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Around the Laboratories

Cover photograph: The twilight world of the LEP electron-positron collider, now under construction at CERN. A forthcoming article will describe the impressive progress to date (Photo CERN X631.2.85).

Particle physics and technological spin-off

by John Dowell

In these cost-conscious days, public sector activities are having to cope with reduced levels of funding, and with more candidates vying for less and less money, the knife is poised to cut still deeper.

To defend themselves against such attack, particle physicists have been quick to point out that their area of Big Science is a highly fruitful source of technological development which has produced a wealth of valuable spin-off across a wide area of modern high technology industry.

In this article, John Dowell of the University of Birmingham, UK, and a member of CERN's Scientific Policy Committee, describes this impressive spin-off from particle physics, providing numerous examples. A longer version was prepared by a group of UK physicists as part of the evidence to the Kendrew Committee currently investigating the case for UK participation in particle physics (see September 1984 issue, page 288).

Technological spin-off from fundamental science has several time scales. Short term developments are typified by improvements to equipment manufactured by firms in close contact with the field. The high rate of innovation in the particle physics field produces technology available to industry and applicable over a very wide range of activities.

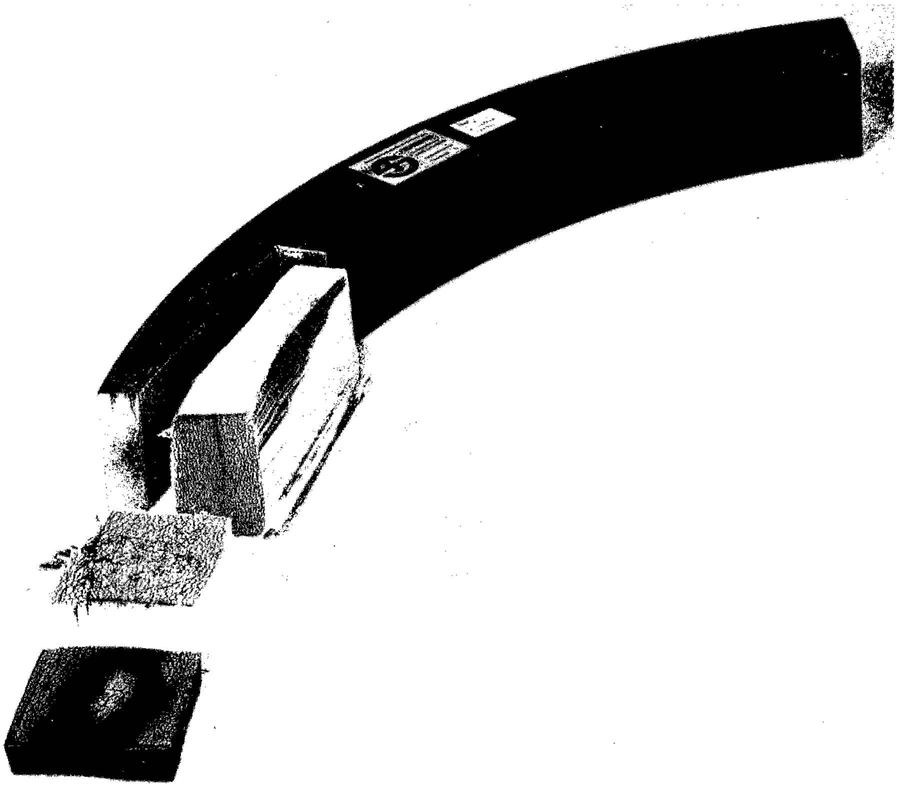
Medium term development is led by the need for fundamental science to press technology to the limit. Here, physics is at an important advantage as its practitioners are well qualified to invent and exploit the instrumentation required. Such instrumentation frequently finds extensive application in other areas of scientific research as well as in the commercial and medical fields. The developments also include whole areas of application arising from a particular discovery such as, for instance, the muon spin rotation technique.

Very long term spin-off permeates vast areas of technology and affects our whole culture. Such developments from fundamental studies are rare and unpredictable and the timescale of the resulting technological impact is long. An outstanding example is the development of the quantum theory to account for the behaviour of matter at the atomic level and which now underlies all of the technologies involving matter on the molecular, atomic and nuclear scales, including all of modern electronics.

Short term effects

To gauge short term technological spin-off, studies at CERN have measured the 'economic utility' to firms with CERN contracts*. This was assessed in hard cash terms based on increased sales and cost savings arising out of the CERN contracts and additional to the value of the contract itself (see January/February issue, page 8).

Short term technological spin-off



The CERN Task Force of the British Overseas Trade Board noted that particle physics requirements have had a significant impact on techniques for handling epoxy and plastics.

(Photo CERN 55.4.84)

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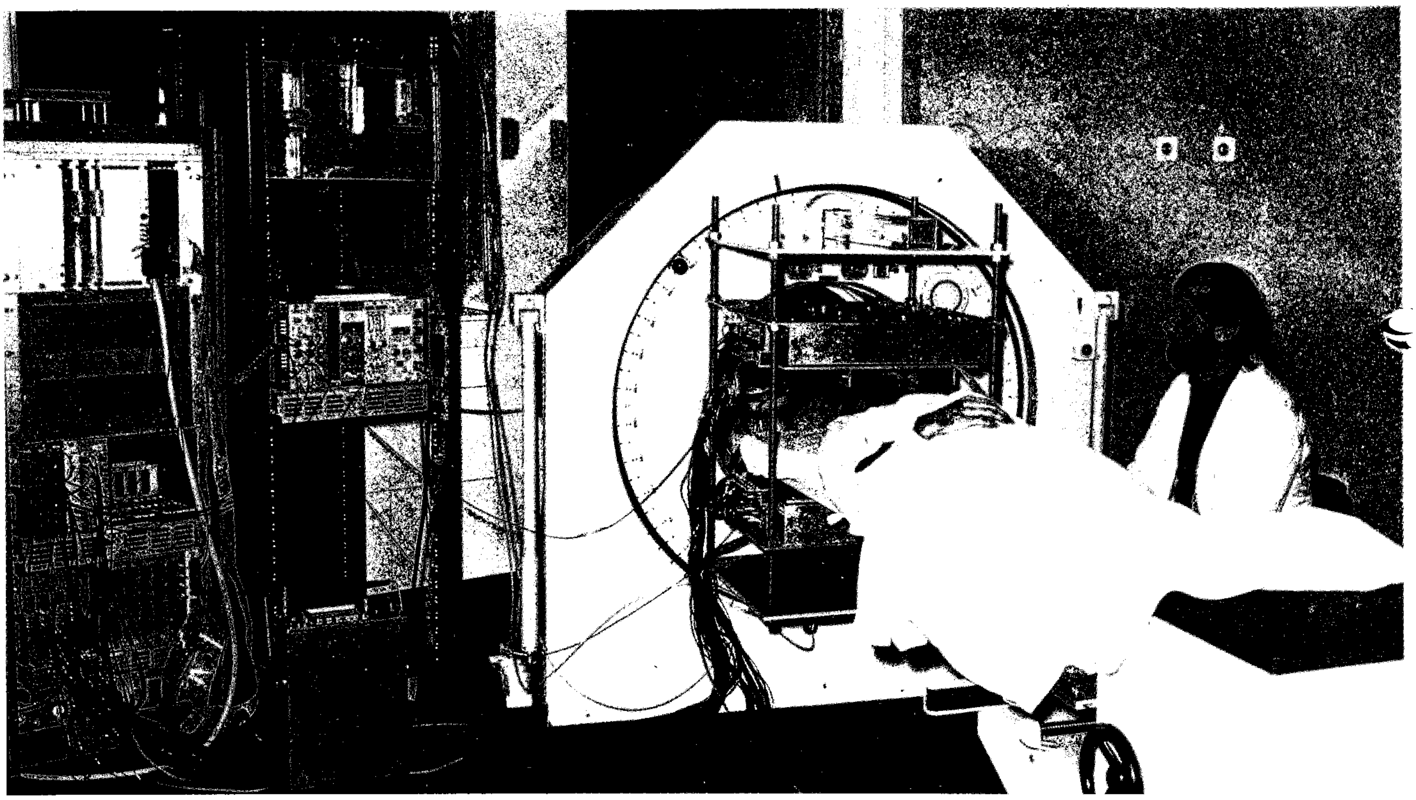
* *Economic Utility Resulting from CERN Contracts — a study by M. Bianchi-Streit, N. Blackburne, R. Budde, H. Reitz, B. Sagnell, H. Schmied and B. Schorr, available from CERN Publications, 1211 Geneva 23, Switzerland.*



A view of a positron camera developed at CERN being used for tomographic imaging at a major Geneva hospital.
(Photo CERN 419.2.82)

from CERN's work covers an impressive range, including computers, electronics, telecommunications, power generation and distribution, cryogenics, vacuum technology, optics, precision mechanics, magnet technology, steel and welding, car design, railways, shipbuilding, subway control, refrigeration, oil prospecting, materials storage, television, and solar energy.

Particle physics requirements have also had a significant impact in manufacturing techniques and the industrial application of new materials. The CERN Task Force of the British Overseas Trade Board notes a number of examples:

— construction of low mass, high strength structures using glass reinforced epoxy and plastics such as kapton, mylar and kevlar;

— fabrication of epoxy-resin mouldings to new standards of reproducibility and uniformity;

— development of epoxy resins for use as electrical insulators (now replacing ceramics in many applications);

— development of conducting plastics with moderate resistivities and precisely defined characteristics;

— production of multicore superconducting wires using hydrostatic methods;

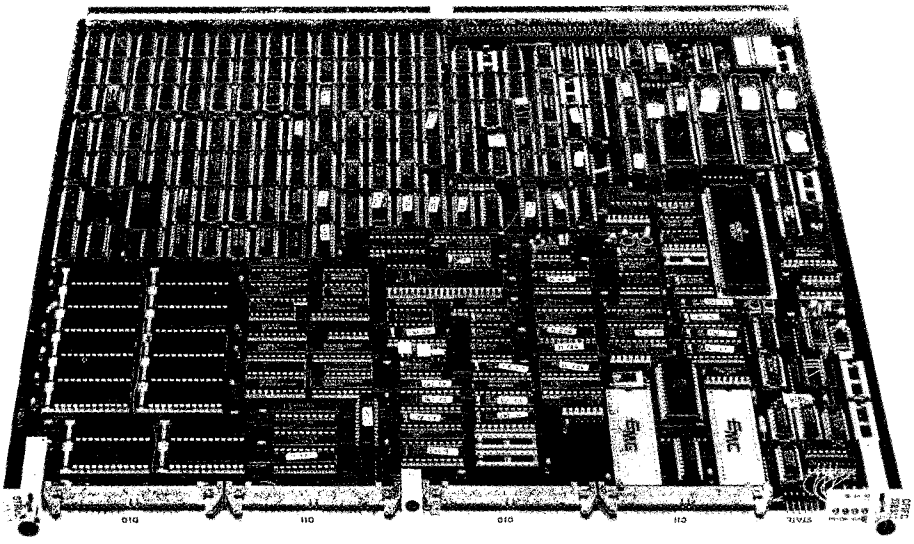
— invention of the flat cabling technique (known worldwide as the Rutherford technique) now widely used for transformer coils as well as for superconducting coils;

— development of high quality electrical insulation for use at low temperature.

Technology transfer

With the increasing application of particle accelerators and radioactive sources it is not surprising that particle detectors have followed suit. This kind of spin-off extends from the earliest detectors developed for nuclear research (Geiger counters) through all kinds of scintillation counters to multiwire proportional chambers. Although important development work has taken place in the fields of application themselves, the real innovations in detectors have come from the nuclear/particle physics area.

A good example is the multiwire proportional chamber (MWPC), invented in 1968 by Georges Charpak working at CERN. It provides a sensitive, high precision, versatile, two dimensional detector of radiation. The vast range of sizes



Fastbus, the new data acquisition electronics system standard for high energy physics, looks like following its predecessor, CAMAC, which was widely adopted in many other sectors.

(Photo Dr. B. Struck)

and types of MWPC are one of the principal detection techniques in particle physics. In addition, applications in medicine, materials science and biochemistry are starting to appear — positron tomography and X-ray imaging being two good examples.

The positron (antielectron) was one of the earliest discoveries of article physics. It is emitted by certain radioactive substances and is produced along with an electron by sufficiently energetic gamma rays. Positrons annihilate with electrons in ordinary matter to produce two gamma rays each of energy 511 keV, which fly off in opposite directions. Detection of the two gamma rays defines a line through the point where the positron annihilation occurred. Measurement of a number of such approximately intersecting lines defines the position of the positron emitter in space. Suitable MWPCs provide excellent two dimensional detectors for the annihilation gamma rays. Coupled with appropriate electronics (also developed for article physics applications) and readily available small computers, a 'user friendly' system can be provided.

In the medical sector, such systems are now undergoing clinical trials. *In vivo* images can be produced in acceptable scan times from radiographically acceptable radiation doses. Applications to date include blood flow in peripheral limbs and in the brain, arthritic bone lesions, thyroid studies, bone marrow studies, and bone metastases and various research studies using animals.

The MWPC has lately proved to be a useful large area two dimensional X-ray imaging detector with applications in X-ray diffraction, medicine, non-destructive testing, etc. The high quantum efficiency for 8 keV X-rays in a suitably constructed chamber reduced to two hours the time necessary for an X-ray diffraction study which would have taken several days by traditional methods. In the area of non-destructive testing, a gamma-ray imaging detector has been developed using a cobalt-60 source for examination of large underwater welded structures.

These applications and others use standard MWPC technology, but recent developments such as the multistep avalanche detector promise additional possibilities.

Electronics and Computing

A notable feature of particle physics has been the development of modular data acquisition systems which have subsequently gained wide acceptance outside the field. An initial example was the Harwell 2000 series of the early 1960s, but this has been followed by Nuclear Instrumentation Modules (NIM), CAMAC and now Fastbus. NIM and CAMAC crates, power supplies and modules are available from many manufacturers world-wide and CAMAC, in particular, is a natural choice for high quality, medium speed, computer-controlled data acquisition systems.

