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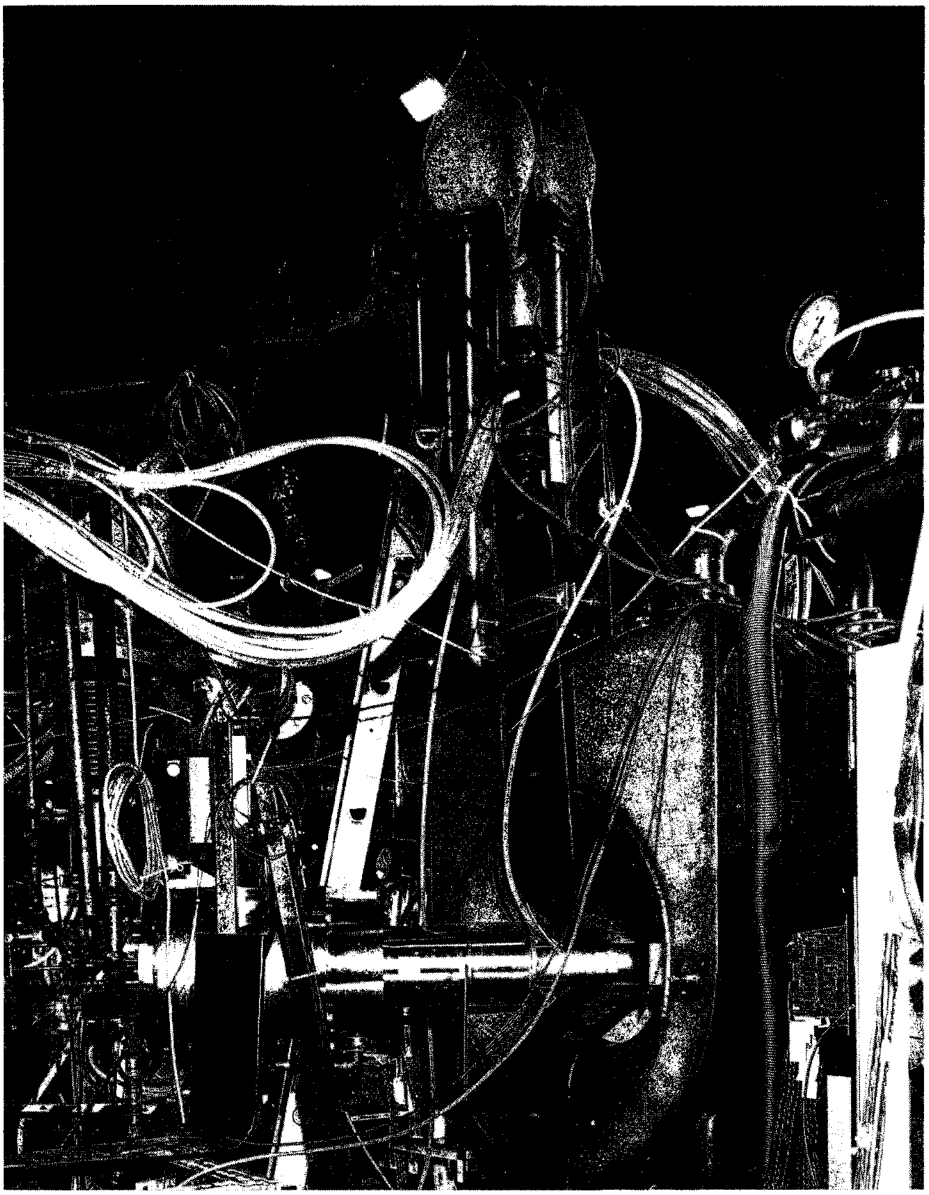
A view of the recent CERN exhibition at the University of Leuven in Belgium. To conform with the architecture of the splendid Gothic hall at the University Centre, bubble chamber tracks took on the form of somewhat abstract stained glass windows. (Photo CERN 126.9.80)

Spin at Lausanne

From 25 September to 1 October, some 150 spin enthusiasts gathered in Lausanne for the 1980 International Symposium on High Energy Physics with Polarized Beams and Polarized Targets. The programme was densely packed, covering physics interests with spin as well as the accelerator and target techniques which make spin physics possible.

Part of the apparatus used at the Argonne ZGS to measure polarized proton-proton cross-sections. One year after the closedown of the ZGS, these results are still a talking point wherever spin physics is discussed.

(Photo Argonne)



The physics

While major physics conferences these days are dominated by the promise of the 'new orthodoxy'–standard electroweak theory plus quantum chromodynamics providing a basis for the understanding of all basic interactions (except gravity) in terms of quark-lepton interactions – this was far from being the case at Lausanne.

Spin physics has given indications of new phenomena which are not readily explained in terms of existing ideas. Using high energy non-polarized proton beams on non-polarized nuclear targets, the polarization of the produced lambda hyperons shows that spin is not just a detail confined to low energy interactions.

At Lausanne, Oliver Overseth presented latest polarization results from the long-standing Michigan/Minnesota/Rutgers/Wisconsin collaboration at Fermilab. This now provides polarization measurements of charged, as well as neutral hyperons, and preliminary data shows that the polarization of positively-charged sigma particles is opposite to that of the lambda and cascade particles.

Any hyperon polarization is puzzling if it is assumed that 400 GeV proton-nucleus collisions must be so complex that any spin effects are averaged out. However Overseth turns this argument around: if polarization is observed in these reactions, then something simple must be happening!

These hyperon results are supported by data at other energies from Brookhaven, the CERN ISR and Serpukhov. One promising suggestion is that the hyperon polarization comes directly from the strange quarks picked up from the sea of virtual quark-antiquark pairs surrounding the target nucleons. This sea is itself unpolarized, but candidate mechanisms have been proposed which could explain why single quarks coming from this sea would have a definite spin state.

The same Fermilab experimental programme has provided indications of hyperon magnetic moments. Final results, covering a wider range of hyperons, are still awaited, but the data amassed so far at Fermilab and from other experiments (such as the HYBUC bubble chamber at CERN) give results which are not easily explained in terms of any conventional quark model.

More unexplained results come from spin studies using polarized beams and/or polarized targets, such as those carried out at the Argonne ZGS before its closure last year. (There was a lot of discussion on the possibility of continuing this valuable work at Argonne at other machines and at higher energies.) Another open book is the spectroscopy of dibaryon resonances, reported at Lausanne from a number of different experiments. With all this evidence, specialists are adamant that spin is an essential consideration, important in all energy regimes.

Quantum chromodynamics, handcuffed to perturbation theory, has had little to say about the kinematical areas where these spin effects occur and about spin in general, although at Lausanne Stanley Brodsky of SLAC proposed how the spin of quark and gluon interactions could lead to selection rules.

The Lausanne meeting contained its own mini-conference–a roundtable discussion initially entitled 'Is spin physics worthwhile?' – with theory, experiment and machine specialists taking part. However the participants were so convinced that spin physics is worthwhile that the first resolution was to change the title of the discussion.

The ensuing physics discussion soon turned to the merits of quantum chromodynamics as a serious theory of strong interactions. Elliott Leader challenged his fellow theorists to propose the 'cleanest' tests of QCD. This invitation was directly taken up by Stan Brodsky who was of the view that QCD predictions for certain exclusive channels were extremely clean, and that if these predictions turned out to be wrong, he for one was ready to give up QCD.

As well as the effects seen in hadron experiments, there is now a lot of interest in the physics that can be done using polarized electron beams. The major results obtained at SLAC on polarization effects in deep inelastic scattering showed up the delicate interference between weak and electromagnetic interactions, and could be the herald of a new type of physics experiment. The discussions at Lausanne mirrored this growing interest in polarized electron beams and the experiments which could be done with them at new machines such as LEP and HERA.

The Lausanne meeting provided a very welcome opportunity for spin specialists to meet and exchange views. It was easy to get the impression that it also gave them a chance to **vent some of their frustrations.** Although some unexplained spin effects are now several years old, some people were of the view that the message is not getting across. As it has been voiced in high (energy) circles recently when referring to some of these recent spin results – 'to believe that high energy physics is now understood is just plain foolish!'

The technology

The provision of the necessary experimental conditions to study high energy spin physics began with the work on polarized targets which became feasible following development of the dynamic polarization method in the early 60s and mastery of the technologies of high magnetic fields and low temperatures. The ideas came from A. Abragam at Saclay and were first pursued there and at the Berkeley Laboratory under C.D. Jefferies.

The present state of the art was reviewed at the Symposium by T.O. Niinikoski, a specialist in the use of extremely low temperatures in polarized targets at CERN, where polarized target research had been led for many years by M. Borghini. Among the new polarizable materials which hold out the promise of higher polarization (and/or ha more easily polarizable nuclei) a lithium deuteride, pursued particularly at Saclay, where polarizations of over 70 per cent have been achieved, and ammonia, with which 90 per cent polarization has been achieved, used at Bonn, Stanford and CERN. The techniques of frozen spin targets, where the target material can be polarized and then transferred, retaining its polarization, to a location providing greater detector access, seem to be well mastered.

Performance of polarized sources has also advanced steadily. Polarized negative hydrogen ions (reviewed by W. Haeberli) are of particular interest for multiturn injection in proton accelerators. The technique using atomic beams is under deve opment, for example, at Bonn, Dubna, Zurich and Argonne (for use at the Brookhaven AGS following closure of the ZGS) and is yielding negative ion beams of several μA. The ionization method developed at CERN, in collaboration with ANAC of New Zealand (achieving the record current of 110 μA of polarized protons) is being applied successfully at Zurich to negative ions. A new method, proposed by Haeberli, where polarized neutral atoms collect an electron on passing through a paramagnetic vapour such as sodium, is also giving promising results at Wisconsin and at KEK, Japan.

A team at CERN, with the assistance of a Lausanne / Michigan / Rockefeller collaboration, has fastened onto the atomic beam polar-

Polarization in electron rings

One of the main talking points at the Lausanne Symposium was the likelihood of achieving polarization in electron rings at high energy. The realization that synchrotron radiation could result in polarization in an electron storage ring came from A.A. Sokolov and I.M. Ternov in 1964. Experiments were proposed on SPEAR in 1971, following reports of polarization measurements from Orsay and Novosibirsk, and large polarization effects were recorded two years later. Since 1973, Stanford has also pursued the polarization monitoring technique by backscattering of a laser beam, proposed by D. Fryberger and D. Prescott (the technique had earlier been suggested by V.N. Baier and V. Khoze in the Soviet Union). The laser polarimeter was operated on SPEAR in 1977 and a version for the PEP storage ring is now under construction.

ized proton source configuration to propose a polarized jet target as an internal target for an accelerator providing a density of over 10^{12} atoms per cm^3 (reported by W. Kubischta). L. Dick, in discussing the physics which would be possible with such a target, talked of future plans for a very high density target (over 10^{15} atoms per cm^3) which could allow measurements with precision of 10^{-7} and make it possible to see such refined effects as the neutral current interference with the strong interaction. A new range of polarization physics with high precision will also be possible on the LEAR storage ring at CERN (reported by K. Kilian), given the high intensities of the low energy antiproton beams.

Polarized electron sources have been a speciality at Stanford, where a Yale team installed the first source, known as PEGGY, in 1974. The latest work, led by Charlie Sinclair, has achieved emission currents of 60 A from a gallium arsenide photocathode. Typical emerging beams at 120 Hz have 40 per cent polarization and 0.5 A currents. Improvements are being sought with gallium aluminium arsenide cathodes and other semiconductor materials. Charlie Prescott covered the interest in polarized beam physics with the proposed Single Pass Collider at SLAC.

It is particularly in the area of polarized beams in accelerators and storage rings that a great deal of new information and interest has welled up in recent years. This was reflected at the Symposium by the presence in force, for the first time at one of these polarization meetings, of leading accelerator physicists.

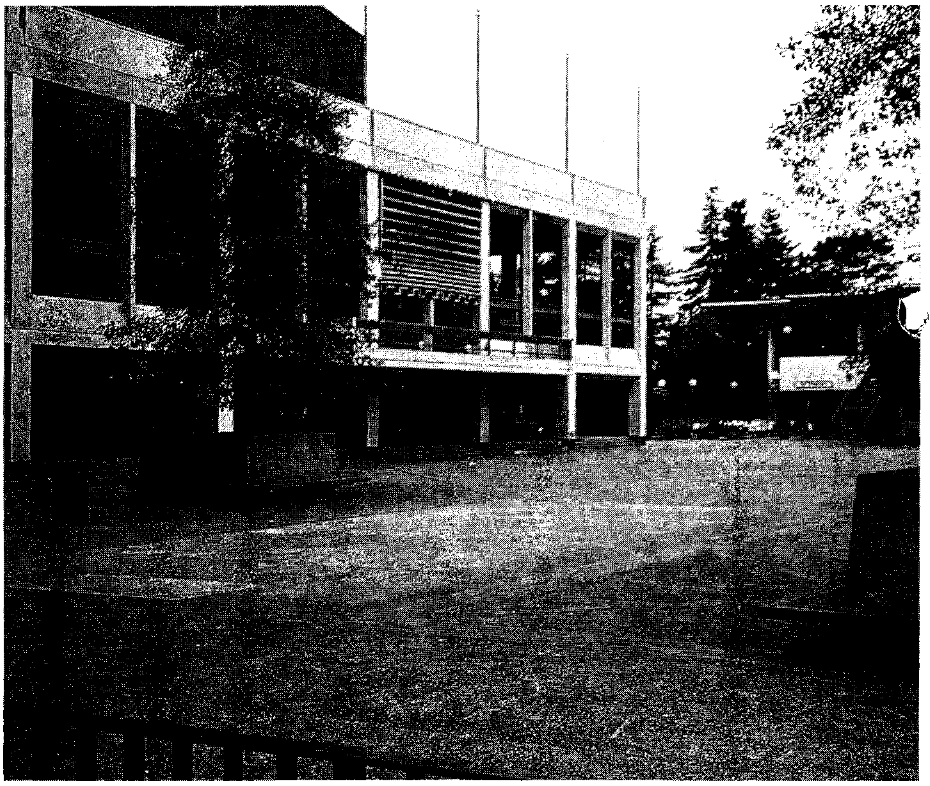
Polarized proton beams in accelerators were covered recently in the CERN COURIER (see May issue, page 104), but in passing them by it is still worth acknowledging the achievement of GeV range polarized beams at the Argonne Zero Gradient Synchrotron. It was an Argonne / Michigan / CERN group who first pushed this work theoretically and experimentally from 1974. There was interest at that time in polarized beams in the CERN PS, but this development was halted to give priority to other projects. Argonne thus carried the polarization flag alone and, with the closure of the ZGS, it has now been passed to Brookhaven, KEK and Fermilab.

While Argonne pushed polarized protons, polarized electrons were investigated mainly by Stanford, using the SPEAR storage ring. The main concern now is whether polarization will be retained in the higher energy machines. A full review of the problem was given by J. Buon. The happy news from the PETRA storage ring at DESY (see July/August issue, page 196) was reported by R. Rossmanith. While polarization is seen with a single beam, it is absent with two beams, so it is obvious that some beam-beam conditions spoil the polarization. The hunt for stable polarization colliding beam conditions will be pursued. Alex Chao, leaning on the experience with SPEAR, showed the calculated conditions in which polarization is expected in PEP. Looking further into the future, Bryan Montague has been studying the problems of retaining polarized beams in LEP and of spin rotation in the colliding beam regions.

The accelerator physics behind these calculations on the degree of polarization which can be attained led to much discussion at the Symposium. A favourite candidate to help retain polarization is the Siberian Snake, a magnetic field inversion technique so-called because it was invented at Novosibirsk. The full extent of its abilities requires further detailed study, but it is already clear that two Snakes would be needed in an electron storage ring.

Covering a wide and ambitious programme, the interdisciplinary aspect of the Lausanne meeting was striking, and it was stimulating to see the high level of interaction between particle physicists, condensed matter specialists and the accelerator fraternity.

New nuclear physics at Berkeley Conference



The Zellerbach Auditorium at Berkeley, where the plenary sessions of this year's international nuclear physics conference were held.

(Photo C. Ekström)

One of the highlights of the summer was the International Conference on Nuclear Physics, held at Berkeley in August. These big meetings — the previous one was in Tokyo in 1977 — provide a periodic focus for the nuclear physics community, Among the 980 participants at Berkeley, there was a party of Chinese physicists, the first time there has been a major Chinese involvement at such a meeting. After plenary sessions in the morning, most afternoons were devoted to parallel sessions, and for the many people following more than just a highly specialized topic, there were the inevitable conflicts of interest.

In his closing remarks, Herman Feshbach of MIT summed up the Conference as having highlighted 'new' topics — new nuclear degrees of freedom, new reaction mechanisms, possible new forms of nuclear matter, new aspects of weak interactions in nuclei, new nuclear symmetries, etc. These new phenomena or ideas contrast sharply with the conventional nuclear spectroscopy which dominated the field until quite recently.

During the Conference, there was much speculation on possible new forms of nuclear matter — pion condensation, the transition of nuclear matter to quark matter, nuclear phase changes, transitions from weak to strong nuclear couplings, etc. While as yet there is little experimental evidence to go on, future studies with high energy heavy ion beams (such as are planned for example at Berkeley, Darmstadt, Dubna and Tokyo), or using antiproton beams in the LEAR ring at CERN, could provide some firm guidelines.

Superheavy nuclei, a highly controversial topic of a few years ago, was this time conspicuous by its absence. There appeared to be very few new results to report on this front, and all the speculation seems to be dying down.

The Conference banquet was graced by no fewer than seven Nobel prizewinners — Glenn Seaborg, Luiz Alvarez, Aage Bohr, Ben Mottelson, Owen Chamberlain, Edwin McMillan and Emilio Segrè. Alvarez, in a memorable after-dinner talk, put forward some relatively new ideas on how the dinosaurs could have been wiped off the face of the prehistoric earth (see panel).

A memorable confrontation occurred at the Conference proper, held in Berkeley's Zellerbach Auditorium, when Marcos Moshinsky's talk on the relative merits of different nuclear collective models provoked an intense discussion with fellow experts Igal Talmi (as chairman of the session), and Bohr. In the same session, devoted to nuclei with large angular momentum and deformation, there were some good presentations on the properties of nuclei with very high spin, where angular momenta of up to 30 units are now encountered regularly. This provides an effective continuum of nuclear spin states and seems to be opening up a new field of study.

The present status of giant resonances and of the distributions of charge and magnetization in nuclei was systematically reviewed in terms of multipole contributions. Accurate measurements of charge and matter distributions were reported, in addition to direct evidence, coming from isomer shift measurements, that fission isomers are in fact shape isomers.

The subject of heavy ion reactions seems to be in a very formative stage, holding out much promise for the future. New heavy ion projects are using knowledge gained from particle accelerators, and there are also signs that the detector technology developed for particle physics experiments could soon be exploited further in the nuclear physics area. Other new techniques, involving lasers for example, are extending the range of experiments which can be carried out.

Overall, the Conference paid a lot of attention to topics and phenomena which only a few years ago would have been considered exotic. With many novel ideas being put forward and with new projects afoot, a lot of fresh ground could have been covered by the time of the next meeting, scheduled to be held in Florence in a few years.

We are grateful to Bjorn Jonson and Curt Ekström of the ISOLDE collaboration at CERN for helping us prepare this report.

When dinosaurs walked the earth...

Geologists (among them Luis Alvarez' son) have analysed layers of rock that were laid down at about the same time as the dinosaurs ceased to exist, some 65 million years ago. Neutron activation analysis reveals unusual concentrations of heavy elements such as iridium, possibly indicative of intense meteorite activity.

The evidence suggests that this was due to just one huge meteorite, about 10 km diameter, which hit the earth and produced a thick dust cloud, blocking out the sun for several years. As a result, vegetation withered and animals died, so that eventually there was no food left for the biggest animals of them all, who starved to death. No vertebrates heavier than about 25 kg appear to have survived. Some smaller animals, the ancestors of the mammals, fared better as they could eat decaying vegetation and insects. As the dust cloud dispersed, plant life restarted from the remains of the root systems, and evolution continued, although highly affected by the meteorite catastrophe.

Computing Conference at Bologna

rom 9–12 September a Europhysics Conference on Computing in High Energy and Nuclear Physics, organized by the Computational Physics Group of the European Physical Society, was held in Bologna, attracting some 150 participants. Its purpose was contact and exchange of information between experimental physicists (from both fields of research) and computer experts (on whom the successful outcome of the research has become increasingly dependent). Proceedings of the Conference will be published as a special issue of Computer Physics Communications.

Review papers by Leon Van Hove and M. Macfarlane set the research scene in high energy and nuclear physics respectively, and there were papers by B. Giraud, D. Ponting, Z. Szymanski and K.J.F. Gaemers which brought out some of the many areas of theory where the power of large computers is essential for solving the present problems. On the technical side, G. Franke, M. Masetti and M. Regler made the link with experiments showing the crucial role of computers in all stages of data acquisition and analysis.

The continued rapid evolution of computer hardware and software is keeping experimenters on their toes, not only in terms of improving their present techniques, but sometimes radically rethinking how to approach the task of data reduction. Progress was very evident in areas of mass storage, on-line systems, programming languages, large-scale data transmission, etc. Mervyn Hine reported on the first experience in the high energy physics field with high speed data communication by satellite—the STELLA project.

The trend towards 'decentralization' of computing power was very clear. More and more tasks are being undertaken by the local computer at the experiment, thanks to the growing power and falling costs of microprocessors and the growing skill in making use of them. It seems probable that we are in the early days of this trend and it is also probable that the abilities which are emerging, spurred on by the needs of physics, will find many applications in other fields.

