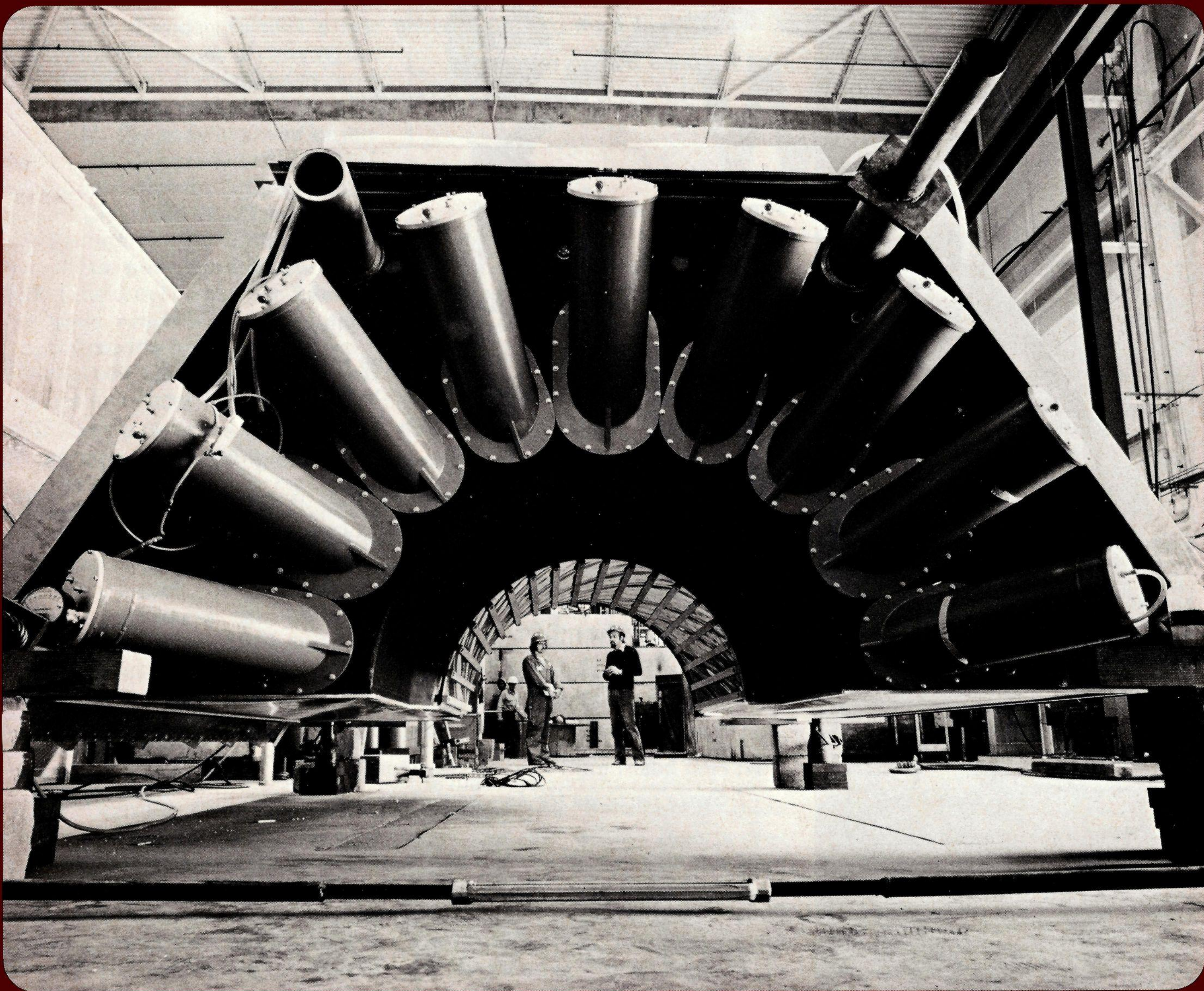
CERN COURIER



VOLUME 20 7 OCTOBER 1980

CERN COURIER
Journal of High Energy Physics

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CERN COURIER is published ten times yearly in English and French editions. The views expressed in the Journal are not necessarily those of the CERN management.

Printed by: Presses Centrales S.A.
1002 Lausanne, Switzerland
Merrill Printing Company
765 North York, Hinsdale,
Illinois 60521, USA

Published by:
European Organization for Nuclear Research
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Tel. (022) 83 61 11, Telex 23698
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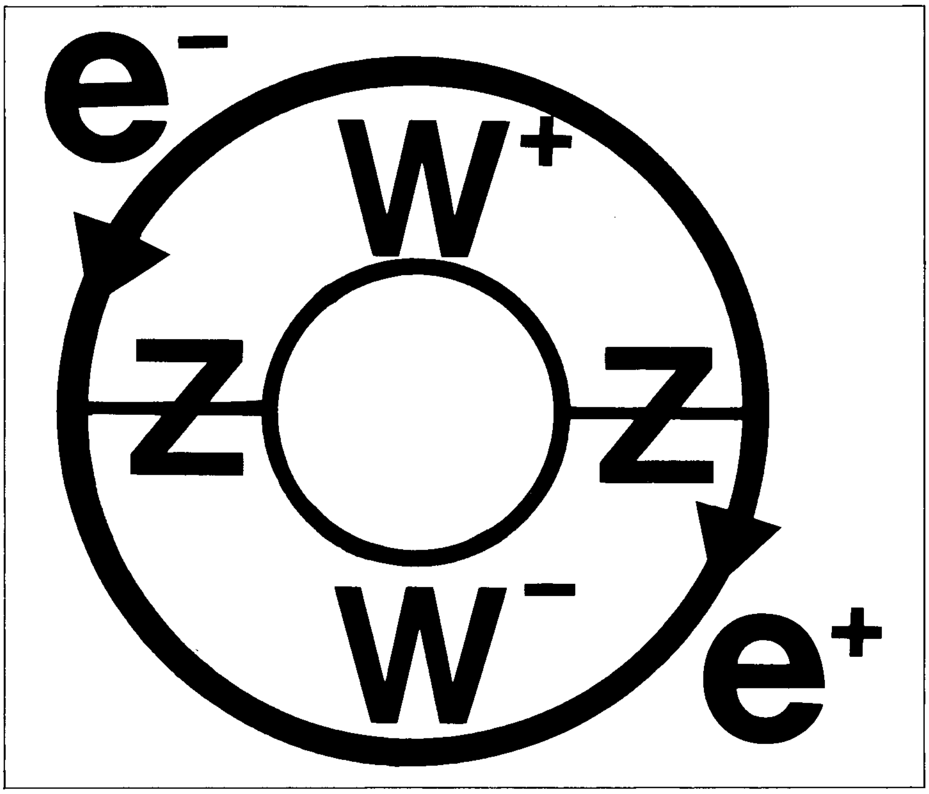
Contents

Part of the Cherenkov counter array for the DELCO experiment by a Caltech/SLAC/Stanford collaboration to be installed at the new PEP electron-positron ring at SLAC. DELCO has already done valiant service at SPEAR and now hopes for more physics honours at the PEP ring. (Photo Joe Faust)

Thinking on experiments at LEP

Symbol used at Uppsala to convey what the 'International Conference on Experimentation at LEP' was all about. It is expected that a high proportion of the experimental programme at the proposed large electron-positron storage ring will be given to the study of the postulated W and Z bosons. The diagram shows the coupling of the Z^o to a W^+W^- pair.



From 16–20 June some 350 physicists gathered at the University of Uppsala in Sweden to take a first look at the challenges of carrying out experiments at the proposed large electron-positron storage ring, LEP, at CERN. The meeting was organized by the University and the European Committee for Future Accelerators, ECFA. Tord Ekelöf was Scientific Secretary of the Conference and helped to put together this brief report, held over from our September issue which already contained lengthy reports from the large international conferences on high energy physics and accelerators.