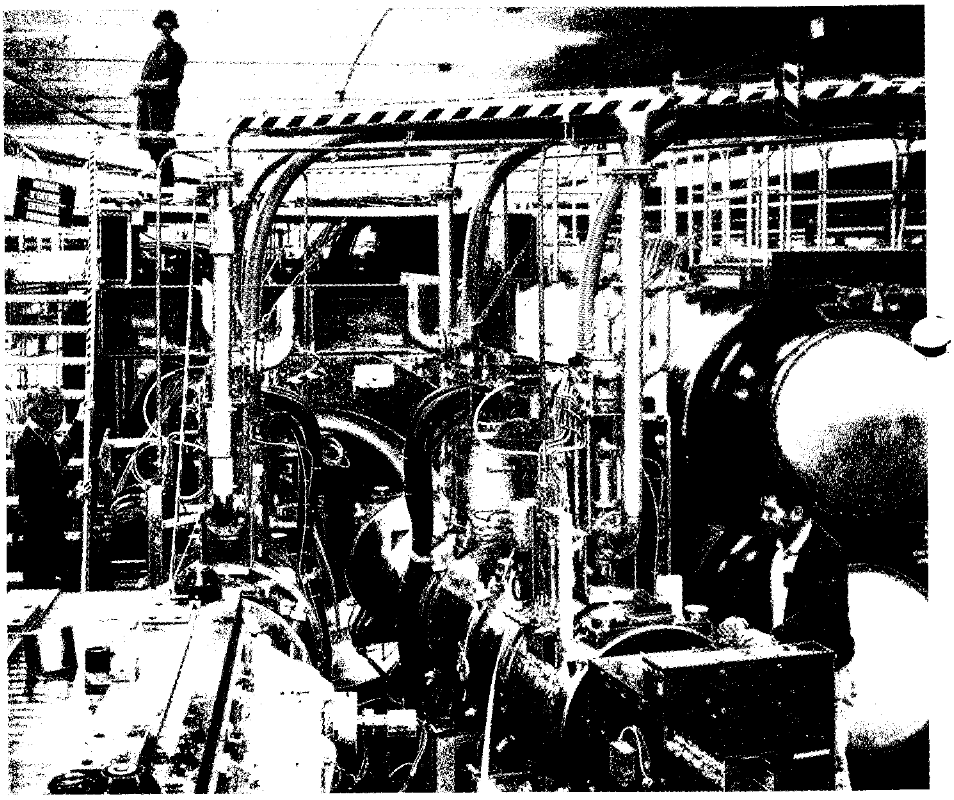
As well as the hardware, particle physics groups have also developed sophisticated software. For instance the Data Handling Division at CERN has supplied CAMAC software to at least 25 users outside the particle physics field (in astronomy, medicine and other branches of physics) over the last few years. Fastbus has only been available for a short time but new modules are appearing on the market every month and it seems likely to become the future standard for very high performance systems.

In other specialized areas of data acquisition, such as the implementation of economical, high speed systems with thousands of channels of time-to-digital or amplitude-to-digital conversion, particle physics has played a pioneering role.

Particle physicists were one of the first groups of scientists to use on-line computers for monitoring the performance of apparatus and for data acquisition and have been in the forefront of this technology since the early sixties. The combined software and hardware expertise at CERN has been recognized by Electricité de France, which made a detailed study of the multi-computer system used to control the 450 GeV Super Proton Synchrotron and has adopted several of its features for the control of its new generation of nuclear power stations. Elements of the SPS control system have been employed in seven other Laboratories.

Particle physicists have been major users of large computer systems for off-line data analysis for many years. They pioneered techniques for maintaining suites of programs which could be used by many physicists in different institutions and yet be under simultaneous development. A very large number of routines for ray tracing, data manipulation and display, curve fitting and pattern recognition have been developed and are widely used for applications beyond the particle physics field.

In particular, UK particle physicists were quick to realize the need for a communications link between all university departments working in the field and the Rutherford Appleton Laboratory. Initially only a means of providing remote job entry to the RAL mainframe computers, this developed into a network linking multi-user computers in the universities to RAL, CERN and DESY. The UK part of this network was extended to form SRCNET. The immense advantages of such networks have been recognized both nationally, with the introduction of the Joint Academic NETwork, and internationally.



Cryogenics and superconductivity provide one of the most striking examples of spin-off from particle physics. Bottom right is a large superconducting magnet developed for use at the CERN Intersecting Storage Rings.

(Photo CERN 397.9.80)

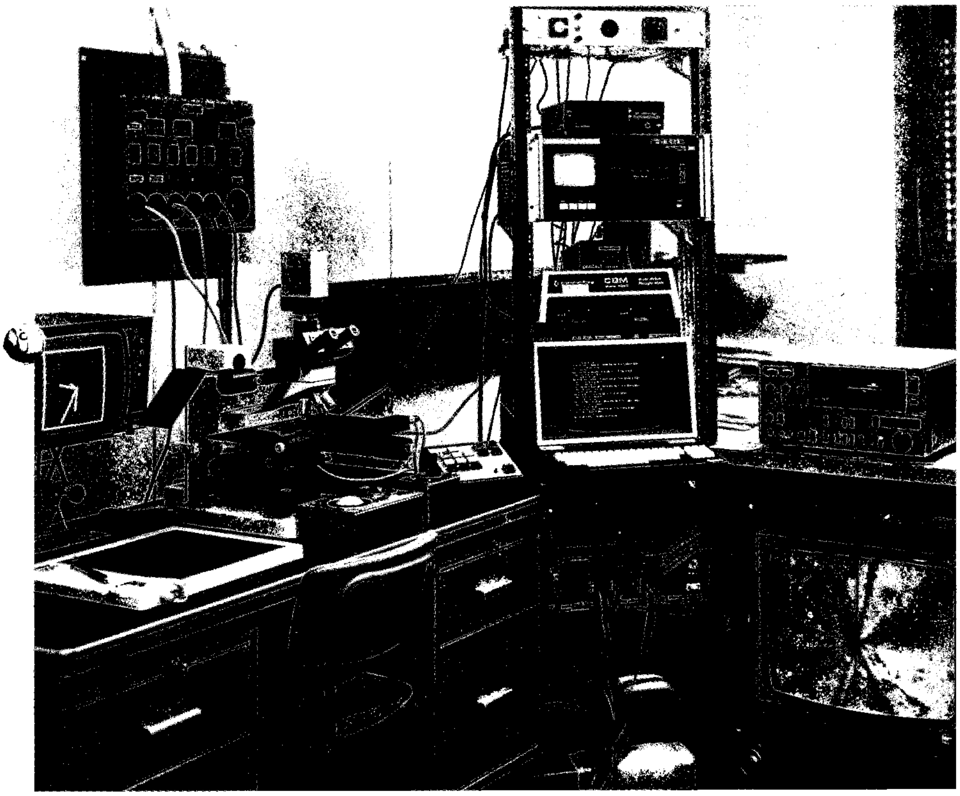
Superconducting Magnet Technology

Cryogenics and superconductivity provide one of the most striking examples of particle physics spin-off. Kammerlingh Onnes discovered the properties of superconductivity back in 1911. Unfortunately the materials he was working with had a critical field level of 1/20 Tesla and it was some 50 years before a new class of material, niobium-zirconium alloy, was developed in the US, capable of operating at high magnetic fields. In the early 1960s the high energy physics community saw the value of superconductivity and pressed for the development and construction of specialised magnets for their work. Very important contributions to this technology were made at Rutherford Appleton Laboratory.

When RAL entered the field of superconducting magnet construction the only conductor available was 0.5 mm niobium-zirconium wire which had to be embedded into copper. This was a laborious, difficult and uncertain process. In collaboration with Imperial Metal Industries, RAL embarked on a highly successful programme of conductor development which has resulted in intrinsically stable forms of conductor and cabling tech-

Another example of particle physics ingenuity: a computer-aided digitized microscope for scanning tiny slices of exposed photographic emulsion.

(Photo CERN 233.4.83)



niques now used world-wide for constant and ramped currents.

Special problems in the mechanical stability of superconducting magnets arise due to the need for good thermal matching of the materials in large structures cooled to a few degrees Kelvin. Extensive work by RAL in conjunction with outside firms on the electrical and mechanical properties of materials in this temperature range has resulted in very stable structures.

The requirements of particle physics have forced the pace of development of superconducting technology to the substantial advantage of other users. Examples are computer programs for magnetic field calculation, wiggler magnets, industrial purification and separation systems, magnetohydrodynamics, power generation and transmission, fusion, d.c. motors, and energy storage.

Probably the most successful and well known use of superconductivity is in medical nuclear magnetic resonance imaging, where Oxford Magnetic Technology has been very successful.

New fields

In addition to technological spin-off, actual discoveries in particle physics and related sectors have opened up new areas.

One such example is muon spin rotation. Like the positron, the muon was one of the early discoveries of particle physics. A gift of nature, revealed some twenty years after the discovery of the muon, is that both the production and the decay of the muon violate parity conservation (left-right symmetry). This apparently arcane and very fundamental property means that when a muon is produced in pion decay it has spin and magnetic moment polarized in a known direction, and when it decays the polarization of the decay electron tells us the polarization of the muon at the moment of its death. Thus the muon acts like a tagged subatomic magnet. It lives for 2.2 x 10^{-6} sec, long enough for it to interact with solids, liquids and even gases at moderate pressure. Many fundamental physical and chemical interactions occur in this 10^{-6} to 10^{-9} sec timescale. Magnetic forces in the material act on the muon during its lifetime and rotate its spin. The muon thus acts as a probe of the structure on the atomic scale and the measured muon spin rotation is used as a tool in solid state physics, chemistry and biophysics, especially for the study of short lived species and their dynamics. The exploitation of this technique has grown remarkably over the past ten years.

While some of the medical uses of positrons have already been mentioned in connection with multiwire proportional chambers, they are also being considered for use in materials testing, and applications could well emerge soon.

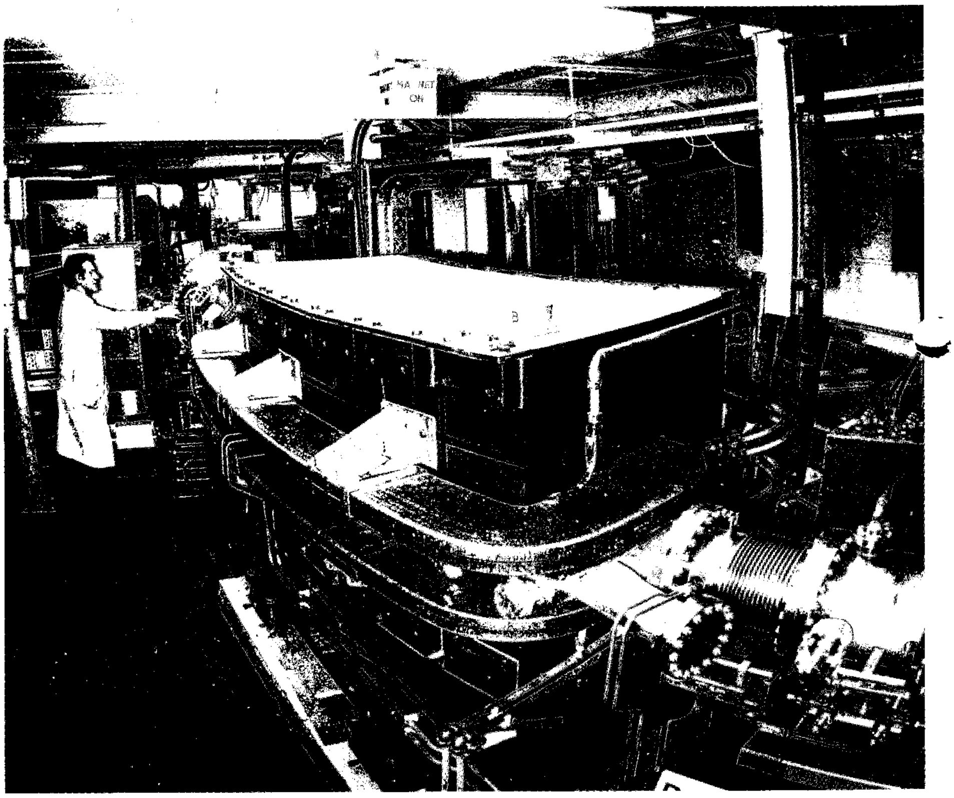
Particle accelerators

Particle accelerators were conceived and built to make laboratory particle physics experiments possible, but now they have a long list of other applications. Radioisotope production for use in medical research, diagnosis and treatment, for monitoring and control of thin films, for industrial radiography, etc. has become an industry. The market for thallium-201 alone is currently $30M per annum in the USA.

Radiotherapy using X-rays from low energy electron accelerators

Synchrotron radiation — a by-product of electron accelerators — is now a useful research tool in its own right. Seen here is one of the bending magnets of the Synchrotron Radiation Source at the UK Daresbury Laboratory, with an exit port for synchrotron radiation visible in the foreground.

(Photo Daresbury)



or radioactive isotopes is a familiar and well established medical technique. The use of protons, neutrons, alpha particles and pions produced by accelerators has been under study for some time and has distinct advantages over more conventional techniques in some cases. Negative pions slow down as they pass through material and at rest are absorbed by nuclei to release their rest mass energy in the form of short range particles ejected from these nuclei. The pion thus acts as an atomic size 'depth charge', depositing practically all its energy around its stopping point so that, unlike X-rays which affect all the tissue through which they pass, the pions destroy the cancer cells with much less damage to the surrounding healthy tissue. The effective cancer destroying dose is much higher than with conventional techniques.

The use of pions in radiotherapy was proposed in the 1950s by two British physicists who first observed the pion in nuclear emulsions. The accelerator technology to produce intense pion beams suitable for treating patients was developed in the following 20 years. The number of patients treated at the SIN Laboratory in Switzerland has increased by a factor of ten since 1981. Clinical experience appears promising: certain tumours, in particular in the head and neck, respond well to such treatment. Thick tumours near radiosensitive structures such as the eye (which cannot be treated by conventional techniques) can be treated by particle beams. Other types of particle beam are also being evaluated.

Synchrotron Radiation

Perhaps one of the most surprising spin-offs from accelerator technology has been the construction in recent years of custom-built accelerators in the few GeV range to produce synchrotron radiation. The parasitic use of the synchrotron radiation from accelerators in use for particle physics studies was so successful as to warrant the building of such machines. It is hard to believe that the necessary accelerator development would ever have taken place without the particle physics input.

Synchrotron radiation, produced when a beam of electrons is bent in a magnetic field, provides a continuous spectrum which extends from X-rays through ultraviolet and visible wavelengths to the infrared. The source can be made very intense, highly collimated and polarized. These features make synchrotron radiation a unique and invaluable tool in many branches of science which could easily form the subject for another CERN Courier article.

Other accelerator applications include non-destructive testing and sterilization by electron beams, ion implantation in semiconductors, radiation processing, heavy ion fusion research, and studies using secondary neutron beams.

After such an impressive list of concrete achievements, it is natural to ask what are likely to be the long term applications. It is difficult, if not impossible, to answer this question and it is worthwhile to repeat the often quoted remark of Rutherford when he was asked about the possibility of nuclear power — 'Anyone who expects a source of power from the transformation of these atoms is talking moonshine!' The possibilities of future applications arising from particle physics range from fusion catalysis using new stable particles, with all its implications for power generation, to prospecting for oil and minerals using neutrino beams.