Despite the decentralization trend, the large central number-crunchers are not exactly short of customers. On the contrary, the demand on the central systems continues to grow.

Around

However its nature is changing because of the higher quality input coming from the more sophisticated local computers. There is call for more storage capacity, faster output devices, cleverer graphics facilities, etc., to respond to the new input. B. Zacharov, given the way costs and abilities of computers have moved, proposed a fresh look at the function of the 'main computer', suggesting a parallel attack to the number-crunching process with many small systems rather than a single powerful hierarchical computer.

A relentless theme was the need for accepted standards and practices through all the stages of data processing. This has been promoted recently by the European Committee for Future Accelerators who set up a Working Group led by E. Lillestöl and E.M. Rimmer. Similar efforts are under way in the USA.

With the increasing size of experiments and of the number of physicists involved in the collaborations necessary to carry them out, this need has become urgent. It would greatly ease the participation of groups spread around many countries if standards can be agreed. A modular approach with compatible interfaces would then be possible in building up the data acquisition and analysis system of an experiment. Individual Universities would be able to tackle a part of the system and make a useful contribution fully compatible with what is coming in from other centres in the collaboration.

Subgroups have been set up to study the possibilities in special areas—Microprocessor buses, facilities and applications / Data acquisition / Graphics, histogramming and command processors / Software libraries / FORTRAN / Off-line calibration and analysis / Bookkeeping and documentation. It could prove very fruitful if standards can be established in all these areas in the same way that the CAMAC hardware standards have proved so very fruitful over the past decade.

The help of Rudi Bock in supplying the information for this article is greatly appreciated.

Mervyn Hine (left) and Ben Segal inspect the antenna installed at CERN for the STELLA project on high speed data communications by satellite. First experience gained from this project was reported at the recent Conference on Computing in High Energy and Nuclear Physics, held in Bologna.

(Photo CERN 438.1.80)

*** Stop Press — two ISABELLE prototype dipole magnets have now reached the 5 T design field.**

BROOKHAVEN
5 T magnet

After a sequence of tantalizing disappointments, tests in September with two new superconducting magnets have brought encouragement to the Brookhaven team building the ISABELLE proton-proton storage rings. For the first time, a magnet topped 5 T—an achievement of deep psychological significance as it means the field level needed to operate ISABELLE at 400 GeV has been attained.

A particular aim in the construction of these latest prototypes was to examine the effect of heavily stressing the magnets, so that they were much more mechanically rigid than their predecessors. One of the magnets was 'double shrunk'—a first shrink of the coils was made into aluminium bands to take most of the precompression, and a second shrink was made to compress this structure into the steel yoke of the magnet. Less friction was achieved between the coils and an attempt was made to avoid the outer coil bonding to posts.

The result was much faster training of the magnet. The elusive target of 5 T was reached after sixteen quenches and the field peaked at 5.1 T, very close to the highest field possible according to the 'short sample' characteristics of the superconductor.

Interestingly, the second of the two magnets (on which measurements were still in progress at the time of writing) did not have the aluminium bands. It began training at the same level, but after five or six quenches its performance started to fall below the levels recorded with the 'double shrunk' magnet. More magnets and more tests are required to rub home these results, but it is a good omen to have achieved a faster training cycle, and to have achieved the design field.

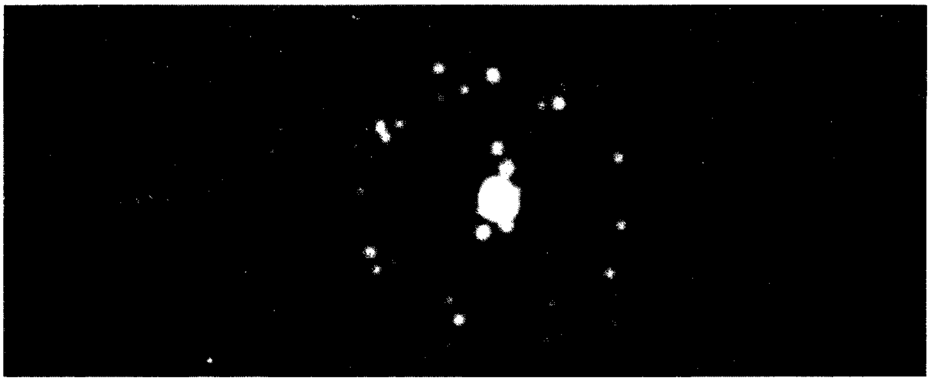
CERN/SACLAY New Cherenkov radiation techniques

Advances in detector techniques have to go hand in hand with new accelerators. Only when the right detection techniques have been developed can the potential of a new machine be fully realized. With the LEP electron-positron ring for CERN still on the drawing board, attempts are being made to envisage what detector packages would be required to do physics under these new conditions (see October issue, page 291).

Looking back over the progress which has been made on the detector front, one of the most significant advances came in the late sixties when the Charpak team at CERN developed multiwire proportional chambers and drift chambers. These devices soon became the everyday tools of particle physics, and were quickly adopted by other research fields as well.

To satisfy the demands of modern physics experiments, where physicists are searching for rarer and rarer events amid ever-increasing event rates, new techniques are required. One of these is the multistep avalanche chamber, another product of the Charpak stable. This is designed to reduce problems due to the space charge of positive ions and improve the detection of rare events amid a copious background (see March 1979 issue, page 5).

One of the first applications of this new multistep chamber is for the imaging of Cherenkov photons, a development not originally foreseen. Cherenkov photons emitted in a transparent medium by fast charged particles can be focused into a ring whose radius is a measure of the particles' mass and momentum. However localization of these photons in the visible wavelength region is limited to surfaces of a few tens of cm^2, the maximum size of conventional image intensifiers. Localization over larger surfaces is conceivable using a suitable photosensitive gas in a multiwire chamber, but in practice it is difficult to obtain sufficiently large gains using chambers filled with such gases.



Cherenkov ring imaging, as recorded on a TV screen monitoring a multistep chamber using a new substance, Tetrakis-dimethylamino-ethylene (TMAE), as photosensitive vapour. The large beam spark shows TMAE's extreme photosensitivity.

Following pioneer work by Tom Ypsilantis, the difficulty has been overcome with the help of the new multistep chambers. At CERN, Fabio Sauli and collaborators have developed a detector with a multistep preamplification element coupled to a triggered spark chamber and which can image the Cherenkov ring produced by (ultraviolet) photons with energies above 7.5 eV, the ionization potential of triethylamine, TEA. Although maybe too slow for present needs, the 'old-fashioned' spark imaging method can be used for exploratory work, and coupled to a TV digitizer, specially developed by a team from Padua, the patterns can be analysed by computer.

To detect these photons requires a suitable photo-ionizable gas, but limitations are encountered because most easily ionizable substances exist only as solids at room temperature. In addition, detector windows have to be made of special materials which can transmit the short wavelength photons that ionize such substances as TEA. Typically, detector windows have to be constructed of calcium fluoride crystals. The manufacture of large windows, covering several square metres, is difficult using such materials.

An alternative photo-ionizable substance has been suggested by

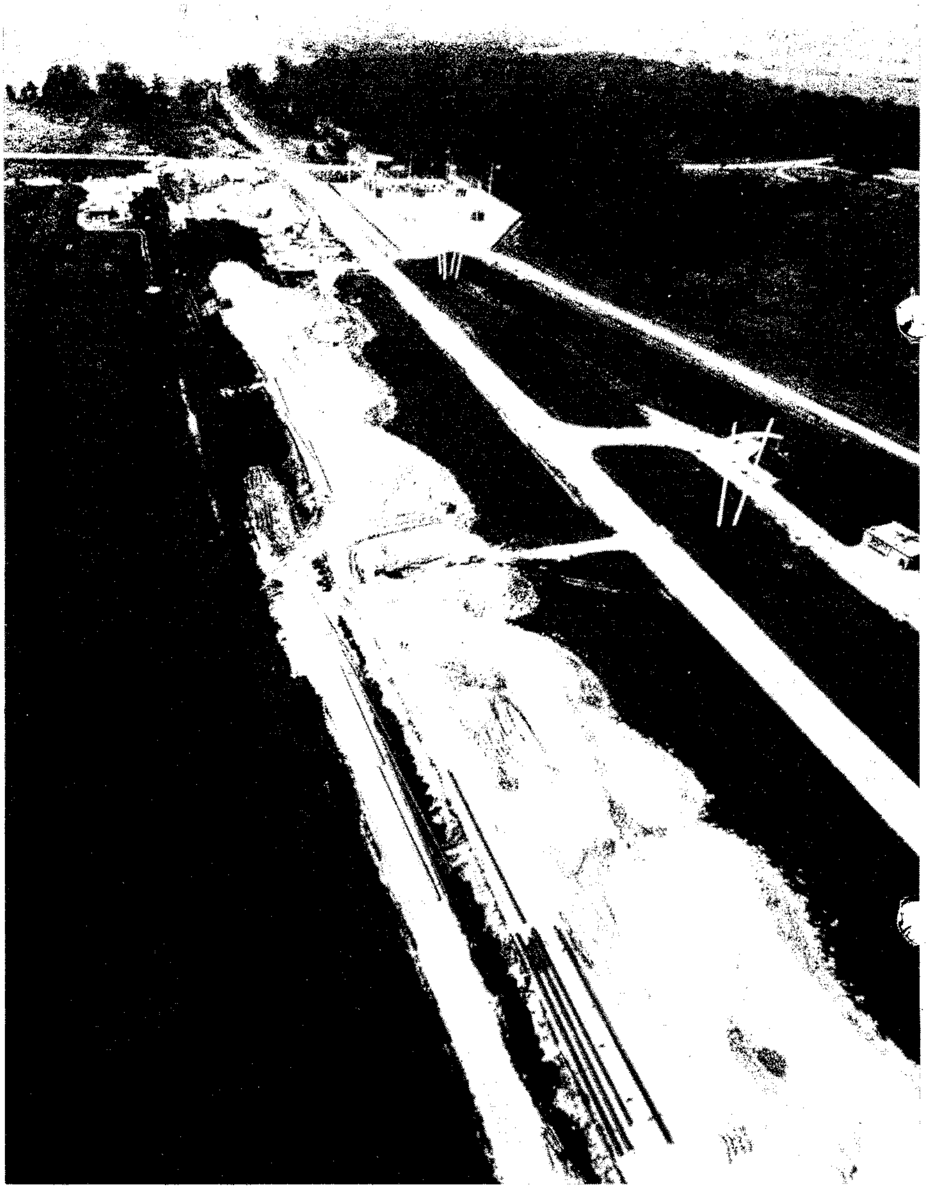
D. F. Anderson of Los Alamos which appears to offer significant advantages for this work. Called Tetrakis-dimethylamino-ethylene (TMAE), it was originally developed as a tracer material for military use. Its big attraction is that it can be readily ionized by photons with energies as low as 5.4 eV. This longer wavelength radiation undergoes reduced aberrations and losses in the radiating material. In addition, windows can be made of fused silica, much easier to work with than calcium fluoride crystal.

Preliminary tests using TMAE-equipped detectors have been made at CERN and the results are promising. One disadvantage is that TMAE is not an easy material to work with as it combines aggressively with oxygen, however if these difficulties can be mastered, considerable improvements in particle identification can be expected.

Large area imaging Cherenkov counters using multistep chambers with a suitable photosensitive gas and with TV digitization are to be constructed by a CERN/Saclay collaboration for a new experiment at Fermilab by a CERN / Columbia / Fermilab / Saclay / Stony Brook team. This study, for the Meson Laboratory, covers the production of energetic muon pairs and other particles and is designed with Tevatron operation in mind. It is hoped to be able to identify hadron pairs up to about 300 GeV.

This summer, major modifications have been under way in the Fermilab Neutrino Area. The target area is being extended to accommodate the longer target trains necessary for more flexible radiation handling and the higher energies that will be available later. The target area is visible upstream, upper centre. A new primary beam pipe is being installed to allow protons to be targetted closer to the experimental areas for special beams (visible in lower centre of photo). Finally 15 000 tons of iron shielding taken from the Argonne ZGS, is being installed downstream (out of range of the camera) to harden the shield so that experiments can be done closer to the target. The hardened shield will also remove the higher energy muons expected in the future. The Fermilab Main Building and part of the Main Ring can just be seen, top left.

(Photo Fermilab)



FERMILAB Tevatron Workshop

The Fermilab 1000 GeV Tevatron is becoming a reality. Before the initial physics programme, the beams and the detectors are firmly determined, it is important to look closely at the important physics questions that arise at the higher energies that will be available. A Workshop, held at Fermilab on 24–31 July, studied the physics opportunities offered by the Tevatron fixed target programme. More than fifty physicists, including a dozen theorists, from the USA, Europe and Asia, participated in the Workshop.

Whenever a new accelerator facility is turned on, there is always the chance of discoveries that no one has anticipated. Although that is certainly possible at the Tevatron, it is considerably less likely today since quantum chromodynamics (QCD) may be the theory of strong interactions and there is a good theory of electroweak interactions. Both have been formulated and partially tested in the Tevatron energy range, and it is likely that they will remain valid there. One important role of the Tevatron programme will be to test further these theories. On the other

Members of the Fermilab Users Executive Committee for 1980–1981 are (left to right) F. Turkot, M. Schwartz, J. Rutherford, T. Devlin, V. Peterson, S. Hagopian, C. Ankenbrandt, P. Hale. T. Romanowski, L. Jones (Chairman), R. Gustafson, and K. Goulianos. This committee serves to represent the worldwide community of Fermilab Users.

(Photo Fermilab)

hand, there are fundamental unsolved problems in particle physics today and there are a number of ways of providing new experimental input to grand unification, the flavour problem, and spontaneous symmetry breaking from fixed target physics at higher energies.

From the perspective of possible experimental input to solving fundamental problems in particle physics, some of the principal questions identified at the Workshop were: Is QCD really the correct theory of strong interactions?; Is the standard model really the correct electroweak theory?; What is the physics of spontaneous symmetry breaking?; Are there fundamental Higgs bosons, or is there dynamical symmetry breaking giving composite bosons, or perhaps no particle states below the TeV scale?; Is there a grand unification of QCD and the electroweak theory, and if so what is it?; Why are there several families of quarks and leptons and how many are there?; What are the values of the masses of the different neutrinos?; Does the tau lepton have its own neutrino?; What are the quark mixing angles?; And finally are there unexpected discoveries to make? These unexpected discoveries could come in two kinds. First, there could be truly unexpected findings, such as a fourth family, heavy neutral leptons, light coloured Higgs, and things as yet unconsidered. Second, there could be results that fit within the framework of the theories we have. Is the weak isospin of the right-handed muon really zero? Are the charged currents all really left-handed? Many of these kinds of questions can be checked.

The Workshop also identified a number of experimental programmes of great significance. These include the study of the charged baryon mass spectrum and the study of rare processes, such as the decay of a positive sigma into a proton, muon and electron, which are expected and whose rates are predicted by new theories. Other possibilities include the search for right-handed charged currents and effects caused by Higgs bosons. The measurement of the total cross-section of the neutrino-neutron interaction could show effects due to intermediate weak bosons. The study of the neutral currents and precise determinations of the Weinberg mixing angle probe theories of grand unification. The study of quark and hadron jets is an interesting way to test QCD predictions.

After developing this list of physics topics, the Workshop considered in some detail what measurements were necessary for such experiments and whether the measurements were feasible. One

Dick Lundy, Head of the Magnet Department in the Energy Saver Division at Fermilab points out the new 'smart bolts' that have been integrated into the doubler magnets.

(Photo Fermilab)

interesting outcome was that some of the most important experiments should use dedicated, rather than multipurpose, detectors. An example was the sigma decay, where a dedicated experiment might hope to gain more than a thousand times the sensitivity of a multipurpose detector for such a rare decay. The high resolution detectors are often multipurpose, (except for their triggering devices, often quite specific). Another result of the Workshop was that groups of experimenters working on a common programme could be of great value, and that this would require planning and foresight on the part of experimenters and the Laboratory; examples are scaling violation tests, full determination of the structure of the neutral current, interactions for a given family, or measuring the momentum transfer dependence of the Weinberg angle.

Over a few years, the fixed-target Tevatron will produce perhaps 10^9 charmed particles and 10^6 b-quarks. As probes of new physics, these will allow discoveries that are hard to predict now, and will leave room for clever experimenters to do important experiments.

Each working group wrote up its ideas by the end of the Workshop and these contributions are being brought together as Proceedings. The final document should reflect the broad and exciting range of opportunities to do new fundamental physics at the Tevatron.

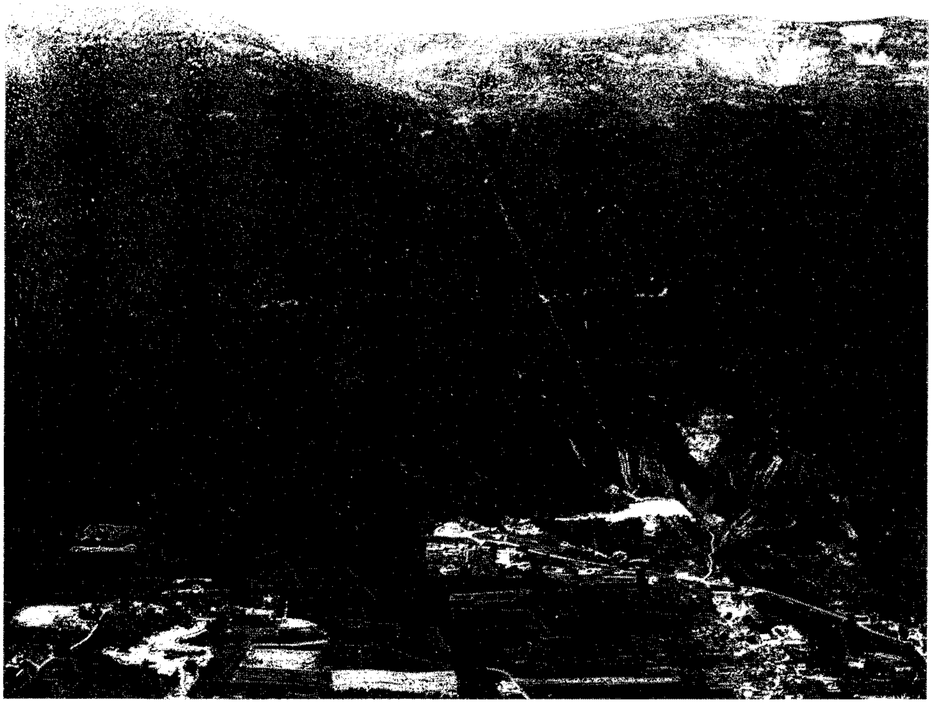
Smart Bolts at the Doubler

Shortly after starting production of dipoles for installation in the Fermilab Doubler an 'improved' version of the cryostat was adopted. With that design considerable cost savings could be made and a potential source of leaks could be suppressed by eliminating the need to weld the nitrogen shields together at 32 places where suspension blocks passed through. However a chronic failure pattern began to appear with this design during magnet testing. The design specifications require that the variation of the dipole field direction be stable to ± 10^{-3} radians. After cycling between 300 K and 4 K, magnets often changed field direction by several milliradians in one thermal cycle.

An extensive investigation finally showed that the rapid cooldown of magnets which causes a large thermal gradient along the length of the magnet led to breakage of the 'anchor', the one mechanical constraint between the cold coil and the warm iron yoke. Two major changes were made to remedy this problem. Four anchors were used rather than one to reduce the likelihood of breakage, and the older cryostat design which provided better control of the suspension block positions was restored. As a further precaution, threaded holes were put into the warm iron yoke at the suspension locations and spring-loaded bolts, so-called 'smart bolts', were used to provide a constant radial force (1000 pounds) on the suspension blocks, independent of the changes in size of the collared coil due to temperature. Magnets with these modifications have been cycled for more than fifty cycles, a number estimated to be near the maximum expected during the life of the accelerator. During these tests the direction of the magnetic field only changed in the order of 10^{-4} radians, well within the required stability. All doubler dipoles previously built are being reworked to incorporate these modifications.

An additional benefit of the smart bolts added to the magnet yoke comes from the ability to move the collared coil inside the yoke even after final assembly and measurement. Quadrupole and skew quadrupole error fields are generated in the magnet aperture if the collared coil is not centred in the warm iron yoke. By intentionally moving the coil it is possible to cancel out similar field components which may arise from errors in conductor placement during coil construction.

CERN
Tunnelling for LEP



A view of the Jura mountains where the new pilot tunnel for LEP is planned. At this point, the mountains are some 1700 metres above sea level.

(Photo CERN 505.7.80)

On 18 September the CERN Finance Committee approved a contract with a Franco-Swiss consortium for a tunnel under the Jura mountains where it is planned to build the large electron-positron storage ring, LEP. The aim of this preliminary exercise is to investigate the rock formations and other features (such as location of water courses) which will be encountered in the tunnelling of the LEP ring if the project is authorized.

Ten kilometres of LEP's 30 km circumference would pass under the Jura and, though the probable tunnelling conditions around the rest of the ring are known from SPS construction experience, it is felt important to gain knowledge of the sub-Jura conditions before launching the project. The test tunnel will start from a shaft almost 70 m deep near the village of Crozet and will run for just over 4 km at right angles to the mountain range finishing 1 km below the mountain at the point where it is intended to have one of the LEP beam collision regions.

The boring of the tunnel will also provide information on the likely speed with which the LEP tunnel could be constructed along that part of its route. Following authorization of LEP, it would serve as an access and service tunnel for the ring.

