history to my colleague A. Pais. It concerns Emile Nohel, the son of a Jewish farmer in Czeckoslovakia, who entered the University of Prague in 1904 and approached Anton Lampfa for advice about his studies. Lampfa, Einstein's predecessor in the chair of physics, advised Nohel against going into physics because 'all the original work has been done, the laws have been established, and important new developments are not to be expected.'



Preparations for an underground experiment by the Irvine/Brookhaven/Michigan group to search for proton decay and other new phenomena. This and similar experiments will put new physics ideas to the test.

People and things

Hideki Yukawa

Hideki Yukawa

Last month saw the death of Hideki Yukawa at the age of 74, after five years of grave illness bravely borne. In 1949 he became the first Japanese to receive a Nobel Prize. He graduated in physics from Kyoto in 1932 along with Sin-itiro Tomonaga, who went on to receive the Nobel award in 1965. His contributions to physics ranged over a wide field, covering atomic structure, beta decay, nuclear structure and field theory. However he is best known for his theory of nuclear forces, first presented in 1934, based on the exchange of particles predicted to be several hundred times heavier than the electron. These particles, the pions, were discovered in cosmic ray experiments in 1947, and the Yukawa model remained a cornerstone of nuclear theory for many years. In 1943 he received the Cultural Medal, the highest award in Japan, and six years later the Nobel Physics Prize.

To commemorate this Prize, the Institute for Fundamental Physics was set up at Kyoto University, and Yukawa remained as Director for many years. In 1946 he inaugurated the journal 'Progress of Theoretical Physics' which brought Japanese theoretical physics to world attention, and was its Editor until his death. A visit to CERN in the late 1950s impressed on him the importance of high energy accelerators, an influence which eventually led to the establishment of the Japanese KEK Laboratory. Throughout his life he was a great promoter of peace and was a leading figure in a movement to abolish nuclear weapons.

Ettore Pancini

Italian physicist Ettore Pancini died prematurely on 1 September. In 1946, with Marcello Conversi and Oreste Piccioni, he discovered that the cosmic ray meson (the muon), contrary to general belief at the time, could not be the particle postulated by Hideki Yukawa as the carrier of the short range nuclear force. By establishing that the muon behaves as a heavy electron, these experiments opened up the field of leptonic physics. This work also led to the idea of a universal weak interaction, and pointed the way to the study of mesic atoms.

After graduating from Padua, in 1940 Ettore Pancini went to Rome to study cosmic ray physics, a career which was soon interrupted by the war in which he went on to play an important role. In 1950 he was appointed Professor of Experimental Physics at Genoa, which during his ten year residence became a centre of international renown. He then moved to Naples. An original and rationalistic thinker and a gifted experimentalist, he continually provided stimulus for further research.

Bruno Tallini

With the premature death of Bruno Tallini in September, the European particle physics community has lost one of its most active members. He had been involved for more than two decades in bubble chamber experiments, dividing his time between data taking at CERN and film analysis at Saclay. Lately he served at CERN as Chairman of the BEBC Users Committee and then as a member of the SPS Experiments Committee. In the last few years his interests turned towards testing the predictions of grand unified theories and he played an important role in developing the instrumentation for the new underground laboratory being built in the Frejus tunnel in France.

Earlier this year a symposium was held at Yale University to celebrate the sixtieth birthday of Feza Gürsey, well known for his many im-

Maurice Goldhaber (left) was one of those who took part in a recent symposium at Yale to celebrate the sixtieth birthday of theoretician Feza Gürsey (right).

portant contributions to theoretical physics. Among those contributing were Y. Nambu, L. A. Radicati, M. Klein, F. J. Dyson and M. Goldhaber. The proceedings of the symposium will appear in a forthcoming dedicated Festschrift volume.

Wolfgang Paul is retiring as head of Bonn University's Physics Institute. Soon after arriving at Bonn in 1952, he was encouraged by Heisenberg to begin construction of the 500 MeV (now 2.5 GeV) electron synchrotron, the first European machine to use the alternating gradient technique. At CERN he has served variously as Leader of Nuclear Physics Division, Chairman of the Electronic Experiments Committee, Federal Germany's delegate to CERN Council (a position he continues to hold) and as both member and Chairman of the Scientific Policy Committee. At DESY, he has been a Director, President of the Directorate and Chairman of the Scientific Council. He continues to be active in machine development, one of his recent achievements being the remarkable 'neutron bottle' at the Institut Laue–Langevin, Grenoble. For many years Professor Paul has been one of the most influential European physicists in ensuring support for high energy physics and for the CERN and DESY Laboratories. The progress of the LEP project in particular owes a great deal to his commitment.

Synchrotron radiation news

At the end of August a circulating electron beam was achieved for the first time in the VUV (vacuum ultraviolet) ring of the US National Synchrotron Light Source at Brookhaven. Commissioning of the X–ray ring of the NSLS is imminent.

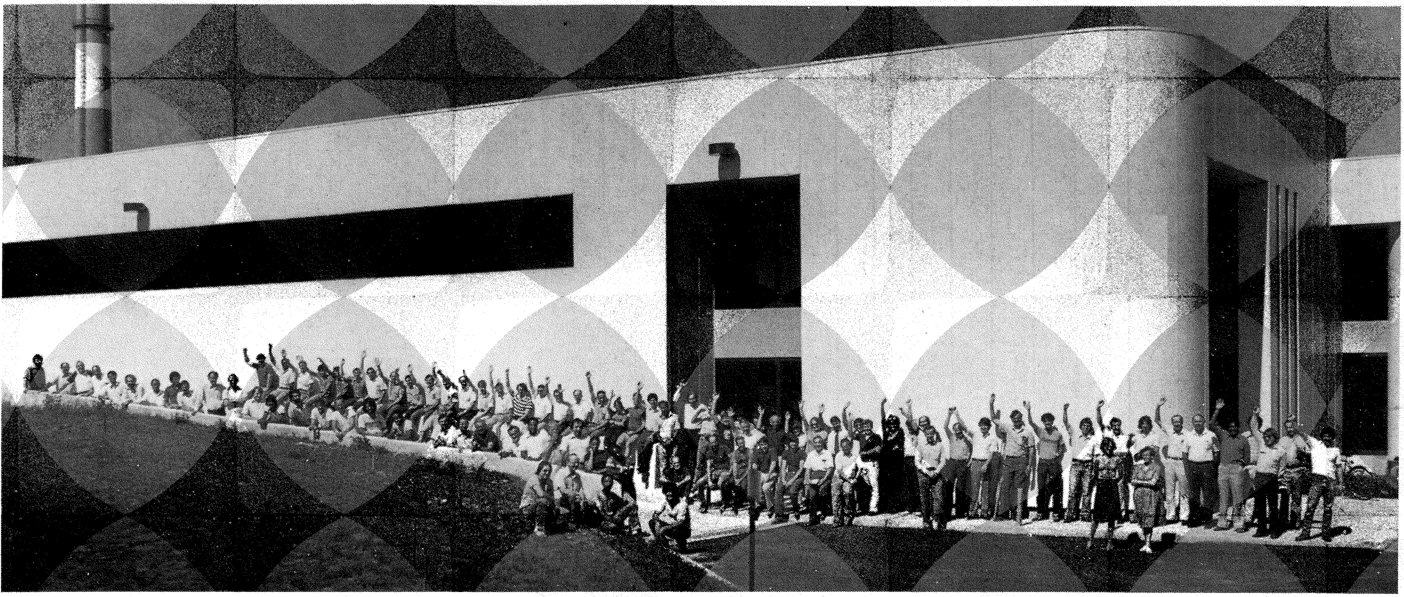
A group at the University of Science and Technology of China, Hefei, led by Pao Chung-mou, is planning an 800 MeV electron storage ring as a synchrotron radiation source. It would provide high intensity ultraviolet and soft X–rays out to about 2 keV. A wiggler magnet is being designed to give higher energy radiation, extending the

The new User's Executive Committee at Fermilab. Members include; seated Jeff Appel (Secretary, Fermilab), Dick Gustafson (Chairman, Michigan), Jim Walker (Fermilab) standing — Mike Shaevitz (Columbia), Frank Turkot (Fermilab), Mel Schwartz (Stanford), Maris Abolins (Michigan State), Sharon Hagopian (Florida State), Jerry Rosen (Northwestern), Gaurang Yodh (Maryland), Larry Jones (Michigan), Tom Romanowski (Ohio State). Vince Peterson (Hawaii) is also on the Committee.

(Photo Fermilab)

In August, circulating beam was obtained in the vacuum ultraviolet storage ring of the new National Synchrotron Light Source at Brookhaven. To celebrate the occasion, NSLS staff posed in front of their building.

(Photo Brookhaven)



available range out to about 10 keV.

In July, a first section of the linac injector operated at 30 MeV. Prototype bending and quadrupole magnets plus vacuum chamber and other components have also been built. The site selected near the University has space for future expansion, such as a 2.5 GeV electron machine for nuclear physics.

The work is supported by the Chinese Academy of Science and about a hundred scientists and engineers from the University and elsewhere are involved. A design report for the synchrotron radiation facility is being prepared and it is hoped to have authorization in about six months. The Chinese scientists greatly appreciate contacts of all kinds with their colleagues elsewhere.

Conferences

From 11—14 January, an International Colloquium on Baryon Nonconservation (ICOBAN) will be held at the Tata Institute of Fundamental Research, Bombay. Over fifty theorists and experimenters are expected to participate. Topics will include present and planned experiments on proton decay and neutron-antineutron oscillations as well as theoretical and cosmological aspects of baryon nonconservation. Further details from Dr. V.S. Narasimham, Secretary, ICOBAN, TIFR, Homi Bhabha Road, Bombay — 400 005, India.

From 17—23 February an International Conference on Instrumentation for Colliding Beam Physics will be held at the Stanford Linear Accelerator Center. It is the second in a series which started at Novosibirsk in 1977 and will cover recent technological developments in the construction and operation of detectors for colliding beam experiments. Further details from Ruth Thor Nelson, SLAC Bin 14, Box 4349, Stanford, CA 94305, USA.