Particle physics is clearly a particularly fruitful source of spin-off at every level from short term feedback to industry through to the seeding of whole new technologies. This success arises from the fact the field is concerned with fundamental science and stretches high technology to the limit. Prediction is notoriously unreliable but history demonstrates how frequently discoveries which have been regarded at the time as utterly remote from any kind of application have turned out to be of the greatest practical importance. We have no reason to believe that the future will be different.

A tribute: the discovery of proton constituents

by Jack Steinberger

It is sometimes profitable to turn away from the preoccupations of current research to relive the discoveries of yesteryear. Last year, the retirement of Wolfgang ('Pief') Panofsky as Director of the Stanford Linear Accelerator Center was marked by a special 'Pief-fest' when friends and colleagues from all over the world paid tribute (see November 1984 issue, page 389).

One of the speakers was Jack Steinberger of CERN, who described the scientific achievements made with SLAC's electron beams and their context in current thinking. This extract from his talk covers the realization that the proton, far from being an indivisible particle, has a definite composite structure. As with most physics breakthroughs, this did do not happen overnight, at least for most people.

'We honour 'Pief' Panofsky because we are his friends, and we recognize and admire his contributions to physics and to society. Among these achievements is the creation of the Stanford Linear Accelerator Center (SLAC). Under the direction of Pief, SLAC has become a great Laboratory, a focus and centre for particle physics and physicists. And SLAC can congratulate itself on two fundamental discoveries, one of which I will cover. These successes are not only to the credit of the experimenters responsible, but also in large measure to the credit of Pief, as father of the Laboratory, as director, as guru, and as a participant. In our early days Pief and I had the pleasure of working together, in the days when interesting physics could be done in a few weeks by one or two people.

Jack Steinberger (left), seen here with Klaus Tittel.

Before embarking on the story of the electron scattering experiments at SLAC which are responsible for our understanding of nucleon structure, it is necessary at least to mention the electron scattering experiments performed here at Stanford by Hofstadter and colleagues and which found the nuclear form factors.

Among the earliest inelastic lepton-hadron experiments were those of Panofsky and others on electroproduction of pions at the Stanford University 800 MeV linear accelerator in the mid 1950s. In the light of subsequent developments, one of the more interesting results was the realization that it is of greater interest to detect the (inclusive) final electron than the produced pion, the method followed previously.

In the early sixties the energy of electron beams was increased by a factor of ten, to 6 GeV with the turn-on of the Cambridge Electron Accelerator (CEA) and of the Deutsches Elektronen-Synchrotron (DESY). The inelastic electron scattering work then centred on the dynamics of the production of baryon resonances.

Design of the SLAC 20 GeV and 8 GeV spectrometers began soon after construction of the two-mile 20 GeV electron accelerator had started in 1961. These massive and very carefully designed instruments reflect the fact that from the beginning of the project it was anticipated that inclusive scattering would play a dominant role in the experimentation at this machine, characterized by high intensity and small duty cycle.

The discovery of proton constituents

Inelastic measurements at SLAC began in the summer of 1967. The first important results were presented at the Vienna meeting in 1968, showing what happens when electron beams probe deep inside nucleons. Kinematic dependence of the reaction rate is quite flat, in marked contrast to the form-factor dependence observed for elastic scattering and resonance production. Just such results had however been predicted by J. D. Bjorken for nucleons with 'elementary constituents' in 1967. To quote two of his sentences: 'I also think the problems raised here are quite fundamental, dealing, in what seems to be a direct way, with the question of whether there are any 'elementary constituents' within the nucleon. Use of the lepton as a probe is a unique and possibly powerful way of attacking the problem'.

Panofsky, in his rapporteur's talk at the Vienna meeting said: 'Therefore theoretical speculations are focused on the possibility that these data might give evidence on the behaviour of pointlike, charged structures within the nucleon.' However, the understanding of the impact of these early results at the time of the Vienna Conference was not yet clear. Recalling later the climate of those days, R. Taylor wrote in 1980: 'Even by the time of the Liverpool Conference in 1969 many eminent theorists believed that 'Vector Dominance' was the most sensible explanation of this deep scattering. The confirmation of Bjorken's conjecture was gradual rather than a sudden event on a given date.

It was probably R. Feynman who was the first to see the meaning of these first results in the way they are presently understood. Bjorken recalls: 'Feynman visited SLAC in the midst of the first ('scaling') data presented at Vienna. He had been doing the parton model for hadron-hadron collisions and instantly (overnight) recognized what was behind the new ideas, and went beyond where I had gone (at least in some directions). After he left, Manny Paschos and I did our paper on partons. I expected Feynman to write something on his own, and was too shy to suggest a joint paper or call him up and discuss what to do. Feynman in turn didn't write up his ideas until later.'

For mortals the appreciation came more gradually. At the Kiev Conference in 1970, more data were shown, presented in a new way. The fact that the proton contains quasi-free pointlike constituents was finally established and accepted.'

J.D. Bjorken—predicting the outcome of experiments with electron beams probing deep inside nucleons.

Around the Laboratories

HERA Experiments

Letters of intent for experiments at the HERA electron proton collider should be submitted before the end of June for examination by DESY's Physics Research Committee.

Construction work underway for the North Hall of the HERA electron-proton collider at the German DESY Laboratory. In the background looms the 30 m-high HERA surveying tower.

(Photos DESY)

DESY Equipment for HERA

As the civil engineering work for the new HERA electron-proton collider gets underway in earnest, orders are being placed for the first equipment and components for this 6.5 km underground ring to collide 820 GeV protons with 30 GeV electrons.

For the proton ring, the tooling for the 9 m 'hybrid' superconducting dipole magnets is complete (see October 1984 issue, page 330). The design of the hybrid magnet is complete and four full-size units will be assembled at Brown Boveri. Meanwhile a 1 m prototype is ready for testing. Final decision on dipole design is expected sometime this summer.

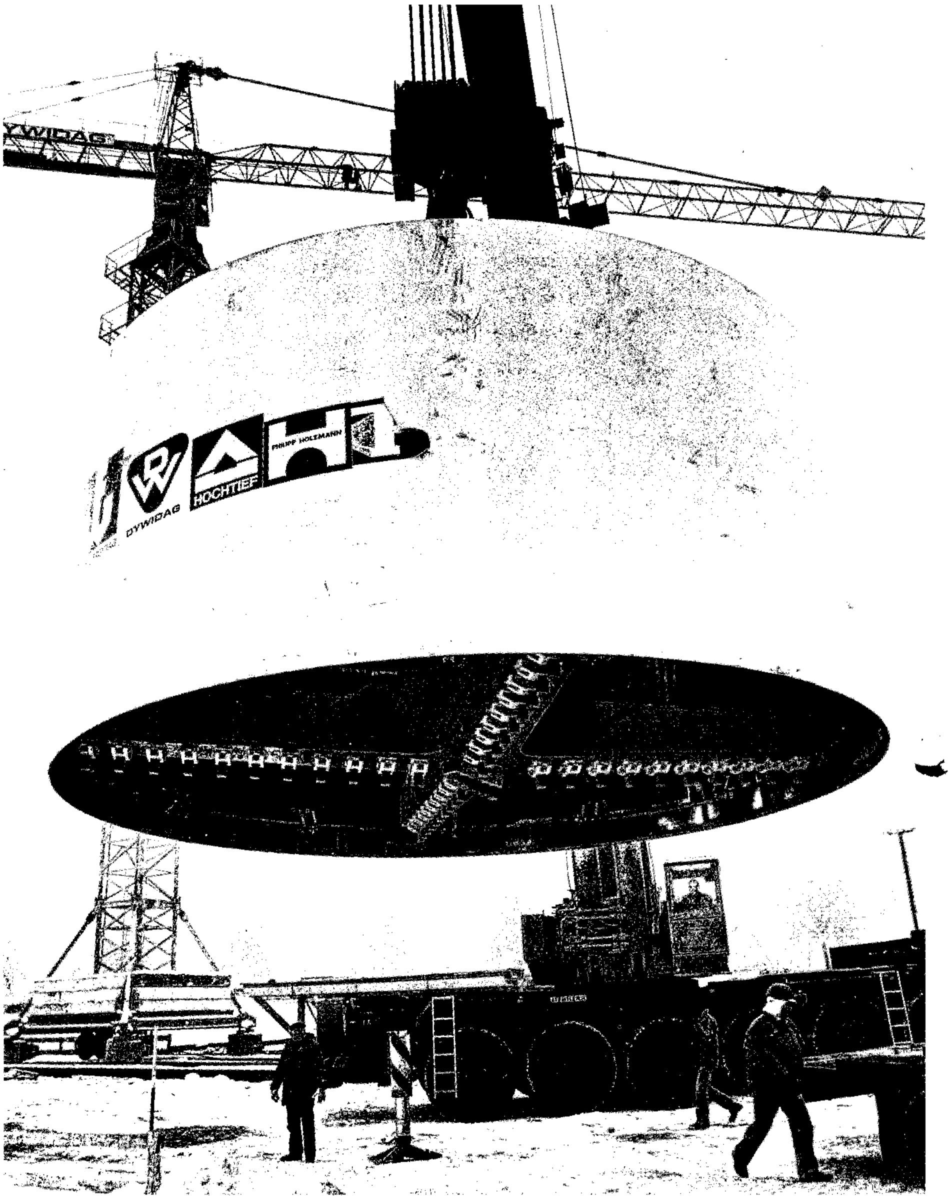
An order has been placed for 465 km of superconducting cable — enough for half the dipoles. Production at a rate of 10 km per week (1922 m is needed for each magnet) is scheduled to start in December.

Two 'warm iron' quadrupoles have been measured at DESY, attaining both around 120 T/m at 4.38 K compared with the design figure of 90 T/m. The construction of two cold iron quadrupoles is progressing well at Saclay. 115 km of superconducting cable have been ordered for construction of the quadrupoles. Tests are also progressing for the correction coils wound round the beam pipe.

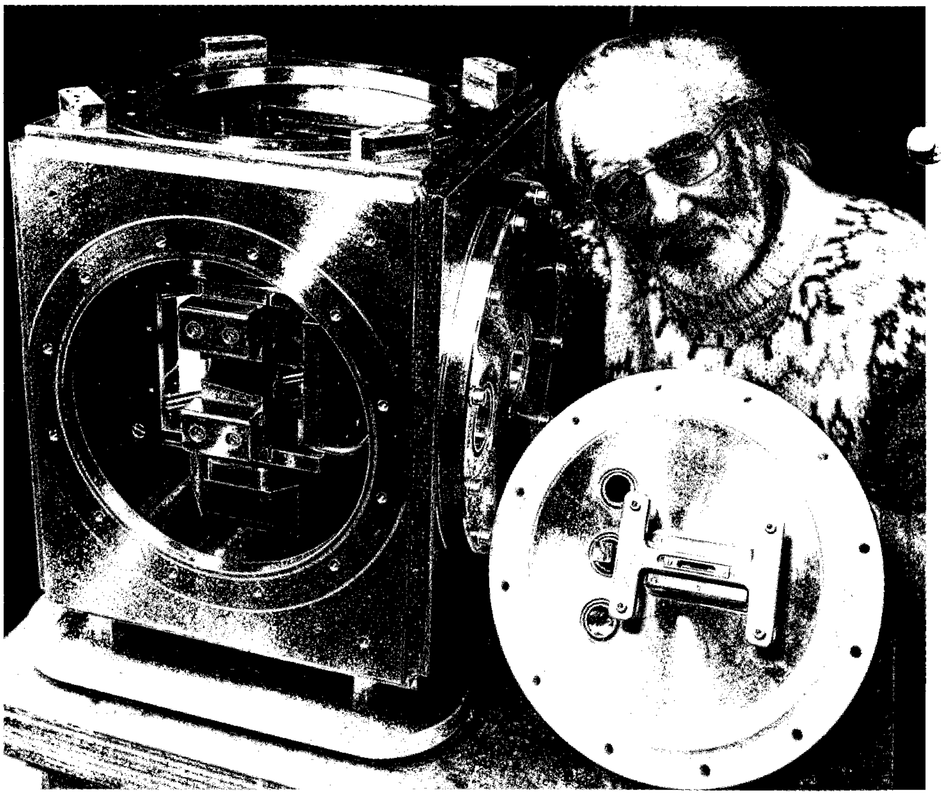
To handle all these superconducting magnets will require Europe's biggest refrigeration plant. Three identical plants have been ordered each providing 6500 W isothermal at 4.3 K, 275 W nonisothermal at 4.5 K, 20.5 gr/s of helium for lead cooling, and 20 000 W between 40 and 80 K for shield cooling.

The first plant should be fully operational in October 1986, providing helium for a magnet measurement facility. The remaining two plants will arrive in 1987. A fourfold transfer line to distribute the helium around the HERA ring is being developed by the cryogenic group at the Schweizersiches Institut für Nuklearforschung (SIN), and a 100 m prototype should be operational towards the end of this year.

To feed the proton ring, the ion source (providing in fact negative hydrogen ions) has been assembled at DESY. Preacceleration will be handled by a radiofrequency quadrupole, and the order has gone out for the three steel linac tanks to be copper plated at the GSI Laboratory in Darmstadt.



Above, arrival of the head of the drilling machine which soon starts boring the HERA tunnel.



Below, the (negative hydrogen) ion source for the HERA injection linac being assembled by Alfred Stüben at DESY.

For the electron ring, design of the bending magnets is complete and tests have been carried out on magnet modules. The 496 quadrupoles for the electron ring have been ordered and should start to arrive later this year.

The design of the mini rotators which rotate the electron spin so as to provide for longitudinal polarization at the interaction points has been greatly improved. Instead of working only at one fixed energy they now cover the whole energy range from 27.5 GeV to 35 GeV. During the first commissioning phase of the HERA electron ring these rotators can be replaced by single deflecting magnets. The new beam optics for the HERA straight sections now fulfil all spin transparency conditions so that beam polarization can hopefully be maintained.

STANFORD Milestones

A significant landmark was passed in the construction of the SLC Stanford Linear Collider last December when the 'blowtorch' (the injection system and first acceleration section up to the damping ring) put out 2 (S-band) bunches separated by 50 nanoseconds and each containing 5 x 10^{10} electrons with emittance at specification. The next step is to store two such bunches in the damping ring, damp, eject, and accelerate to Sector 10, about one-third of the way down the machine.

Just a few weeks before, the final link in the SLC tunnel was completed on schedule. The two arcs were bored simultaneously and independently with two mining machines. The 9000-foot tunnel does not lie in a plane but follows the contours of the site, remaining underground except for a 440-foot section along one arc. (The bending magnets in the collider arcs will be rotated around the beam pipe at appropriate angles to maintain this course.) The junctions of the arcs with the linac tunnel are complete, and have been blocked off temporarily so that work can continue in the arcs while the linac is running.