It is hoped that tunnelling will start in the very near future. At the same time a thorough geological and hydrological study of the whole LEP region is under way to prepare an 'environmental impact' study for the Spring of 1981.

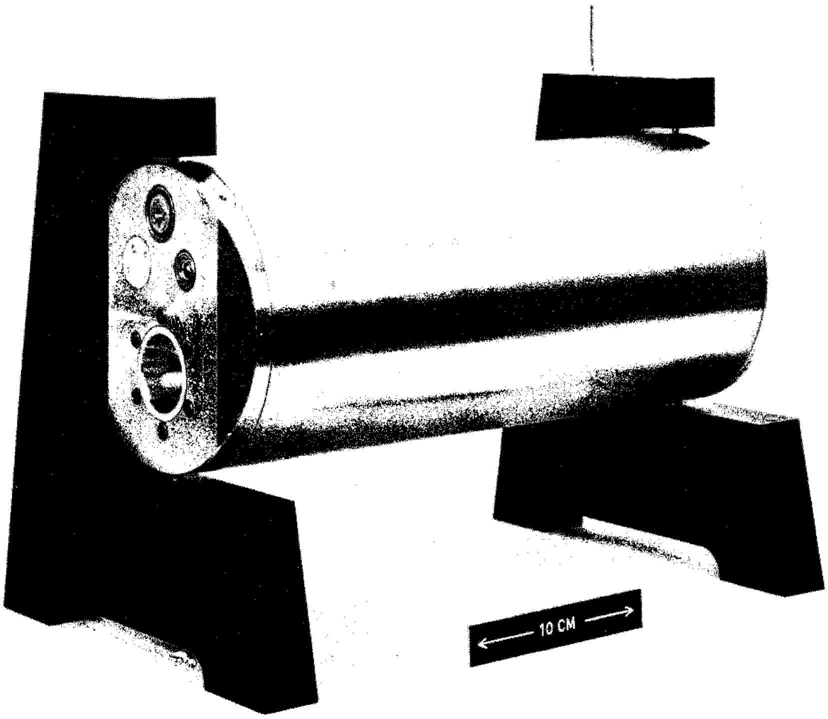
Persistent magnet persisting

A superconducting magnet at CERN has been sustaining a dipole field of more than 4.5 T in the absence of any current supply since March of this year. The only action that is necessary to keep the magnet operating is to top up with liquid helium so as to keep the niobium-tin core cold (and hence superconducting).

This type of magnet has been baptized 'persistent' to distinguish it from the conventional 'permanent' magnet. It uses the phenomenon of superconductivity in an unusual way: when magnetic flux coupled to a conducting loop is changed, currents are induced in the loop in such a way as to conserve the flux– another manifestation of Nature's opposition to change. In a normal conductor the induced currents die away rapidly because of the resistance of the conductor. However with zero resistance superconductor, the induced currents will persist as long as the superconducting state is retained.

This technique has been used in the past to shield a volume inside a tube of superconductor from external field, for example in a 'field shield' at the CERN 2 m bubble chamber (see June 1971 issue, page 155) and at Stanford in an experiment target (see June 1972 issue, page 208). It can also be used to retain a field already established within a volume before the conductor is cooled to its superconducting state. When the external field is removed, currents are induced in the superconductor which oppose any change in the internal field. The induced currents and the field trapped in the enclosed volume persist as long as the magnet stays cold.

The magnet presently operating at CERN has superconducting core 18 cm long and 25 cm diameter with a warm bore diameter of 11 cm. Since it never needs a supply of current from the outside world, this type of magnet can use an efficient cryostat to full advantage and needs very little liquid helium to run it. The core is made from 160 layers of specially-made strips of niobium foil coated with niobium-tin compound a few microns thick. (Foil as wide as 20 cm can be manufactured at CERN.) In March of this year a field of about 4.5 T was trapped in the bore of the magnet and there is no sign of the field falling. All that is needed to sustain it is to top up the cryostat with 1 litre of helium per day; this can be produced with a power of about 80 W.

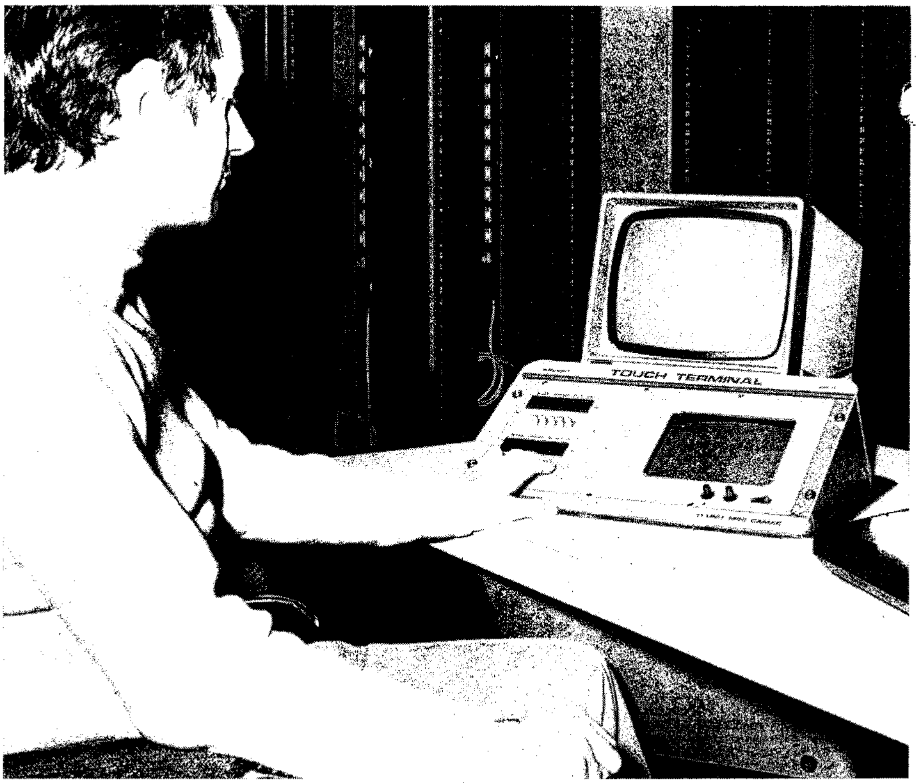


The 'persistent' superconducting magnet which has been sustaining a field at CERN without any current since March.

(Photo CERN 517.1.80)

SPS control system in a box

During the construction of the 400 GeV SPS the control system attracted a lot of attention because it moved accelerator control into a new era. Many subsequent large complex installations both in high energy physics Laboratories and



The 'Touch Terminal' in use for the commissioning of the Antiproton Accumulator Ring at CERN. The compactness of the terminal, which condenses abilities of the SPS control system for more limited applications, can be seen from the photograph.

(Photo CERN 275.2.80)

elsewhere (such as the JET fusion project) have followed its control philosophy. One of its attractive features is the flexibility and ease of use – in the language of the computer world, it has a 'friendly man-machine interface'.

A new development, led by George Shering, has encapsulated the SPS control principles in a much smaller configuration to cater for more limited requirements. Known locally as the 'Touch Terminal' it has already found applications at CERN and is evoking a lot of interest in widely different fields outside the Laboratory.

The terminal has a transparent 'touch panel' on which the captions corresponding to sixteen 'buttons' can be written by computer. Thus, by touch, the operator can arrive at the parameter he wishes to maintain or to manipulate by going through a hierarchy of levels. For example, the touch panel can list the different systems and the operator can select one from them and then the panel will list components of the systems. On selecting a component, its operating parameters can be displayed and any one of these can be selected for manipulation. Accompanying the terminal is a graphics TV screen on which data to be monitored is displayed in an attractive, easily assimilated form.

Built into the terminal is some local computing power so that it can be used for quite extensive 'stand alone' operation, or it can be linked to more powerful computing systems through any standard interface and requires no additional hardware or software system in the host computer.

A mini CAMAC crate in the terminal has an 'Independent Crate Controller' and it is this microprocessor which provides most of the intelligence and relieves any host computer of a considerable load. Other standard components are a graphics display unit and a controller for other functions, which can be built into the front panel. There are further slots available for the link to another computer or for other facilities. The whole box has a front panel some 40 cm x 25 cm and is 45 cm deep.

The first Touch Terminal was built at CERN for analogue signal switching in the SPS control system. It has found temporary use in the commissioning of the Antiproton Accumulator Ring where sophisticated control facilities were desirable at least in the initial phase. Outside interest has developed to the point where a Danish firm, **NESELCO**, is marketing the terminal commercially, and organizations as disparate as the World Health Organization and local municipalities are examining the abilities of the terminal for their own needs.

The WHO interest is particularly intriguing. The basic abilities, the ease of use, the fairly straightforward servicing facilities 'in the field' (thanks largely to the universality of CAMAC), and the absence of monopoly due to CERN's open 'patent' policy, make the terminal particularly attractive for many urgent needs in the developing countries. It is recognized that the potential uses are very wide-ranging and we are in the early days of uncovering applications in other fields.

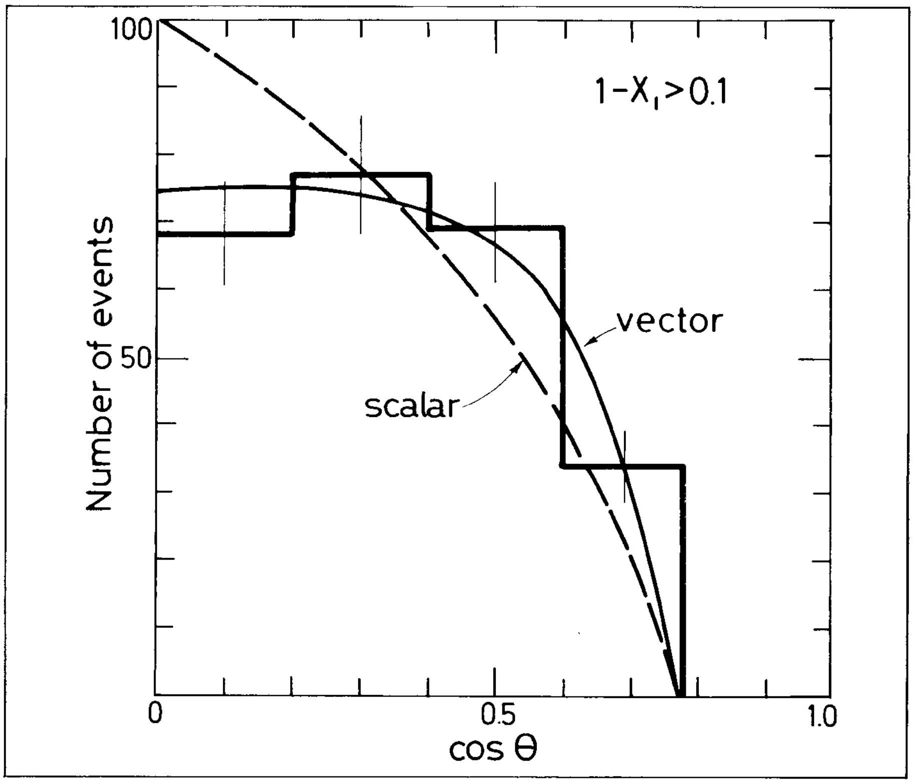
DESY
New results from PETRA

During the last few months, the PETRA electron-positron ring has been running at centre-of-mass energies up to 36.5 GeV with most of the data taken around 30 and 35 GeV. A few thousand multihadronic events have been logged by each experiment Since electron-positron interactions offer a particularly clean way to look at the interactions of leptons, quarks, gluons and photons, a lot of information is contained in these event samples. The main topics of interest are a deeper look into quark and gluon jets, an exploration of two-photon interactions and a first test of electroweak theories at PETRA.

In quantum chromodynamics (QCD) vector (spin one) gluons can be emitted by quarks in a bremsstrahlung-like process. At sufficiently high energies the quarks and gluons manifest themselves as separate jets of hadrons. The three-jet events observed at PETRA (see November 1979 issue, page 358), thus allow a close look at the properties of the gluon. One of the most important tasks is the determination of the strong coupling constant α_s, which measures the effective strength of the quark-gluon force. First results have been reported earlier this year (see April issue, page 60). After increasing the statistics and spending much work on systematics, four groups have announced improved α_s values: JADE gives 0.18 ± 0.03, MARK-J has 0.19 ± 0.02, PLUTO has 0.15 ± 0.03 and TASSO has 0.17 ± 0.02. The values center around 0.17. All errors are statistical and the systematic uncertainties are of the order 0.03.

Two groups have made an attempt to determine the spin of the gluon. The TASSO group studied the angular correlations of the three jets, whereas PLUTO physicists analysed the 'thrust' ('jettiness') of the quark-quark-gluon system. Both sets of data are described well by standard first order QCD involving a spin one gluon and clearly disfavour alternative descriptions using spin zero (scalar) gluons.

The angular distributions of three-jet events in electron-positron annihilations can be used to determine the spin of the gluon. The data from the TASSO group at PETRA favour spin one, rather than spin zero gluons. θ is the angle between the most energetic jet and the direction of the other two in their centre-of-mass system.



Another peculiar feature expected in QCD is the multiple emission of very soft (low energy) gluons. The phenomenon is analogous to soft photon radiation in electrodynamics and reflects itself in modifying the angular correlations between any two particles in a jet event. The PLUTO collaboration has looked into this and the results are encouraging. They bring us closer to understanding the quark-gluon cascade which governs the transition of the initial partons to the final state hadrons.

Current interest focusses also on the particle composition of the jet events. TASSO shows that an event produced at 30 GeV contains an average of 13 charged particles consisting of 10 charged pions, 2.8 kaons and 0.4 protons and antiprotons. Charged multiplicities and particle spectra were also measured by JADE and PLUTO. The fraction of the total energy carried away by neutral particles is 38 ± 4 per cent at 30 GeV as determined in the JADE detector. The JADE group searched for free quarks of charge 2/3. They find no signal and give limits of less than 1 per cent of the muon pair production cross-section for quark masses smaller than 12 GeV.

Among the most remarkable recent developments is the progress in the field of two-photon interactions. Two-photon interactions occur when both incoming electrons emit a virtual photon and the two emitted photons subsequently interact (see June issue, page 152). Two photon interactions allow the study of both the hadron-like nature of the photon and the pointlike coupling of photons to quarks. The PLUTO group has presented a new measurement of the Q^2 dependence of the total hadronic two-photon cross-section (here Q^2 is the mass squared of one of the virtual photons, the other one being almost massless). The data are described well by the rho meson dominance model, thus indicating that the photon primarily interacts like a rho meson at moderate Q^2 values. There is however evidence for hard scattering processes in two-photon interactions. These processes involve photons coupling to bare quarks. Given sufficient energ these quarks show up as separate jets of hadrons, like the well-known jets in electron-positron annihilation.

One way to study the quark-photon coupling is deep inelastic electron-photon scattering. Here the structure of a photon is probed by an electron via emission of a highly virtual photon analogous to the probing of the nucleon structure in deep inelastic electron-nucleon scattering. From the quark-parton model and QCD, one expects that the dominant pattern is the splitting of the struck photon into two quarks. This process is analogous to the pointlike coupling of a photon to two electrons in quantum electrodynamics. In fact, the structure functions for both processes can be computed and should be same (apart from higher order corrections). The PLUTO group has made a first measurement of deep inelastic electron-photon scattering and obtained 120 events with an average squared momentum transfer of 5 GeV^2. The resulting structure functions compare well with the lowest order QCD prediction and with the pointlike quantum electrodynamics processes.

Finally the PETRA experiments are beginning to test the neutral current sector of unified electroweak theories. The reactions under study are Bhabha (elastic) scattering and muon pair production. The interaction is dominated by the exchange of a virtual photon, but with increasing energy one expects also contributions from the exchange of the Z^0 boson, the carrier of the weak neutral force. The interference of both contributions leads to effects of the order 2–5 per cent in the energy range 30–35 GeV. One of the predicted effects is a forward-backward asymmetry in the muon angular distribution. The combined data from JADE, MARK-J, PLUTO and TASSO yield an asymmetry of -0.9 ± 4.9 per cent, whereas an effect of −6 per cent is expected. So the studies are on the verge of being sensitive to electroweak interference effects. From the combined Bhabha and muon data one can derive limits on the lepton coupling to the weak neutral force. Previous determinations using neutrino-electron scattering led to two solutions because of a sign ambiguity. As shown first by the MARK-J group, the PETRA data confirm one of the solutions and disfavour the other one. The relevant point is that the electroweak theories are being verified at much higher momentum transfer than in present neutrino-electron scattering experiments. We certainly will learn more on the weak neutral current from electron-positron machines in the years to come.

RUTHERFORD SNS on solid foundations

David Grey, Head of the Spallation Neutron Source Division at the Rutherford Laboratory, registers his footprints for posterity as the first concrete is poured for the construction of the new neutron source.

(Photo Rutherford)

On 17 September an important milestone was reached in the construction of the Spallation Neutron Source at the Rutherford Laboratory. In a single day almost 400 cubic metres of concrete were poured in the service trench of the former Nimrod synchrotron to form the foundations on which the SNS ring will sit.

The SNS is the world's most intense source of neutrons presently under construction. It involves an 800 MeV protron synchrotron providing 1.3×10^{15} protons per second to produce very high neutron fluxes by spallation in a target (see May issue 1976 for a full description of the project).

The construction programme for the coming years calls for completion of the 70 MeV negative hydrogen ion linac early in 1982 aiming for 20 mA at 50 Hz. This will be followed by the synchrotron magnet ring and vacuum system a year later. The ten 4.5 m-long main dipoles have been ordered and a prototype should arrive at the Laboratory by the end of this year. Injection tests can begin early 1983 and by the middle of that year it is hoped to have two of the six radio-frequency accelerating cavities in operation and the main magnet power supply in action, so that first acceleration with low intensity beams can be started. The r.f. system has to cope with a rapid acceleration rate (100 ms rise time) swinging from a frequency of 1.3 MHz to 3.1 MHz.

Early in 1984 with two more r.f. stations in place, the first low intensity accelerated beams (at an energy of 600 MeV) will be ejected to produce neutrons in a target. Full energy of 800 MeV will be reached some months later when the last two r.f. cavities are in place. Full intensity operation is planned for 1986.

By then a dozen or more experimental stations are planned to be in operation on some of the eighteen neutron beam holes. Up to now seven out of about twenty-five instruments for research with the neutron beams have been approved.

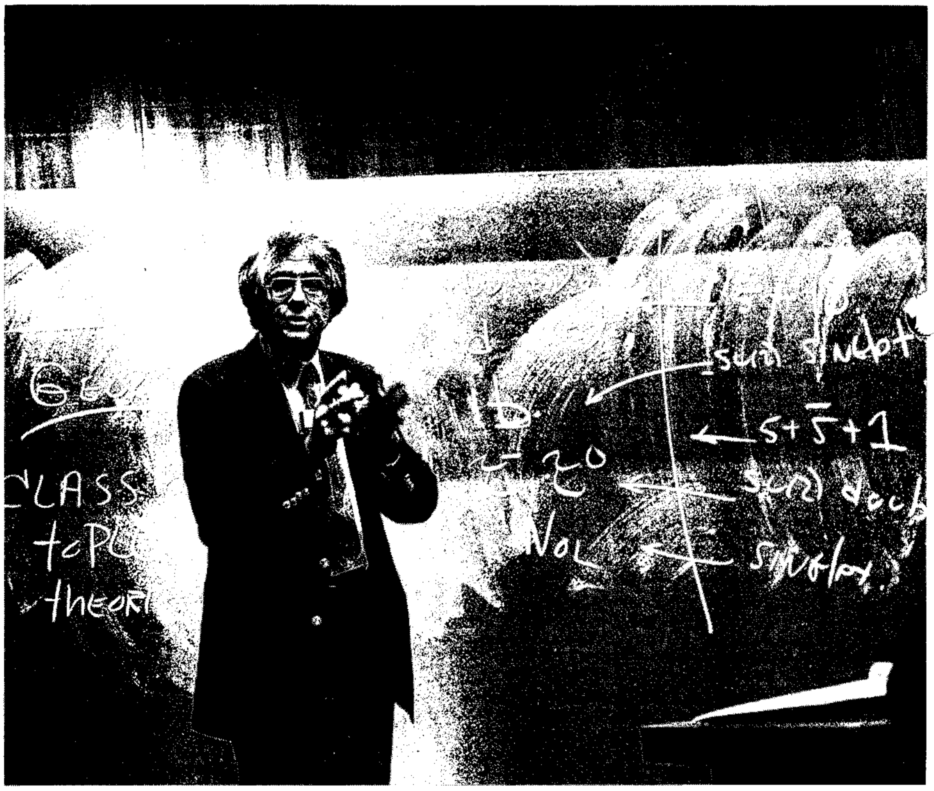
Weinberg, Salam and Glashow on physics

*** In our next issue we will cover the award of the 1980 Nobel Physics Prize to J.W. Cronin and V.L. Fitch.**

Last year the Nobel Prize for physics was awarded to Steven Weinberg, Abdus Salam and Sheldon Glashow for the development of the theory which unifies electromagnetic and weak interactions*. The three recipients each presented a lecture on the occasion of the presentation of the prize, and these lectures have been published in full (together with footnotes, appendices and references) in the July edition of Reviews of Modern Physics (Vol. 52 No. 3). The lectures provide an illuminating insight into the challenges and rewards of modern physical theory and as such are well worth reading in their entirety. In addition, extracts illustrate several aspects of today's physics and physicists.

Sheldon Glashow: making a patchwork quilt of theory into a tapestry. Here he is seen explaining how the long-awaited top quark may not really be necessary.