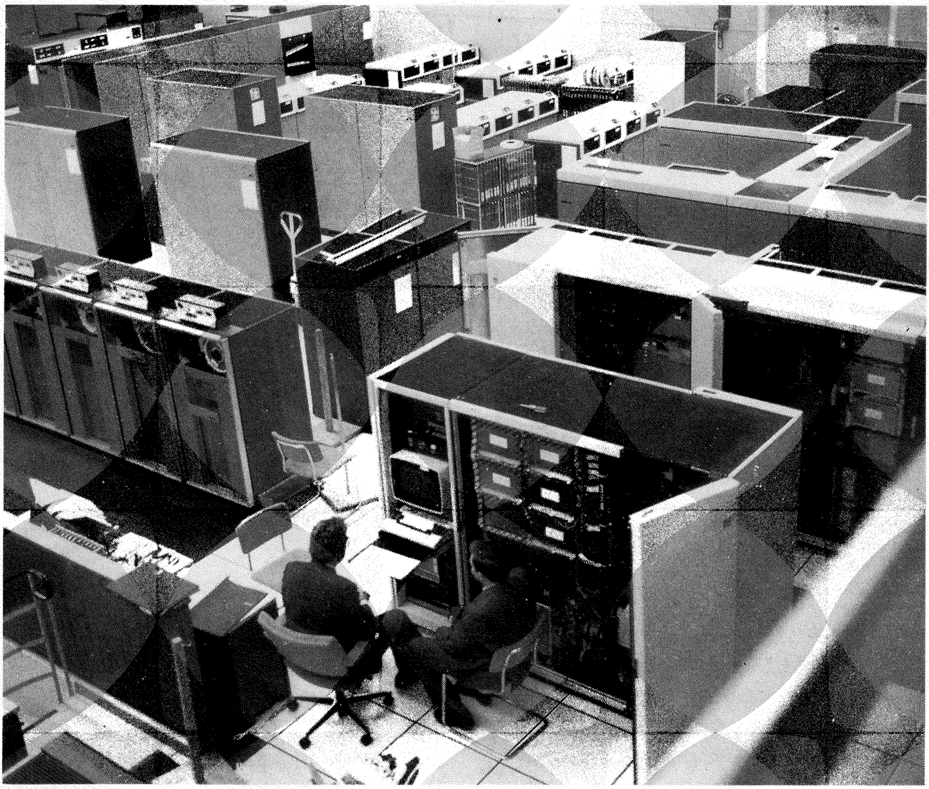
A Europhysics Conference on 'Computing in Accelerator Design and Operation' will be held in Warsaw from 21–24 September 1982. The papers will be grouped under four headings — Design aspects of accelerators, Digital control of accelerators, Operational aspects and experimental data processing, Special applications of accelerators (medicine, industry, synchrotron radiation, etc.). Chairman of the Organizing Committee is Prof. R. Zelazny, and further information is available from Miss J. Clszewska, R. C. C. CYFRONET, Institute of Nuclear Research, 05–400 Otwock–Swierk, Poland.

Electron laser success

A team at Los Alamos, led by Charles Brau, has demonstrated the principle of a high efficiency free electron laser. A 20 MeV free electron laser amplified the light from a conventional carbon dioxide laser with a much higher proportion of electron energy being converted into laser light than can be achieved with conventional magnetic fields. The team is preparing a complete system for operation in 1983 and Brau has predicted

Seen here being checked out in the CERN Computer Centre is the new IBM 3081, which is now working alongside the existing IBM 370/168. The IBM 3032 processor previously in use has been sold.

(Photo CERN 144.9.81)



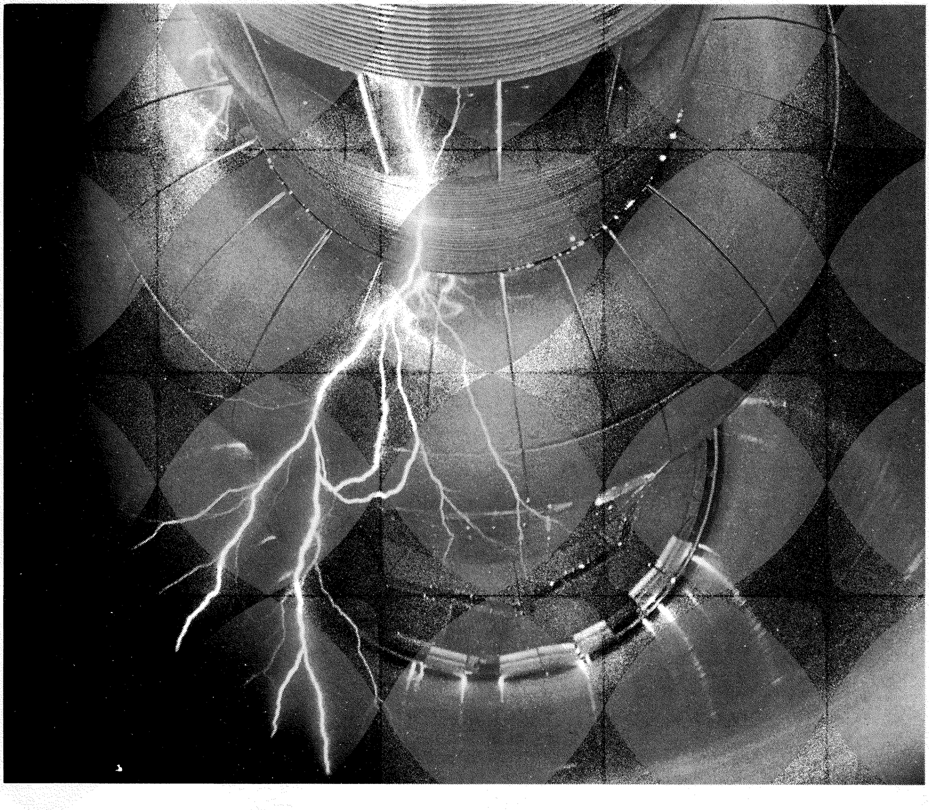
that all the remaining physics question marks over free electron lasers (deemed 'presently the sexiest things in accelerator physics' at the Washington Accelerator Conference in March) will be removed during the next year. Work on the development of electron lasers is also under way at several other research centres.

Argonne Microtron project

Work has started on a prototype magnet to confirm the design of a 2 GeV electron microtron under study at Argonne for use in nuclear and particle physics research. The design has two 25 MeV linacs in parallel linked via a novel magnet system, providing 2 GeV electrons after forty circuits through the two machines. The whole structure would only occupy some 40 by 15 m and would be comparatively economical in power consumption. The protoype magnet is scheduled to be tested next March. Other proposals for a national electron facility in this energy range are being put forward at MIT and Virginia.

ABEL, ready and willing

On 2 October a new ion source and injector system, known as ABEL, was inaugurated at Berkeley. It is to serve as injector of heavy ions into the SuperHILAC, and the range of intense ion beams which can be accelerated will be

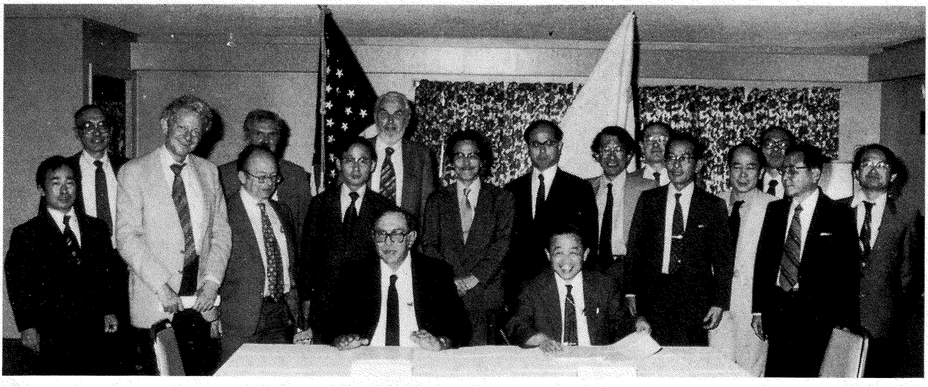


Home-made lightning in the Nuclear Structure Facility at the Daresbury Laboratory. This spark between the intershield and tank occurred with the terminal at 20 million volts during high voltage testing. Commissioning of the machine has been proving more difficult than anticipated.

(Photo Daresbury)

Third meeting of the Japan / U.S. Committee on High Energy Physics held at Fermilab on 26, 27 May. T. Nishikawa (Director General of the KEK Laboratory) and J. Leiss (DOE Associate Director for High Energy and Nuclear Physics) were co-Chairmen. The collaboration has gained further interest with the start of construction of the TRISTAN project in Japan which will complement the planned facilities in the USA.

(Photos Fermilab)



extended up to uranium. Early next year the Bevatron too will be able to accelerate uranium ions. The Bevalac (SuperHILAC linked to the Bevatron) will be unique in the world with this high energy, heavy ion capability.

The heavy ion research programme and future plans at Berkeley are reviewed in the feature article on page 393.

Medical uses for synchrotron radiation

The X-ray synchrotron radiation produced by electron storage rings could provide improved diagnosis in conditions such as coronary artery disease.