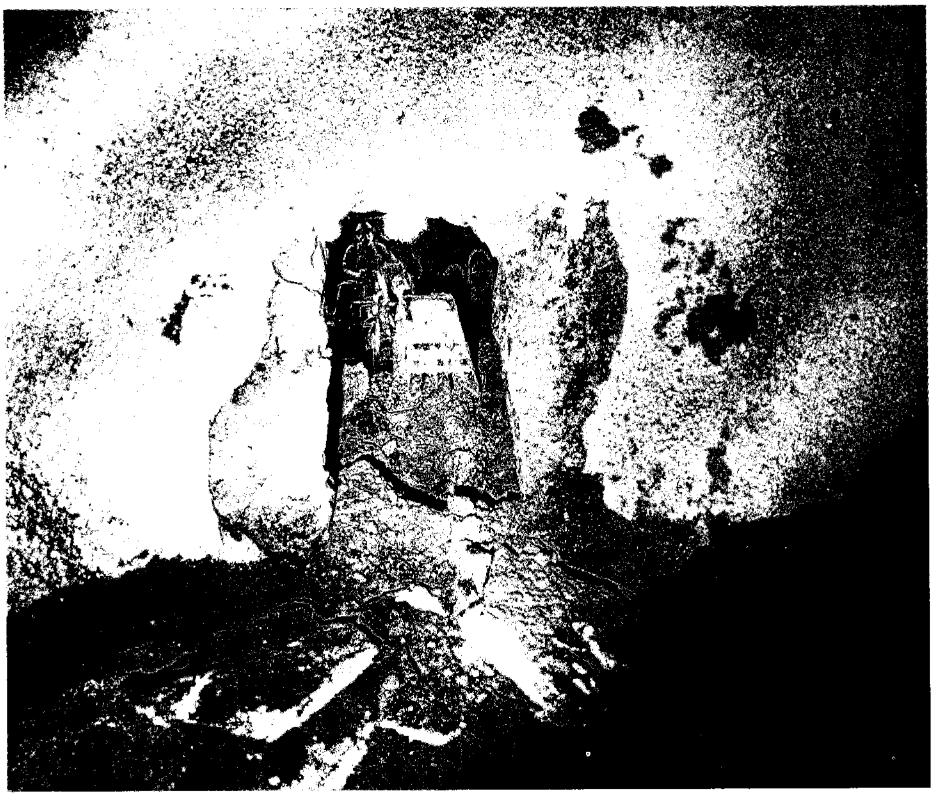
Meanwhile what is probably its last traditional electron scattering experiment was recently approved for the two mile linac. It involves a precision study of the relative contributions of longitudinally and transversely polarized photons exchanged in the scattering process, using different targets. The results will provide a fine test of theoretical ideas.

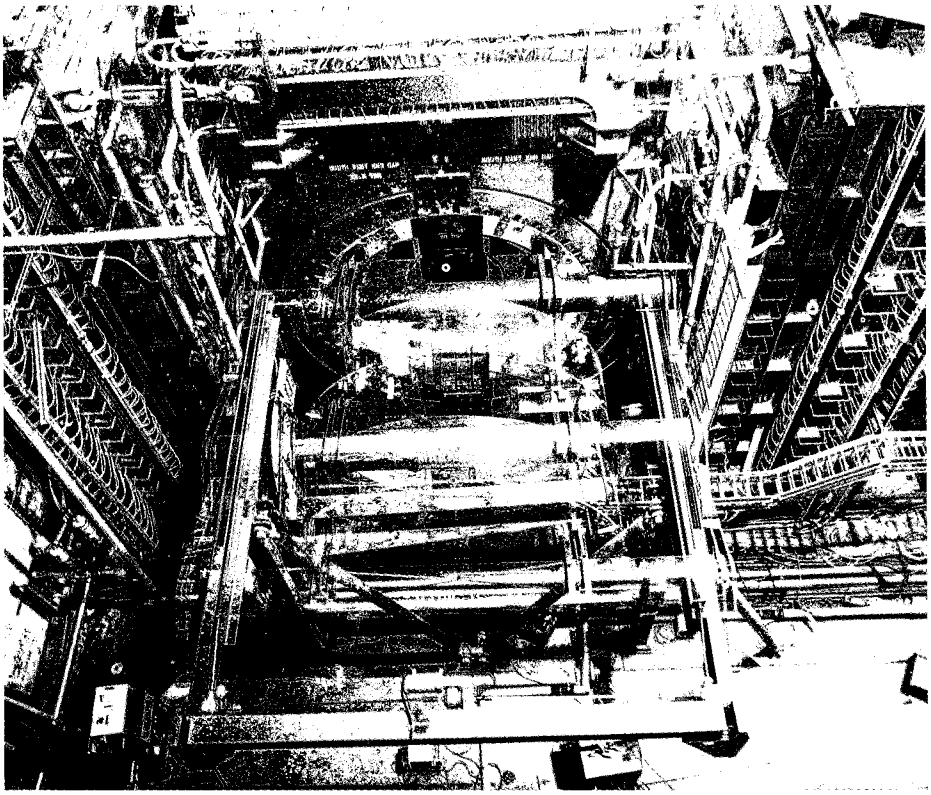
Back in September the new Nuclear Physics Injector (which uses the last portion of the big linac to provide lower energy, high intensity beams — see December 1983 issue, page 424) successfully accelerated a 780 mA beam at 35 MeV into a temporary beam dump. Since this dump was uncooled, the high current test used a short 160 nsec pulse. The full pulse width was then tested at a reduced current.

Over at the PEP electron-positron collider, the Mark II experiment is undergoing a major refit, with a new coil, drift chamber, counters and endcaps making an appearance, ready for its new role as a detector for the SLC.

There is a lot of interest in running several of the PEP intersec-

Late last year, the two tunnel arcs for the new Stanford Linear Collider (SLC) met. Work is on schedule for the machine to be complete in 1986.





Outside the PEP electron-positron collider at Stanford, the Mark II detector is undergoing a major refit, in preparation for its new role as a detector for the SLC.

(Photos Stanford)

tions at higher luminosities, requiring new magnet, power supply, vacuum and detector configurations. Design work is continuing and about 60 physicists participated in a workshop on physics on higher luminosities at PEP, held last November, with a follow-up meeting in March.

CERN New Collider experiment

A newcomer on the scene at the big proton-antiproton Collider during the 1984 run which finished in December (see January/February issue, page 23), was the UA6 study by a CERN / Lausanne / Michigan / Rockefeller collaboration.

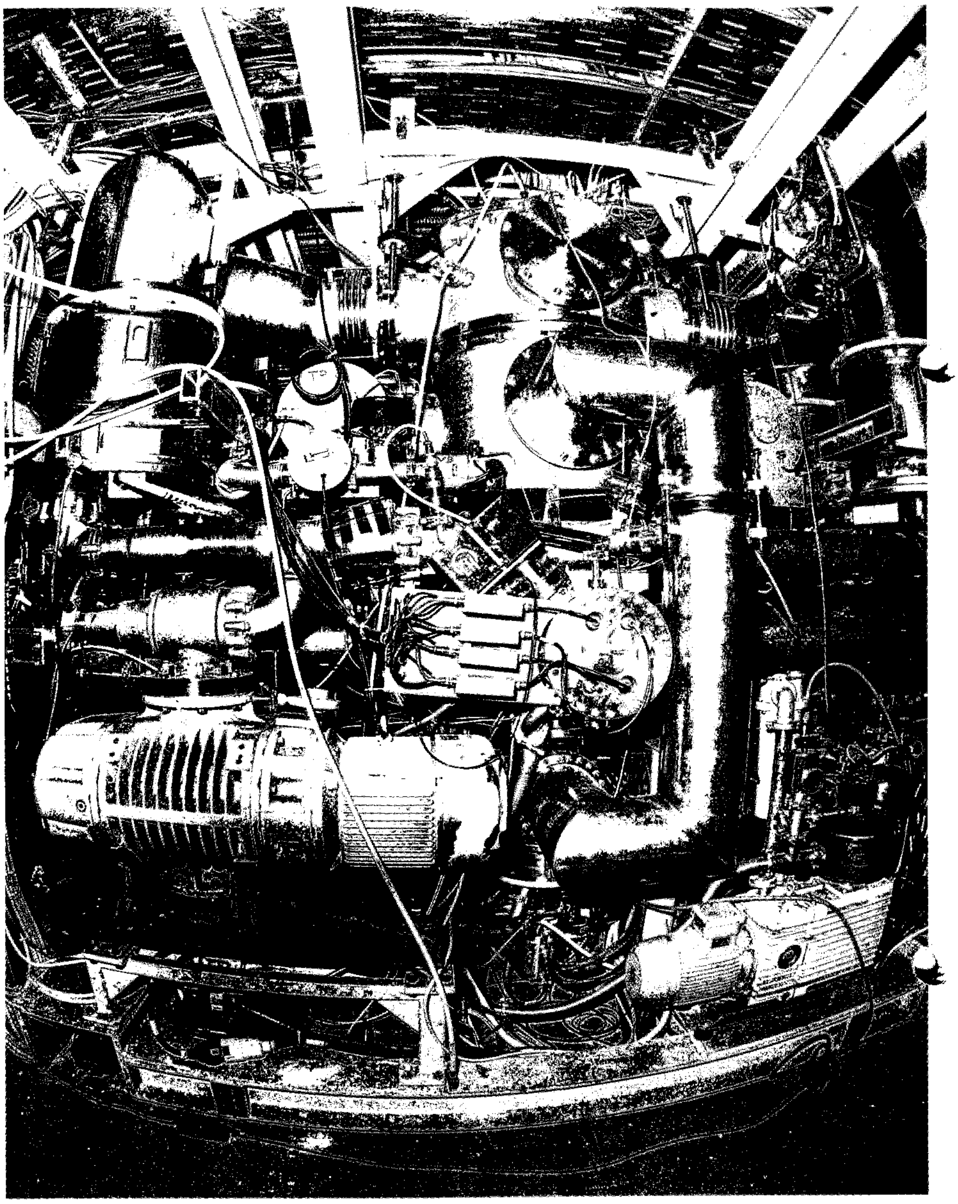
While the other big Collider experiments monitor the results of the collisions between the contra-rotating 315 GeV proton and antiproton beams in the 2.2 km diameter SPS ring, UA6 works in a 'fixed target' mode, the target being a high intensity molecular hydrogen jet which squirts protons across the path of the circulating beams.

Such internal gas targets have a number of attractive features — high luminosity (collision rate) due to multiple traversal of the target by the circulating beam, efficient use of the circulating particles, parasitic operation requiring no allocation of beam time, and a small, well defined source. The problem of compatibility with storage ring vacuum was solved in 1980 using a large differential pumping system.

The UA6 jet fires across both proton and antiproton beams, and in principle such an experiment can monitor the details of both proton-proton and proton-antiproton collisions at the same time. However most of the UA6 detectors are on one side of the jet, and in its initial run last year, the emphasis was on proton-antiproton interactions.

Later, the apparatus will be reconfigured to point in the opposite direction in the SPS tunnel in order to study proton-proton scattering. The exception is a set of silicon solid state detectors nearly at right angles to the beam direction. These can be moved by remote control to record the recoil proton from either type of collision even when the rest of the apparatus is looking at proton-antiproton interactions.

The aims of the experiment are to compare proton-proton and proton-antiproton interactions in the same detector through a vari-

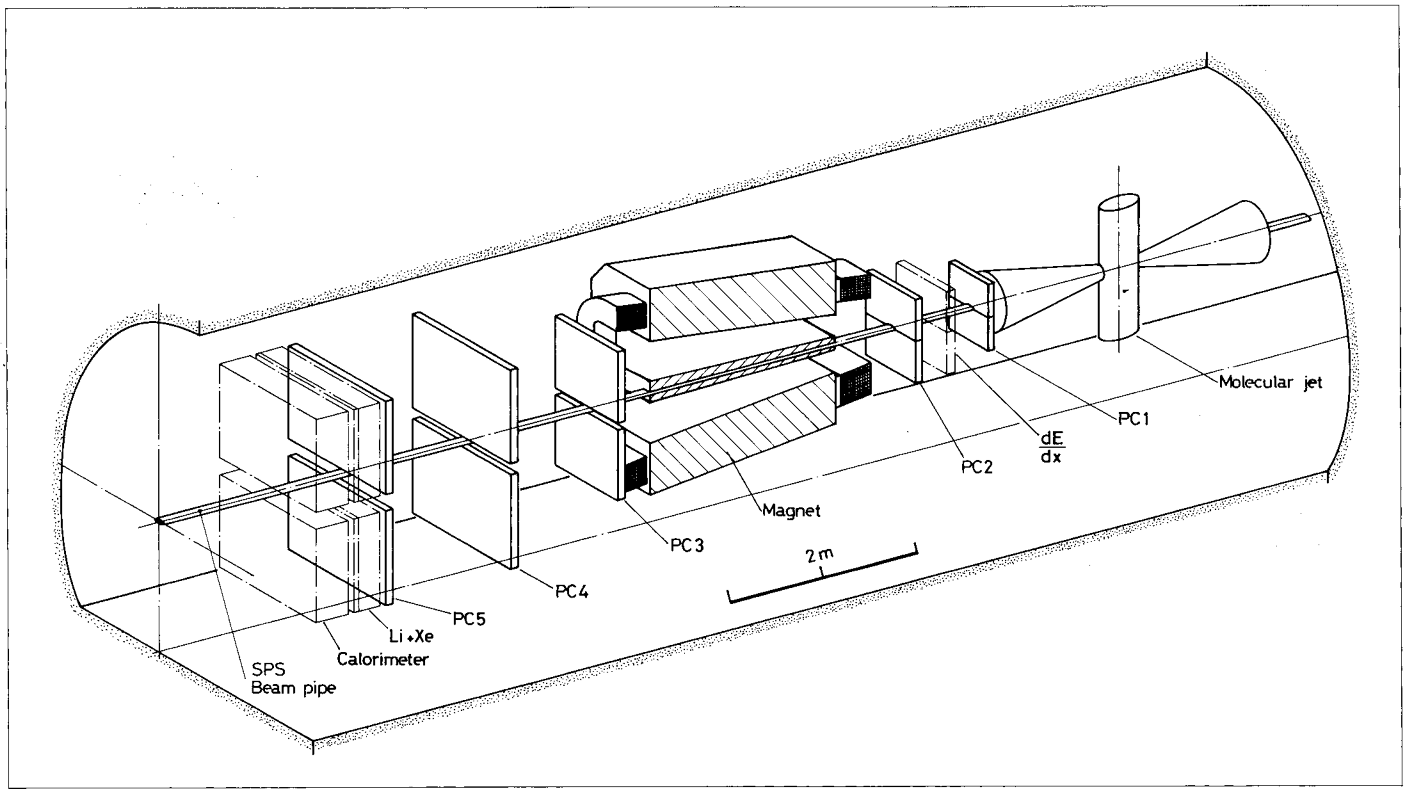


Fish-eye view of the machinery of the gas jet target of the UA6 experiment at CERN, used when the SPS machine is employed as a storage ring for protons and antiprotons. The use of such a gas jet in the delicate vacuum of a storage ring environment was an important breakthrough in experimental technology, and UA6's differential pumping system is one of the most impressive to be found anywhere in the world.