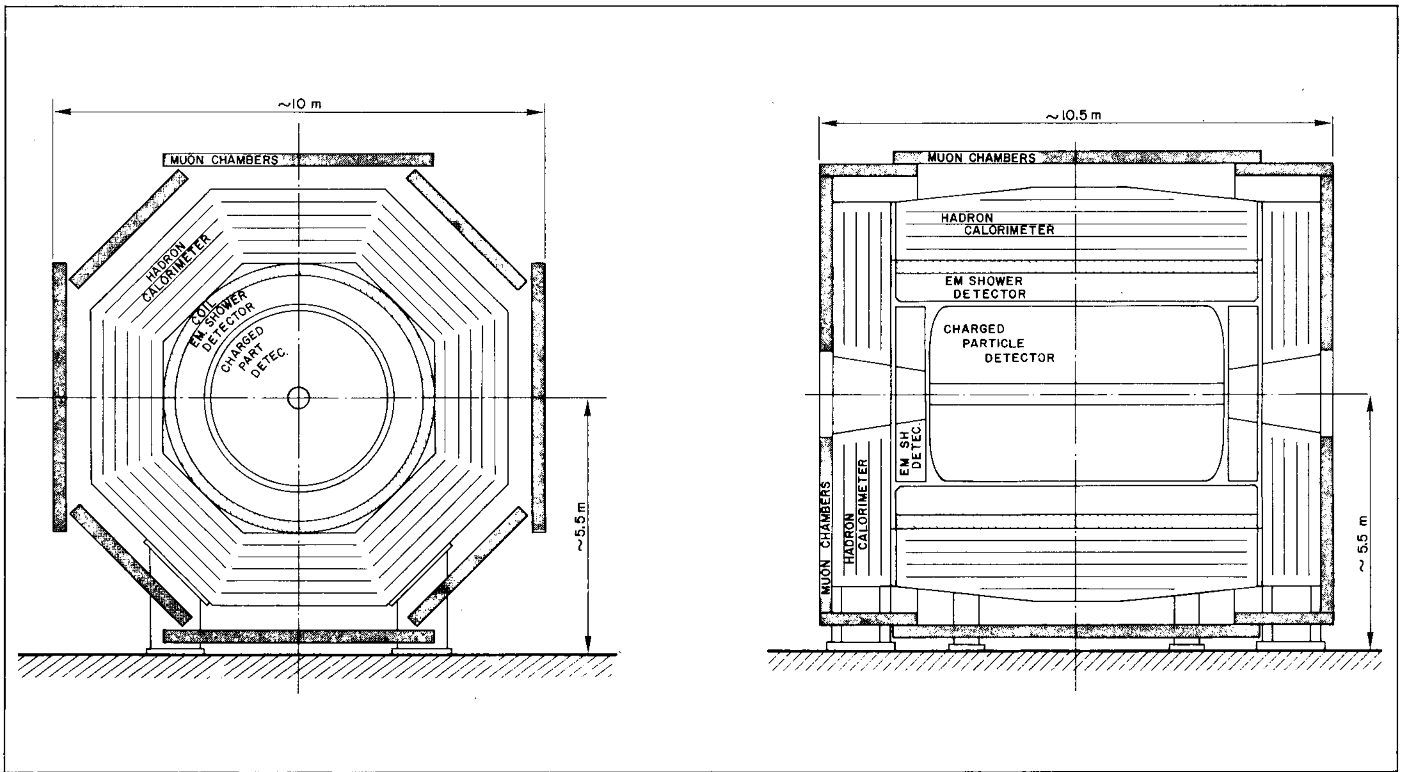
An early look at the experimental programme to be mounted on a new high energy facility is necessary because of the very long timescale needed for the preparation of large and complex detection systems, and because the evolution of the experimental programme can have an impact on aspects of the machine and, obviously, experimental hall design. For example two meetings at rrenia in Italy set the scene for experimentation at the CERN SPS 400 GeV proton synchrotron.

The Uppsala Conference was, however, rather pre-Tirrenia in style and aim. It tried to look at the different 'front-line' experimental techniques and their suitability for the particular conditions of LEP, and to identify techniques which would benefit from more research and development so as to be more thoroughly mastered by the time the LEP programme takes shape. The benefit of the Uppsala Conference was particularly noticeable in the absence for many years of what used to be a regular series of 'International Conferences on Instrumentation for High Energy Physics'. The last in this series was held at Frascati in 1973 and at Uppsala there was much talk of trying to revive some sort of regular 'experimentation' meetings.

The Uppsala Conference was organized in the form of plenary sessions with opening talks introducing the machine and the known physics interests. (As background there were also the written reports prepared by the ECFA LEP Working Group chaired by Antonino Zichichi and the ECFA Working Group on High Energy Physics Activities in the CERN Member States chaired by John Mulvey.) These were followed by invited papers on specific topics — Particle identification, Calorimetry, Track chamber spectrometers, Data handling, Future developments and LEP detector set-ups. There were concluding remarks from Erwin Gabathuler. Supporting this were poster sessions where over sixty presentations were made (a number which in itself speaks for the physics interest in LEP). These poster sessions were very popular and it was difficult to drag their audience away and back to the plenary sessions. They generated lively informal discussions and encouraged the presentation of new ideas as well as tested techniques.

The following topics emerged as requiring further attention. Positional accuracy: some technique is needed to arrive at a measurement accuracy along the wires of drift chambers which reaches the same precision as is achievable in the directions transverse to the wires (100 to 200 μm). Particle identification: firstly, time of flight measurements need to be tightened up from the presently achieved 200 ps region, using scintillators, to some 50 ps, using for example Pestov-type spark gaps. Secondly, the production of an aerogel with a refractive index as low as 1.006 would help Cherenkov methods of particle identification. (The present lower

Proposed detector design for LEP, which emerged from the Les Houches Summer Study in 1978 and subsequent work. Inside the solenoid coil is the inner charged particle detector of 1.8 m radius, surrounded by an electromagnetic shower detector. The flux return yoke serves as hadron calorimeter and muon filter.



limit of the index is around 1.02.) Thirdly, it is important to demonstrate in practice that the Cherenkov ring imaging technique can be used for particle identification with high momentum particles and for large solid angle detectors (approaching 4 π). Fourthly, the precise resolution of the energy loss technique, dE/dx, needs more study. At present many of the detectors using this technique are recording some 40 per cent higher errors in their measurements than expected. More effort should also be given to the possible advantages of pressurizing the gas and of counting the primary ionization clusters.

In the area of calorimetry, improvements in energy resolution are desirable both in measurements of electromagnetic particles (presently at best 10 per cent over the square root of the energy expressed in GeV) and, particularly, of hadrons (presently at best 50 per cent over the square root of the energy expressed in GeV). There is also a need to improve the granularity of the detectors, for example by using imaging techniques.

For data collection and analysis, there is a need for new methods in the monitoring and control of huge detection systems using, for example, laser beams and fibre optics. The use of distributed systems with many computers dedicated to specific tasks (rather than a monolithic approach) looks to be the way to go at all levels of control and data collection in very complex experiments. There is a lot of interest in establishing standards to be used throughout the data handling system (from the trigger to the off-line analysis programs). Apart from other advantages, this would ease the participation in large experiments of small groups from Universities.

The timescale in which some of this work should be done was indicated by Herwig Schopper, CERN Director General designate. In 1981 there will be the first call for proposals. The first approvals can expected in the course of 1982 so that teams can begin construction of their detection systems for installation during 1983–85. Experiments could then start in 1986. Only four intersection regions will be envisaged initially and decisions will be needed on how many experiments to manoeuvre into these halls and to get an optimal mix of large multipurpose apparatus and small specialized set-ups. Thought should be given to the adoption of existing proven systems to LEP conditions. The distribution of the data analysis burden should also not be overlooked. All in all, there are quite a few things to be done before 1986 when electron-positron beams could start colliding in LEP.