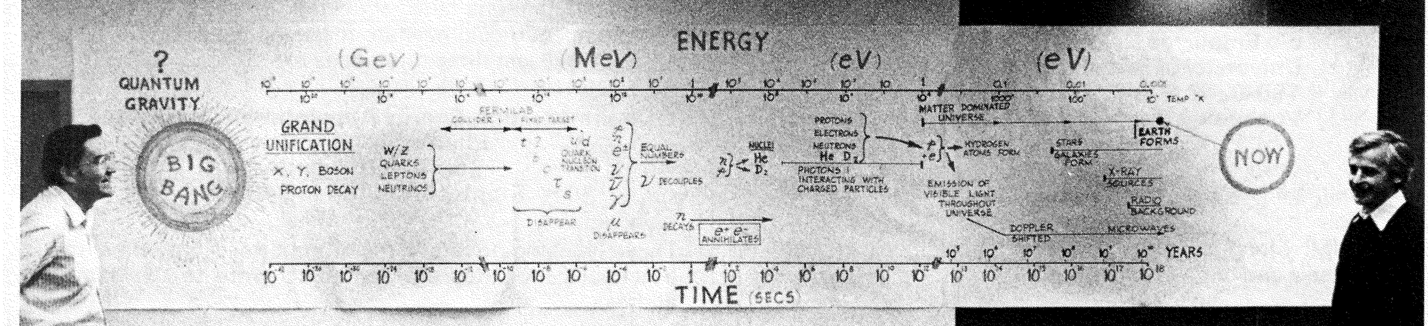
Tests on animal hearts at the Stanford Synchrotron Radiation Laboratory, which uses the SPEAR ring at SLAC, have shown that X-ray pictures can be taken more accurately, more easily and for less cost. A special area for carrying out clinical tests is under construction.

With synchrotron radiation, the X-ray wavelength can be tuned to the value which gives optimal imaging of specific tissues, avoiding the need for painful and expensive catheterization in which a suitable contrast medium has to be injected directly into the coronary arteries. Because of the intensity of the X-rays, very short exposure times are required, thus minimizing blurring due to heartbeats and ensuring a lower radiation dose.

Fermilab Latin America Center

Fermilab is proposing to set up an on-site Latin America Center for Fundamental Physics and Technology to assist scientists and engineers from developing countries. Rather than directly promoting high energy physics, the new institute would set out to provide scientists from developing countries with experience in a broad range of frontier technologies. It is hoped that about 30 fellows would pass through each year.

'Big Bang' wall chart prepared for the Fermilab Saturday morning physics class, showing links between cosmology and particle physics. Prepared by Jim Walker (right) and James Bjorken, the chart covers all time, but with the first second of the universe's existence taking up about half the available space.



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The tentative starting date for this position is 1 July 1982; the actual date can be a matter of negotiation. Applicants should submit a curriculum vitae, together with the names of at least three references, to:

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Those wishing to draw the Committee's attention to potential candidates are invited to write to the same address.

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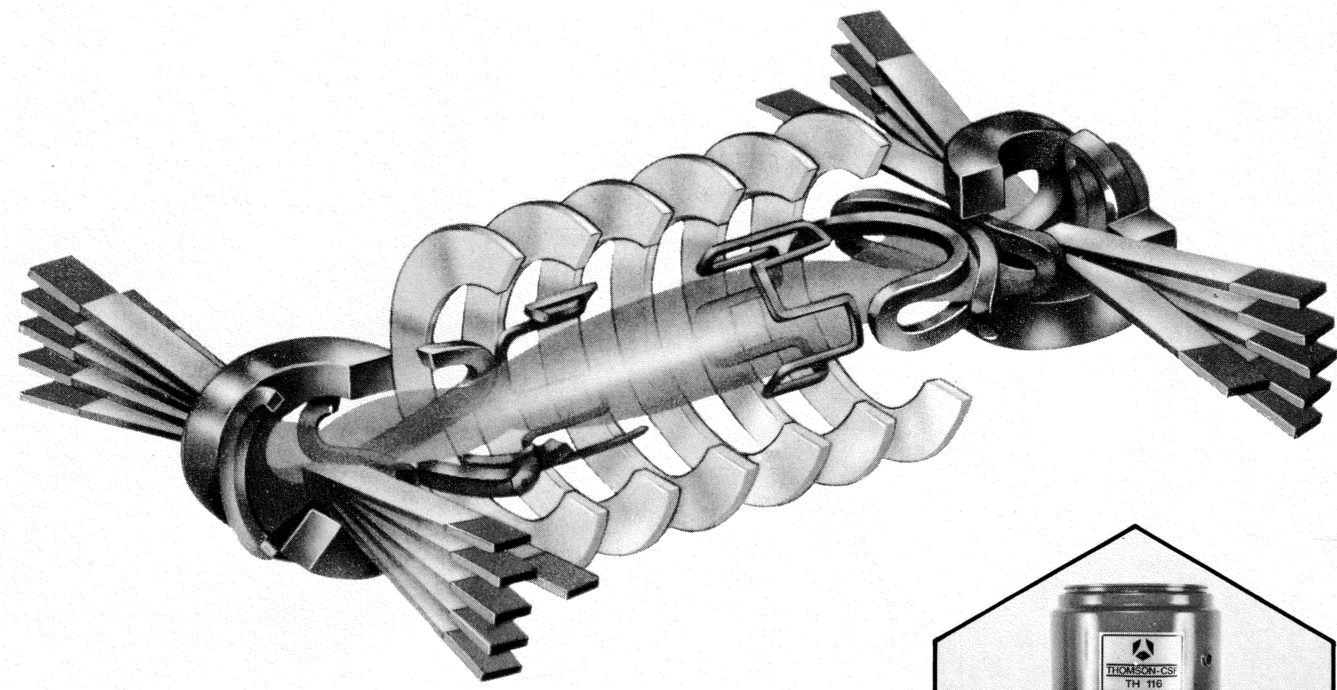

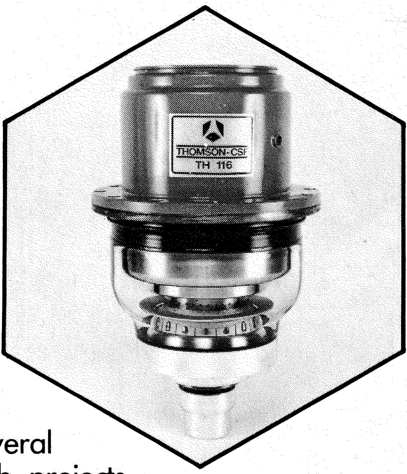

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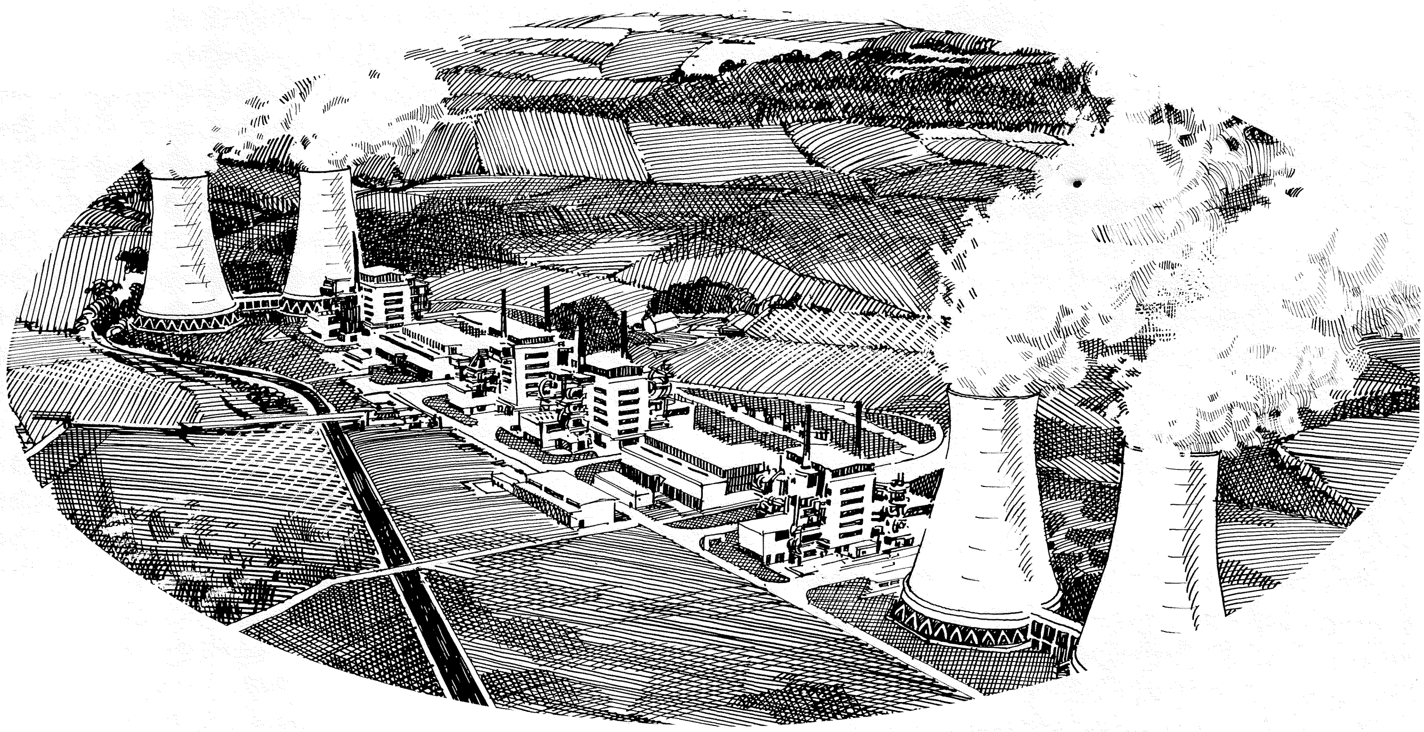

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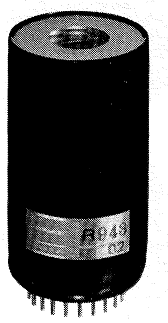