(Photo CERN 420.9.84)

A schematic diagram of the UA6 experiment at the CERN proton-antiproton Collider. To the left of the gas jet are arrays of multiwire proportional chambers (PC), ionization chambers (dE/dx), the spectrometer magnet, lithium-xenon transition radiation detectors and the electromagnetic calorimeter.

On 17 March, the SPS proton-antiproton collider at CERN produced its first physics at a new world record collision energy of 900 GeV. More next month.



ety of reactions. Elastic scattering will be measured at the very small momentum transfers corresponding to the region where interference between Coulomb (charged particle) and nuclear scattering occurs.

Studies of direct photons (coming from electromagnetic interactions of quarks) will extend results obtained at the Intersecting Storage Rings and in fixed target experiments to cover the important proton-antiproton sector. Here, valuable information can be obtained on the importance as a source of direct photons of the annihilation of a quark and an antiquark into a gluon and a photon. This can also yield a clean sample of events involving a gluon, thus allowing the properties of this elusive particle to be studied.

It is also intended to measure the production rates of single electrons and electron pairs produced through the 'Drell-Yan' mechanism (annihilation of a quark and an antiquark through a high energy photon), and the decay of heavy resonances such as the J/psi. The more plentiful neutral pions and eta mesons will also be recorded.

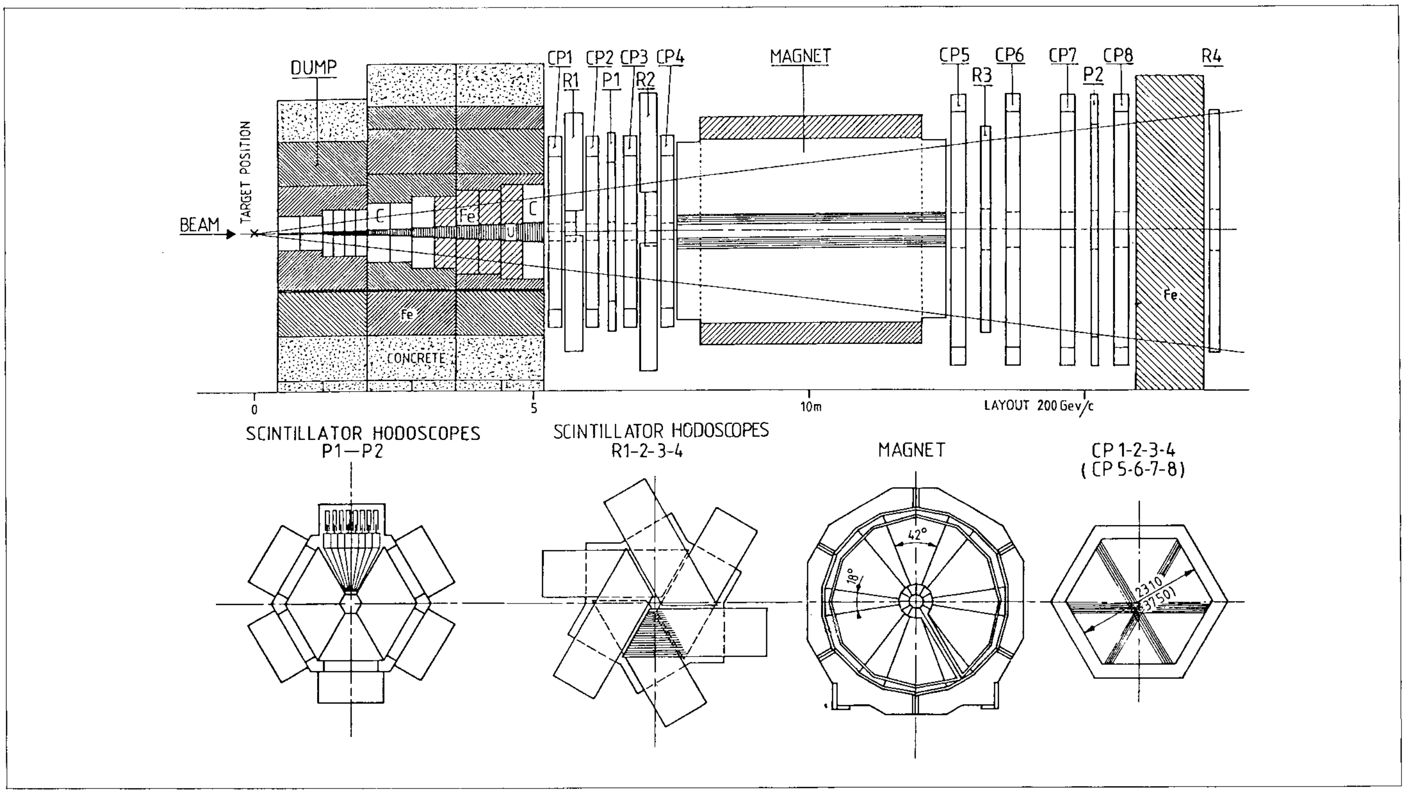
Finally, the production of lambda hyperons will also be investigated. It is puzzling that these heavy baryons emerge from hard collisions with a distinct polarization, which moreover increases with their transverse momentum.

The heart of the experiment is the gas jet itself which can provide up to 4 x 10^{14} atoms cm^{-2}. With the best antiproton intensity achieved so far (5 x 10^{10} antiprotons), this corresponds to a collision luminosity of 8 x 10^{29} cm^{-2} s^{-1}. However because of worries that the jet could generate a background in the nearby UA1 experiment, UA6 luminosity during 1984 was limited to about 10^{29} cm^{-2} s^{-1}.

Charged particles are measured in a double arm spectrometer consisting of a 2 T.m magnet and multiwire proportional chambers. The energy of electrons and photons is measured in electromagnetic calorimeters made of lead and proportional tubes. The 1 cm width of the proportional tubes yields excellent spatial resolution for electromagnetic showers and differentiates clearly between true single photons and two close photons coming from the decay of a neutral pion. Lithium-xenon transition radiation detectors ensure good separation between electrons and charged pions, while ionization chambers reject unwanted neutral meson decay modes.

Two possible upgrades of the experiment are being considered.

Sketch of the apparatus of the NA 10 experiment at CERN which has studied the behaviour of the quark constituents of nuclei over a wide kinematic range.



The first would use a polarized atomic hydrogen jet which, with high polarization, would be useful in further studies of spin effects in the production of lambda particles and neutral pions. The second would use heavier gases to study nuclear effects without the multiple scattering which complicates such studies using thick targets.

With a data sample from the 1984 Collider run, the experiment could soon be producing its first eagerly awaited results.

Special K

Results from the NA10 (CERN / Ecole Polytechnique / Naples / Strasbourg / ETH Zurich) experiment demonstrate the complexity of the detailed scattering behaviour of the constituent particles deep inside nuclei.

The experiment looks carefully at the muon pairs produced when the high intensity, high energy pion beam (a few 10^9 pions per pulse at 194 GeV) from the SPS proton synchrotron strikes a (tungsten) target.

Away from sharp resonances (like the J/psi and the upsilons) which decay into two muons, these muon pairs are produced only by the so-called 'Drell-Yan mechanism' — a quark and an antiquark from the colliding particles annihilate electromagnetically into a short-lived energetic photon, decaying in turn into the muon pair.

Using information on the quark/gluon structure of particles gleaned from previous experiments, physicists hope that they know enough about quark behaviour to calculate the expected features of muon pair production. However other experiments at CERN and Fermilab have demonstrated that the observed muon pair level is systematically higher, the difference being known in the trade as the 'K factor'.

This K-factor has never had the benefit of a universally accepted explanation, and in some circles the idea of accounting for the complexities of quark interactions over anything more than a limited kinematical region by something as simple as a numerical constant was not considered attractive.

With its high beam energies and intensities, the NA10 experiment opened up the dimuon spectrum in a hitherto little explored energy range above the upsilon resonances.

Using conventional kinematic dependence (scaling — which behaves quite well over a fairly wide range), the results of quark calculations do not agree with the muon pair signal observed by NA10 above the upsilons. Moreover the difference cannot be accounted for by a single numerical K-factor.

Refined quark calculations, using more detailed mechanisms, have in the past been able to account for observed scaling violations. Such calculations narrow the gap between the NA10 data and the predictions, but fail to explain the whole effect. However taking all systematic uncertainties into account, the observed muon pair level is not that far above the predicted level.

Previous experiments using pion beams have produced information on the quark-gluon content of the pion, an unstable particle which cannot be formed into targets for beams and probed directly. The new kinematical region opened up by the NA10 experiment also hints that the quark-gluon content (structure function) of the pion does not follow the conventional (scaling) behaviour.

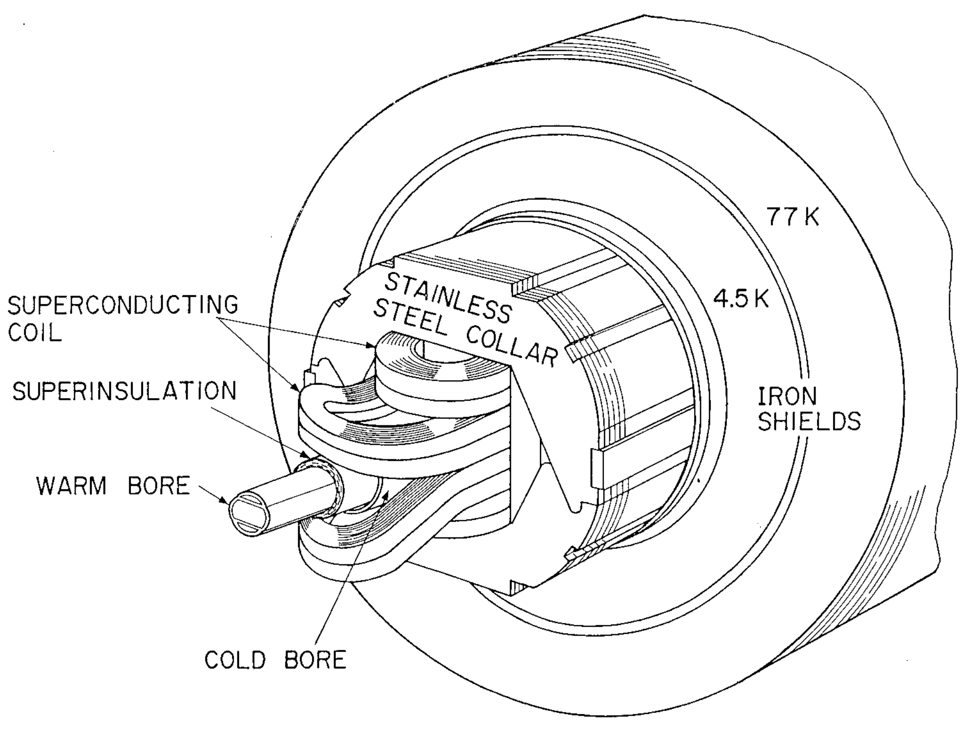
KEK
10 Tesla superconducting dipole

The Japanese KEK Laboratory has been pushing its development project for high field dipole magnets. The development of superconductors to be used in superfluid helium at 1.8 K has continued over several years and ternary and binary alloys based on niobium-titanium were improved to carry 200 kA/cm^2 at 10 T. A dipole magnet (1 m long and with beam bore 90 mm) with tight holding structure was built using the improved superconductor, the coils of which were immersed in the ambient pressure superfluid in a 1.8 K cryostat.

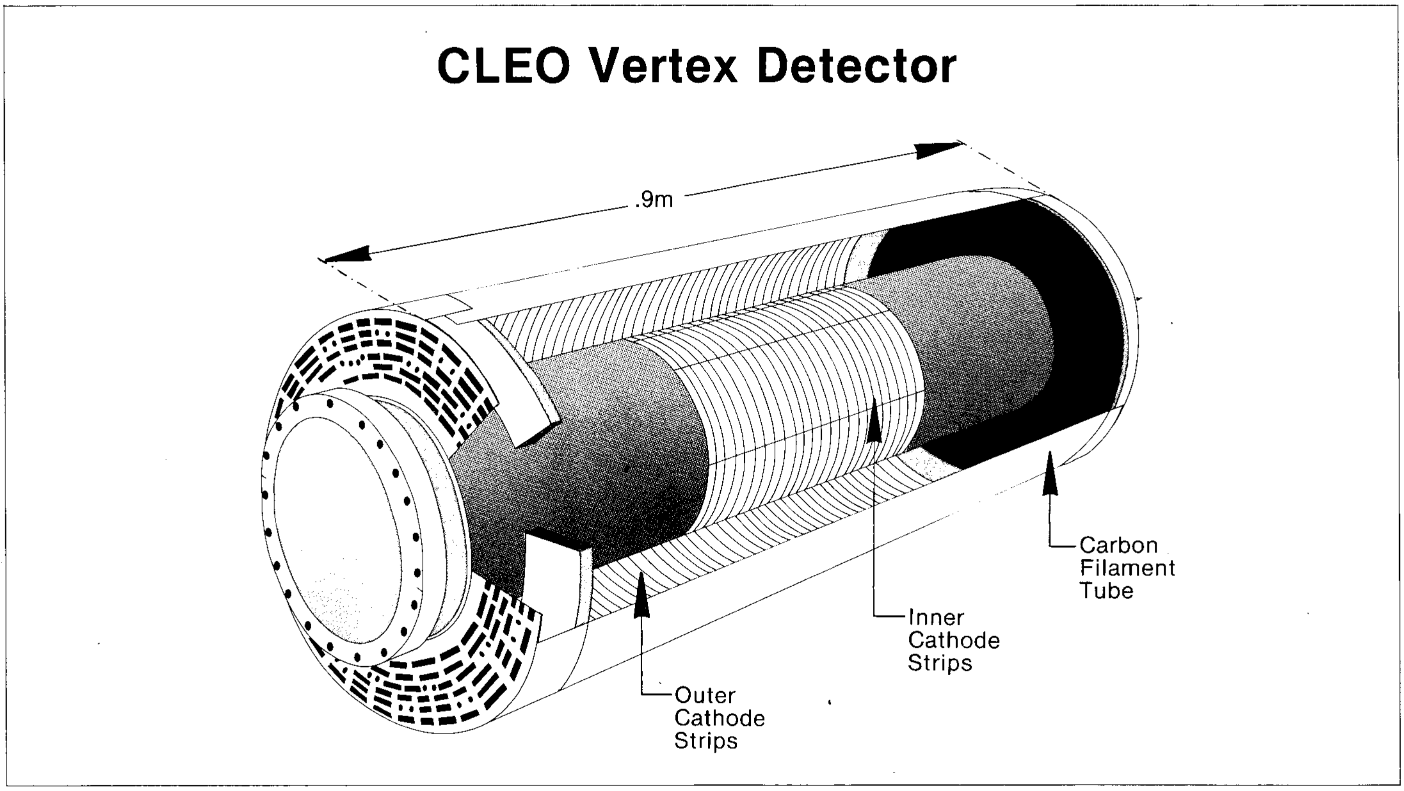
Three excitations were made at 4.2 K and the temperature brought down to 1.8 K. First excitation at this temperature brought 6340 A of current and a big quench. The field at the centre of the beam aperture was 9.3 T, corresponding to a record maximum field of over 10 T.