The Argonne ZGS in retrospect

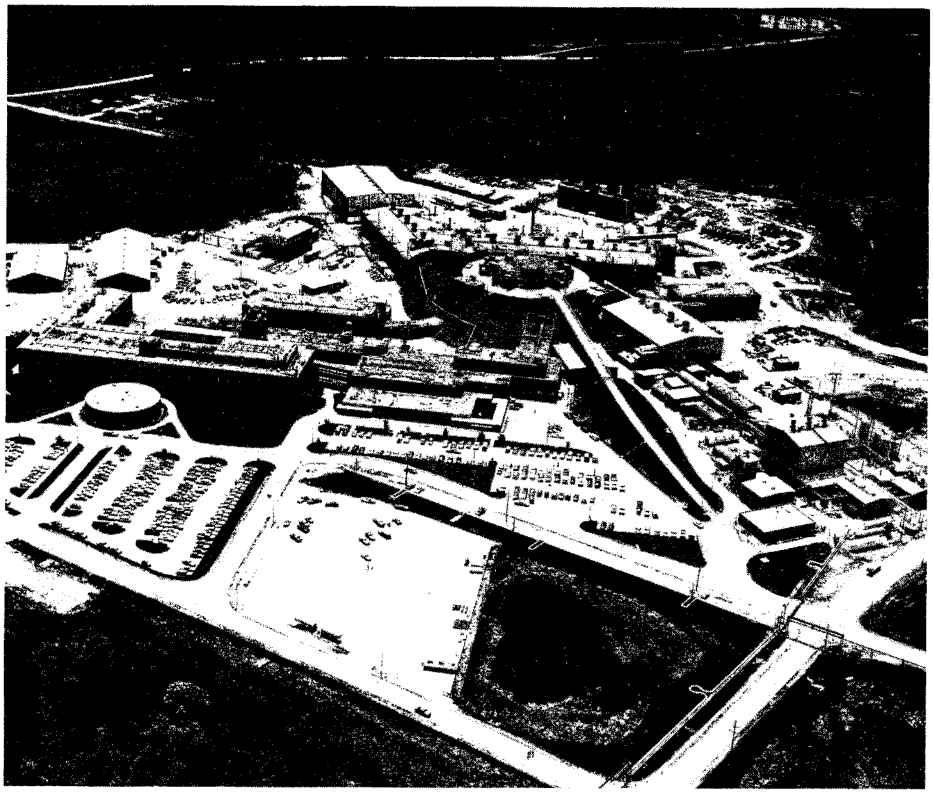
The early stages of construction of the ZGS ring. The Injector Building, Lab and Office Building, and Shop and Assembly Building (on the right) are already looking civilized.

Just over a year ago, on 1 October 1979, the Zero Gradient Synchrotron (ZGS) at Argonne National Laboratory accelerated its last pulse of protons. The accelerator, which operated for about sixteen years, played an important role in clarifying the nature of hadronic interactions during the period when this was of central interest in physics.

The productive lifetime of the machine could have been longer but budget restrictions, arising from the desire to push the energy frontier ahead in a time of constant overall funding, resulted in the closing down of lower energy programmes. Real scientific obsolescence was never at issue. The polarized proton programme, to which the machine had been dedicated during its last eighteen months of operation, was producing surprising and important insights into the effects of spin at both low and high energies. Similarly, the experimental programme using the unpolarized beam was producing interesting results to the end.

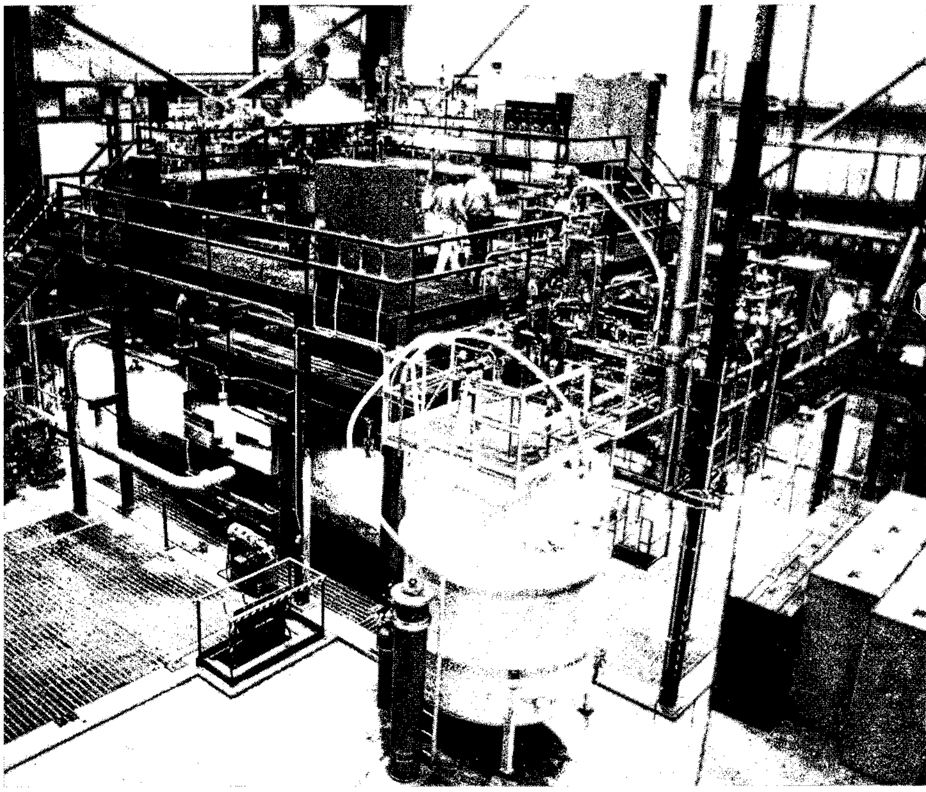
The beginnings of the ZGS can be traced to 1953, when a group of Argonne scientists began to study the design of possible high energy accelerators. A number of schemes were considered and in 1956 the Atomic Energy Commission (AEC) set some general guidelines about the parameters and construction schedule — the result was a 12.5 GeV proton accelerator using zero gradient magnets with vertical focusing being provided by the edge fields of the octants. In 1957 the design was approved and construction funding was authorized.

The ZGS was conceived to be a



The ZGS complex in its heyday. The 12 foot bubble chamber area is at lower right. An experimental hall is upstream of the chamber and other halls are on the opposite side of the ring.

The 12 foot hydrogen bubble chamber at Argonne where the use of large superconducting magnets was pioneered. The ZGS beam entered from the left. The tank in the foreground contained liquid helium for cooling the magnet while it was in operation.



regional facility to provide a powerful research capability for the universities in the Midwest of the United States. The Bevatron in California and the Cosmotron, later to be followed by the AGS, in New York provided good facilities for high energy physics on the west and east coasts, respectively. The ZGS more than fulfilled this mission and was seminal in fostering new research groups at many major universities throughout the central United States.

Its use was, of course, not restricted to Midwest groups and over the years 276 experiments were performed by users from 84 institutions in the USA and many other countries. The close interaction with the university community through the ZGS Users Group, founded in 1958, and the system for the approval of proposed experiments served as a model for other Laboratories. In particular, the user physicists had a strong voice in determining future directions of the research programme, and they collaborated with Argonne scientists and engineers in the design and construction of many kinds of new research tools. The desire of university physicists to have a more formal means of participating in the management of Argonne led to the founding of the Argonne Universities Association, which now plays an important role in formulating Argonne policy and in the peer review of its scientific programmes.