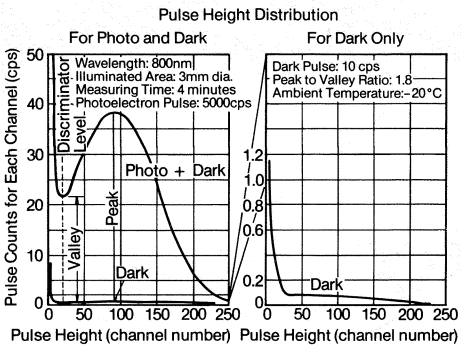
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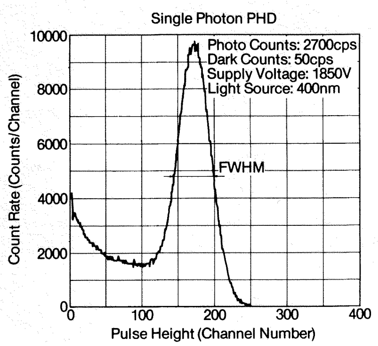
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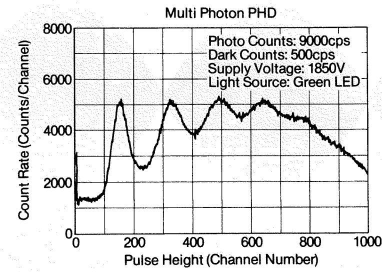
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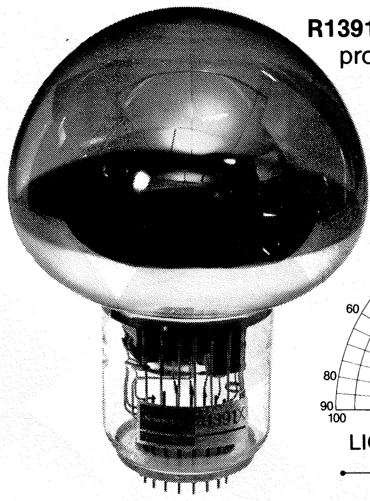

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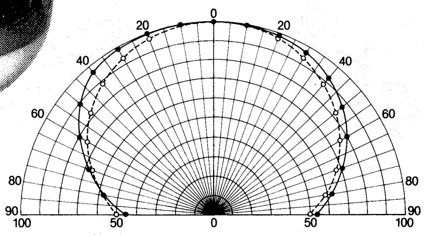

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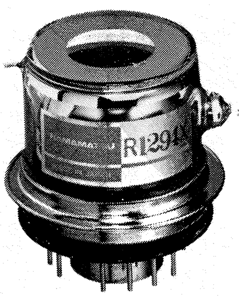

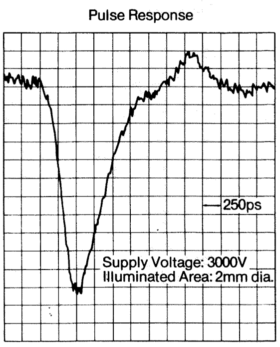
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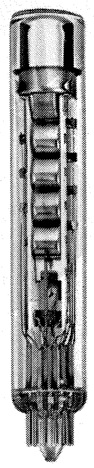

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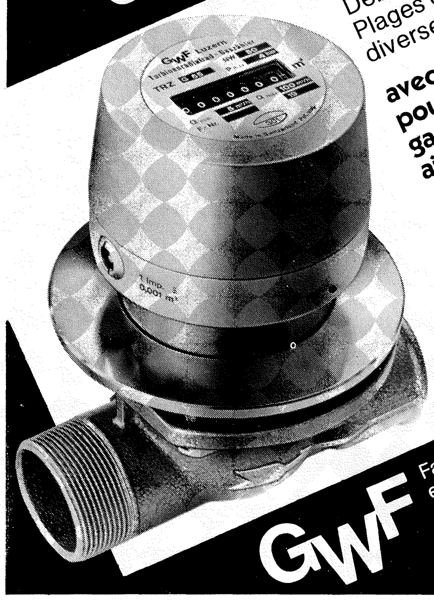

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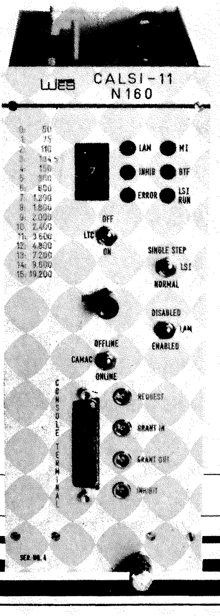

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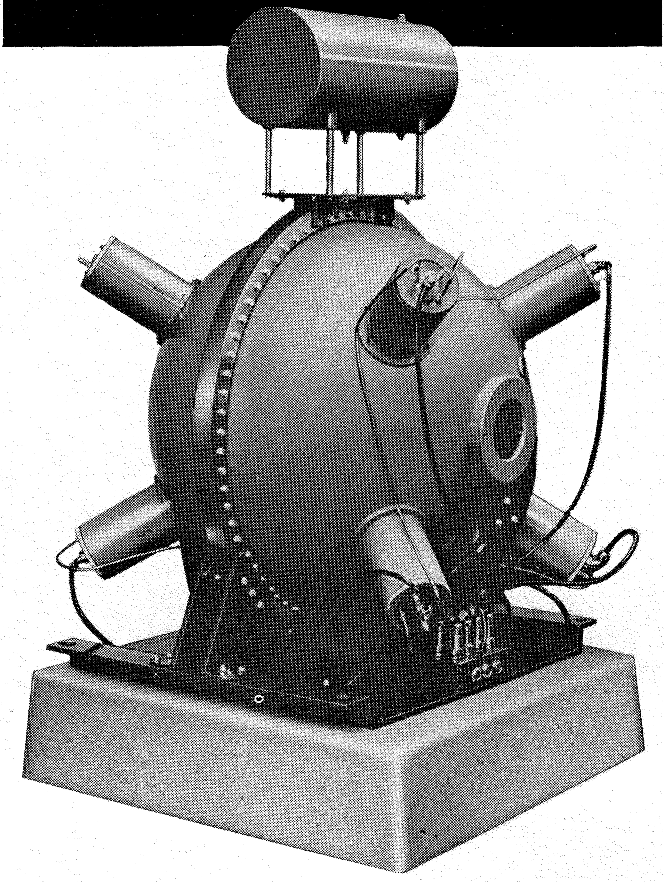

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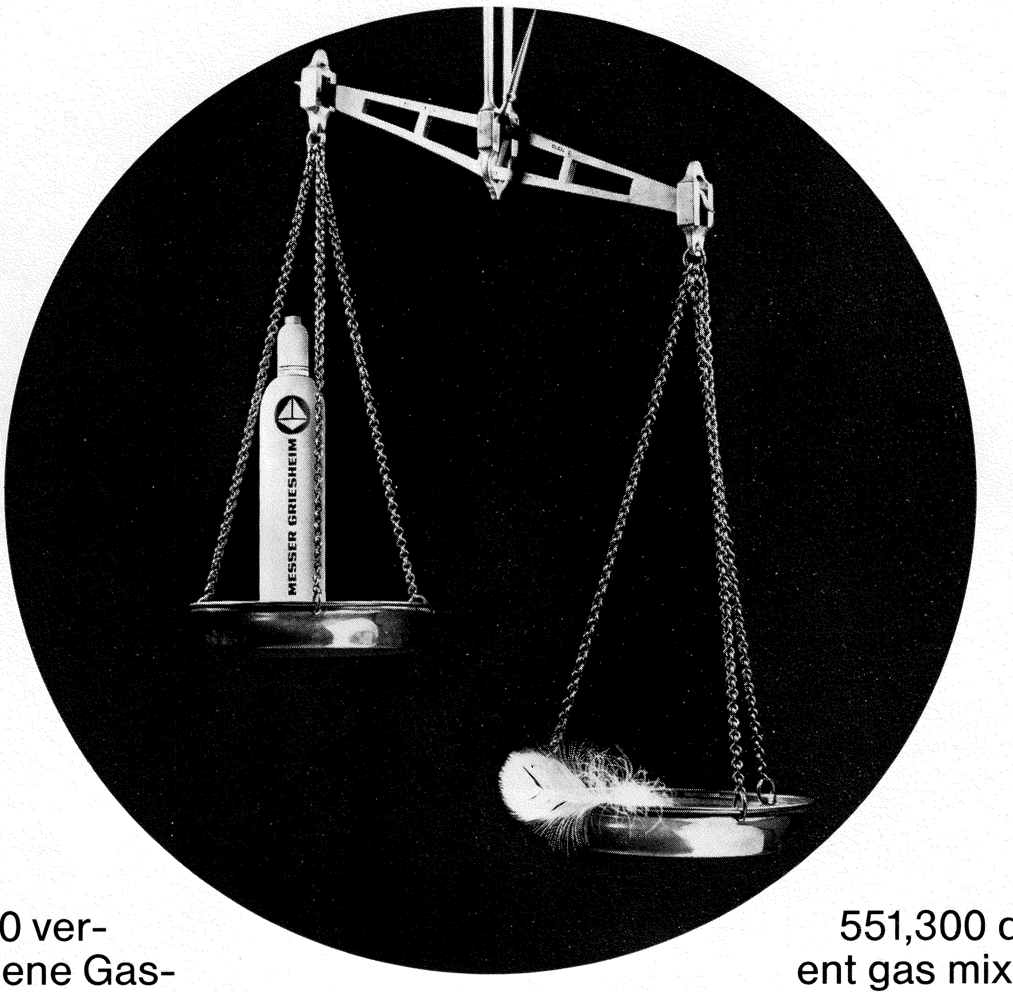
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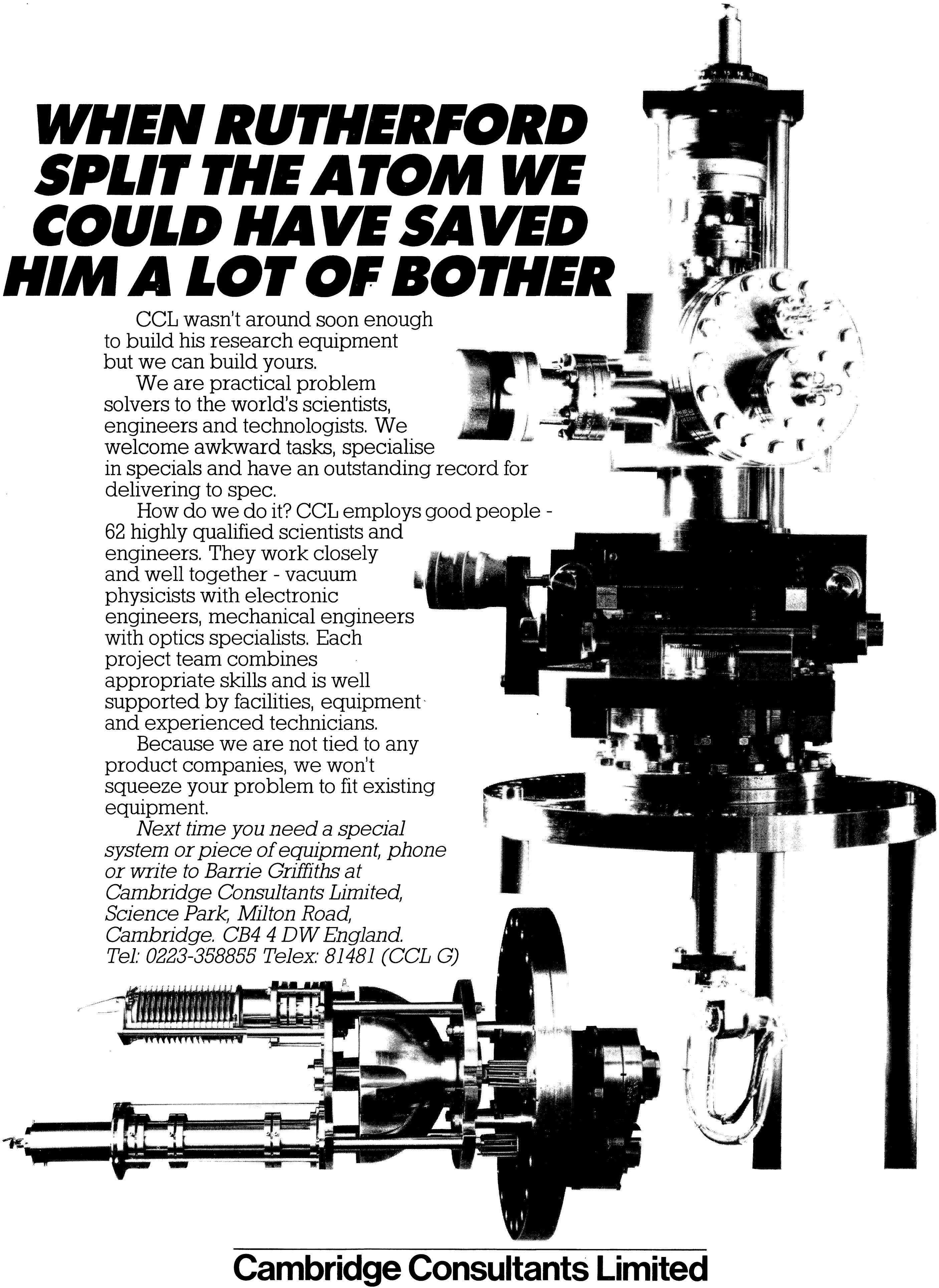