Spurred by this success, the KEK high field magnet group will now go on to build more magnets, with the long term aim of contributing to international collaboration in the construction of future accelerators. The superconductor used in the latest magnet was developed partly at Fermilab as part of the Japan-US collaboration programme.

Diagram of the superconducting dipole developed at the Japanese KEK Laboratory which achieved a maximum field of over 10 T.



Schematic of the new vertex detector for the CLEO experiment at Cornell's CESR electron-positron collider.



CORNELL
A new vertex detector

Last summer, a ten-layer precision drift chamber and a thin beryllium beam pipe were installed in the CLEO detector at Cornell's CESR electron-positron collider, replacing a multiwire proportional chamber as the innermost tracking detector. This new detector was designed and built by members of the CLEO collaboration from Ohio State University and the University of Rochester. The cylindrical drift chamber is 0.7 m long and 0.34 m in diameter, containing 800 sense wires in close-packed hexagonal cells. The cells are small (3.3-4.4 mm half-width) and the isochrones of drift time remain nearly circular in the 1 Tesla magnetic field. The z-coordinate (along the beam direction) is measured both using charge division on each sense wire and with cathode strips on the innermost and outermost layers. Carbon filament tubes form the inner and outer walls of the chamber. The beryllium beam pipe is 0.75 mm thick, so that the total amount of material traversed by a particle from the interaction point to the first layer is about one per cent of a radiation length.

The chamber has been operated at a pressure close to one atmosphere with an equal mixture of argon and ethane. 350 000 hadronic events have been accumulated at the ground state upsilon with the chamber serving as the lowest-level element in the CLEO trigger. With a z-resolution of 500 microns, the three dimensional tracking will allow reconstruction of tracks with 50 MeV/c transverse momentum, a particularly important range for identifying D* decays into D^0 plus a low-momentum pion. The tracking precision will allow trajectories to be extrapolated to the interaction point with a resolution of 175 microns (rms), aiding in the measurement of decay vertices and the identification of rare charm decays, and in the reconstruction of B-decays.

While the vertex detector was being installed, the electronics for the main drift chamber was upgraded to allow measurement of ionization loss. This extends the range of particle identification to low momentum tracks which do not penetrate the coil to the outer chambers.

During recent running at the higher energy of the fourth (4S) upsilon resonance, the current drawn from the vertex detector wires increased sharply due to synchrotron radiation. Tests indicated that these hard X-ray photons hit the beryllium beam pipe after an initial bounce far upstream! The problem was solved by inserting shadowing rings about one metre away from the interaction point.

The new vertex detector represents the first step in the upgrading of CLEO towards the proposed CLEO-II configuration. CLEO-II will have a new drift chamber, time-of-flight system and caesium iodide crystal calorimeter, all inside a large diameter superconducting coil, and iron shielding with muon chambers outside the coil.

Meanwhile the CESR collider has been reaching new heights in producing collision luminosity. Operation with seven bunches in each beam has become routine. CESR physicists and operators have worked very hard to deliver what is hoped is a record in peak luminosity at electron-positron colliders — 3.6×10^{31} cm^{-2} s^{-1} with 75 mA per beam at 5.3 GeV. The luminosity delivered to each experiment on a good day was 1.3 pb^{-1}.

People and things

CERN Council

At the CERN Council session which ended on 22 February Herwig Schopper was unanimously reappointed Director General of CERN for three years from January 1986. This ensures continuity in the management of the Laboratory through to the completion of the 50 GeV stage of LEP construction. Council also appointed J.C. Kluyver (Netherlands) as the second Council Vice-President. At the same time, Council decided to set up a 'Working Group on the Scientific and Technological Future of CERN' under the Chairmanship of Carlo Rubbia. Its terms of reference are 'to explore various options for the long term future of CERN, taking into account existing facilities, emphasizing respective pros and cons; in working out these options, realistic boundary conditions concerning financial and manpower limitations should be taken into account'.

Austria-CERN, 25 years

As early as 1951, Austrian scientists and politicians were interested in the creation of the new CERN Laboratory. This early phase is associated with the names of Berta Karlik, Fritz Regler and Hans Thirring. But it was in 1958 that final negotiations took place between Cornelis Bakker, CERN Director General at the time, and Regler. Austria became a member of CERN on 1 July 1959.

First Austrian delegate to CERN Council was Walter Thirring who

Four Presidents of CERN Council and two Directors General: left to right, Paul Levaux (President 1975-77), Jean Teillac (President 1978-81), Leon Van Hove (Research Director General 1976-80), Herwig Schopper (Director General 1981-), Wolfgang Kummer (President 1985-) and Sir Alec Merrison (President 1982-84). Schopper has been reappointed Director General for a further three years from 1986.

(Photo CERN 483.2.85)

at the same time and under very difficult circumstances created a small group to analyse emulsion and bubble chamber film. A joint effort by Regler and Thirring managed, with the help of the late President of the Austrian Academy of Sciences, E. Schmid, to found a special institute for high energy physics in Vienna. Its first Director was W. Kummer, now President of CERN Council, later followed by H. Pietschmann and W. Majerotto.

Work in the early years concentrated on the analysis of bubble chamber film, mainly together with Douglas Morrison and collaborators. In 1957 a small counter group was set up, followed by an electronics and detector group.

The Institute now employs about 50 staff, 20 of them being physicists, who have contributed to many notable experiments. The biggest effort went into the famous UA1 experiment at the CERN Collider which discovered the W and Z particles. A sizeable group is also already at work on the Delphi experiment for LEP at CERN.

To commemorate the 25th anniversary of Austria's joining CERN and the forming of the first high energy physics group in the country, a celebration took place last November in the Auditorium of the old University of Vienna (the same room where 170 years ago Beethoven first conducted his 7th symphony). Speeches were made by President of the Academy of Science E. Plöckinger, W. Majerotto, Minister of Science and Research H. Fischer, W. Thirring and CERN Director General H. Schopper.

An Open Day with a big exhibition (put together with the help of the CERN exhibition team) was organized at the Institute, and some 300 visitors were suitably impressed by the exotic equipment used in today's particle physics research.

(From Gunther Neuhofer)


Director of the Vienna Institute of High Energy Physics W. Majerotto (right) gives explanations to CERN Director General Herwig Schopper during the celebrations to mark the 25th anniversary of Austria's joining CERN and of the founding of the Vienna Institute.

Wire Chamber Meeting

From 25-28 February next year, another (the fourth) Vienna Wire Chamber Conference will take place. This time it has been decided to widen the scope of the conference, so that as well as looking into the latest developments in the application of wire chambers in high energy, nuclear and astrophysics, and in biology and medicine, comparisons would be made with alternative technologies. Further information from the Institut für Hochenergiephysik, Nikolsdorfergasse 18, 1050 Vienna, Austria.

Pedro's progress

Our correspondent at DESY, Pedro Waloschek, has published a book in German, together with Oskar Höfling, a well known physics textbook author, entitled 'The World of the Smallest Particles ('Die Welt der kleinsten Teilchen', Rowohlt 1984, 512 pages, 210 pictures and 68 tables, 42 DM).

The book is intended for non physicists, uses no formulae and introduces the reader into atomic and subatomic physics, up to the level of the latest discoveries at CERN and the secrets of today's theoretical picture. It includes a semi-popular description of the quark model with colour forces and electroweak interactions.

After the first edition was sold out in six months, a second one, including the news of the Rubbia and van der Meer Nobel Prizes and

This photograph was taken in the prestigious Deutsches Museum in Munich where a CERN exhibition was visited by many thousands of visitors last October and November. The presentation was organized in close collaboration with the Max Planck Institute and Munich University. *(Photo CERN)* *other recent data, came out last December.*

Pedro is particularly proud that the drawings (all made by Werner Knaut at DESY) and analogies included in the book are now used by colleagues to prepare talks and lessons...

We wish Pedro all further success with his writing career.

Accelerator Summer School

The fifth US Summer School on High Energy Particle Accelerators is to be held at the Stanford Linear Accelerator Center from 15-26 July. For the first time, the programme includes a symposium on research in the growing number of accelerator-based sciences including high energy physics, nuclear physics, light source physics, heavy ion physics, free electron laser physics, and the physics of high intensity beams. Further information from the School Administrator at SLAC, PO Box 4349, Bin 11, Stanford, California 94305, USA.

People's Republic of China member of the C11 Commission on Particles and Fields of the International Union of Pure and Applied Physics (IUPAP) is Zhou Guangzhao. In the January/February issue (page 22) we got it wrong. Our apologies to all concerned.

Soviet theoretician Dmitrij Volkov of the Kharkov Institute of Physics and Technology celebrates his sixtieth birthday this year.

ACCELERATOR SCIENTIST

NATIONAL SYNCHROTRON LIGHT SOURCE

An opportunity exists at the National Synchrotron Light Source at Brookhaven National Laboratory for an accelerator scientist experienced in experimental or theoretical particle beam physics. The research activities of the successful candidate will be directed to the development of high intensity electron storage rings for synchrotron radiation production, and of other methods of coherent radiation production from relativistic electron beams.

Applications, including a curriculum vitae with list of publications and the names of three references, should be sent to: Claudio Pellegrini, National Synchrotron Light Source Department, Building 725B, Brookhaven National Laboratory, Associated Universities, Inc., Upton, New York 11973. Equal Opportunity Employer m/f.

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Experimental Physicist

A position is available for an experimental physicist at the Swiss Institute for Nuclear Research.

SIN operates a 600 MeV isochronous cyclotron which is used to produce a number of meson beams. The position is initially available for three years, with a possible extension for a further two years.

Applicants should have an interest in medium energy nuclear physics, although direct experience in the field is not essential. Apart from participation in activities at SIN, it is expected that the opportunity to take part in an experiment at CERN will be available.

Additional information can be obtained from Dr. Q. Ingram (Telephone 056/99 32 58) or Dr. J. Domingo (056/99 32 51).

Applications, containing curriculum vitae, list of publications and references should be sent as soon as possible, but not later than April 30, 1985 to

SIN, Personnel Division,
CH-5234 Villigen/Switzerland,
Code 523.

INDIANA UNIVERSITY CYCLOTRON FACILITY STORAGE RING EXPERIMENTAL FACILITIES DEVELOPMENT

The Indiana University Cyclotron Facility (IUCF) has an opening for a staff physicist to participate in developing experimental facilities in a dynamic accelerator laboratory of international reputation. This is a continuing full-time position and is included in the IUCF professional ranks. A PhD is required along with experience in basic physics research and experimental design. The salary and fringe benefits will be competitive and are dependent upon training and experience.

This laboratory is engaged in a major facility upgrade consisting of the construction of a storage ring with electron cooling. The "Cooler" ring will offer novel possibilities for performing nuclear physics experiments with beams of unconventional and superior characteristics.

Initial responsibilities for this position involve participation in ongoing research and the development and construction of ultra-thin targets, in the form of gas jets, powder beams or thin whiskers, for use in the high-vacuum environment of the storage ring. Candidates should have experience in design of experimental equipment for nuclear physics research and should be capable of adapting existing technology as well as of undertaking research pertaining to ultra-thin targeting.

Applications, including resume, bibliography, and the names of three persons as reference should be sent to:

Dr. Hans-Otto Meyer
Indiana University Cyclotron Facility
2401 Milo B. Sampson Lane
Bloomington, Indiana 47405

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POSTDOCTORAL POSITION IN EXPERIMENTAL INTERMEDIATE–ENERGY NUCLEAR PHYSICS

The Medium-Energy Physics Group of Los Alamos National Laboratory's Physics Division invites application for postdoctoral positions. The successful candidate will participate in an experiment at the LAMPF accelerator to measure the (π,η) reaction on nuclear targets and another experiment at AGS to study hypernuclei with the (π^+,K^+) reaction. Work could also include participation in the development of a high-energy gamma-ray spectrometer.

To apply, send resume plus three letters of recommendation and a brief letter describing your research interests to:

Dr. J.C. Peng, MS D456
Physics Division, DIV 85-BG
Los Alamos National Laboratory
Los Alamos, New Mexico 87545
505-667-9431

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Candidates should normally be less than 28 years old. Appointments are made for 3 years, with possible extensions of up to 2 years. RAs are based either at the accelerator laboratory where their experiment is conducted, or at RAL depending on the requirements of the experiment. We have in addition home-based programmes on development of detectors, microprocessor systems, etc. Most experiments include UK university personnel with whom particularly close collaborations are maintained.

Please write for an application form quoting VN 303 to

Recruitment Office, R20,
Rutherford Appleton Laboratory,
Chilton, Didcot, Oxfordshire OX11 0QX,
ENGLAND.

ETH ZÜRICH

Postdoctoral Position in Experimental Intermediate Energy Physics

At the Institut für Mittelenergiephysik of the ETH Zurich a postdoctoral position for an experimental physicist is available. The successful candidate will be a member of the ETH part of a collaboration working at the Swiss Institute for Nuclear Research (SIN) in Rare Decay Experiments. The position is available mid 1985 for three years initially with the possibility of prolongation. Additional information can be obtained from **Dr. H. J. Walter (Telephone 056/99 36 44).**

Applications, containing curriculum vitae, list of publications, current interests and the names of two or three referees should be sent soon to

SIN,
Personnel Division,
CH-5234 Villigen/Switzerland,
Code: IMP/19E.