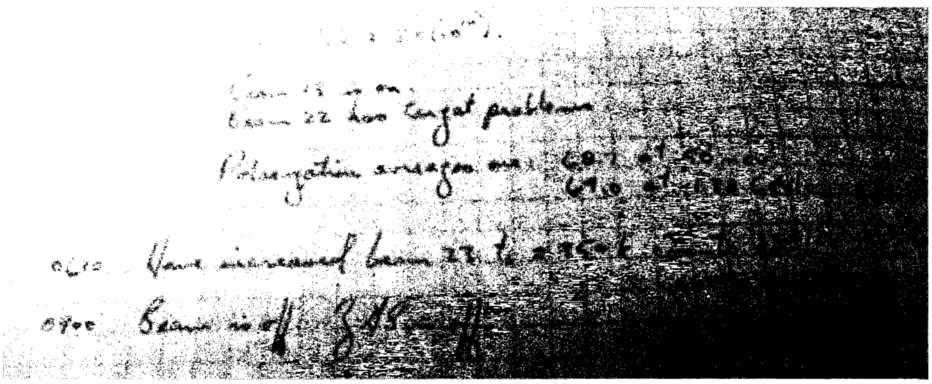
There were a number of pioneering aspects at the ZGS that became standard features for accelerators in later years. One of the more notable was the heavy use of experimental areas served by external proton beams in which several experiments, set up in series, could take data simultaneously. The multiplicity of simultaneous experiments was further increased by the development of proton beam splitting. During the peak years as many as ten simultaneous experiments were provided with particles.

In addition to the accelerator itself, a full complement of experimental equipment was built. In the early days particle separators, Cherenkov counters, spectrometer magnets, a meson focusing horn for the neutrino beam and an array of bubble chambers were brought into operation. The first bubble chamber was the 30 inch hydrogen chamber, built by a collaboration of Midwest universities, notably Wisconsin and Purdue. This chamber had superb resolution with good optics and a 3.2 T magnetic field. It was one of the most reliable ever built, taking over ten million pictures during its operation in the separated beamline. Its experiments covered the whole range of SU3 spectroscopy induced by pion, kaon and antiproton beams. A first attempt to provide a polarized proton beam was also carried ou here.

The 30 inch chamber moved to Fermilab in 1971, where it provided the first bubble chamber studies of high energy collisions and is still operated occasionally. Two other conventional bubble chambers followed the 30 inch into operation at Argonne, the 20 inch Northwestern University helium bubble chamber and the 40 inch Michigan University heavy liquid bubble chamber.

The first practical demonstration of superconducting magnets came with the operation at the ZGS of a 10 inch helium bubble chamber in 1967. The magnet was built with twisted cable made of superconductor developed at Argonne. During the first experimental run 476 000 pictures were obtained in a 25 day period. Most were of stopping nega-

The final entry in the ZGS logbook on 1 October 1979: '0900 Beam is off. ZGS is off.' The first entry in the logbook dates back to 13 August 1963.



tive kaons in helium for the Argonne/Carnegie Mellon collaboration that had built the chamber. This superconducting magnet is now on display at the Smithsonian Institution in Washington.

Neutrino physics was always considered a prime area of research for the machine, and in June 1964 a proposal was submitted to the AEC to build a 12 foot hydrogen bubble chamber as a simple target for neutrino beams. Approval was given the following January and in June 1965 it was decided to use a superconducting magnet. Despite the innovative nature of many systems of the chamber, the first pictures were taken in September 1970. When the chamber was closed down in 1978, close to 7 million pictures had been obtained for seventeen different experiments. Although the career of the 12 foot chamber has ended, the pioneering superconducting magnet lives on as part of the new High Resolution Spectrometer being constructed at PEP by an Argonne/Berkeley/Indiana/Michigan/Purdue/SLAC collaboration.

The prodigious amount of film being produced by the Argonne bubble chamber demanded rapid analysis and this problem was successfully attacked by the construction of a series of 'POLLY' measuring devices using the new idea of close interaction between an on-line computer and the operator.

Another visual device, a streamer chamber, was built by an Illinois/Argonne collaboration and came into operation in 1972. A series of experiments was conducted on backward production of mesons, as well as studies of pion-pion elastic and inelastic scattering.

A simple but well engineered spectrometer was built to study meson spectroscopy (the split A_2 was used to set the scale of accuracy needed!). The resulting detector, called the Effective Mass Spectrometer (EMS), became the focus of experiments in many other areas of physics. During its eight years of operation it was used for 21 experiments, nearly half of them with the polarized proton beam. In 1975 the beamline feeding the EMS was rebuilt using superconducting magnets and, in its new form, was operated routinely for four years. At the time of its commissioning, it was the only superconducting beamline in existence.

The need for wider ranges of measurements in spin physics led to the development of polarized targets. Beginning in 1965 with a simple target (using a lanthanum magnesium nitrate crystal for an experiment to measure the spin and parity of the N*(2190) resonance in pion-proton elastic scattering) a progression of targets were designed and constructed at Argonne. The most recent, PPT-IV, was used with the polarized proton beam to measure nine observables which allowed the determination of the five proton-proton scattering amplitudes. For part of this programme a longitudinally polarized target was used together with a longitudinally polarized beam.

The ZGS itself underwent constant improvement during its lifetime. Development of diagnostic devices provided better understanding of beam characteristics. A new set of vacuum chambers, made of titanium and incorporating pole-face windings to trim the main guide field, were built and installed. The resulting simultaneous slow extracted

After pushing the button to turn off the ZGS a year ago, Ron Martin (left), who was Director of the Accelerator Research Facilities Division for many years, addressed the group gathered in the Main Control Room to witness the shutdown.

Members of the Accelerator Research Facilities and High Energy Physics Divisions, along with others involved in ZGS operation, on the last day of ZGS running.

(Photos Argonne)

beams to both external proton experimental areas had very good spill quality. An intensity improvement programme was based on negative hydrogen ion charge-exchange injection and the use of a rapid-cycling booster injector. Eventually, negative hydrogen ion injection alone accounted for the record ZGS intensity of 7×10^{12} protons per pulse achieved during the last neutrino run in 1977.

The development of rapid cycling synchrotrons led to the construction of a 500 MeV machine initially intended as the ZGS booster. It is now in routine use as a pulsed slow neutron source and serves a large community of scientists for condensed matter studies.

In the original design of the ZGS, consideration was given to the possibility of accelerating polarized protons and in 1970 this idea was taken up again, since by that time a practical polarized proton source had been developed for nuclear physics. Three years later the first polarized protons were injected and accelerated to 6 GeV. With this achievement the ZGS became a unique source of high energy polarized protons.

The accelerator also developed a split personality — operating for a number of months in the conventional (unpolarized) mode and then switching to operation with polarized protons. This alternating system continued until March 1978, when the ZGS became dedicated exclusively to polarized beam operation. In the fall of 1978 polarized deuterons were accelerated to 12 GeV yielding an effective 6 GeV polarized neutron beam. The polarized proton beam intensity and polarization were steadily improved and during the last months of ZGS operation a beam energy of 11.75 GeV and an intensity of several 10^{10} protons per pulse were achieved with a polarization of 70 per cent.

In addition to its contributions to high energy physics, the ZGS programme, which was only a part of the activities in a large research Laboratory, has had spin-off impacts on a range of technologies. Many skills and devices developed for the needs of high energy physics research have been transferred over the years to other programmes at Argonne. The superconducting magnet group became expert in building magnets for magnetohydrodynamics, accelerator physicists are working on controlled thermonuclear fusion, the solar energy programm is developing a non-imaging light concentrator first built for a Cherenkov counter, and the negative hydrogen ion injection technique is crucial to the success of the Intense Pulsed Neutron Source. A major new programme that grew out of the accelerator activities is heavy ion fusion which is now under intense development. It is clear that the energies and talents that created and exploited the ZGS while at the same time looking for new areas to explore, constitute an invaluable resource for other high technology programs.

The research programmes of the Argonne high energy physics groups are being continued using Fermilab, PEP, and LAMPF. In addition the expertise in accelerator technology is being brought to bear on problems of antiproton cooling and collection at Fermilab and the challenge of accelerating polarized protons on the Brookhaven AGS.