(Photo CERN 310.12.79)



The objectives of physics and physicists

Weinberg:

'Our job in physics is to see things simply, to understand a great many complicated phenomena in a unified way, in terms of a few simple principles. At times, our efforts are illuminated by a brilliant experiment, such as the 1973 discovery of neutral current neutrino reactions. But even in the dark times between experimental breakthroughs, there always continues a steady evolution of theoretical ideas, leading almost imperceptibly to changes in previous beliefs.'

Salam quotes Feynman from an interview in the magazine 'Omni':

'As long as it looks like the way things are built [is] with wheels within wheels, then you are looking for the innermost wheel — but it might not be that way, in which case you are looking for whatever the hell it is you find!' In the same interview he remarks 'a few years ago I was very sceptical about the gauge theories... I was expecting mist, and now it looks like ridges and valleys after all.'

Salam also cites Einstein:

'There is the apocryphal story about Einstein, who was asked what he would have thought if experiment had not confirmed the light deflection predicted by him. Einstein is supposed to have said, "Madam, I would have thought the Lord has missed a most marvellous opportunity." I believe, however, that the following quote from Einstein's Herbert Spencer lecture of 1933 expresses his, my colleagues', and my own views more accurately. "Pure logical thinking cannot yield us any knowledge of the empirical world; all knowledge of reality starts from experience and ends in it."

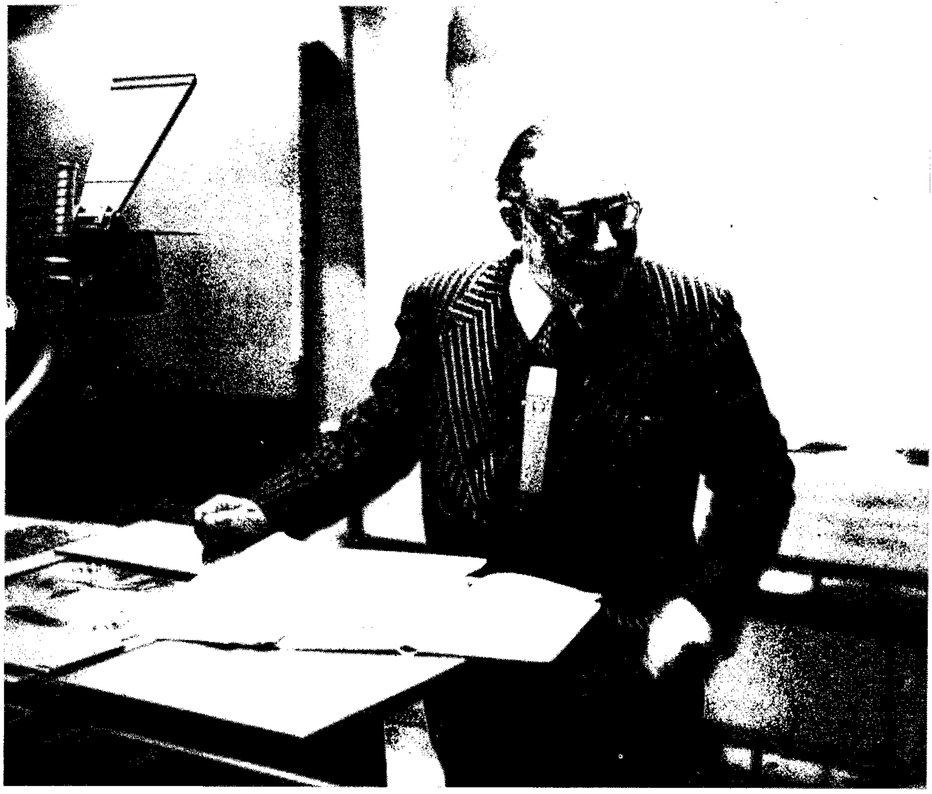
Glashow takes a more personal viewpoint:

'In 1956, when I began doing theoretical physics, the study of elementary particles was like a patchwork quilt. Electrodynamics, weak interactions, and strong interactions were clearly separate disciplines, separately taught and separately studied. There was no coherent theory that described them all. Developments such as the observation of parity violation, the successes of quantum electrodynamics, the discovery of hadron resonances and the appearance of strangeness were well-defined parts of the picture, but they could not be easily fitted together.

Things have changed. Today we have what has been called a "standard theory" of elementary particle physics in which strong, weak, and electromagnetic interactions all arise from a local symmetry principle. It is, in a sense, a complete and apparently correct theory, offering a qualitative description of all particle phenomena and precise quantitative predictions in many instances. There

Abdus Salam: after a brief foray into experimental physics as a student, he soon turned his attention to theory. A wise move, it would appear.

(Photo CERN 371.10.79)



are no experimental data that contradict the theory. In principle, if not yet in practice, all experimental data can be expressed in terms of a small number of "fundamental" masses and coupling constants. The theory we now have is an integral work of art: the patchwork quilt has become a tapestry.

Tapestries are made by many artisans working together. The contributions of separate workers cannot be discerned in the completed work, and the loose and false threads have been covered over. So it is in our picture of particle physics.'

Salam, the senior of the three prizewinners, describes his early years in physics research:

'I started physics research thirty years ago as an experimental physicist in the Cavendish, experimenting with tritium-deuterium scattering. Soon I knew the craft of experimental physics was beyond me — it was the sublime quality of patience — patience in accumulating data, patience with recalcitrant equipment — which I sadly lacked. Reluctantly I turned my papers in, and started instead on quantum field theory with Nicholas Kemmer in the exciting department of P.A.M. Dirac.'

The search for electroweak unification

Glashow toyed with the idea of electroweak unification at an early stage in his physics career:

'Schwinger, as early as 1956, believed that the weak and electromagnetic interactions should be combined into a gauge theory. The charged massive vector intermediary and the massless photon were to be the gauge mesons. As his student, I accepted this faith. In my 1958 Harvard thesis, I wrote: "It is of little value to have a potentially renormalizable theory of beta processes without the possibility of a renormalizable electrodynamics. We should care to suggest that a fully acceptable theory of these interactions may only be achieved if they are treated together..." We used the original SU(2) gauge interaction of Yang and Mills. Things had to be arranged so that the charged current, but not the neutral (electromagnetic) current, would violate parity and strangeness. Such a theory is technically possible to construct, but it is both ugly and experimentally false. We know now that neutral currents do exist and that the electroweak gauge group must be larger than SU(2).'

Weinberg talks of his 'love affair' with broken symmetry:

'Sometime in 1960 or early 1961, I learned of an idea which had originated earlier in solid state physics and had been brought into particle physics by those like Heisenberg, Nambu, and Goldstone, who had worked in both areas. It was the idea of "broken symmetry," that a quantum theory could possess an exact symmetry, and that the physical states might nevertheless not provide neat representations of the symmetry. In particular, a symmetry of the theory might turn out to be not a symmetry of the vacuum.

As theorists sometimes do, I fell in love with this idea. But as often happens with love affairs, at first I was rather confused about its implications. I thought (as it turned out, wrongly) that the approximate symmetries — parity, isospin, strangeness, the eightfold way — might really be exact symmetry principles, and that the observed violations of these symmetries might somehow be brought about by spontaneous symmetry breaking. It was therefore rather disturbing for me to hear of a result of Goldstone, that in at least

Steven Weinberg: a 'love affair' with broken symmetry.

(Photo CERN 349.12.79)

one simple case the spontaneous breakdown of a continuous symmetry like isospin would necessarily entail the existence of a massless spin zero particle — what would today be called a "Goldstone boson." It seemed obvious that there could not exist any new type of massless particle of this sort which would not already have been discovered.

I had long discussions of this problem with Goldstone at Madison in the summer of 1961, and then with Salam while I was his guest at Imperial College in 1961–62. The three of us soon were able to show that Goldstone bosons must in fact occur whenever a symmetry like isospin or strangeness is spontaneously broken, and that their masses then remain zero to all orders of perturbation theory. I remember being so discouraged by these zero masses that when we wrote our joint paper on the subject, I added an epigraph to the paper to underscore the futility of supposing that anything could be explained in terms of a noninvariant vacuum state: it was Lear's retort to Cordelia, "Nothing will come of nothing: speak again." Of course, The Physical Review protected the purity of the physics literature, and removed the quote. Considering the future of the noninvariant vacuum in theoretical physics it was just as well.'

Later, Weinberg describes how he fell on the idea of electroweak unification:

'At some point in the fall of 1967, I think while driving to my office at MIT, it occurred to me that I had been applying the right ideas to the wrong problem. It is not the rho meson that is massless: it is the photon. And its partner is not the A1, but the massive intermediate bosons, which since the time of Yukawa had been suspected to be the mediators of the weak interactions. The weak and electromagnetic interactions could then be described in a unified way in terms of an exact but spontaneously broken gauge symmetry. And this theory would be renormalizable like quantum electrodynamics because it is gauge invariant like quantum electrodynamics It was not difficult to develop a concrete model which embodied these ideas. I had little confidence then in my understanding of strong interactions, so I decided to concentrate on leptons.'

Salam's account is more like a saga:

'For me, personally, the trek to gauge theories as candidates for fundamental physical theories started in earnest in September 1956 — the year I heard, at the Seattle Conference, Yang expound his and Lee's ideas on the possibility of the hitherto sacred principle of left-right symmetry being violated in the realm of the weak nuclear force. Lee and Yang had been led to consider abandoning left-right symmetry for weak nuclear interactions as a possible resolution of the kaon decay puzzle.

I remember travelling back to London on an American Air Force transport flight. Although I had been granted, for that night, the status of a Brigadier or a Field Marshal — I don't quite remember which — the plane was very uncomfortable, full of crying servicemen's children — that is, the children were crying, not the servicemen. I could not sleep. I kept reflecting on why Nature should violate left-right symmetry in weak interactions.

Now the hallmark of most weak interactions was Pauli's neutrino. While crossing over the Atlantic, a deeply perceptive question about the neutrino came back to me which

Rudolf Peierls had asked when he was examining me for a Ph.D. a few years before. Peierls'question was: "The photon mass is zero because of Maxwell's principle of a gauge symmetry for electromagnetism; tell me, why is the neutrino mass zero?" I had then felt somewhat uncomfortable at Peierls, asking for a Ph.D. viva, question of which he himself said he did not know the answer. But during that comfortless night the answer came. The analogue for the neutrino of the gauge symmetry for the photon existed: it had to do with the masslessness of the neutrino, with symmetry under a particular transformation later christened "chiral symmetry". The existence of this symmetry for the massless neutrino must imply one of two possibilities for the neutrino interactions. Nature had the choice of an aesthetically satisfying but a left-right symmetry-violating theory, with a neutrino which travels exactly with the velocity of light; or alternatively a theory where left-right symmetry is preserved, but the neutrino has a tiny mass — some ten thousand times smaller than the mass of the electron.

It appeared at that time clear to me what choice Nature must have made. Surely, left-right symmetry must be sacrificed in all neutrino interactions. I got off the plane the next morning, naturally very elated. I rushed to the Cavendish, worked out the Michel parameter and a few other consequences of the symmetry, rushed out again, got onto a train to Birmingham where Peierls lived. To Peierls I presented my idea: he had asked the original question; could he approve of the answer? Peierls' reply was kind but firm. He said "I do not believe left-right symmetry is violated in weak nuclear forces at all."

Thus rebuffed in Birmingham, like Zuleika Dobson, I wondered where I could go next and the obvious place was CERN in Geneva, with Pauli — the father of the neutrino — nearby in Zurich. At that time CERN lived in a wooden hut just outside Geneva airport. Besides my friends, Prentki and d'Espagnat, the hut contained a gas ring on which was cooked the staple diet of CERN — Entrecôte à la crème. The hut also contained Villars from MIT, who was visiting Pauli the same day in Zurich. I gave him my paper. He returned the next day with a message from the Oracle: "Give my regards to my friend Salam and tell him to think of something better."

This was discouraging, but I was compensated by Pauli's excessive kindness a few months later, when Mrs. Wu's, Lederman's and Telegdi's experiments were announced showing that left-right symmetry was indeed violated, and ideas similar to mine about chiral symmetry were expressed independently by Landau and by Lee and Yang.

I received Pauli's first, somewhat apologetic letter on 24 January 1957. Thinking that Pauli's spirit should by now be suitably crushed, I sent him two short notes I had written in the meantime. These contained suggestions to extend chiral symmetry to electrons and muons, assuming that their masses were a consequence of what has come to be known as dynamical spontaneous symmetry breaking. With chiral symmetry for electrons, muons, and neutrinos, the only mesons that could mediate weak decays of the muons would have to carry spin one. Reviving thus the notion of charged intermediate spin-one bosons, one could then postulate for these a type of gauge invariance which I called the "neutrino gauge."

Wolfgang Pauli, the father of the neutrino. His correspondence with Salam during the gestation of the new ideas on weak interactions makes interesting reading. One typical remark: if a theoretician says universal, it just means pure nonsense'.

Pauli's reaction was swift and terrible. He wrote on 30 January 1957, then on 18 February and later on 11, 12, and 13 March: "I am reading (along the shores of Lake Zurich) in bright sunshine quietly your paper... I am very much startled on the title of your paper 'Universal Fermi Interaction'... For quite a while I have for myself the rule if a theoretician says universal it just means pure nonsense. This holds particularly in connection with the Fermi interaction, but otherwise too, and now you too, Brutus, my son, come with this word..." Earlier, on 30 January, he had written "There is a similarity between this type of gauge invariance and that which was published by Yang and Mills..." I quote from his letter: "However, there are dark points in your paper regarding the vector field. If the rest mass is infinite (or very large), how can this be compatible with the gauge transformation?" and he concluded his letter with the remark: "Every reader will realize that you deliberately conceal here something and will ask you the same questions." Although he signed himself "With friendly regards," Pauli had forgotten his earlier penitence. He was clearly and rightly on the warpath. Now the fact that I was using gauge ideas similar to the Yang-Mills gauge theory was no news to me. This was because the Yang-Mills theory (which married gauge ideas of Maxwell with the internal symmetry SU(2) of which the proton-neutron system constituted a doublet) had been independently invented by a Ph.D. pupil of mine, Ronald Shaw, at Cambridge at the same time as Yang and Mills had written. Shaw's work is relatively unknown; it remains buried in his Cambridge thesis.

I must admit I was taken aback by Pauli's fierce prejudice against universalism — against what we would today call unification of basic forces — but I did not take this too seriously. I felt this was a legacy of the exasperation which Pauli had always felt at Einstein's somewhat formalistic attempts at unifying gravity with electromagnetism — forces which in Pauli's phrase "cannot be joined — for God hath rent them asunder." But Pauli was absolutely right in accusing me of darkness about the problem of the masses of the Yang-Mills fields; one could not obtain a mass without wantonly destroying the gauge symmetry one had started with. The problem was to be solved only seven years later with the understanding of what is now known as the Higgs mechanism.'

Renormalization

With the first formulations of the electroweak theory, the spanner in the works was their renormalization — there appeared to be no neat way of avoiding troublesome infinities in the calculations.

Weinberg:

'The next question now was renormalizability. The Feynman rules for Yang-Mills theories with unbroken gauge symmetries had been worked out by deWitt, Faddeev, and Popov and others, and it was known that such theories are renormalizable. But in 1967 I did not know how to prove that this renormalizability was not spoiled by the spontaneous symmetry breaking. I worked on the problem on and off for several years, partly in collaboration with students, but I made little progress. With hindsight, my main difficulty was that I adopted a gauge now known as the unitarity gauge: this gauge has several wonderful advantages, it exhibits the true particle spectrum of the theory, but it has the disadvantage of making renormalizability totally obscure.

Finally, in 1971 't Hooft showed in a beautiful paper how the problem could be solved: The proof was subsequently completed by Lee and Zinn-Justin and by 't Hooft and Veltman.

I have to admit that when I first saw 't Hooft's paper in 1971, I was not convinced that he had found the way to prove renormalizability. The trouble was not with 't Hooft, but with me: I was simply not familiar enough with the formalism on which 't Hooft's work was based.'

Salam:

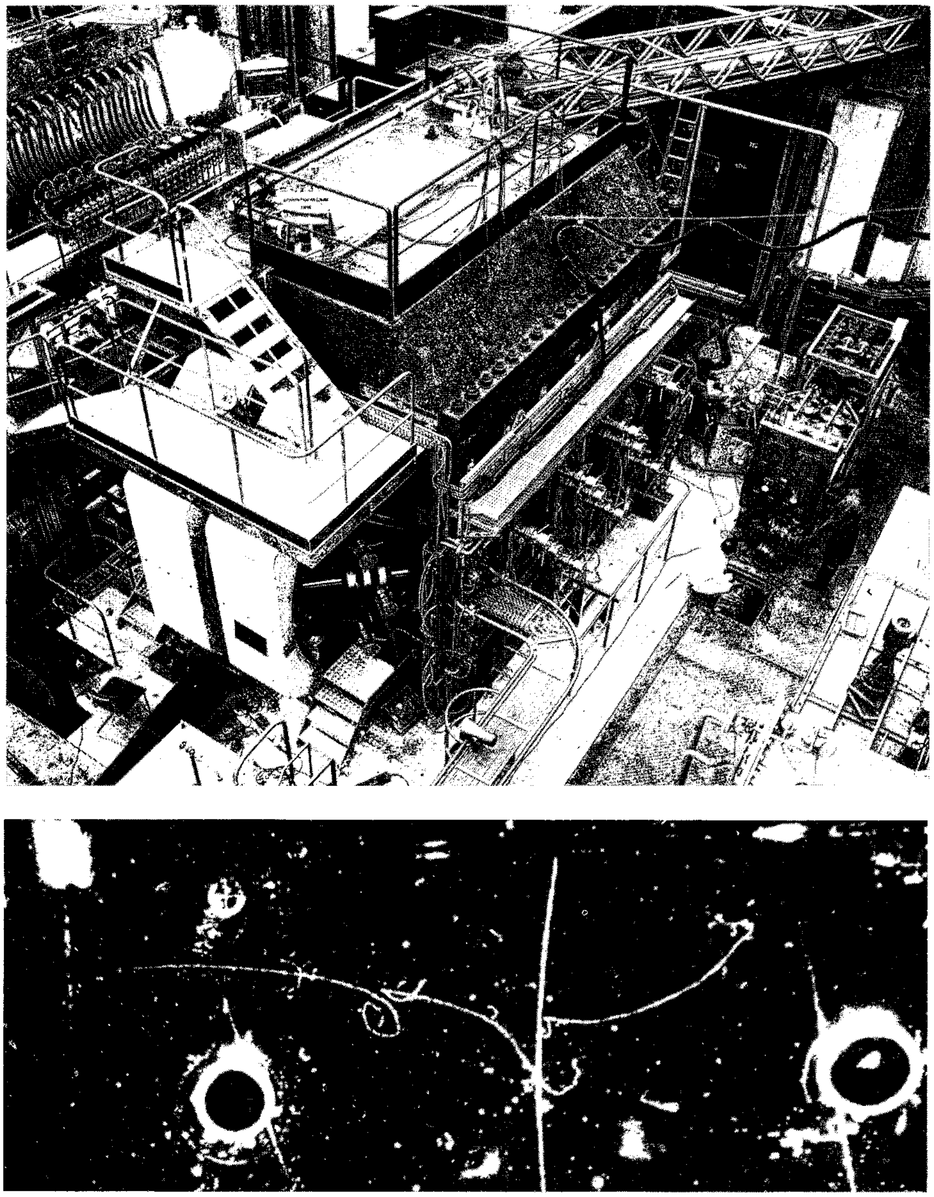
'Both Weinberg and I suspected that this theory was likely to be renormalizable. Regarding spontaneously broken Yang-Mills-Shaw theories in general this had earlier been suggested by Englert, Brout, and Thiry. But this subject was not pursued seriously except at Veltman's school at Utrecht, where the proof of renormalizability was given by 't Hooft in 1971. This was elaborated further by that remarkable physicist, the late Benjamin Lee, working with Zinn-Justin, and by 't Hooft and Veltman. In Coleman's eloquent phrase " 't Hooft's work turned the Weinberg-Salam frog into an enchanted prince."

Glashow:

'Our labours were in vain. In the spring of 1971, Veltman informed us that his student Gerhart 't Hooft had established the renormalizability of spontaneously broken gauge theory. In pursuit of renormalizability, I had worked diligently but I completely missed the boat.'

The neutral current

Electroweak unification implied the existence of a neutral current, enabling weak interactions to happen without altering the electric charges of the participating particles. However the neutral current



The heavy liquid bubble chamber Gargamelle in position at the CERN 28 GeV proton synchrotron where in 1973 it was the scene of the discovery of the neutral current (below). According to Weinberg, the electroweak theory predicted rates for the neutral current which were low enough to have escaped earlier detection, so there was every reason to look harder.

(Photo CERN 143.4.71)

was not discovered until the experiments at CERN with the Gargamelle bubble chamber in 1973, six years after the publication of the electroweak ideas.

Weinberg describes how he did not give up hope:

'Of course, the possibility of neutral currents was nothing new. There had been speculations about possible neutral currents as far back as 1937 by Gamow and Teller, Kemmer, and Wentzel, and again in 1958 by Bludman and Leite-Lopes. Attempts at a unified weak and electromagnetic theory had been made by Glashow, and Salam and Ward in the early 1960s, and these had neutral currents with many of the features that Salam and I encountered in developing the 1967–68 theory. But since one of the predictions of our theory was a value for the mass of the intermediate boson, it made a definite prediction of the strength of the neutral currents.