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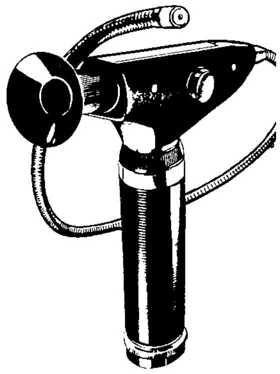

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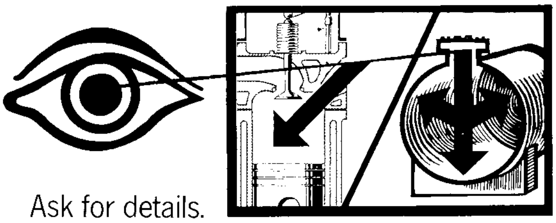

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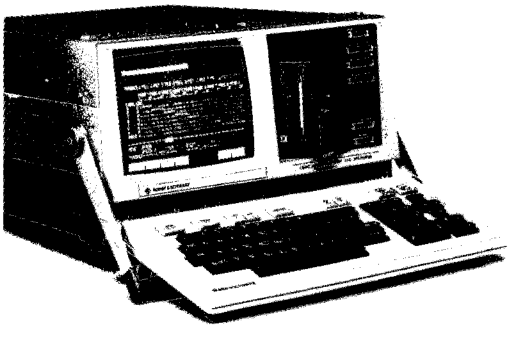

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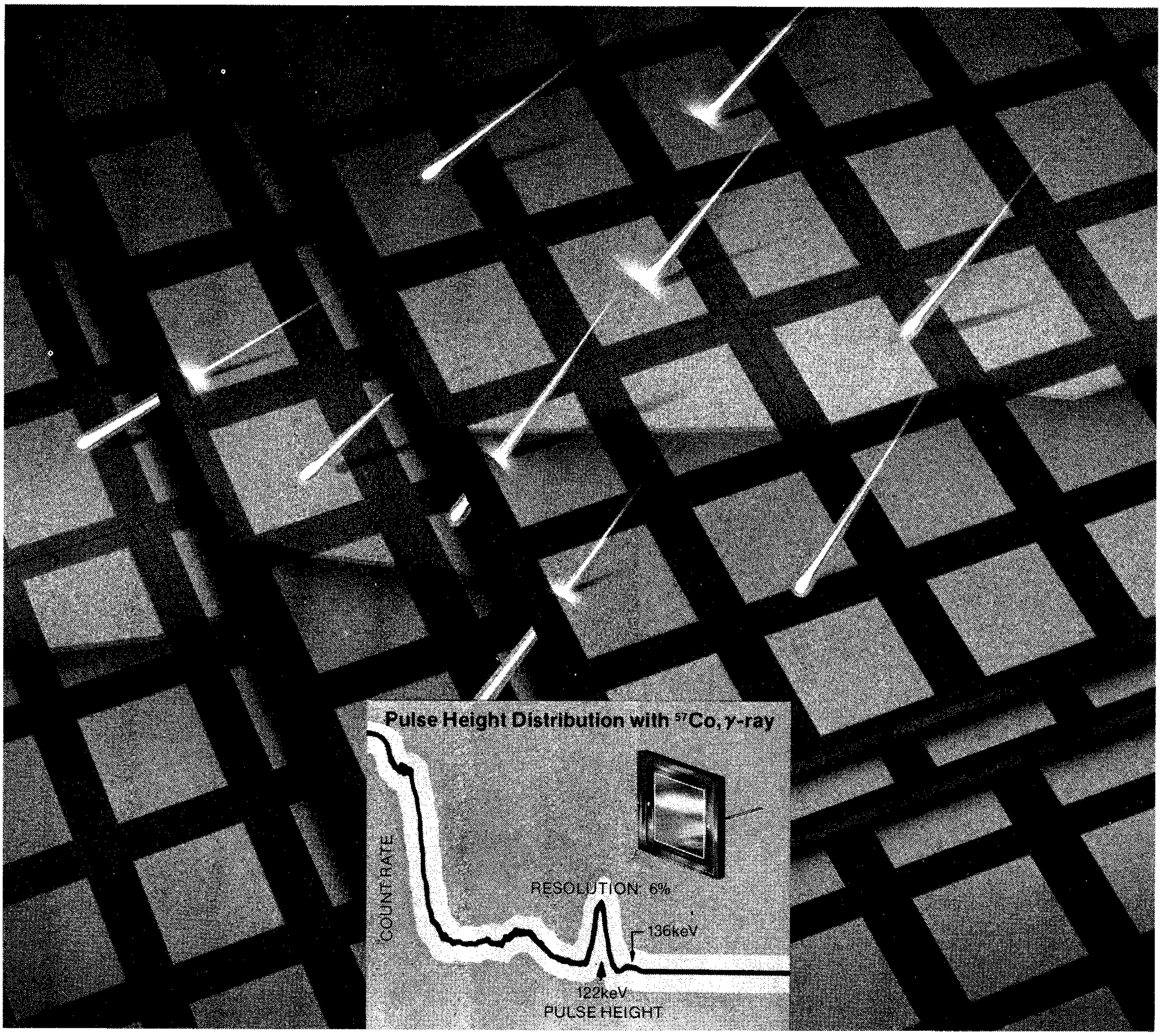
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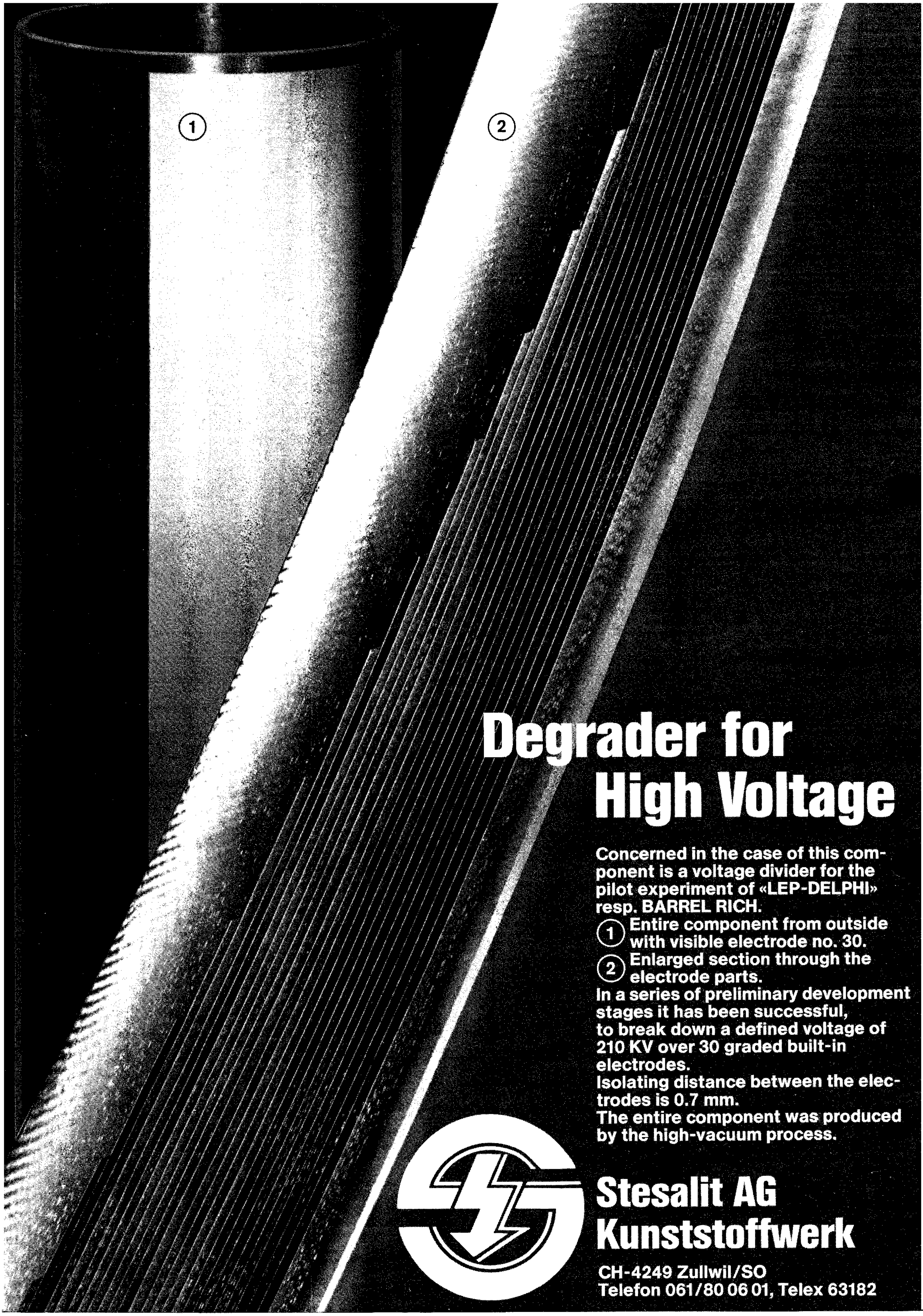
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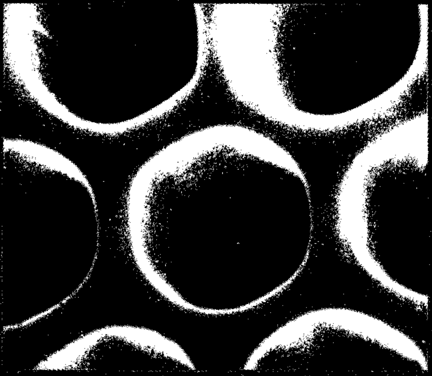
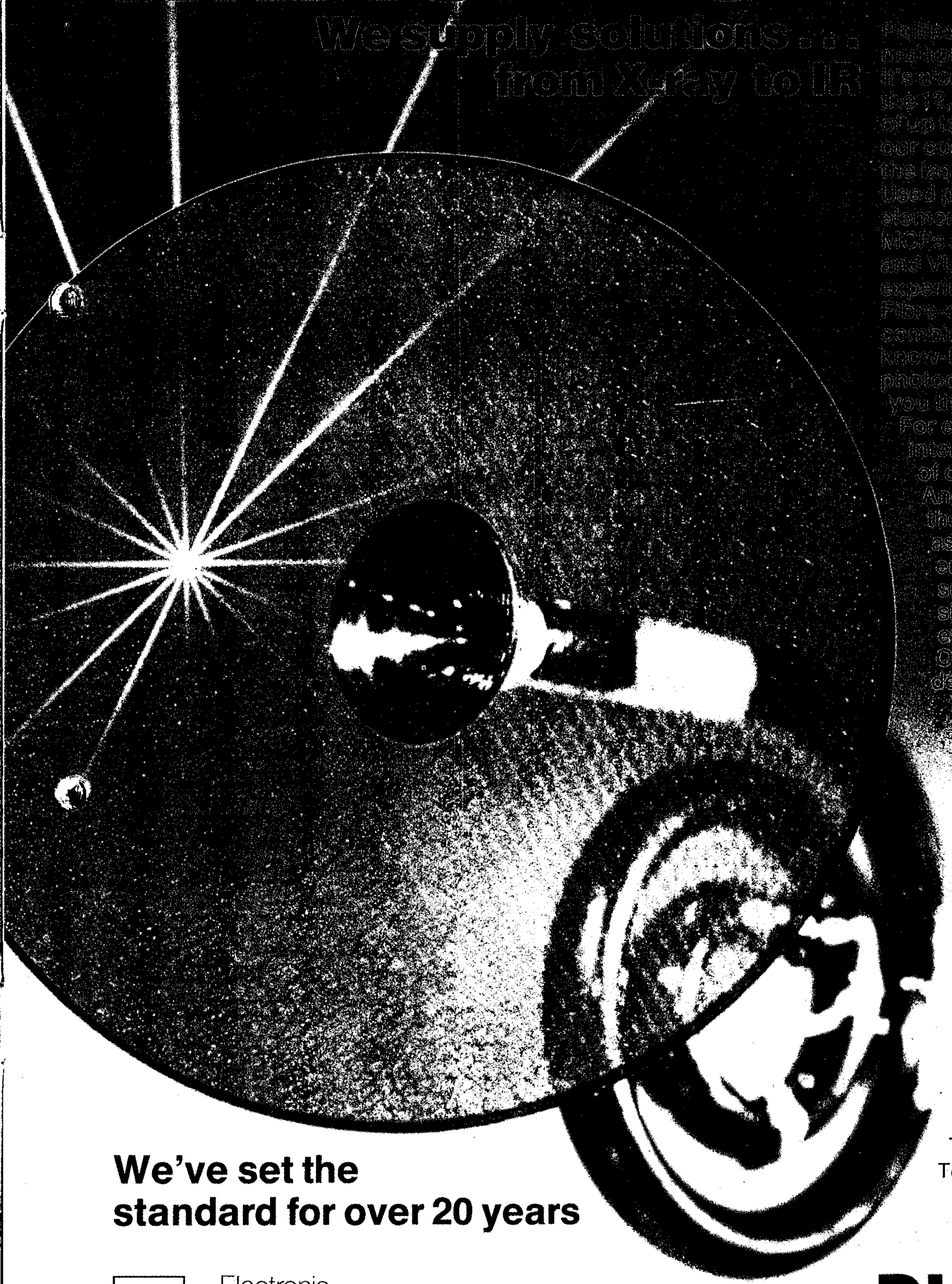


Detail of microchannel plate



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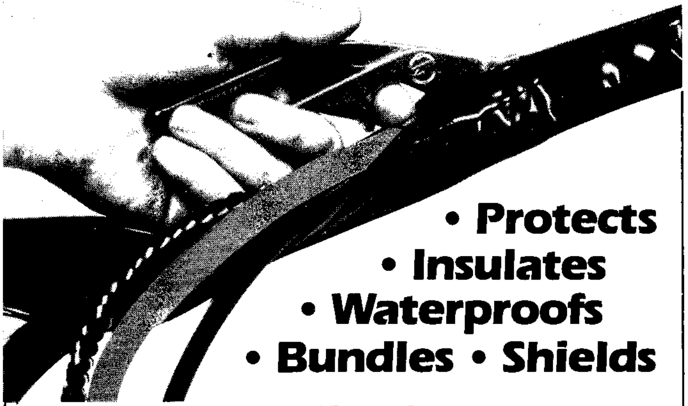

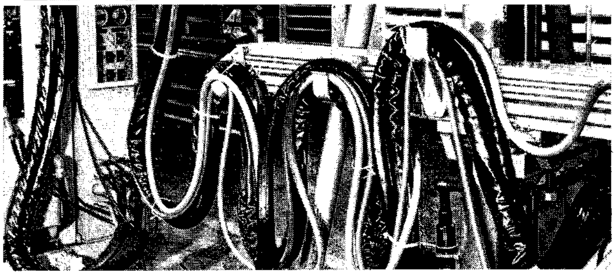

Zippertubing Jackets offer a simple yet effective means of protecting wire, cable and other lines from physical abuse, as well as electrical, shielding and temperature extremes. Easy to install, it's simply wrapped around the line(s) and zipped shut by means of a special closure trac. The trac can be reopened for inspection or rework, or permanently sealed.

Specifically designed for the most difficult applications, Zippertubing is ideal for bundling and protecting Umbilical Cables; Manipulator Arm Lines; Robot and Remote Handling Equipment Cables; Simulator Cables; CCTV Cables; for shielding Instrument and Control Cables; and dozens of other uses.