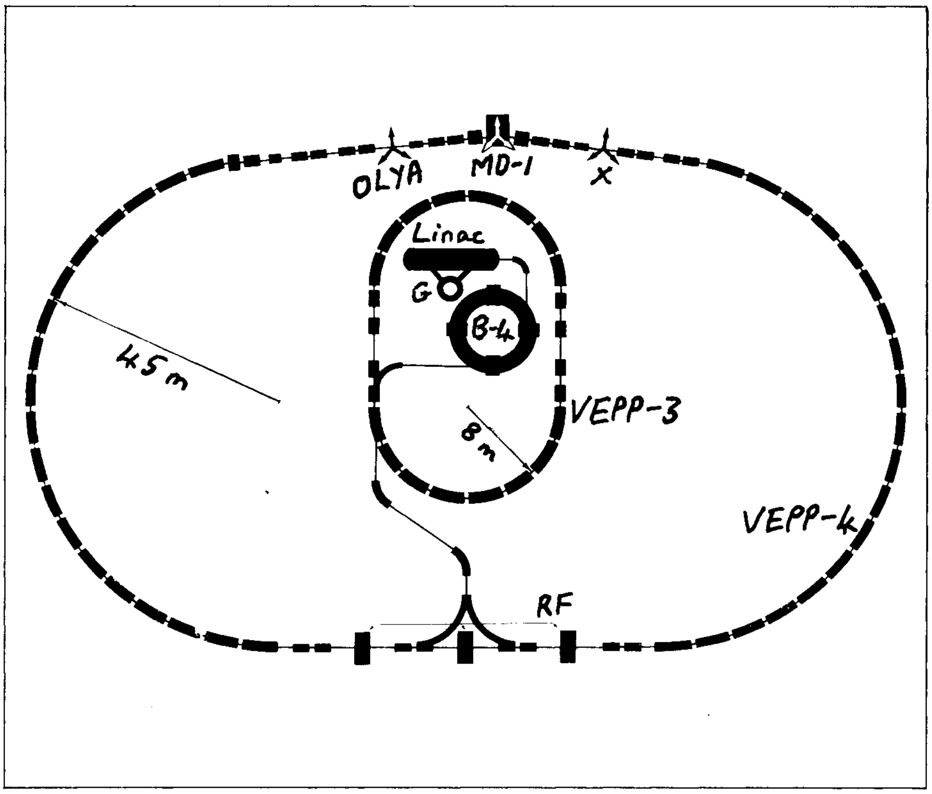
This article provides only a skeletal picture of the activities centred around the ZGS. Nothing has been said of the many people who dedicated a good fraction of their careers o the programme and its achievements but, at the Symposium on the History of the ZGS held in September 1979 at Argonne, it was apparent that all of the participants were proud of their associations with the ZGS and viewed its passing with regret. The proceedings of the symposium, published by the American Institute of Physics (AIP Conference Proceedings No. 60), provide a graphic view of the ZGS era, ranging from political climates to scientific and technical achievements.

NOVOSIBIRSK VEPP-4 begins experiments

The 7 GeV electron-positron storage ring VEPP-4 at the Institute of Nuclear Physics, Novosibirsk, has been brought into action at low energies (up to 3 GeV per beam) and has started experiments in the J/psi particle mass region. The maximum luminosity achieved so far is 3×10^{28} per cm^2 per s at 1.85 GeV with currents of 0.85 mA per beam.

VEPP-4 uses a modified configuration of the VEPP-3 storage ring as injector. VEPP-3 is operated as a booster and is fed by the B-4 synchrotron at an energy of 350 MeV operating at 1 pulse per second. The synchrotron receives electrons and positrons at 7 MeV, positrons coming from a convertor bombarded with 45 MeV electrons from a high current linac. The linac is powered by a gyrocon (the new technique of producing r.f. power invented at Novosibirsk which was described in our July 1977 issue, page 231) operating at 30 MHz with a power of 60 MW and pulses of 11 ms.

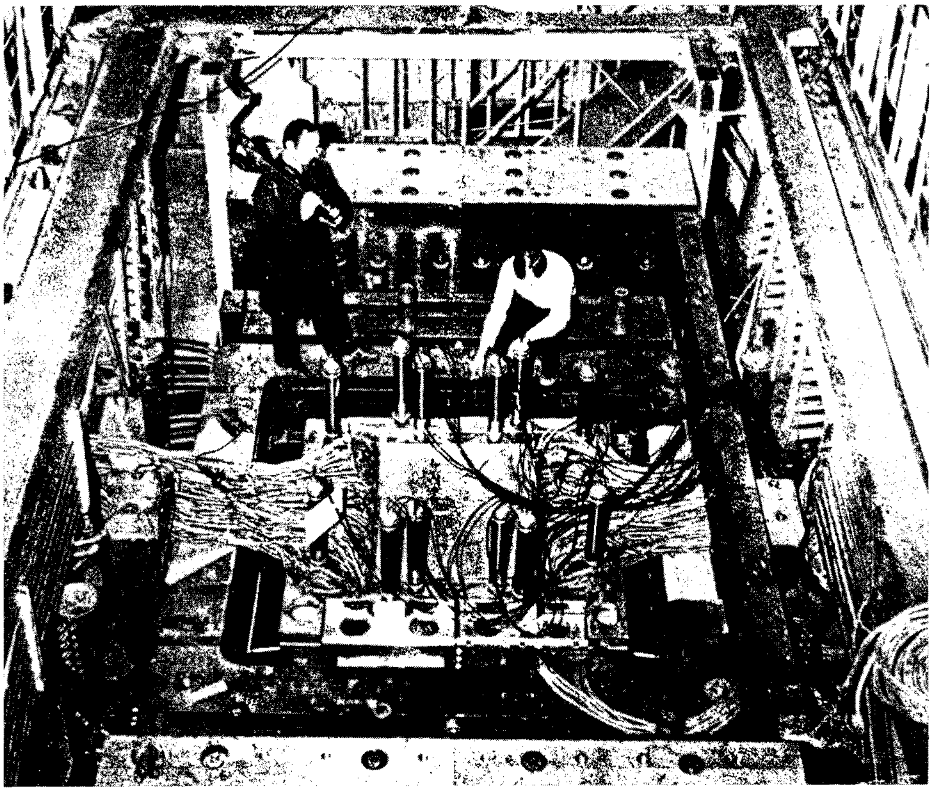
The VEPP-4 ring itself has two arcs of magnets of 45 m radius arranged in such a way as to leave two straight sections, one 40 m long (used for injection and r.f. cavities) and one 55 m long (used for three beam collision regions in series). The central collision region will have a magnetic detector, MD-1, with transverse magnetic field which is part of the magnetic lattice of the ring. MD-1 will be installed towards the end of this year and initial operation has been carried out with other magnets in its place. One of the other collision regions has the detector called OLYA already installed and it



Schematic drawing of the 7 GeV VEPP-4 storage ring configuration at Novosibirsk. The linac is powered by a gyrocon and feeds a synchrotron, known as B-4, with both electrons and positrons. The previously existing storage ring VEPP-3 is used to boost the energy before transferring the particles to VEPP-4. There are three beam collision regions in series in the same straight section. The central position is occupied by the magnetic detector MD-1 which is part of the magnetic lattice. The detector OLYA is in another.

The magnetic detector MD-1 with the upper part of the magnet removed. It is hoped to complete the detector and install it in VEPP-4 before the end of the year.

(Photos Novosibirsk)



is this detector which has been used in the first experiments.

The r.f. system for the main ring will also use a gyrocon and it is delays in bringing this unit into action which have limited initial operating energies to those corresponding to the J/psi mass, since the alternative existing r.f. power sources could not cope with the synchrotron radiation at energies near 7 GeV. It is however expected to push the energy per beam to 5.5 GeV before the end of the year and thus carry out a detailed study of the upsilon mass region. The first experiments have included very precise measurements of the psi and psi prime particle masses using the technique developed on VEPP-2M where the K and phi measurements were improved also using the OLYA detector (see June 1977 issue, page 192). The technique uses the resonance depolarization of electron and positron beams, polarized in VEPP-3, to give an absolute energy of calibration to better than 10^{-4}. The resulting data gives the J/psi mass as 3096.93 ± 0.09 MeV and the psi prime mass as 3686 ± 0.1 MeV, an improvement in accuracy by a factor of more than twenty.