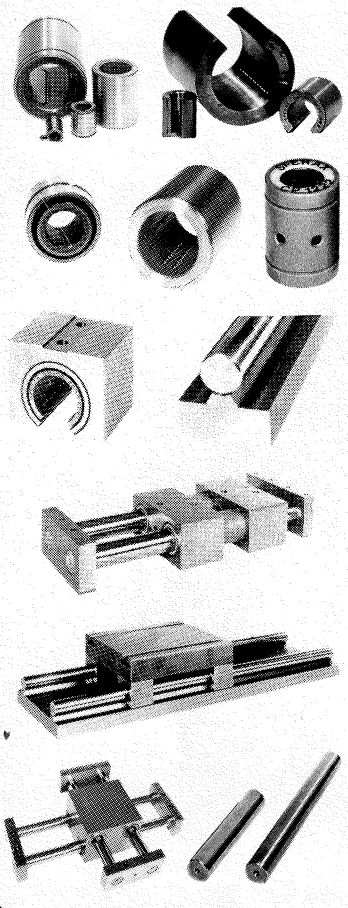

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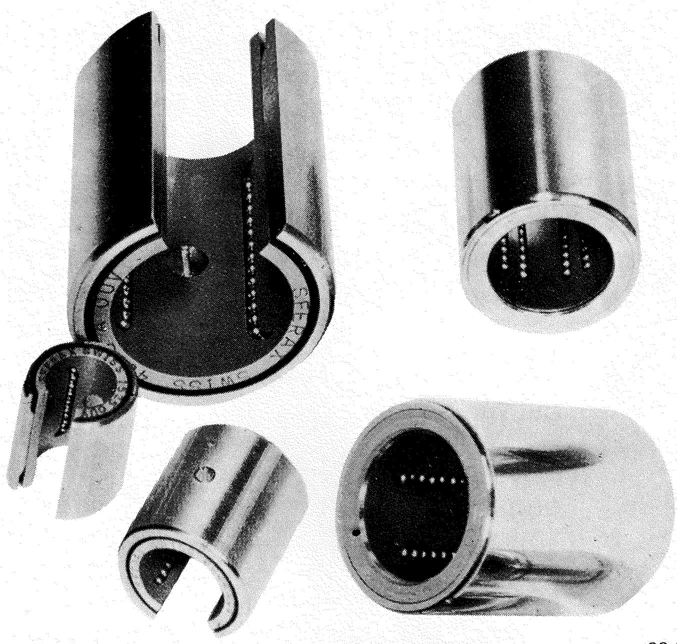

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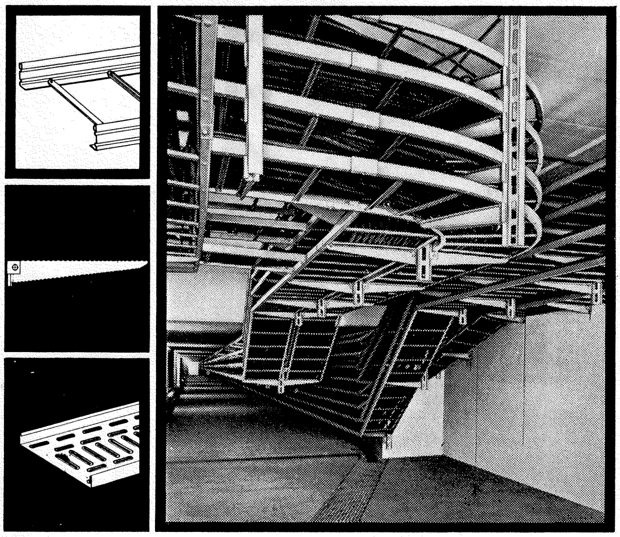

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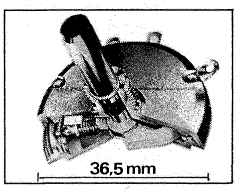

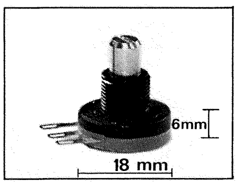

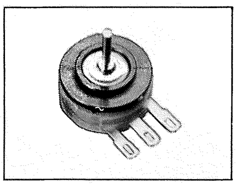

Serie 718 3 different types:
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Resistance range
718 LL and 718 S: 1 Ω to 100 k Ω
718 LC: 10 Ω to 30 k Ω

Independent linearity

	STANDARD	BEST PRACTICAL
Model 718 LL:	± 0,4%	(± 0,15%)
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Electrical angles 270°, 280°, 300°, 320°, 340°, 350°. Special: 357°.

Serie 714 724

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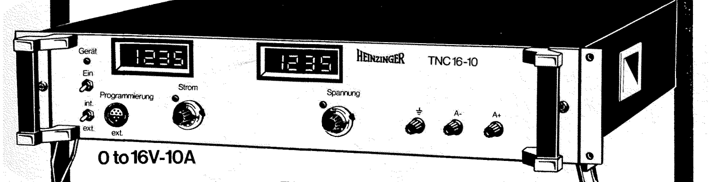

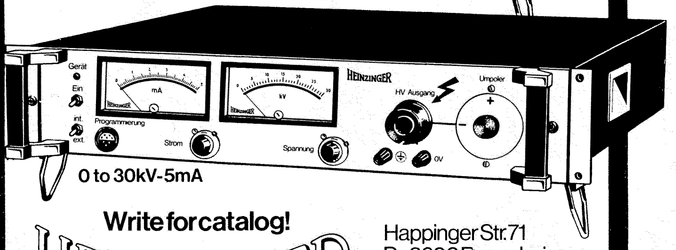

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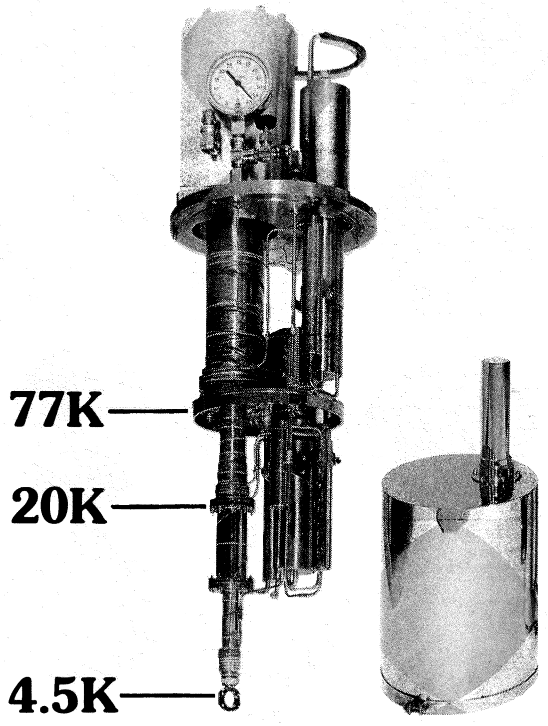

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For more information, write or call Advanced Products Department, Air Products and Chemicals, Inc., Box 2802, Allentown, PA 18105. (215) 398-8419.