More important, now we had a comprehensive quantum field theory of the weak and electromagnetic interactions that was physically and mathematically satisfactory in the same sense as quantum electrodynamics — a theory that treated photons and intermediate vector bosons on the same footing, that was based on an exact symmetry principle, and that allowed one to carry calculations to any desired degree of accuracy. To test this theory, it had now become urgent to settle the question of the existence of the neutral currents.

Late in 1971, I carried out a study of the experimental possibilities. The results were striking. Previous experiments had set upper bounds on the rates of neutral current processes which were rather low, and many people had received the impression that neutral currents were pretty well ruled out, but I found that in fact the 1967–68 theory predicted quite low rates, low enough in fact to have escaped clear detection up to that time. So there was every reason to look a little harder.'

Glashow's encounter with the problem of the neutral current was somewhat more lengthy:

'When I came upon the model in 1960, I had speculated on a possible extension to include hadrons. To construct a model of leptons alone seemed senseless: nuclear beta decay, after all, was the first and foremost problem. One thing seemed clear. The fact that the charged current violated strangeness would force the neutral current to violate strangeness as well. It was already well known that strangeness-changing neutral currents were either strongly suppressed or absent. I concluded that the interme-

Abdus Salam celebrates the award of his Nobel Prize with members of the Gargamelle team. Salam learnt of the neutral current discovery from Paul Musset (on Salam's right in the photo) in the street in Aix-en-Provence, on his way to the 1973 European Conference on High Energy Physics.

(Photo CERN 392.10.79)

diate boson of neutral currents had to be made very much heavier than its charged current counterparts. This was an arbitrary but permissible act in those days: the symmetry breaking mechanism was unknown. I had "solved" the problem of strangeness-changing neutral currents by suppressing all neutral currents: the baby was lost with the bath water.

I returned briefly to the question of gauge theories of weak interactions in a collaboration with Gell-Mann in 1961. We showed that a gauge theory of weak interactions would inevitably run into the problem of strangeness-changing neutral currents. We concluded that something essential was missing. Indeed it was. Only after quarks were invented could the idea of the fourth quark and the GIM (Glashow-Iliopoulos-Maiani) mechanism arise.

From 1961 to 1964, Sidney Coleman and I devoted ourselves to the exploitation of the unitary symmetry scheme. In the spring of 1964, I spent a short leave of absence in Copenhagen. There, Bjorken and I suggested that the Gell-Mann-Zweig system of three quarks should be extended to four. We called the fourth quark the charmed quark. Part of our motivation for introducing a fourth quark was based on our mistaken notions of hadron spectroscopy. But we also wished to enforce an analogy between the weak leptonic current and the weak hadronic current. Because there were two weak doublets of leptons, we believed there had to be two weak doublets of quarks as well.

The weak current Bjorken and I introduced in 1964 was precisely the GIM current. The associated neutral current, as we noted, conserved strangeness. Had we inserted these currents into the earlier electroweak theory, we would have solved the problem of strangeness-changing neutral currents. We did not. I had apparently quite forgotten my earlier ideas of electroweak synthesis. The problem which was explicitly posed in 1961 was solved, in principle, in 1964. No one, least of all me, knew it. Perhaps we were all befuddled by the chimera of relativistic SU(6), which arose at about this time to cloud the minds of theorists.

Five years later, John Iliopoulos, Luciano Maiani and I returned to the question of strangeness-changing neutral currents. It seems incredible that the problem was totally ignored for so long. We argued that unobserved effects would be expected to arise in any of the known weak interaction models and showed how the unwanted effects would be eliminated with the conjectured existence of a fourth quark. After languishing for a decade, the problem of the selection rules of the neutral current was finally solved. Of course, not everyone believed in the predicted existence of charmed hadrons.

This work was done fully three years after the epochal work of Weinberg and Salam and was presented in seminars at Harvard and at M.I.T. Neither I, nor my co-workers, nor Weinberg, sensed the connection between the two endeavours. We did not refer, nor were we asked to refer, to the Weinberg-Salam work in our paper.

The relevance became evident only a year later. Due to the work of 't Hooft, Veltman, Benjamin Lee, and Zinn-Justin, it became clear that the Weinberg-Salam ansatz was in fact a renormalizable theory. With GIM, it was trivially extended from a model of leptons to a theory of weak interactions. The ball was now squarely in the hands of the experimenters.'

Especially amusing is Salam's story of how he first came to hear of the discovery of neutral currents:

'I still remember Paul Matthews and I getting off the train at Aix-en-Provence for the 1973 European Conference and foolishly deciding to walk with our rather heavy luggage to the student hostel where we were billeted. A car drove from behind us, stopped, and the driver leaned out. This was Musset whom I did not know well personally then. He said: "Are you Salam?" I said "Yes." He said: "Get into the car. I have news for you. We have found neutral currents." I will not say whether I was more relieved for being given a lift because of our heavy luggage or for the discovery of neutral currents. At the meeting that great and modest man, Lagarrigue, was also present and the atmosphere was that of a carnival — at least this is how it appeared to me.'

The future

Weinberg is in poetic mood:

'I suppose that I tend to be optimistic about the future of physics. And nothing makes me more optimistic than the discovery of broken symmetries. In the seventh book of The Republic, Plato describes prisoners who are chained in a cave and can see only shadows that things outside cast on the cave wall. When released from the cave at first their eyes hurt, and for a while they think that the shadows they saw in the cave are more real than the objects they now see. But eventually their vision clears, and they can understand how beautiful the real world is. We are in such a cave, imprisoned by the limitations on the sorts of experiments we can do. In particular, we can study matter only at relatively low temperatures, where symmetries are likely to be spontaneously broken, so that nature does not appear very simple or unified. We have not been able to get out of this cave, but by looking long and hard at the shadows on the cave wall, we can at least make out the shapes of symmetries, which though broken, are exact principles governing all phenomena, expressions of the beauty of the world outside.'

Despite its successes, Glashow does not hold out much hope for the present form of the electroweak theory:

'Let me stress that I do not believe that the standard theory will long survive as a correct and complete picture of physics. All interactions may be gauge interactions, but surely they must lie within a unifying group. This would imply the existence of a new and very weak interaction which mediates the decay of protons. All matter is thus inherently unstable, and can be observed to decay. Such a synthesis of weak, strong, and electromagnetic interactions has been called a "grand unified theory", but a theory is neither grand nor unified unless it includes a description of gravitational phenomena. We are still far from Einstein's truly grand design.'

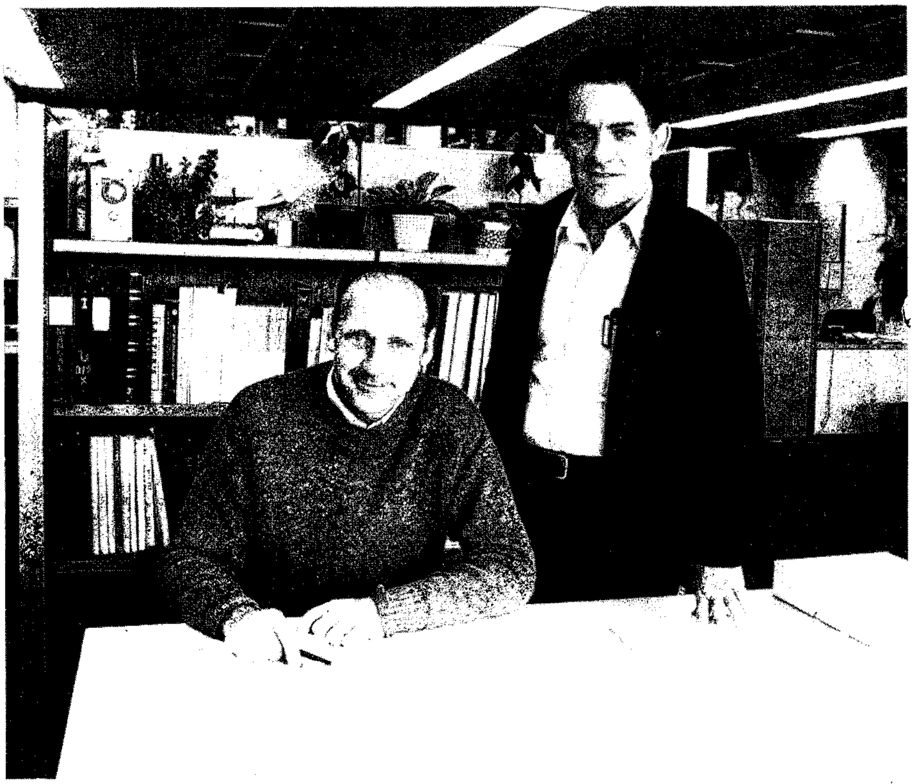
Salam expresses 'amazement':

'All I can say is that I am forever and continually being amazed at the depth revealed at each successive level we explore. I would like to conclude with a prediction which J. R. Oppenheimer made more than twenty-five years ago and which has been fulfilled today in a manner he did not live to see. More than anything else, it expresses the faith for the future with which this greatest of decades in particle physics ends: "Physics will change even more... If it is radical and unfamiliar... we think that the future will be only more radical and not less, only more strange and not more familiar, and that it will have its own new insights for the inquiring human spirit."

People and things

Peter Koehler (seated) and Chuck Brown took over leadership of the Fermilab Research Division in October. Peter serves as Research Division Head succeeding John Peoples who has completed a five year term in the office. Peoples now joins the Accelerator Division. Chuck Brown will act as deputy head of the Division.

(Photo Fermilab)



Wolfgang Gentner

Wolfgang Gentner died in Heidelberg on 4 September at the age of 74. He was an influential personality in physics for many years and played an important part in the development of CERN and in the furtherance of physics in the Federal Republic of Germany.

He was born in Frankfurt (Main) and received his physics degree there before moving to work with Marie Curie in Paris. He returned to Germany in 1935 where he began his long association with Heidelberg University. It was there that he made his first acquaintance with the world of accelerators, being involved in the construction of a Van de Graaff proton machine and in the design of a cyclotron. He gained cyclotron experience on the machine which Joliot had built in Paris.

After the war he was nominated Director of the Institute of Physics in Freiburg and it was from there that his involvement in CERN began. He was party to the early discussions on the creation of the Laboratory and then went to CERN to lead the Division responsible for construction of the 600 MeV synchro-cyclotron. It is his signature which tops the page of the logbook recording first operation of the machine on 1 August 1957. Perhaps even more importantly in those early days, Professor Gentner played a significant role in formulating the first physics programmes for the SC and for the 28 GeV proton synchrotron.

In 1960 he moved to head the Max Planck Institute for Nuclear Physics in Heidelberg, which remained his base for the next 20 years. His contacts with CERN remained strong: he was a member of the Scientific Policy Committee and became its Chairman in 1968. He was for many years German delegate to the CERN Council and from 1972–74 was President of the Council.

His humour, his influence, his passion for physics and his devotion to the ideals of CERN will be sadly missed. A memorial ceremony is planned to be held at CERN early in 1981.

On people

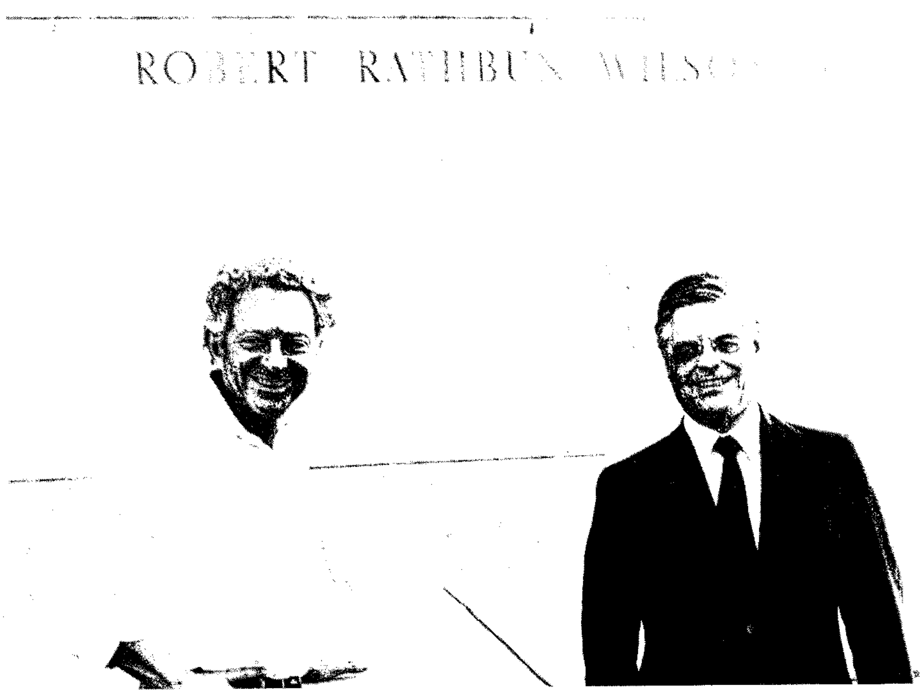
Sharing the 1980 Wolf Prize in Physics with Michael E. Fisher of Cornell and Leo Kadanoff of the University of Chicago is Kenneth G. Wilson of Cornell. The prestigious award, made at the Israeli Knesset on 18 September, acknowledges the significant developments made by the three physicists in the study of phase transitions. As well as his work on critical phenomena, Wilson is also widely known for his research in elementary particle physics. He was Ford Foundation Fellow at CERN in 1962–63.

Among the recipients of this year's Ernest Orlando Lawrence Memorial Awards is Nicholas P. Samios of Brookhaven National Laboratory. The Lawrence awards are made to US citizens who are early in their careers and have made recent meritorious contributions to the development, use or control of atomic energy.

Richard W. Kadel is the newest Wilson Fellow at Fermilab. Prior to joining Fermilab Kadel spent three years working with the Mark-J collaboration at DESY. He earned his Ph. D. in high energy physics at Princeton in 1977. At Fermilab he is working with the Colliding Detec-

Leon Lederman and Robert Wilson at the ceremony to name the central laboratory building at Fermilab 'Robert Rathbun Wilson Hall'. The ceremony took place on 18 September. Other speakers at the occasion included Norman Ramsey, president of Universities' Research Association (URA); Edwin L. Goldwasser, vice-chancellor for Research of the University of Illinois; Harry Woolf, chairman of the URA Board of Trustees and of the Institute for Advanced Studies; and Andrew Mravca, area manager, Batavia Area Office of the U.S. Department of Energy.

(Photo Fermilab)



tor Facility Group. Kadel is the third Wilson Fellow now working at Fermilab. The other two are John Cumalat and David Neuffer. The Wilson fellows programme was established to honour Fermilab's first director and now director emeritus, Robert R. Wilson. The appointments are for three years.

Among the awards that will be made at the Royal Society's meeting in London on 1 December is the Royal Medal to Sir Denys H. Wilkinson and the Hughes Medal to Francis Farley. Wilkinson, now vice-chancellor of the University of Sussex, receives his medal for his work in nuclear physics, beta decay, and the fundamental symmetries of nuclear interactions. Farley, dean of the Royal Military College of Science, Shrivenham, is honoured for his participation in the series of ultra-precise measurements of the muon magnetic moment, carried out at CERN.

Kjell Johnsen, who led the construction of the Intersecting Storage Rings at CERN, has been appointed Technical Director of the ISABELLE project at Brookhaven, with responsibility for the machine itself. Jim Sanford continues as overall Project Head. Meanwhile there is good news from the ISABELLE magnet front (see page 340).

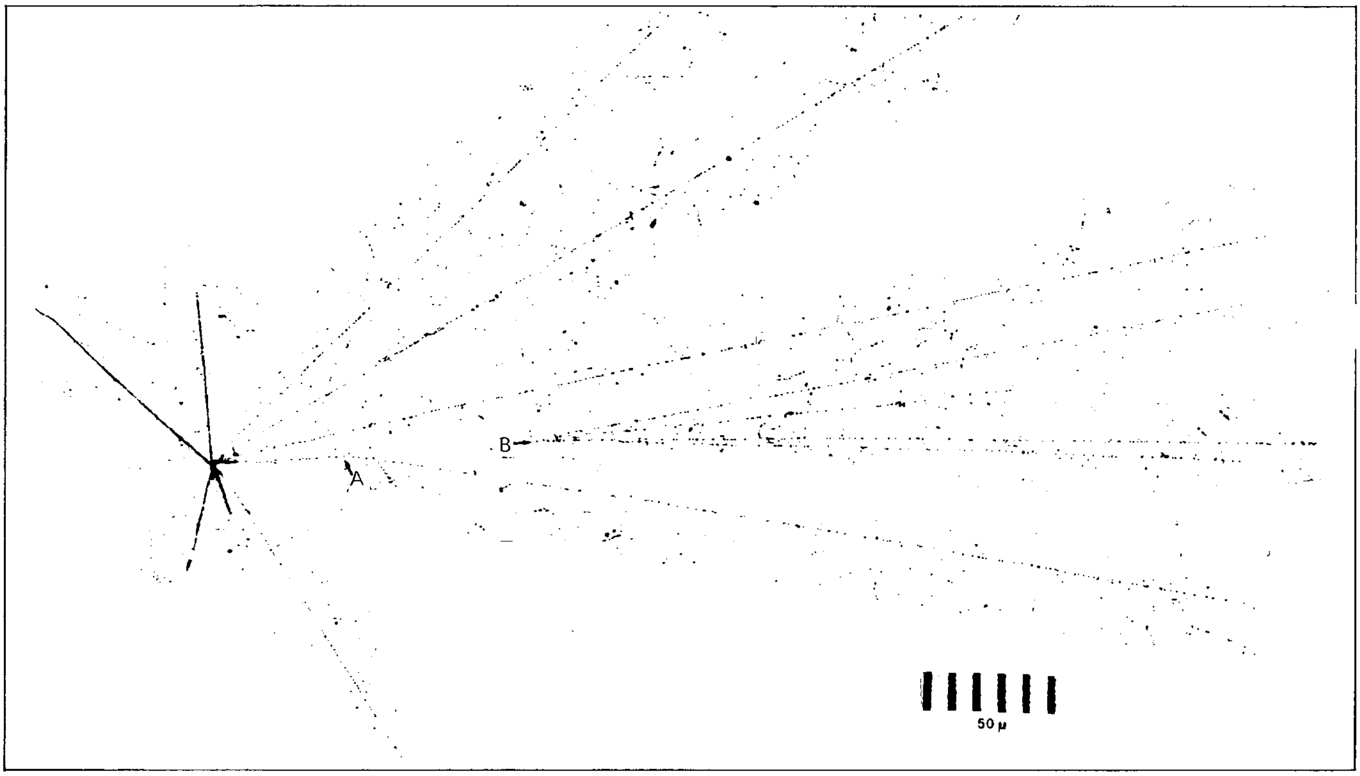
Out of Woods Hole

Each year the high energy physics programme in the USA is reviewed by a subpanel of the HEPAP (High Energy Physics Advisory Panel) meeting at Woods Hole. This year the subpanel was chaired by Sam Treiman and emerged with the following recommendations:

The Fermilab 400 GeV accelerator, the newly commissioned PEP storage ring and the CESR facility at Cornell must be used as fully as possible to exploit for physics the large investments already made. Construction of the Energy Saver and of ISABELLE must proceed with all deliberate speed. Necessary research and development funds must be provided to ensure their success. University-based groups should receive increased support to assure vitality of their efforts on immediate experimentation and also on detector development for the future. Accelerator studies and technical research should begin immediately toward the goal of starting the construction of a very large accelerator (electron energies of several hundred GeV or proton energies of 10 TeV or more) during the second half of this decade.

For the nearer future the subpanel looked at the proposals from Stanford (Single Pass Collider Project to collide electrons and positrons at 50 GeV per beam), from Cornell (the 50 GeV electron-positron storage ring) and the electron-proton colliding beam schemes for Fermilab (proposed by Canadian groups and by Columbia). It was decided to delay recommendations on these possibilities for at least a year.

The subpanel laboured in an atmosphere of great concern about the low level of funding of the high energy physics programme, which has been further compounded by lack of compensation for inflation (what Sid Drell, HEPAP Chairman calls 'the painful reality'). Bill Wallenmayer, Director of the HEP Division in the Department of Energy, acknowledged that the accelerator Laboratories are falling to operation levels of 50 per cent of their full capacity because of lack of funds.



First observation in nuclear emulsion of the photoproduction of a charmed baryon and a charmed meson, as seen by the photon/emulsion and Omega/photon collaborations at CERN. A 25 GeV photon coming in from the left produces among other things a track which appears to undergo a sizeable deflection (point A). Not seen in the emulsion but picked up by the Omega spectrometer downstream is a neutral lambda coming from the interaction region. The deflection is thus interpreted as the decay of a positively charged charmed baryon into the neutral lambda and a charged pion. Another secondary vertex (point B) gives a spray of particles, also detected in Omega, and corresponds to the decay of a neutral charmed meson into a kaon and three pions. An earlier experiment by the same group was hampered by poor emulsion quality, but the latest run, using 6000 pellicles of emulsion manufactured by the State Research Institute for Photochemical Projects, Moscow, is producing excellent results.

PEP dedication

Among the speakers at the dedication ceremony for the new PEP electron-positron collider at SLAC on 5 September was Frank Press, President Carter's advisor on science and technology. He spoke of the moves being made to boost the funds available for basic research in the US, and read the following message from the President to the staff of SLAC and the Lawrence Berkeley Laboratory:

'Congratulations on the dedication of the collaborative Positron-Electron Project (PEP), at the Stanford Linear Accelerator Center.

The operation of this new endeavour by two of this country's, and the world's, leading Laboratories for research in high energy physics, represents a major step forward into this exciting frontier of science.