DARMSTADT Heavy ion beams for the future

A new facility to provide higher energy beams of heavy ions has been designed at GSI Darmstadt. It consists essentially of adding a synchrotron to the upgraded existing UNILAC linear machine so as to move the peak energy up to 14 GeV per nucleon. The new machine goes by the name of SIS for Schwerlonen Synchrotron.

The interest in heavy ion beams is widespread for research into many aspects of nuclear and atomic physics as well as radiobiology and radiotherapy. The linear accelerators Superhilac at Berkeley and UNILAC at Darmstadt are now providing beams of many types of ion up to 10 MeV/amu. For very refined experiments in this energy range the 30 MeV tandems at Daresbury and Oak Ridge are coming into action. They will be joined by cyclotrons at Caen (GANIL), at Michigan and possibly at Munich (SUSE).

The converted proton machines — the Dubna Synchrophasotron, the Berkeley Bevalac and Saturne II at Saclay — extend the energy as high as 3.5 GeV/amu though for a more limited range of ions at present. For the future there are proposals at Tokyo (the Numatron synchrotron and stacking ring) and, to cover an energy range up to 20 GeV/amu, at Berkeley (the VENUS project allowing colliding beams — see December issue 1979, page 406), at Dubna (the Nuklotron) and at Darmstadt (the SIS).

For SIS it is hoped to develop ion sources to provide currents as high as 10 mA, stripping off electrons to produce highly charged states which are most useful for acceleration. The injected currents into the upgraded UNILAC, used as injector for the synchrotron, are hoped to provide two or three orders of magnitude higher ion beam intensities than presently obtainable.

For the synchrotron ring, conventional magnets were selected rather than superconducting because of the faster rate at which they can be pulsed. The ring, almost 800 m diameter, will have 128 bending magnets and 80 quadrupoles. The bending magnets will be of the window-frame type capable of a peak field of 1.8 T. The vacuum will be down to 10^{-11} torr so as to retain the intensity with all ion charge states. The r.f. system will have 12 cavities which will need to cover frequencies from 0.83 to 7.6 MHz to cover the energy range for all types of ion.

An upgrade of UNILAC to provide peak energies up to 25 MeV/amu and higher intensities is already under way. This will serve also to improve its suitability as an SIS injector. Construction of prototype SIS machine components has started.

KARLSRUHE/ JÜLICH SNQ project

For about a year a study has been under way in the Federal Republic of Germany (particularly at the nuclear research centres of Karlsruhe and Jülich but with participation from the Universities, industry and other research centres such as SIN and CERN) to design an accelerator facility for research with neutrons. It is nown as SNQ (Spallations-Neutronenquelle) and a preliminary design report has been issued.

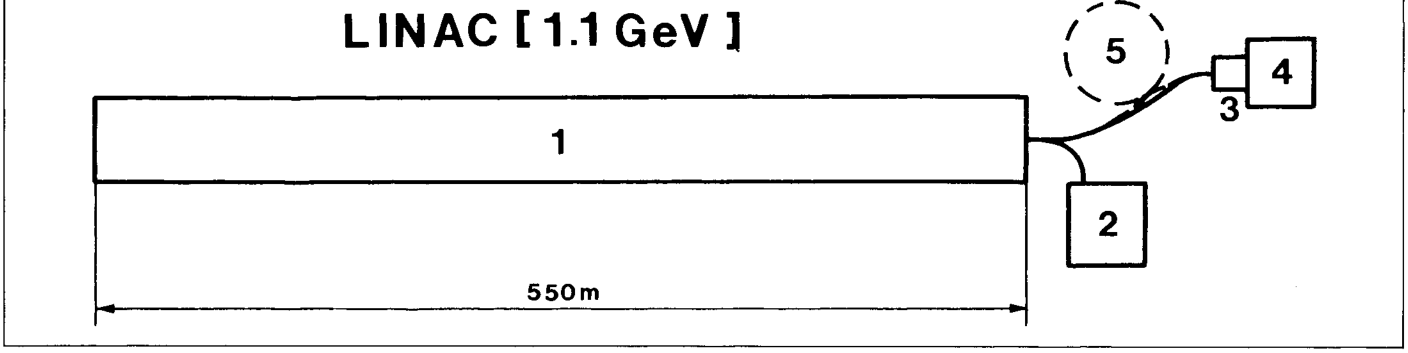
Research with neutrons has moved to accelerator-based facilities in recent years since this is the only feasible route to higher neutron fluxes than can be obtained from nuclear fission reactors. The high fluxes, both quasi-continuous and pulsed, are required for experiments in the physics of condensed matter, chemistry, biology and medicine, and there are some applications in nuclear and particle physics, in particular for neutrino experiments, as well.

These research interests have been reflected in the number of projects which have been proposed. Los Alamos has a neutron laboratory at the 800 MeV LAMPF proton linac and a storage ring is being built to extend the neutron research possibilities. From next June pulses will be available for the production of neutrons from the 500 MeV synchrotron in the BSF Booster Synchrotron Facility at KEK. At Argonne, physics with neutron beams began in 1978 on the Booster which had been intended for the ZGS, and the IPNS Intense Pulsed Neutron Source is being prepared (see September issue 1978, page 301). At Rutherford an 800 MeV proton synchrotron is being built as the SNS Spallation Neutron Source (see May issue 1976, page 170), to replace the NIMROD proton synchrotron.

The goal of the design study in Germany is a neutron source with time-averaged thermal fluxes comparable with those of a high flux fission reactor and with time structure optimized for thermal neutron scattering. Proton pulses with 0.5 ms pulse width and 100 pulses per second were specified for the SNQ. For this reason the study settled on a 1.1 GeV proton linear accelerator as there is now confidence in the feasibility of high intensity, high energy linacs. The power requirements and particle losses should be lower than in an equivalent synchrotron. The linac is 550 m long and has two injectors so as to have a source in reserve. The first seven accelerating tanks are of Alvarez structure, each 12 m long, operating at 108 MHz to give an output energy of 105 MeV. The rest of the linac consists of 64 tanks of disc and washer structure operating at 324 MHz. It is hoped to achieve a peak output current of 100 mA and an average current of 5 mA.