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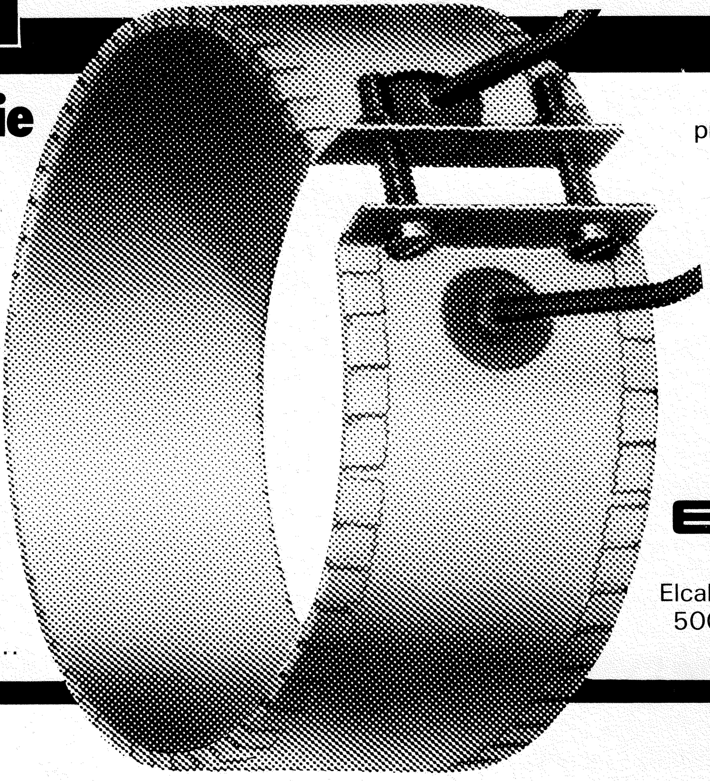

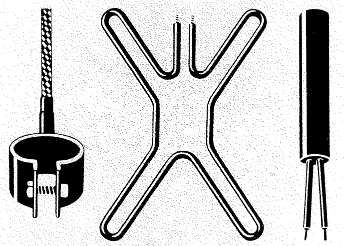

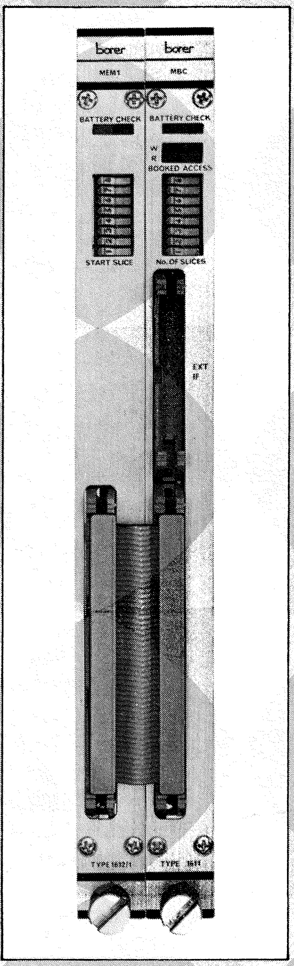
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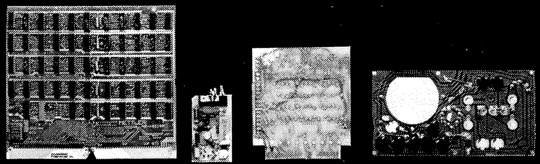

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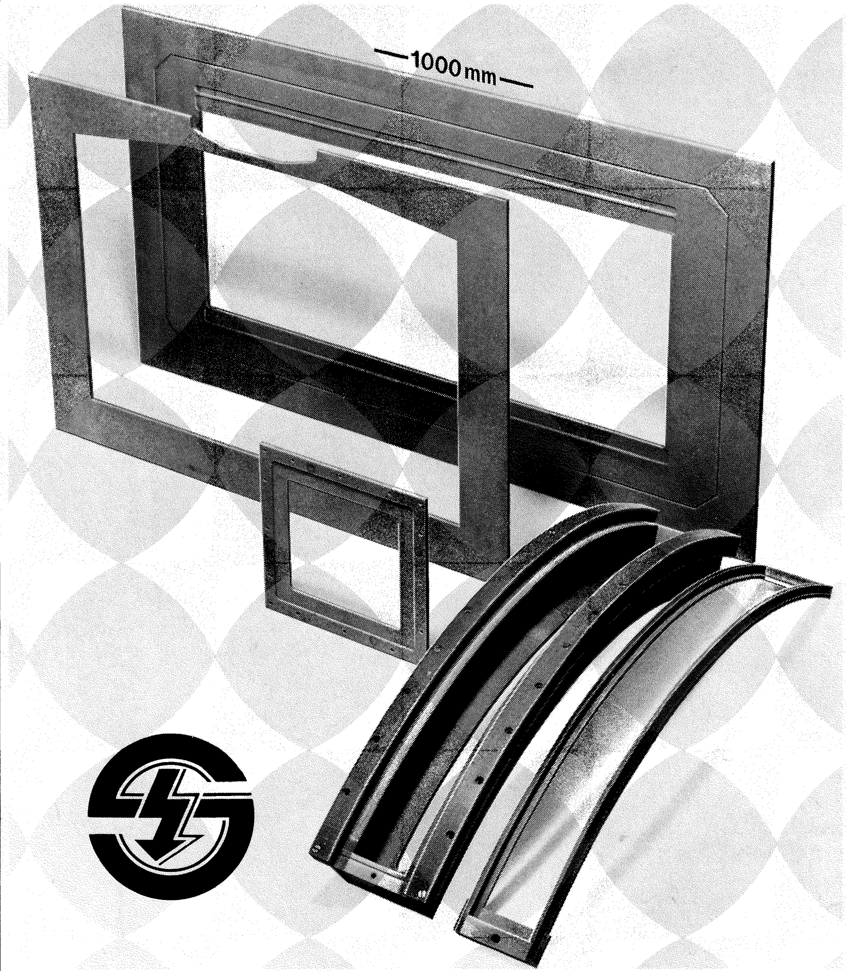

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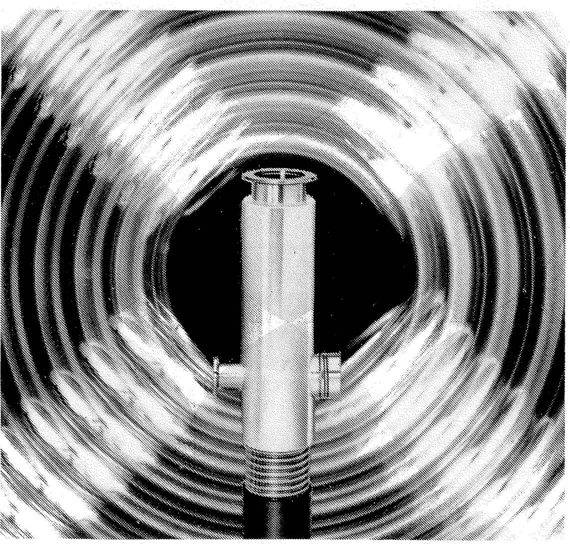

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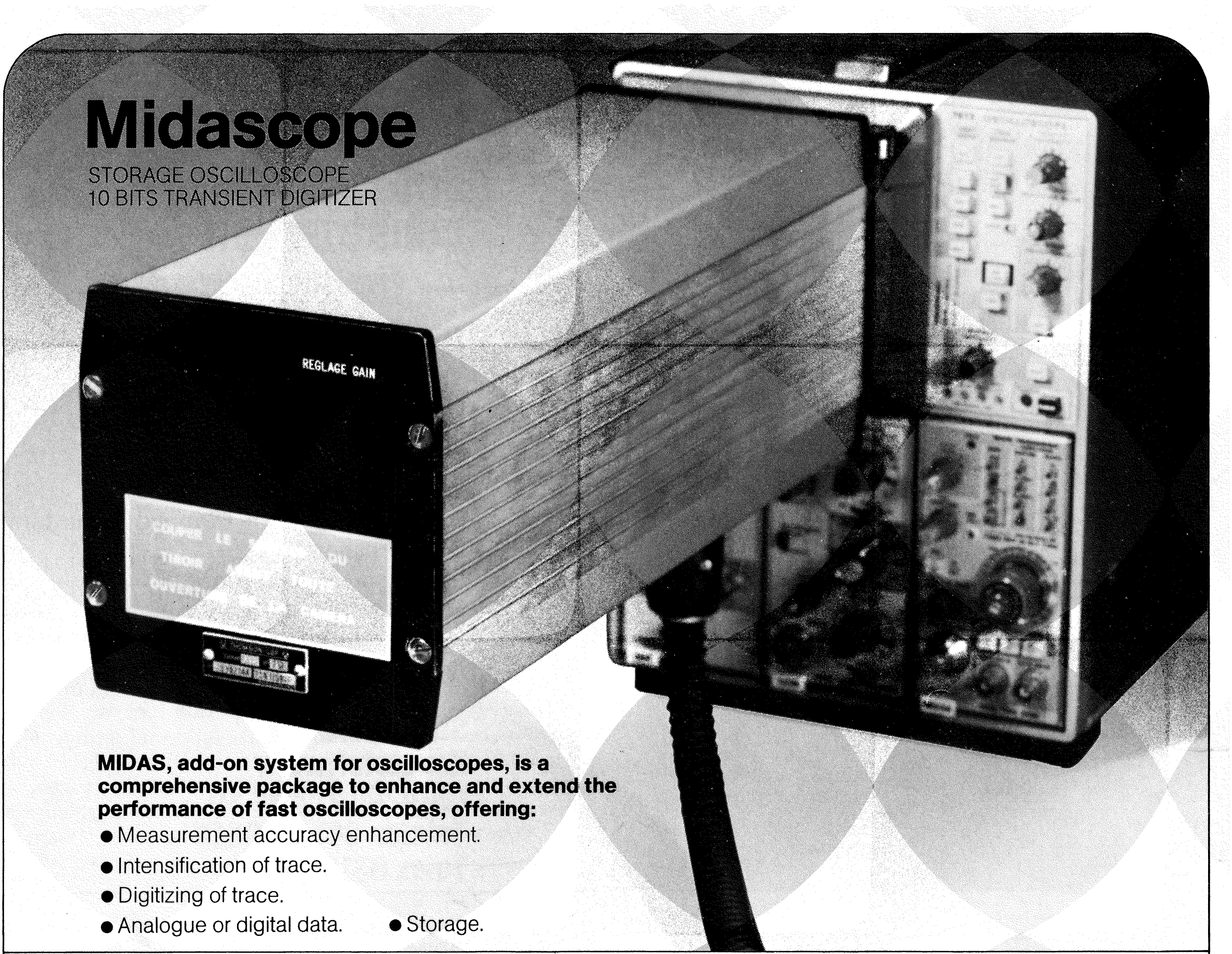