Through PEP you have a more powerful instrument to continue the search for elementary particles, and to seek a greater understanding of the fundamental properties of matter and the universe. This is basic research of the highest order, of which my Administration and the Nation are both very proud.

I welcome the opportunity to express my appreciation to all who have worked for many years to make this effort a reality. And to those who will be working with this fine facility, I extend my best wishes for success in their important scientific quest.'

ISOLDE: and then there were three!

Discovering exotic nuclear behaviour is something of a speciality at ISOLDE, the CERN on-line isotope separator. Last year a new kind of radioactivity was revealed when the emission of two neutrons was seen in the decay of the rare isotope lithium-11 (see November 1979 issue, page 354) and later, in experiments by an ISOLDE/Orsay collaboration, from sodium-31, 32 and 33.

In a further study of lithium-11 decay, neutron counters were connected in parallel and timed by a 'flying clock' microprocessor which enabled neutron correlations to be analysed in the playback of the magnetic data tape. Now a signal due to three neutrons is found which cannot be attributed to accidentally coincident single and double neutron emissions. Like the two-neutron effect discovered last year, the three-neutron disintegration is a by-product of beta decay and is said to be 'beta-delayed'.

In addition, the resultant beryllium-8 nucleus is so unstable that in turn it too decays, giving off two alpha particles. Thus the ISOLDE

Alice in (high energy physics) Wonderland? This detail from the recent CERN exhibition at the University of Louvain gives the uncanny impression that on passing through the archway, the visitor finds himself in the SPS tunnel.

(Photo CERN 126.9.80)

experimenters are able to observe five particles resulting from the decay of a lithium-11 nucleus.

Quote of the month

Pief Panofsky to the Chicago meeting of the American Physical Society: 'the present annual cost of the US particle physics programme (about $ 350 million) is not chickenfeed — the cost of chickenfeed in the US is ten times that amount'.

Superconductivity at SIN

A comprehensive article by G. Vécsey in the September issue of Europhysics News describes activities at the SIN Laboratory in the application of superconductivity. The SIN superconducting pion channel for cancer therapy was described in our previous issue. There is also a major development programme to produce high field superconducting magnets for magnetic confinement fusion. SIN is participating in the international project called the 'Large Coil Task' which will assemble six D-shaped coils, 4.5 m high, at Oak Ridge to provide a peak field of 8 T. SIN, in collaboration with Brown-Boveri, will provide one of the coils (three other coils are coming from the USA, one is coming from Japan and one from Karlsruhe, in collaboration with Siemens). For the future, there is research into several materials capable of higher fields, such as niobium-tin, niobium-aluminium and vanadium-gallium. This work also involves CNEN at Frascati and ECN at Petten.

More on superconductivity

From 24–26 September, Argonne National Laboratory sponsored a Conference on the subject of ternary superconductors. As the name implies, these superconductors are composites of three basic materials. Research in Europe and the USA has indicated that some such composites achieve the superconducting state at higher temperatures (around 20 K) and can tolerate maximum field twice as high as the more familiar binary superconductors.

A Chirper and an Analyser

Two improved portable radiation monitors have been developed at the Los Alamos Scientific Laboratory and are now being manufactured by outside industry. One, known as the 'Wee Pocket Chirper', is a tiny battery-powered monitor which 'chirps' when exposed to radiation, at a chirp rate proportional to the level of radiation. It weighs under 30 grammes and is based on a cadmium telluride chip rather than a gas-filled Cherenkov counter. The other monitor is a multi-channel analyser capable of distinguishing the energy spectrum of the radiation. It is also much lighter than its predecessors and can display and record its readings.

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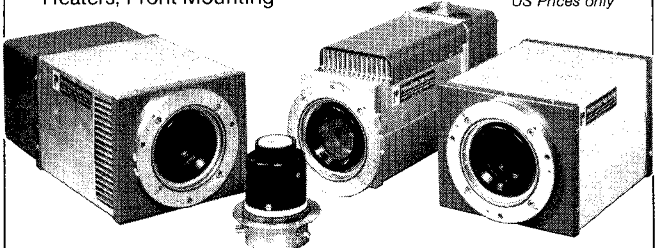

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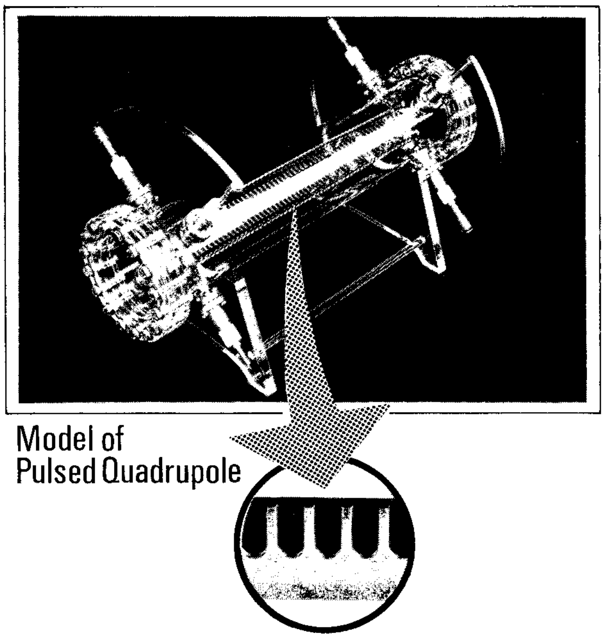
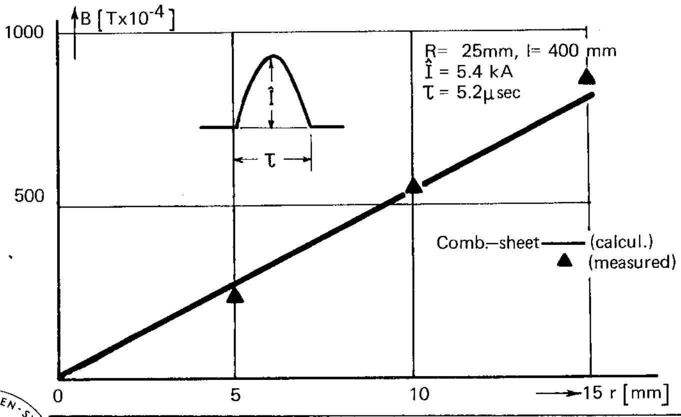


Model of Pulsed Quadrupole

Field of Quadrupole



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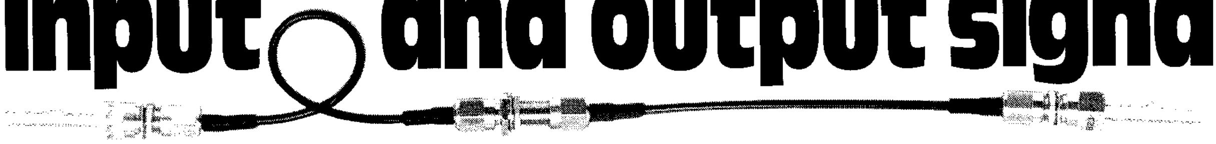
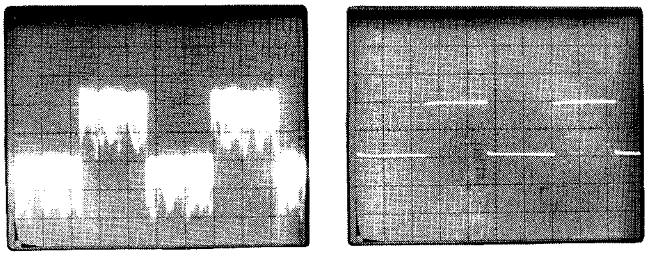
Between your electric input and output signals



the interference-free SUHNER Fiberoptic-System.



Compare the same signal after crossing an area of strong electromagnetic interference: Left on a copper coax line, right on an optical glass fibre.

Light signals travelling along glass fibres are immune to electromagnetic interference

They cannot influence each other (no crosstalk).

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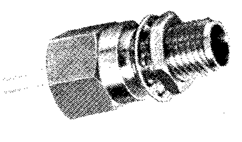
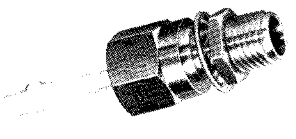
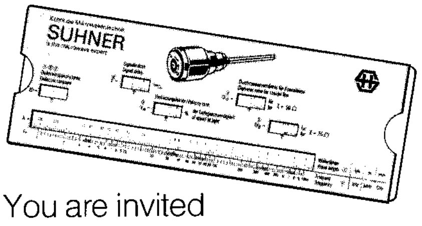
Transmitter and receiver of the system are electrically isolated.







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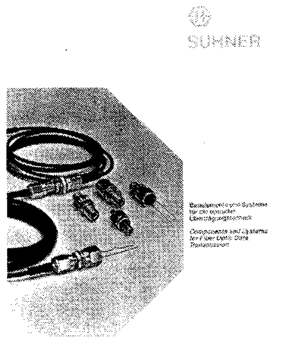
Detailed technical literature is available. Don't forget to ask for your free data slide rule that covers the entire RF spectrum.



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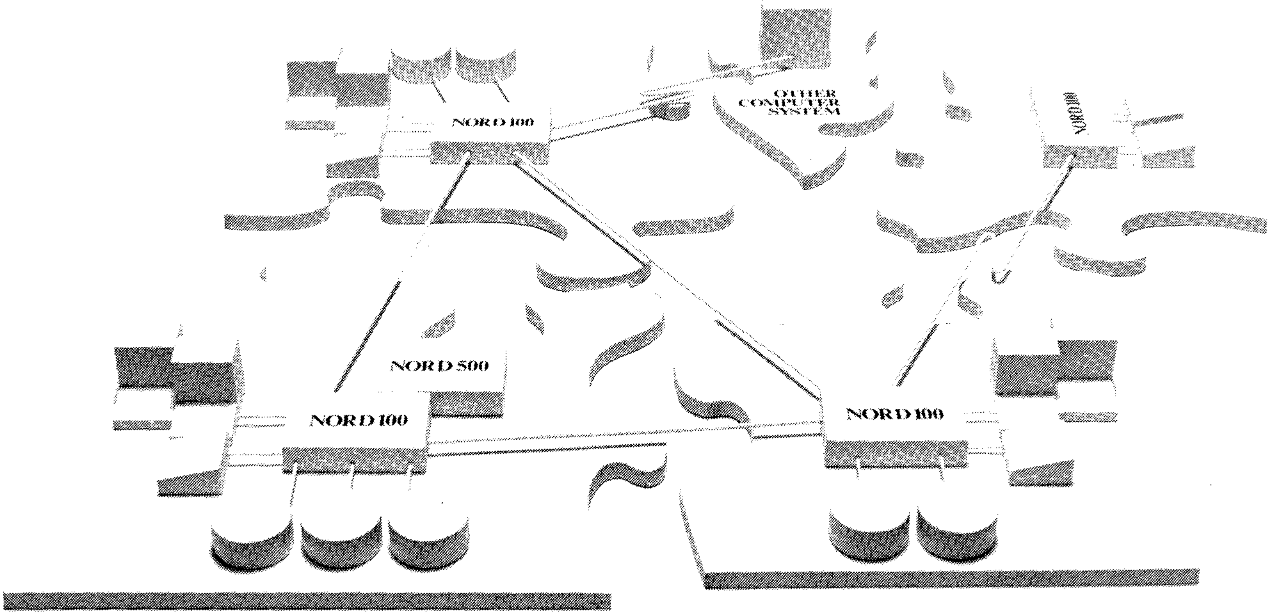
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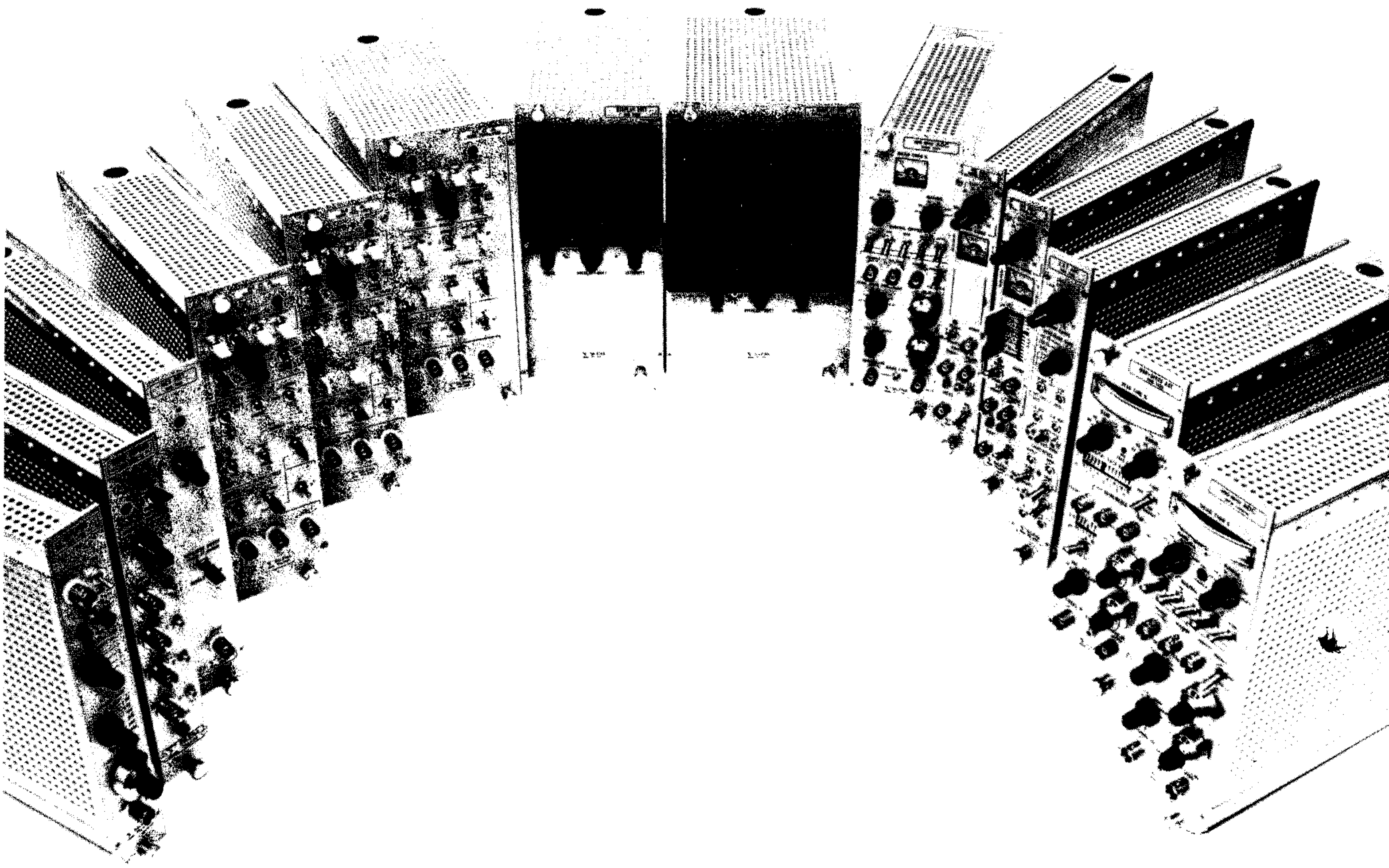

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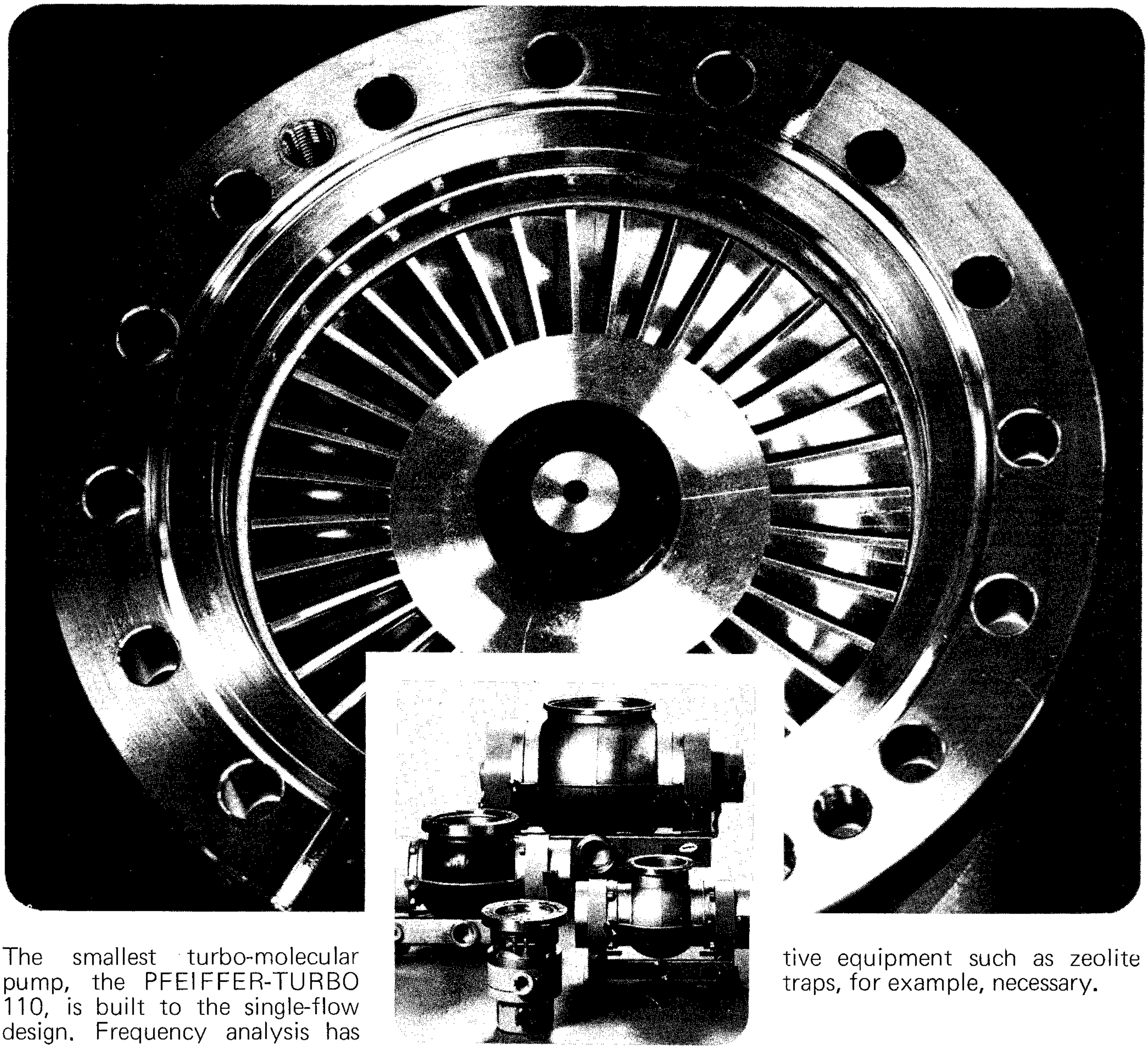
for the production of extremely clean high and ultra-high vacuum