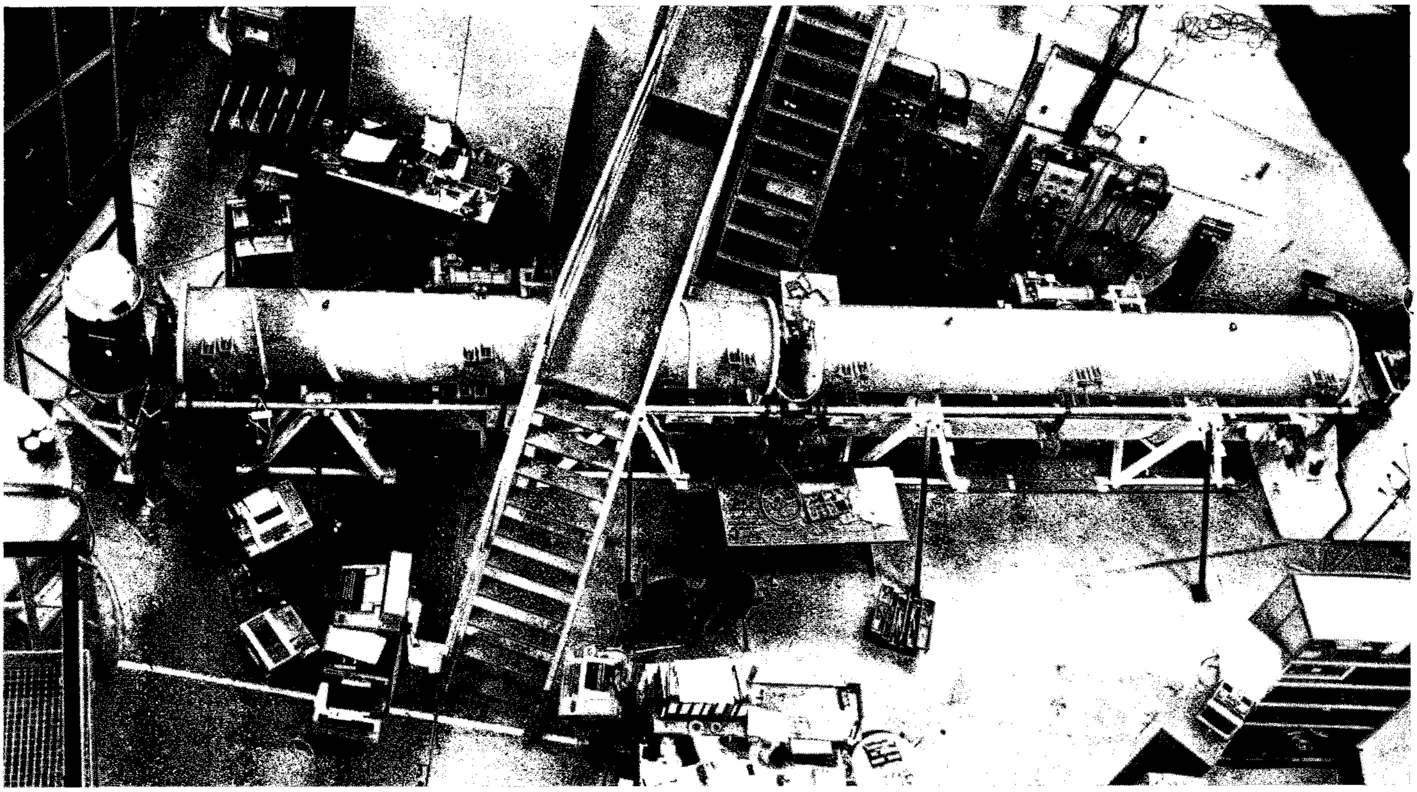
As an option for shorter pulses of even higher intensity, a 'compressor ring' is envisaged to stack the particles and then send them to the neutron production target with single turn ejection. A ring of 60 m diameter has been studied to cater for high space charge, to stack the trains of incoming particles from the linac and to eject a compressed pulse cleanly.

Schematic drawing of the components of the proposed SNQ spallation neutron source now under study in the Federal Republic of Germany. A 1.1 GeV linac (1) would feed an experimental hall (2), the neutron production target (3) and the neutron hall (4), with, as an option, a compressor ring (5) and possibly a second target for the production of short high energy pulses.



A CERN/Padua/Rutherford/Sussex collaboration is to carry out an experiment at the high flux reactor at the Institut Laue-Langevin (ILL), Grenoble, to look for the neutron-antineutron transitions predicted by some grand unified theories. It will use the H18 cold neutron beam, seen here in use for a previous experiment by a Bayreuth team looking for neutron electric charge. The H18 beam exit is on the right.

(Photo ILL)



A lot of study has gone into target design to minimize problems of heat and maintenance, and to maximize the flux of neutrons produced by spallation. The resulting design has a lead target wheel rotating between water moderators.

Studies are continuing and a final report is expected in May 1981.

CERN/ILL Looking for neutron-antineutron oscillations

CERN is one of the participants in a new experiment which illustrates well a trend in physics thinking. Recently it has become clear that the continual quest to simplify our description of Nature could be on the verge of a major new breakthrough. With the once separate theories of weak and electromagnetic phenomena now apparently unified, theoreticians are becoming bolder and are proposing ambitious 'grand unification' schemes which encompass both the strong and the electroweak interactions (see November 1978 issue, page 116).

One outcome of these latest proposals is that the proton, traditionally considered a stable particle, could in fact be unstable (see May 1979 issue, page 116), and experiments are under way to put the grand unified theories to the test by looking for signs of proton decay (see May issue, page 114, where incidentally the project in a Utah silver mine should have been attributed to Harvard/Purdue/Wisconsin and not Harvard/Pennsylvania/Wisconsin).

As the proton is the lightest baryon, its instability would mean the end of baryon number as an absolute conservation law. Exact conservation laws in physics, such as those of energy momentum and electric charge, are the result of deep symmetries. However no symmetry has yet been found to account for the apparent conservation of baryon number, and physicists are justified in looking for its violation.

To this end, some new particle physics experiments are leaving their traditional stamping grounds at high energy accelerators. Proton decay studies are being mounted deep underground, and now a new type of experiment, looking for a different manifestation of baryon non-conservation, is scheduled for the high flux reactor at the Institut Laue-Langevin (ILL), Grenoble.

It has been suggested that the neutron and its antiparticle could mix. While this is inconceivable in conventional terms, it is allowed in grand unified schemes in much the same way (although for different reasons) that the two neutral kaons (which also are mutual antiparticles) can mix in weak interactions. This would mean that particle states contain both neutron and antineutron components giving, in principle, a continual oscillation between neutrons and antineutrons with a definite cycle time. The new experiment, to be carried out by a CERN/Padua/Rutherford/Sussex collaboration, will look for signs of such neutron-antineutron transitions.

Current grand unified theory dogma gives a proton lifetime of the order of 10^{31} years, which implies that neutron-antineutron oscillations could take place over a cycle of about a year, although much shorter oscillation times cannot yet be ruled out.

Neutrons (and therefore antineutrons) carry no electric charge, but neutrons and antineutrons have equal but opposite magnetic moments. Thus neutrons and antineutrons have different energies in a magnetic field, which would suppress any mixing. In order not to spoil the oscillations, the experiment has to be carried out in a very low magnetic field. Because of the different interaction properties of neutrons and antineutrons with matter, the search also has to be carried out in a high vacuum.

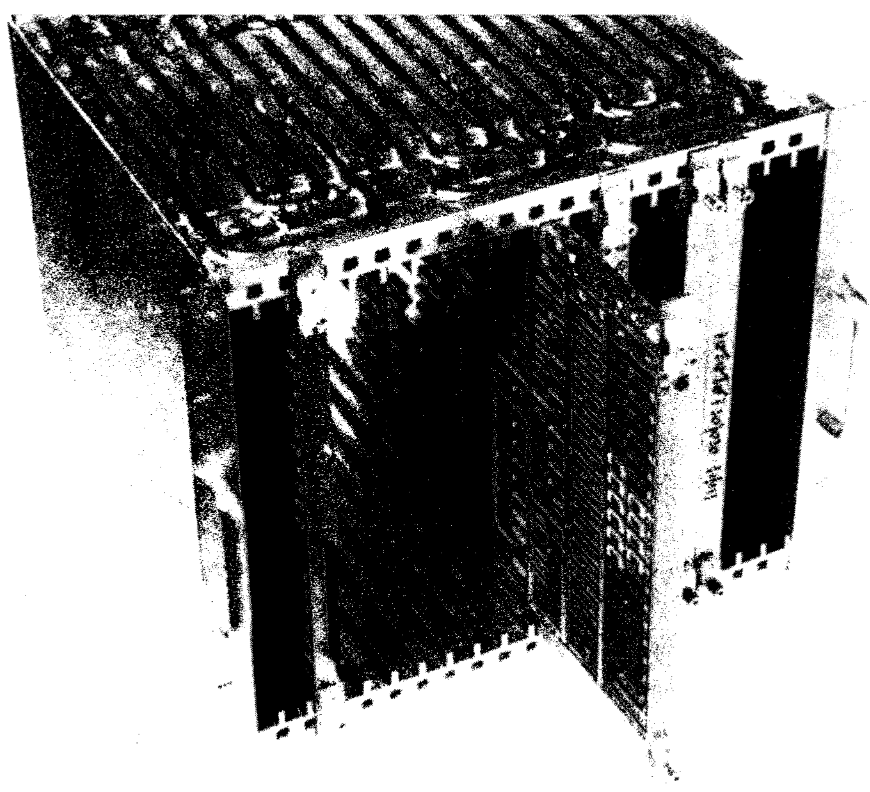
In addition, the experiment requires a high flux of neutrons, together with a long observation time for any given neutron. This led the experimenters to choose a beamline using cold neutrons. Reactor core conditions provide high flux, but the large average temperature of the neutrons restricts the observation time. On the other hand, loss of coherence on the walls and the low density of ultra-cold neutrons would reduce the sensitivity of experiments using neutron storage vessels, which would otherwise appear attractive propositions.