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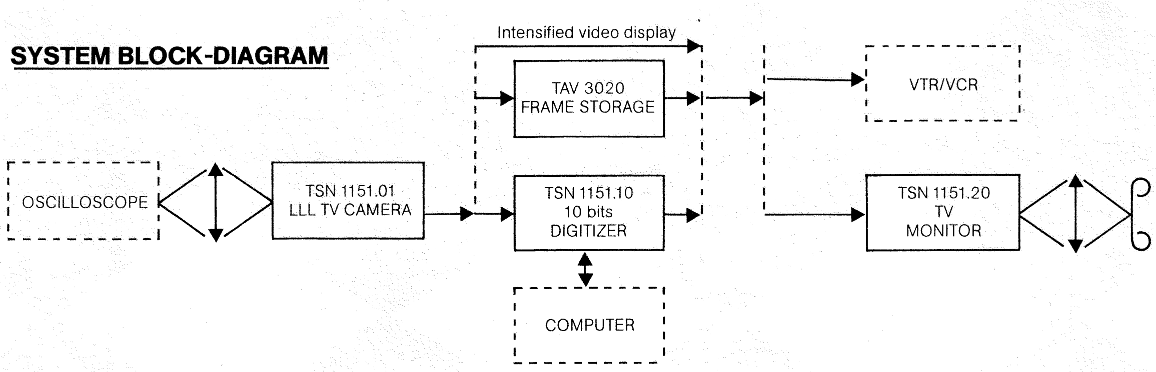

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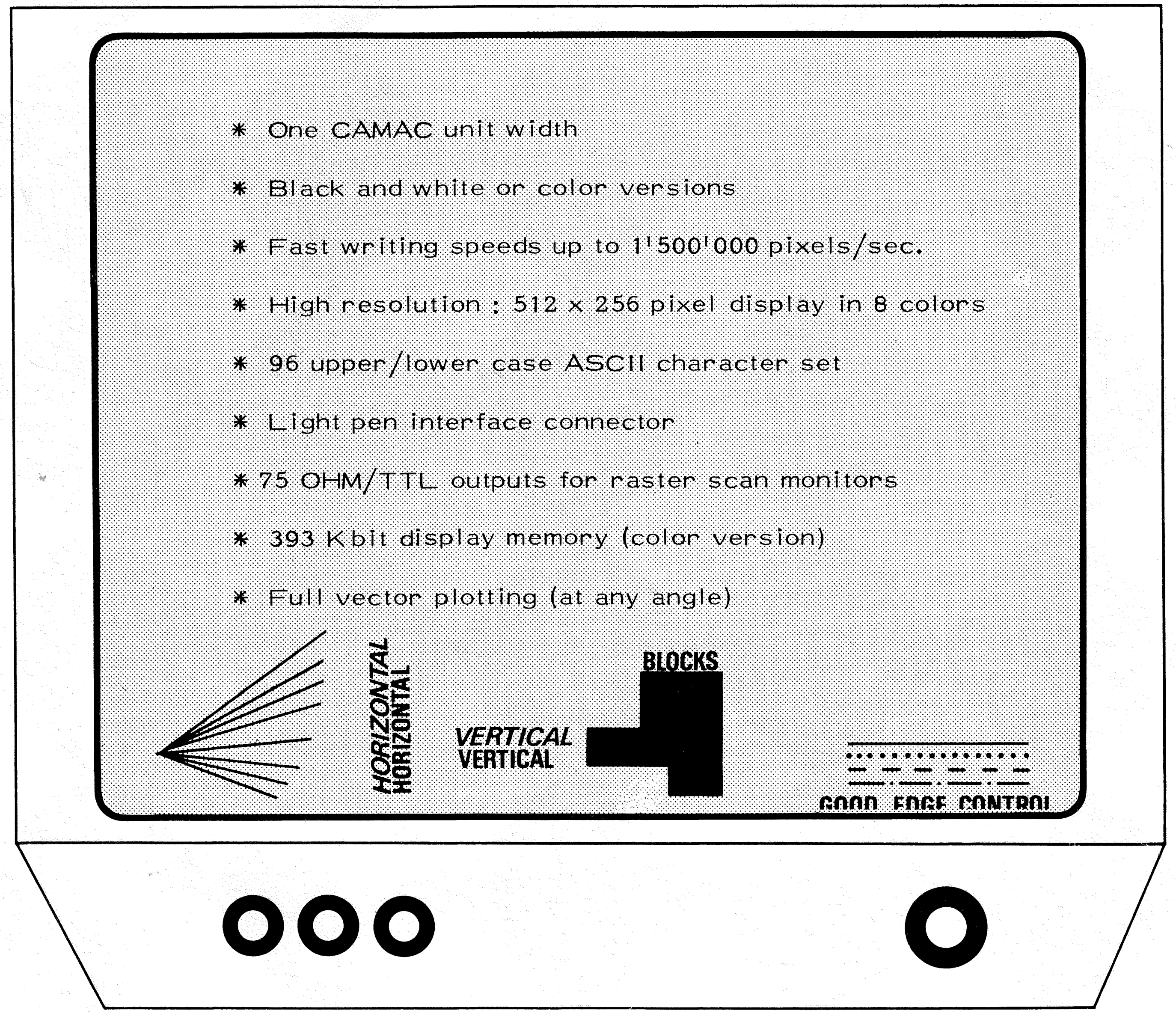

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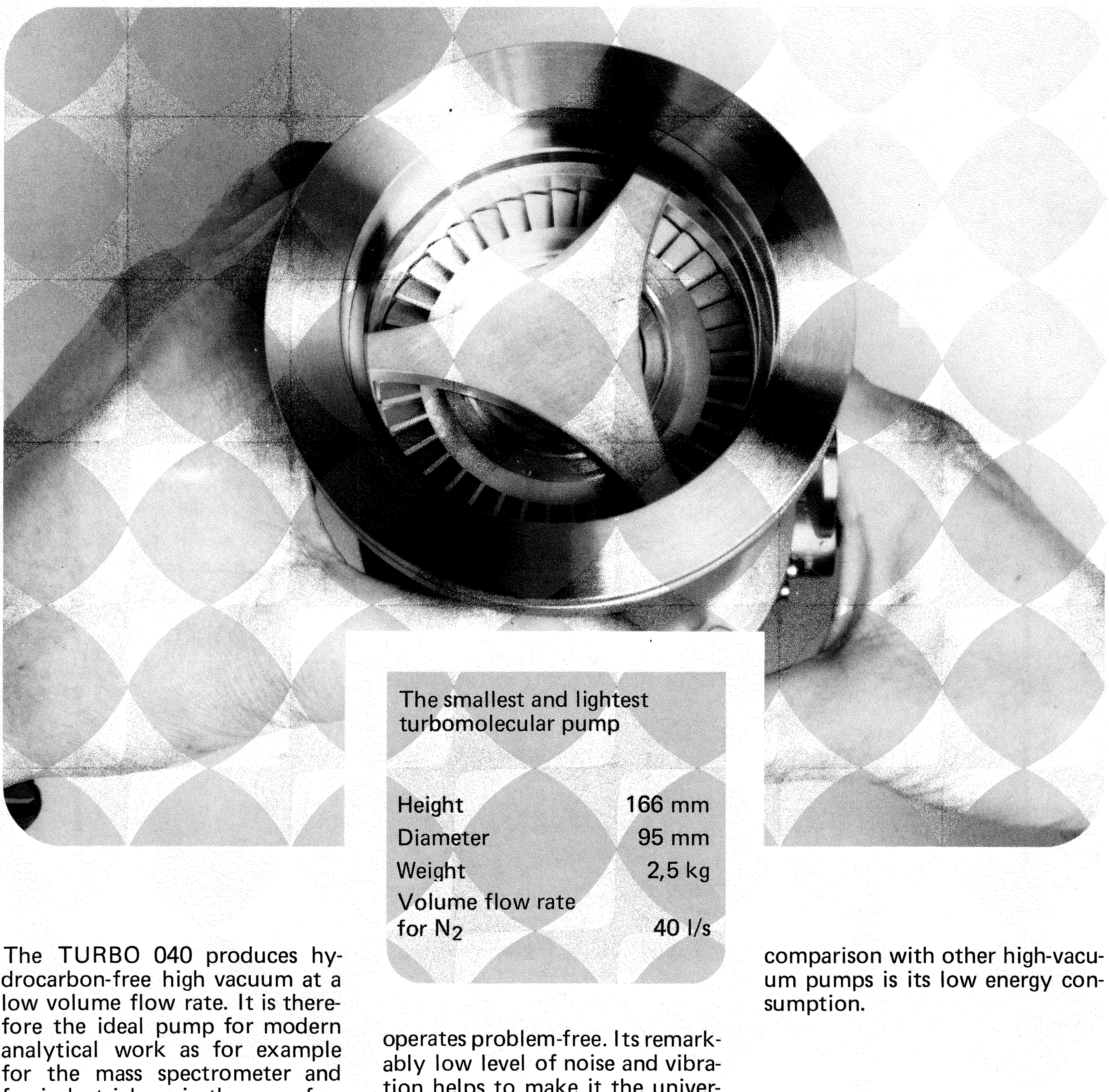