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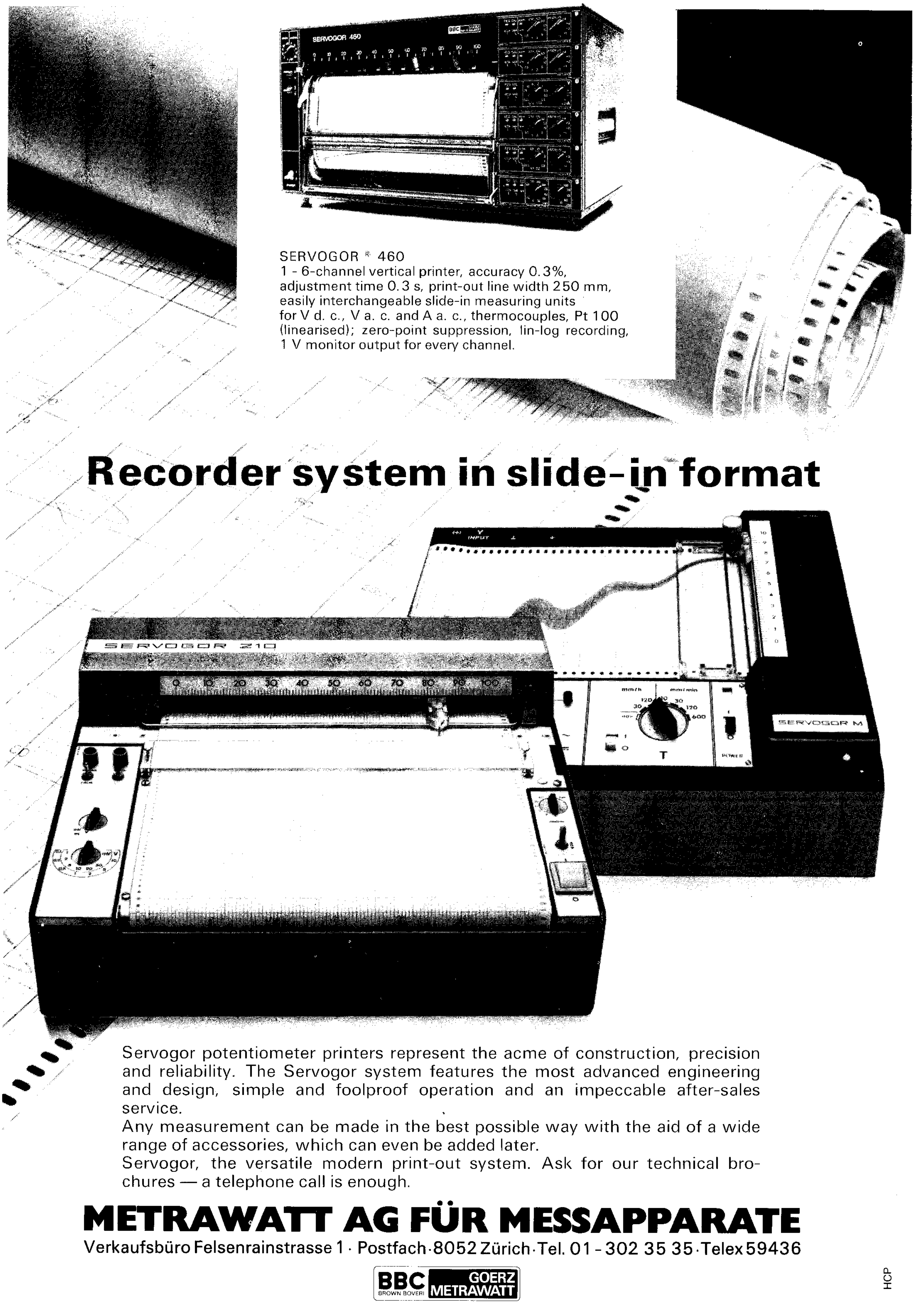
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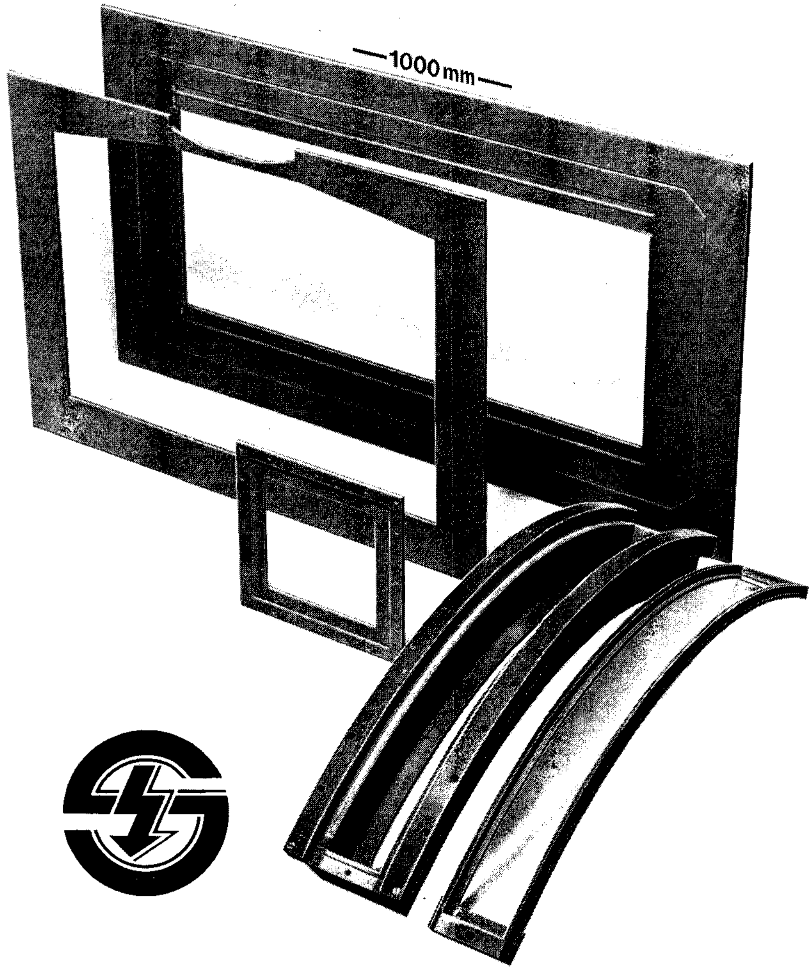
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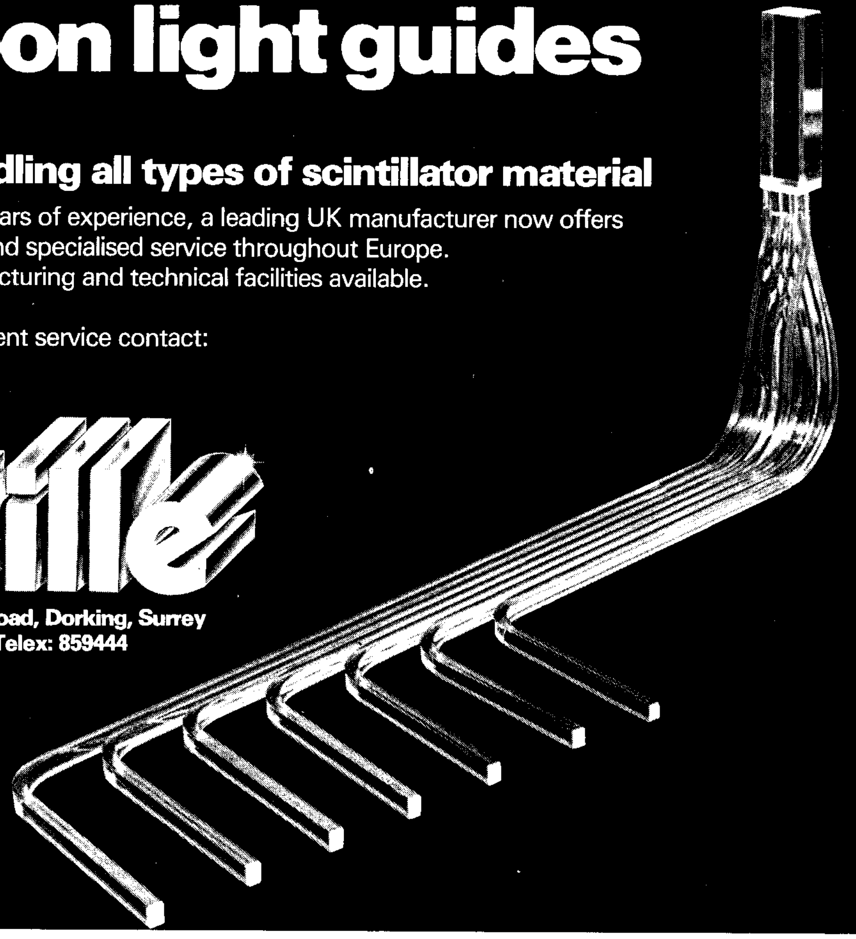


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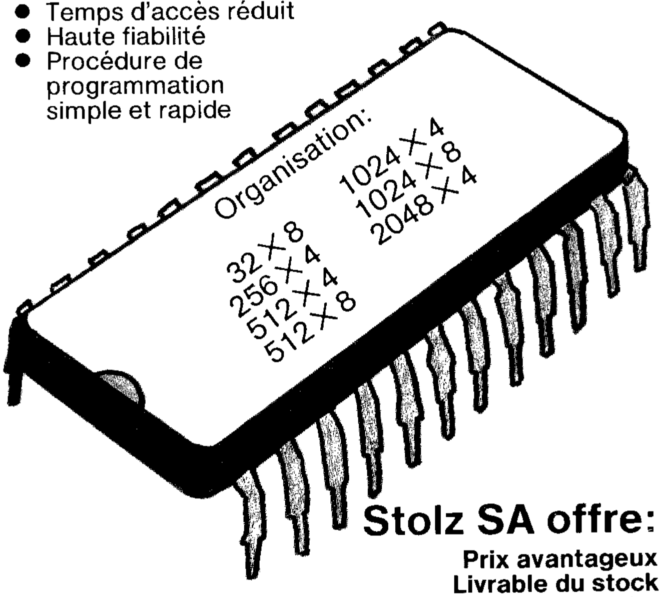
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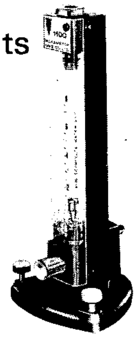
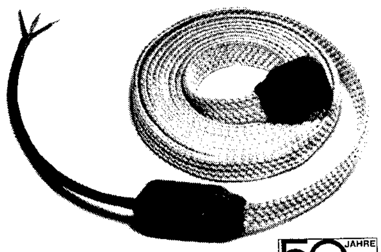

type 1100



SCINTILLATORS
FOR THE PHYSICAL SCIENCES

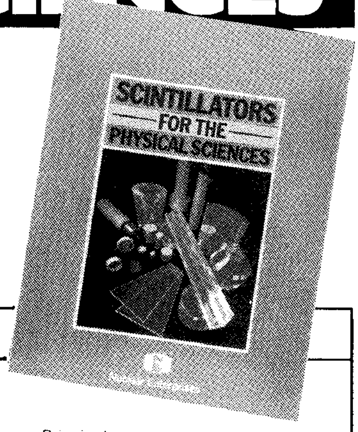


TABLE OF PHYSICAL CONSTANTS

	Scintillator	Type	Light Output (% Anthracene)	Decay Constant, Main Component ns	Wave-length of Maximum Emission nm	Content of Loading Element (% by wt.)	Principal Applications
PLASTIC	NE 102A	Plastic	65	2·4	423	....	γ, a, β, fast n
	NE 104	Plastic	68	1·9	406	....	ultra-fast counting
	NE 104B	Plastic	59	3·0	406	....	with BBQ light guides
	NE 105	Plastic	46	....	423	....	dosimetry
	NE 110	Plastic	60	3·3	434	....	γ, a, β, fast n, etc.
	NE 111A	Plastic	55	1·6	370	....	ultra-fast timing
	NE 114	Plastic	50	4·0	434	....	as for NE 110
	NE 160	Plastic	59	2·3	423	....	use at high temperatures
	Pilot U	Plastic	67	1·36	391	....	ultra fast timing
	Pilot 425	Plastic	....	....	425	....	Cherenkov detector
LIQUID	NE 213	Liquid	78	3·7	425	....	fast n (P.S.D.)
	NE 216	Liquid	78	3·5	425	....	a, β (internal counting)
	NE 220	Liquid	65	3·8	425	0 29%	Internal counting, dosimetry
	NE 221	Gel	55	4	425	....	a, β (internal counting)
	NE 224	Liquid	80	2·6	425	....	γ, fast n
	NE 226	Liquid	20	3·3	430	....	γ, insensitive to n
	NE 228	Liquid	45	....	385	....	n
	NE 230	Deuterated liquid	60	3·0	425	D 14·2%	(D/C) special applications
	NE 232	Deuterated liquid	60	4	430	D 24·5%	(D/C) special applications
	NE 233	Liquid	74	3·7	425	....	a, β (internal counting)
	NE235	Liquid	40	4	420	....	large tanks
	NE 250	Liquid	50	4	425	0 32%	internal counting, dosimetry
LOADED LIQUID	NE 311 & 311A	B loaded liquid	65	3·8	425	B 5%	n, β
	NE 313	Gd loaded liquid	62	4·0	425	Gd 0·5%	n
	NE 316	Sn loaded liquid	35	4·0	425	Sn 10%	γ, X-rays
	NE 323	Gd loaded liquid	60	3·8	425	Gd 0·5%	n
NEUTRON) (ZnS-type) and GLASS	NE 422 & 426	^{6}Li-ZnS(Ag)	300	200	450	Li 5%	slow n
	NE 451	ZnS(Ag)-plastic	300	200	450	....	fast n
	NE 901, 902, 903	Glass	28	20 & 60	395	Li 2·3%	n, β
	NE 904, 905, 906	Glass	25	20 & 58	395	Li 6·6%	n
	NE 907, 908	Glass	20	18 & 62	399	Li 7·5%	n
	NE 912, 913	Glass	25	18 & 55	397	Li 7·7%	n, β (low background)

Note:

BA1 CELLS: All Nuclear Enterprises liquid scintillators are available encapsulated in glass cells of appropriate composition. "Bubblefree" aluminium cells are produced with white reflector and glass windows. Standard sizes with internal diameters 50 to 125mm and internal lengths 50, 75, 125 and 150mm. Special non-standard sizes on request.

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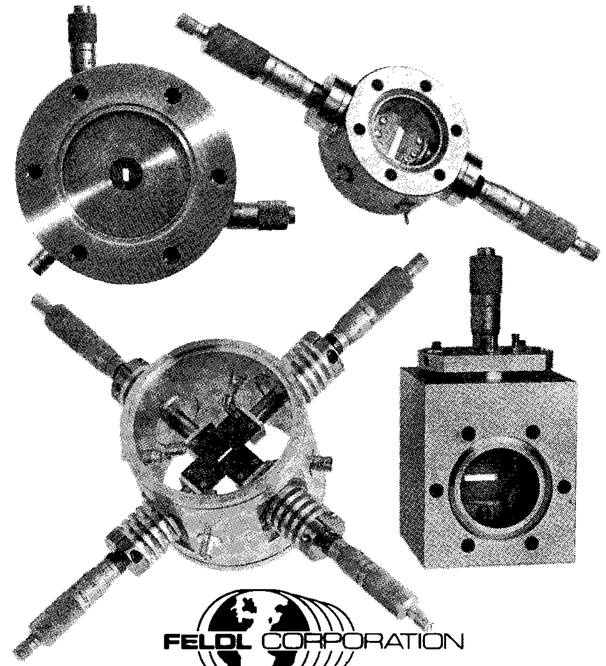

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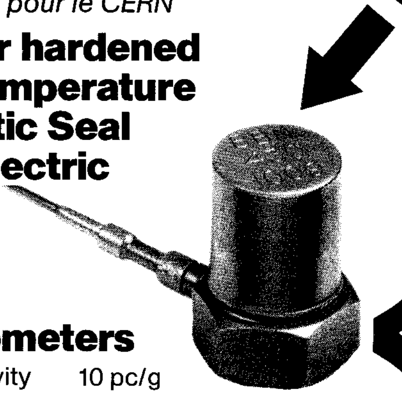

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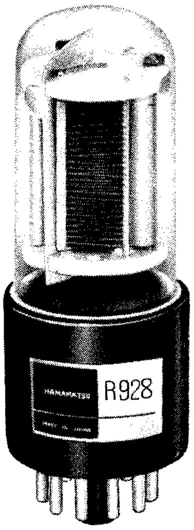
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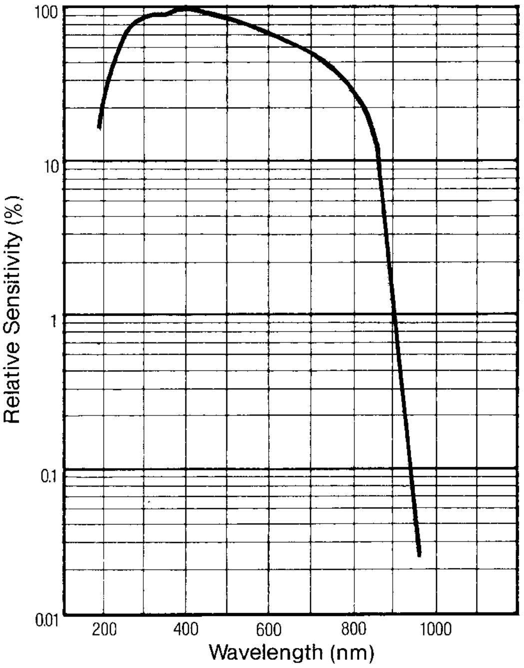
100
10
1
0.1
0.01
Relative Sensitivity (%)
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400
600
800
1000
Wavelength (nm)


HAMAMATSU
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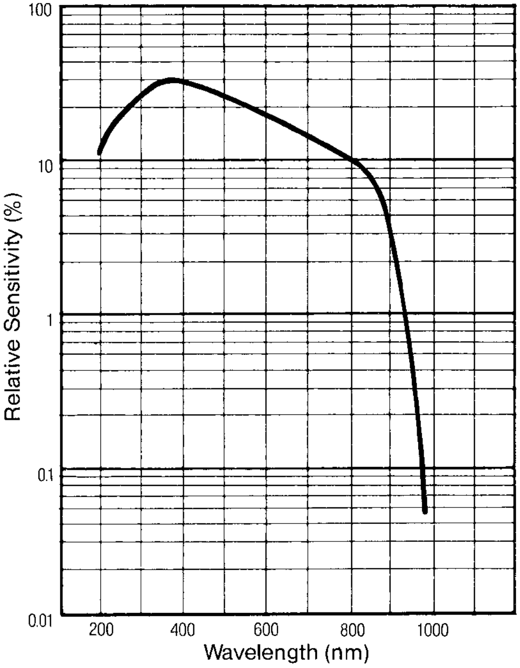
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Relative Sensitivity (%)
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400
600
800
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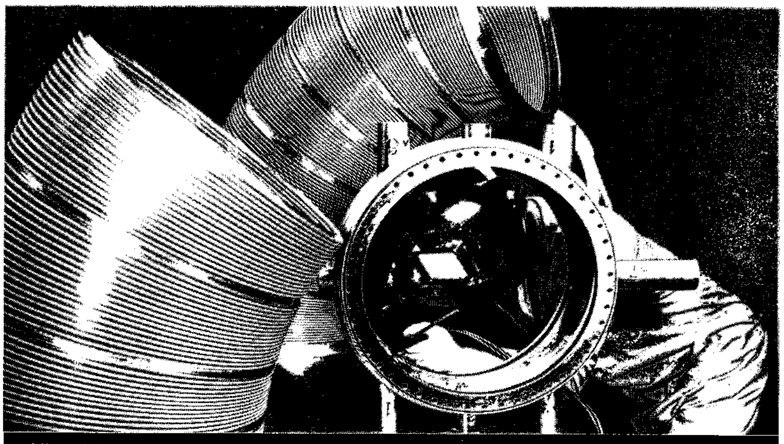
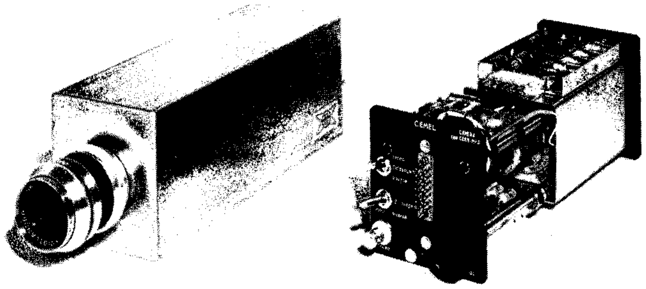
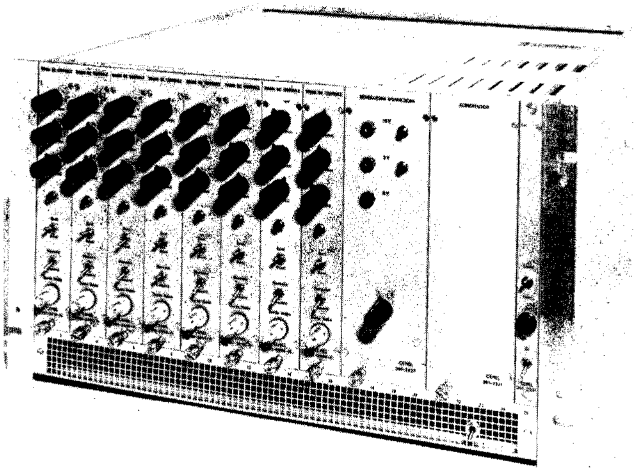
Wavelength (nm)





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DL 1080
programmable
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SCALE
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PANEL
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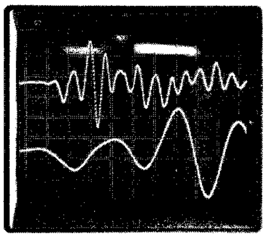
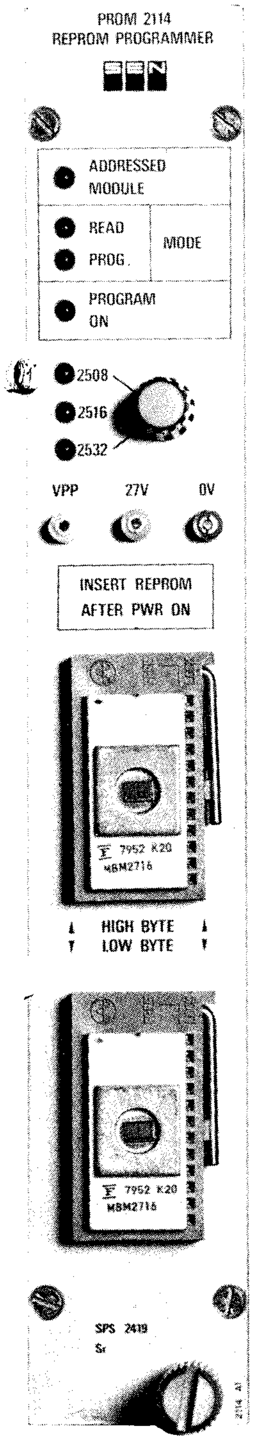


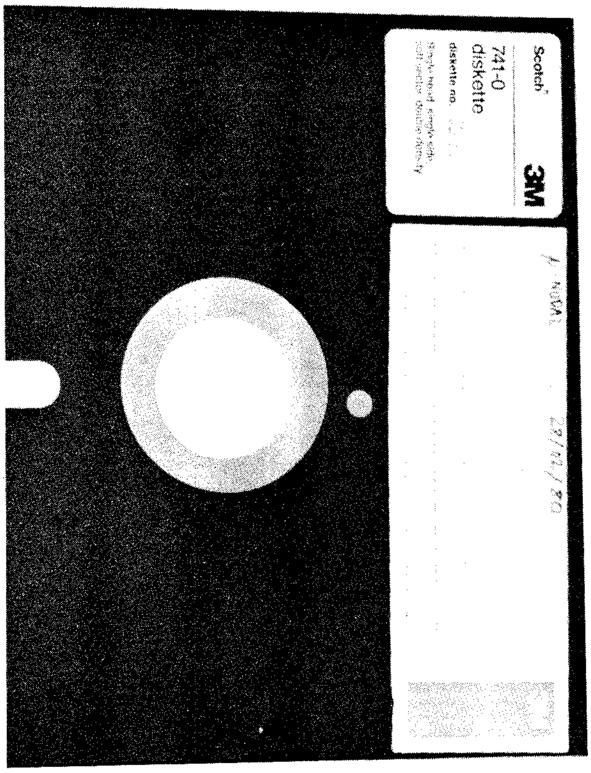
CAMAC

The CAMAC Eprom Programmer Set
RP 2114

from SEN Electronique



- ★ **comes as a package hardware + software**
- ★ **programs all types of Eproms 2508, 2516, 2532**
- ★ **programs two 8bit Eproms simultaneously for ease of operation when used with 16-bit microcomputers.**



description

This double width module contains all the hardware to program Eproms with easy CAMAC commands.