Standard Zippertubing Jackets come in a wide variety of materials for almost any requirement, and with various shielding materials available, laminated inside the jacket. In addition, Zippertubing can engineer a jacket to your custom specifications when necessary. Find out for yourself, call or write for full details.

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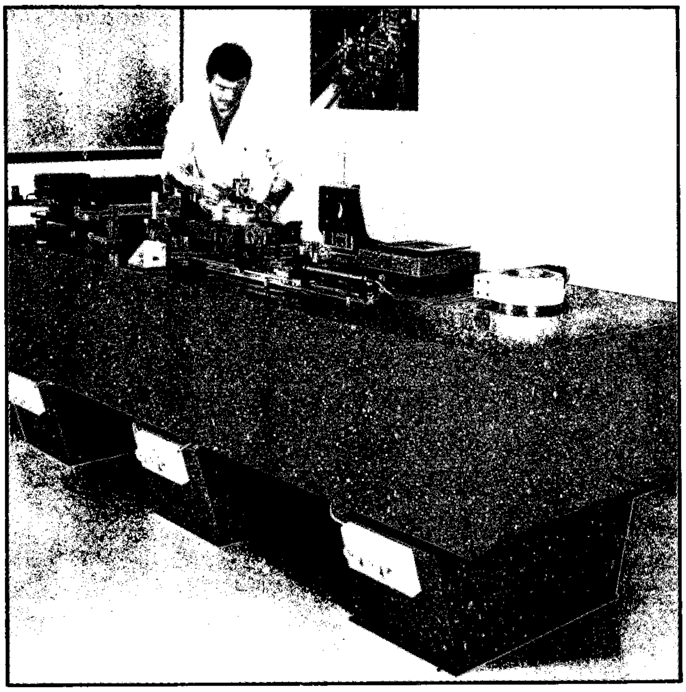

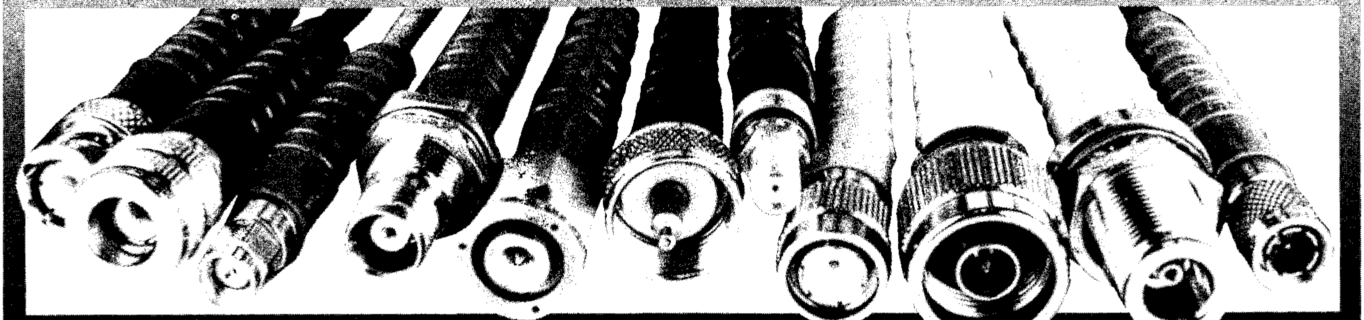

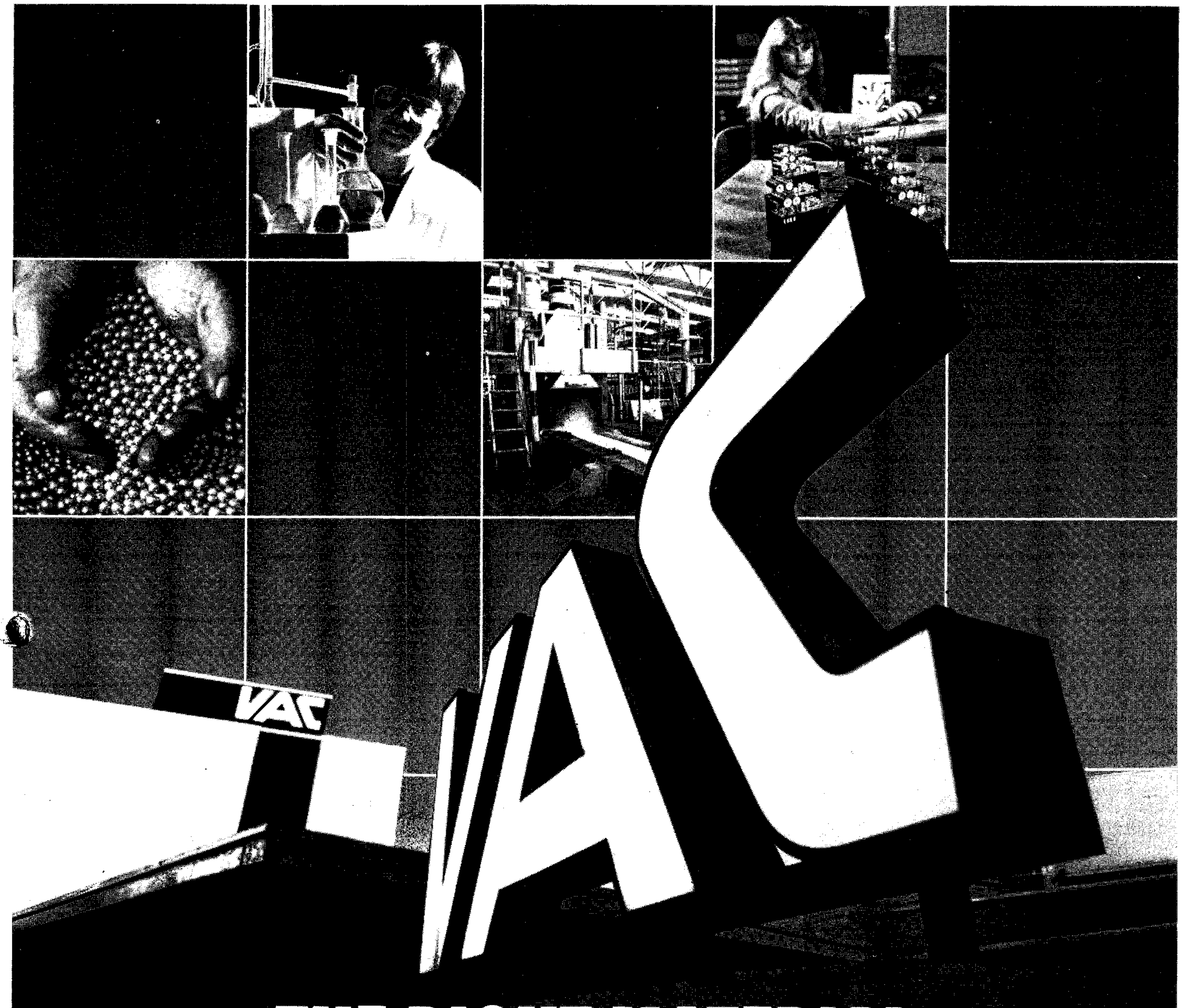
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ADC MOD. 7423 UHS
DEAD TIME %
‰
10 20 30 40 50 60 70 80 90 100
OUTPUT RANGE
RANGE FACTOR
4 8 16
2 32
1 64
mV/CH
CONV. RANGE
1K 2K
512 4K
256 8K
REMOTE
ENABLE
DIGITAL OFFSET
CONTROL
256 512 1024 2048 4096
GATE
PROMPT DELAYED INSPECT
PROMPT CO.
ANT.
DELAYED CO.
RISE TIME PROF (μS)
ULD
16
25
0.5
PEAK DETECTOR
DC SAMP.
DC
DISABLE
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BASELINE
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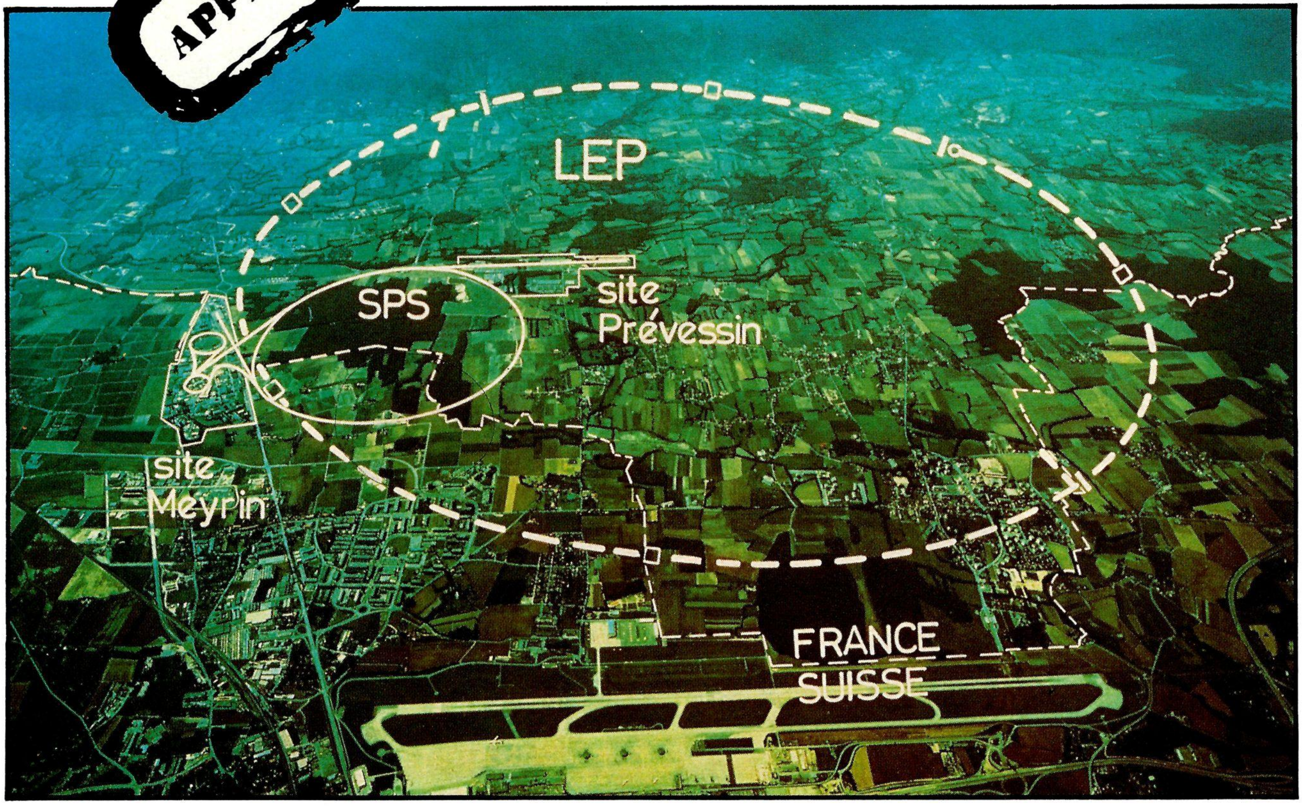
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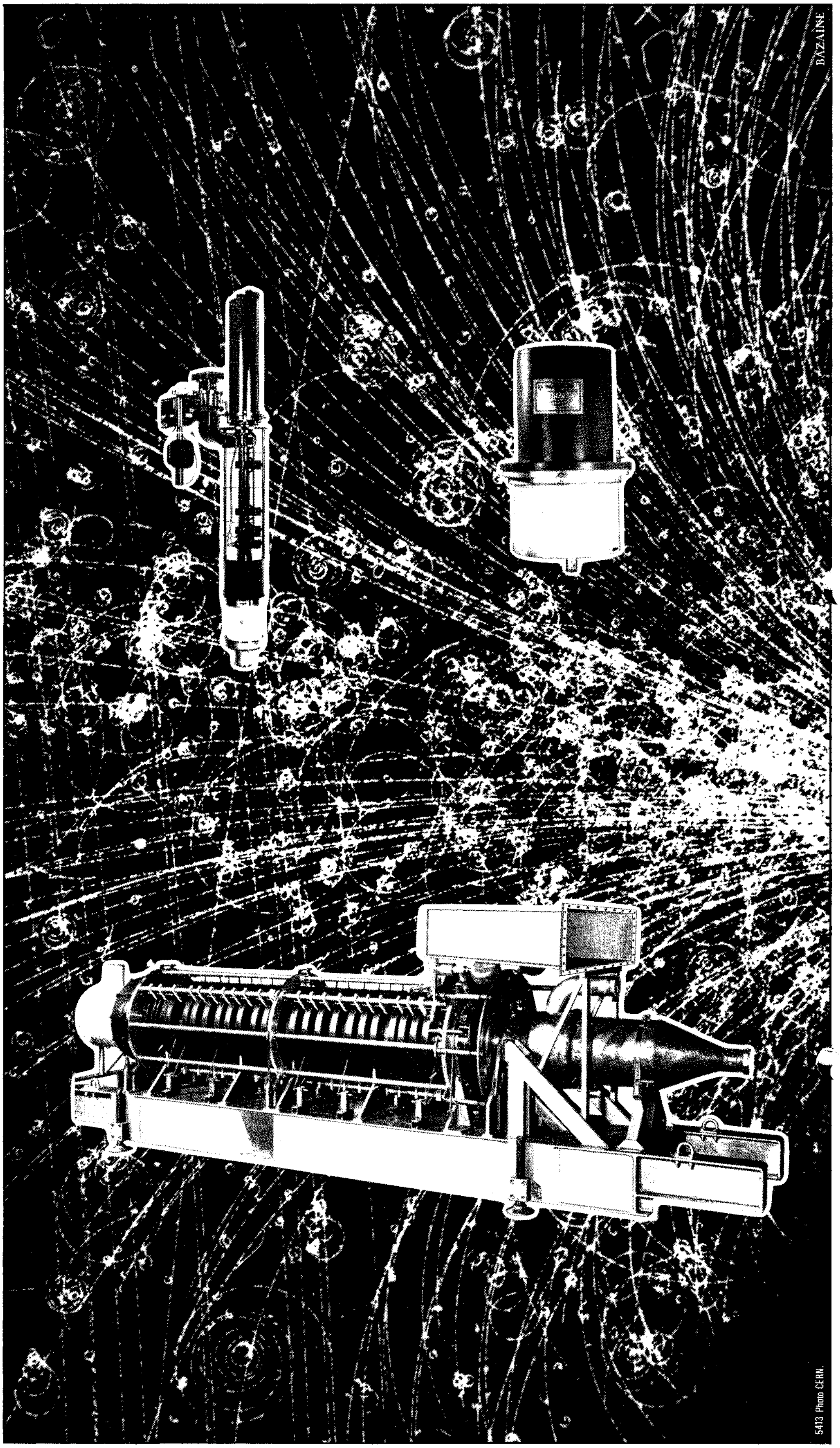
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