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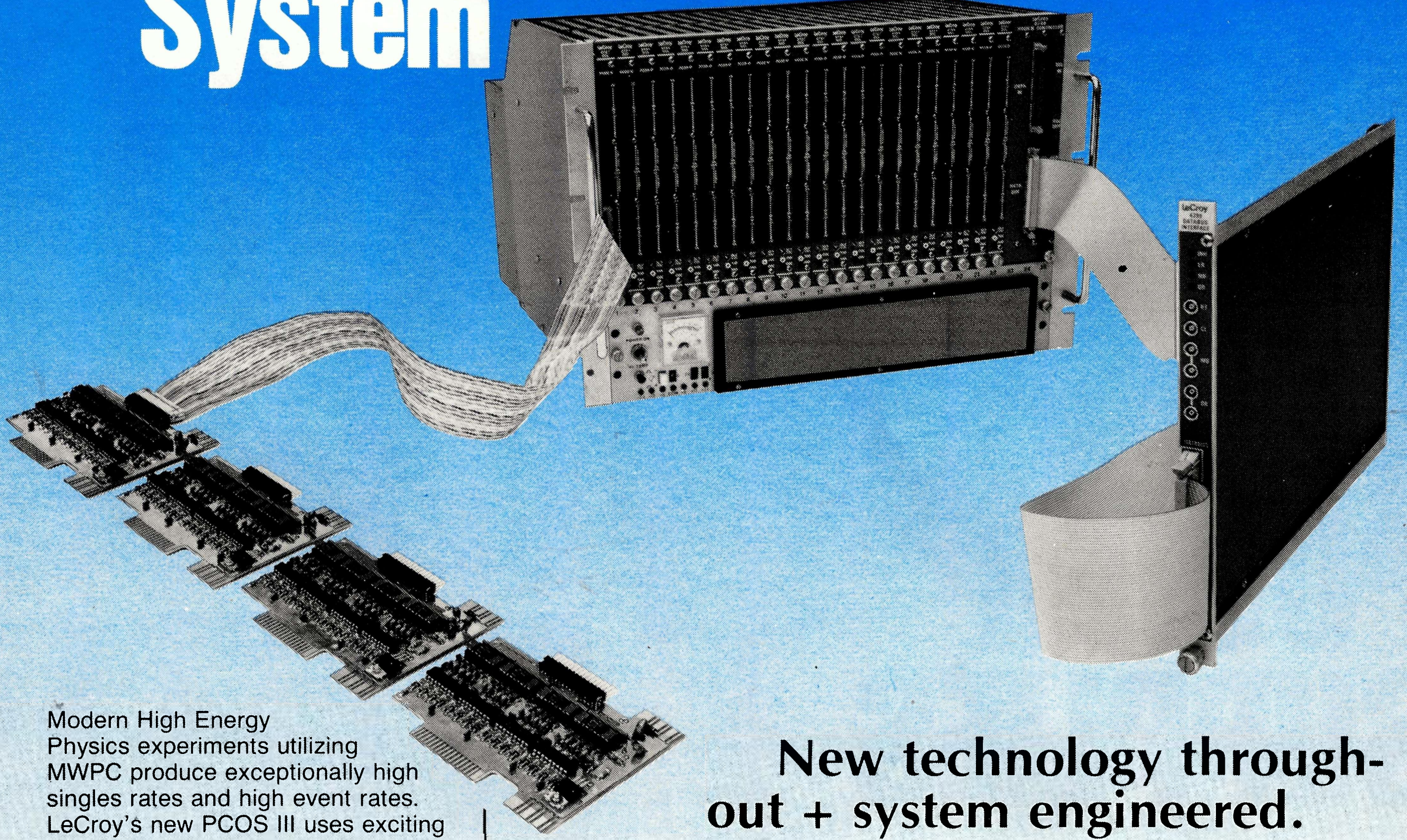

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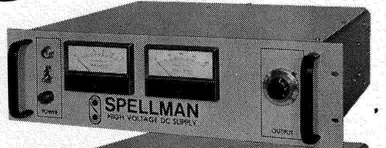
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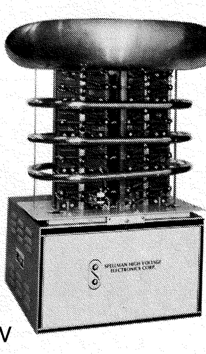
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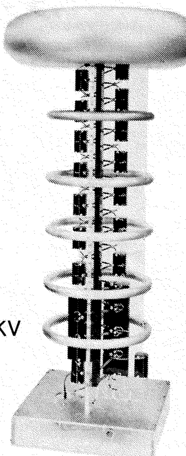
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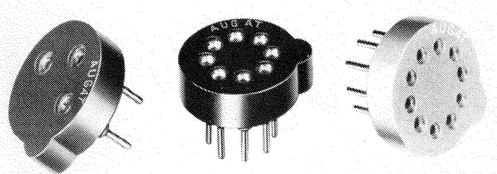

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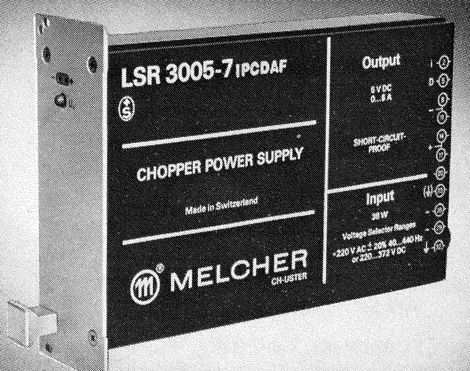

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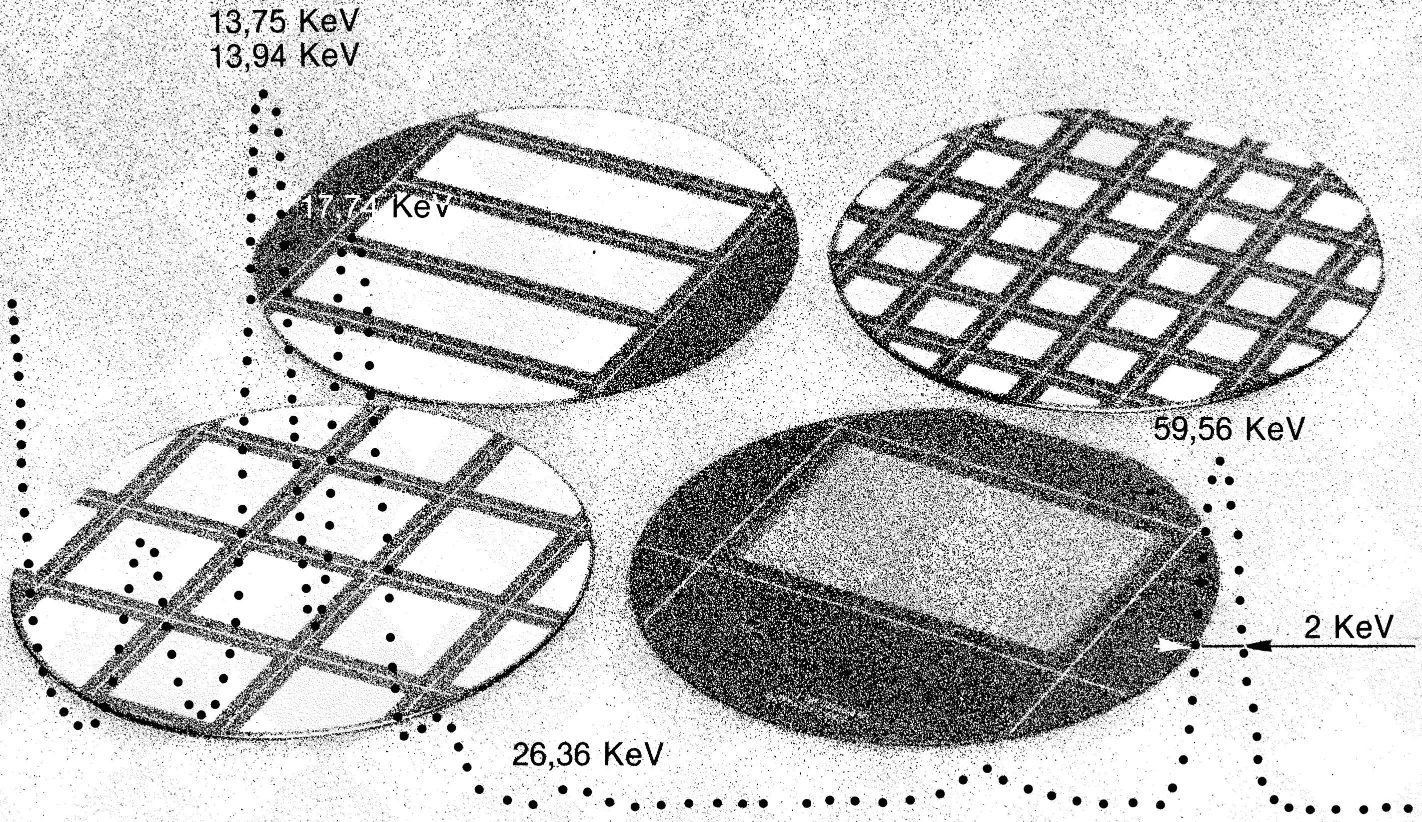
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