A software package allows the user of a SEN ACC 2099/2103 or STACC 2107 system to read, write duplicate, verify, correct and list Eproms.

applications

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- generation of application programs to be used in Auxiliary or Stand Alone Controllers as permanent programs
- back-up of programs as files on our floppy disc system
- etc., etc...

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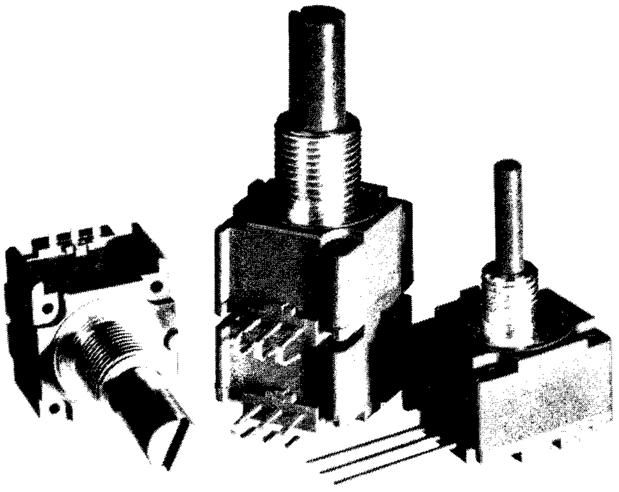

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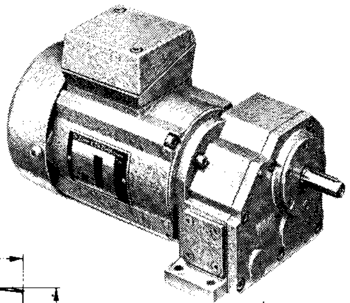
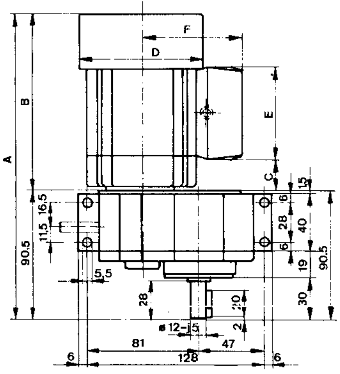
et les nombreuses possibilités de combinaison

p.e. Réducteur type PFV 35/4-10/2 H

Moteur type	A	B	C	D	E	F	G	filet
PFV 30/35	219,5	129	25	90	67	72	60	Pg 9

84 possibilités de réduction





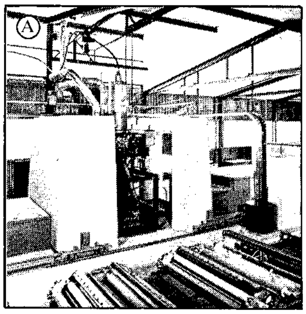
220 V 1 ph, 50 Hz,
4 pôles
14 watts, 0,22 amp.,
avec condensateur
1400/1,7 tr/min
Couple à l'axe de sortie 24 Nm, η 0,3

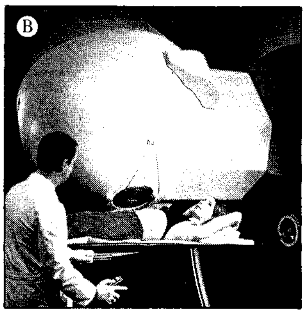
Th. Zürrer + Cie.
Birmensdorferstrasse 470
8055 Zürich (Schweiz)
Telefon 01 35 25 55, Telex 54506 tzco

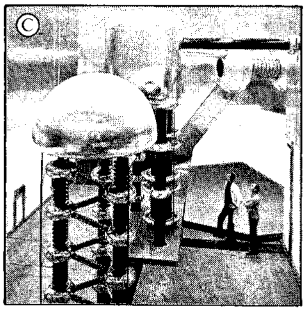
Haefely Today

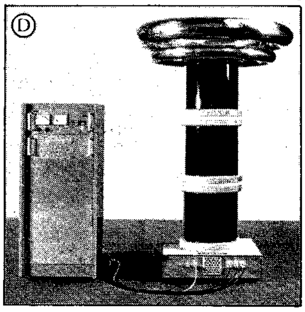
Particle Accelerators High-Voltage DC Power Supplies Irradiation Systems

for Research, Radiotherapy and Industry









Thirty years ago, Haefely built the first ion and electron accelerators for high and ultra-high voltages although requirements at that time were extremely sophisticated.
Today, Haefely is working on ever more ambitious projects and has become a reliable partner with experience in a wide field of activities: ■ DC accelerators for ions and electrons up to 4 MeV ■ High-power electron accelerators for industrial radiation processing, design of complete irradiation systems ■ Electron accelerators with ultra-high stability of the accelerating voltage for high-voltage electron microscopy ■ Neutron generators for cancer therapy and industrial applications ■ High-voltage dc generators with high outpout power ■ High-voltage dc power supplies for pulsed load or with high out put voltage stability ■ Modular high-voltage dc generators
Send for our brochure entitled: "Haefely Today"

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Ⓑ Cancer therapy system with fast neutrons
Ⓒ 850 kV injector power supply
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P.O. Box
CH-4028 Basel/Switzerland
Telephone 061/41 18 17
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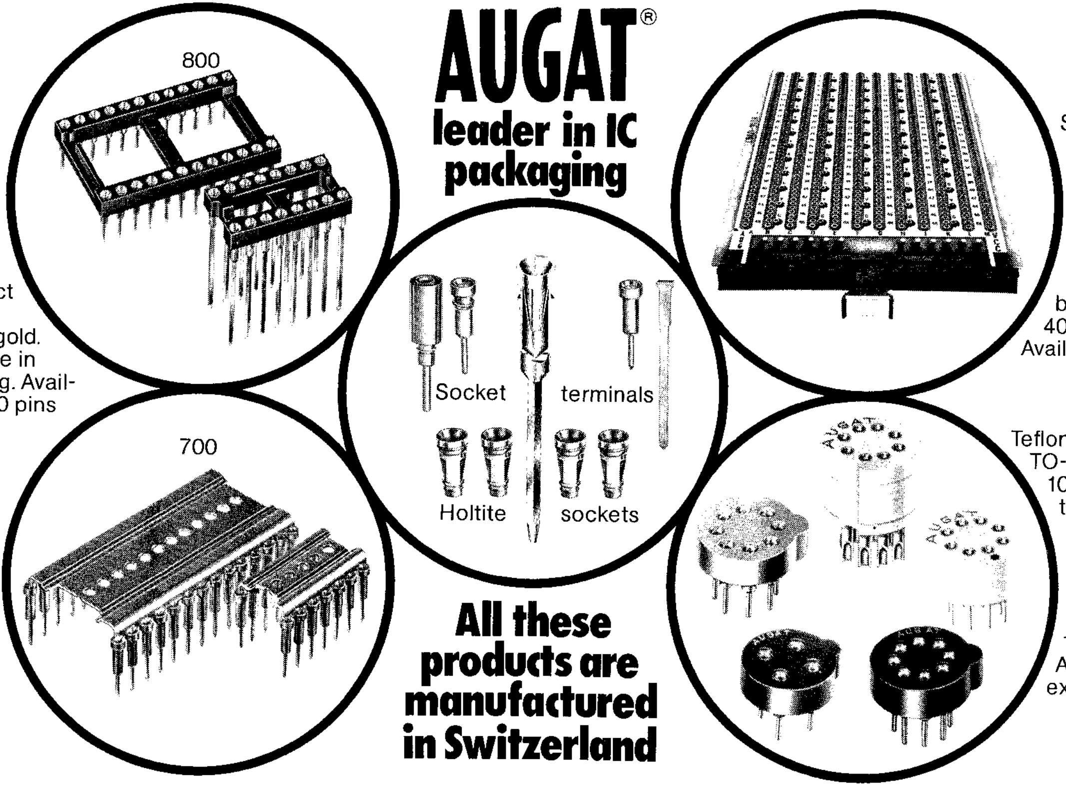
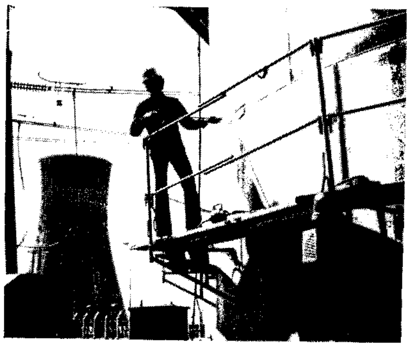
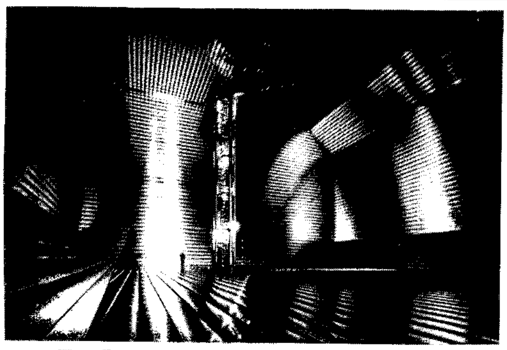
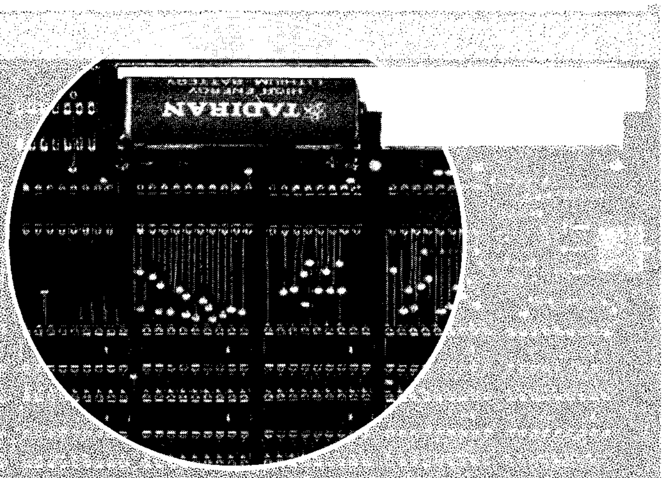
XP2020
XP2020

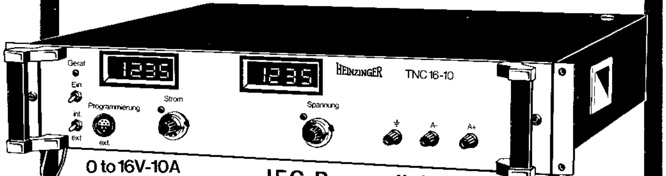


800
700
Socket terminals
Holtite sockets

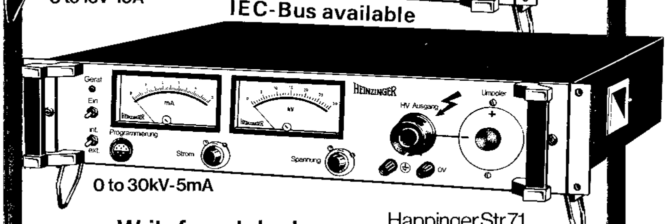




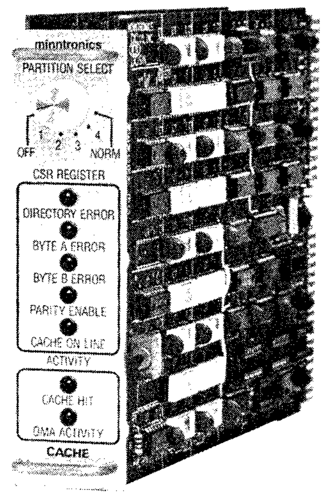

TADIRAN



Gerät
Ein
Programmierung
Strom
Spannung
HEINZINGER
TNC 16-10
int.
ext.

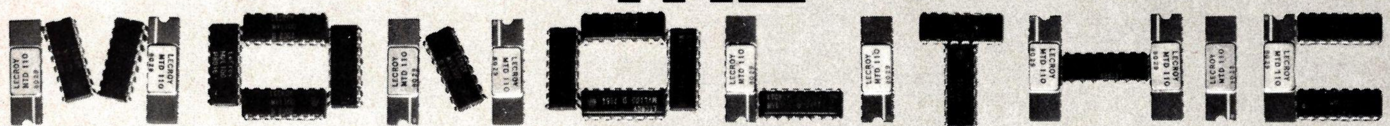


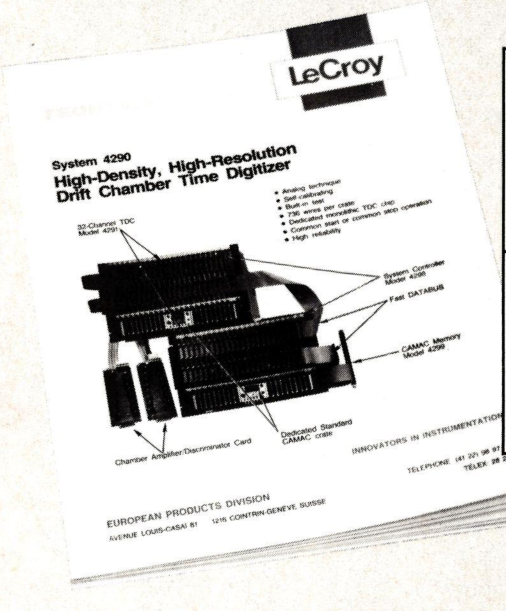
Gerät
Ein
HEINZINGER
HV Ausgang
Umpoler
Programmierung
Strom
Spannung



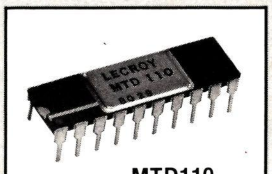
minntronics
PARTITION SELECT
OFF
1
2
3
4
NORM
CSR REGISTER
DIRECTORY ERROR
BYTE A ERROR
BYTE B ERROR
PARITY ENABLE
CACHE ON LINE
ACTIVITY
CACHE HIT
DMA ACTIVITY
CACHE

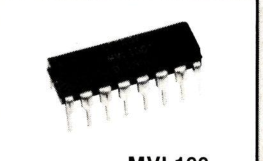

PROVEN!
CX1171B


MONOLITHIC

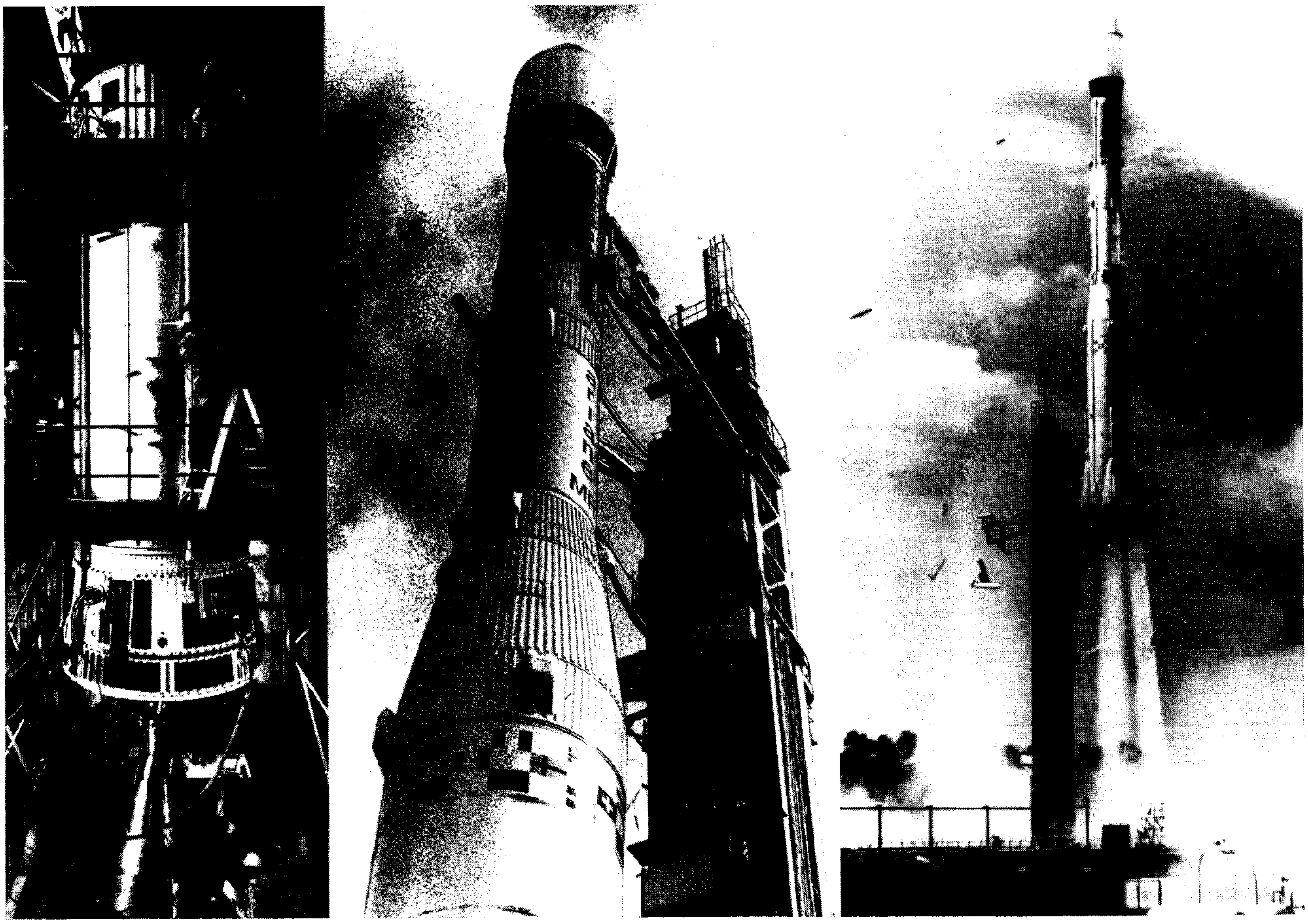


32-Channel TDC Model 4291
System Controller Model 4298
Fast DATABUS
CAMAC Memory Model 4299
Dedicated Standard CAMAC crate
Chamber Amplifier/Discriminator Card





Gases and cryogenics at work



Nitrogen was used to purge and inertise the piping system of the three-stage European rocket ARIANE, successfully launched on 24. 12. 1979. ERNO-Raumfahrttechnik, Bremen had overall responsibility for integrating the second stage of the project.

For starters, we supplied the nitrogen for checking the second stage of ARIANE...

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If that's not food for thought, think of the spices whose aroma we've frozen in time, apples stored fresh for a year, wines whose quality is protected during storage, and a thousand fresh foodstuffs in suspended states of perfection.
Living creatures, too, turn to us for a future. Organs can be put into a deep sleep, blood stored for years, tissues preserved for cancer research, and even champion bulls put on ice. Gases and cryogenics have a thousand faces. To solve a thousand problems.

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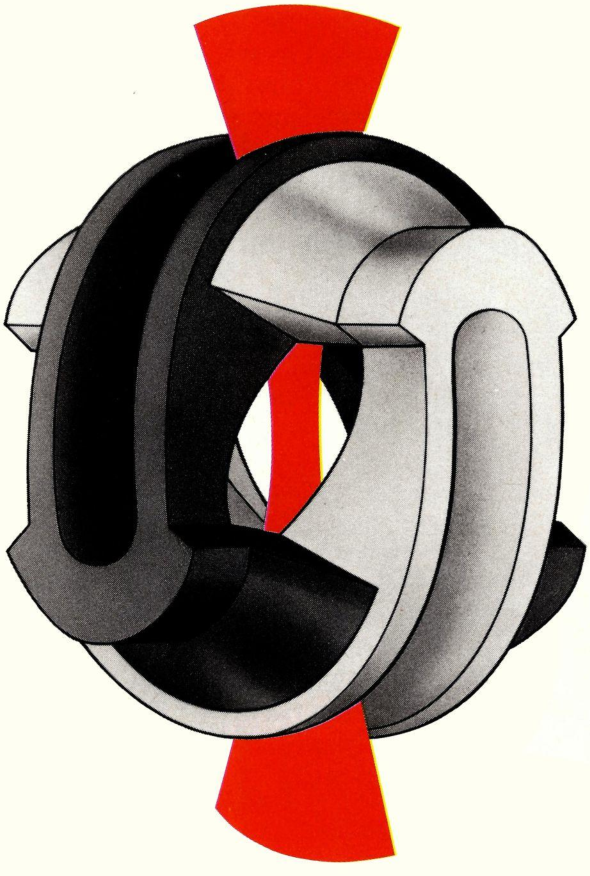

August 5, 1978

EIMAC 8973 tetrodes helped bring fusion power a step closer at Princeton.

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AT 78MHz WITH
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