The ILL cold neutron beam will be passed through a 3 metre vacuum chamber, magnetically shielded by three concentric layers of mu metal to minimize effects due to the earth's magnetic field (the residual field is estimated to be some 10^{-4} gauss). Any antineutrons would be detected by total absorption in a lead/scintillator sandwich — the annihilation of an antineutron would release some 2 GeV of energy and produce particles. The apparatus is housed in a 20 cm thick iron blockhouse, and an anticoincidence counter minimizes stray events from cosmic rays. Further cosmic ray shielding is provided by the concrete and steel cladding of the ILL reactor and experimental hall. The experiment is scheduled to begin running in October.

Some of the participants in the collaboration are used to working at nuclear reactors, while others have a particle accelerator background. This unusual combination of skills gained from both high energy and low energy studies is well-suited to a search which, if successful, would transform new physics thinking into experimental fact.

BROOKHAVEN
Catching the Fastbus

The development of standard interface techniques, like CAMAC, has been one of the big spin-off successes in high energy physics. However despite CAMAC's widespread use in high energy physics and in laboratory instrumentation in general, it has become evident in recent



The high energy instrumentation of the future? A water-cooled 'Fastbus' crate built for an experiment at Brookhaven.

(Photo Brookhaven)

Group photograph taken on 16 July at the first successful operation of the BOOM meson line.

(Photo T. Yamazaki)

years that something else is required which offers increased speed, scope and flexibility to cope with the more stringent demands of new experiments.

The Fastbus data acquisition system has emerged as one of the leading contenders to inherit the CAMAC mantle. A first application, using fast integrated circuits, has been implemented at Brookhaven in an experiment (using over 200 scintillation counters) which looks for delicate symmetry breaking effects in kaon decays (see June issue, page 156). First operation has been satisfactory.

The requirements of the data acquisition system are similar, but not identical, to those of a computer. The Fastbus solution, although based on computer bus (data pathway) design, has been tailored to meet the needs of high energy physics.

It is very quick — in fastest mode a 32-bit word can be transmitted in something like 40 nanoseconds. It is segmented so that many different processes can be handled simultaneously, and can be configured to suit a wide variety of experiments. Single segments can accommodate small experiments while multiple segments can be brought together in large numbers for big experiments or major detectors.

Over 4×10^9 storage locations are available, and the computer-like architecture of the system makes interfacing to computers easy, so that rather than taking the data to the computer, the computer can be brought to the data.

Modules built so far at Brookhaven include a data processor, an interface to an external PDP-11 computer, coincidence latches with 3 nanosecond resolution (providing the main input path for event data), a scaler, a microclock, a 60 nanosecond memory and a predetermined time module for synchronization and input/output handling.

With the advent of Fastbus, its designers can foresee systems with computer-set parameters, and experiments with computer-controlled trigger logic. This could have a major impact on experimental procedure.

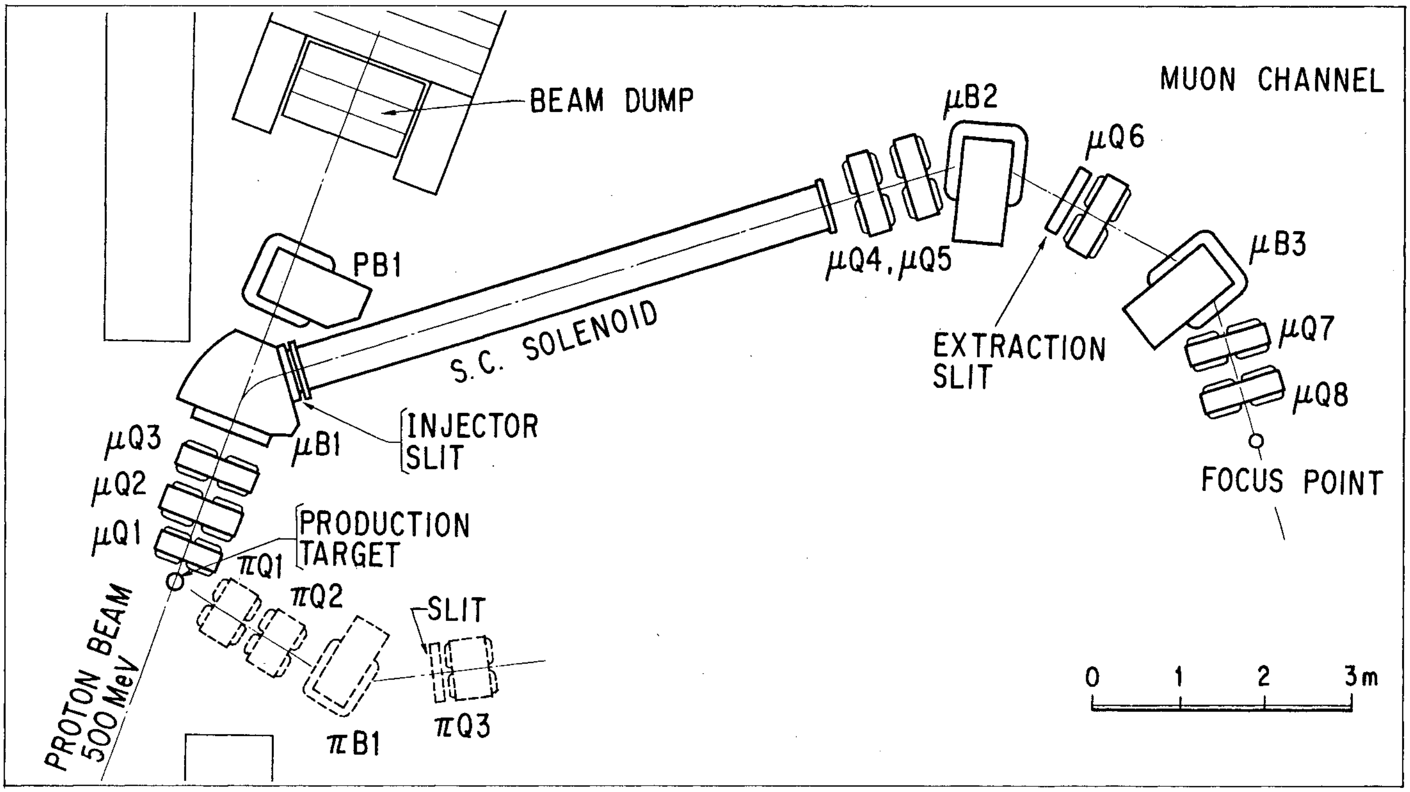
TOKYO/KEK Muon BOOM

The Meson Science Laboratory of the University of Tokyo has completed a pulsed meson facility at the KEK booster. The Tokyo Laboratory was set up in 1978 to promote meson research and the first task, under the leadership of Ken Nagamine with H. Nakayama and J. Imazato, has been to construct a superconducting muon channel at the KEK 500 MeV booster synchrotron. The facility goes under the name of BOOM and produced its first muons on 16 July.

The channel is of similar design to the muon channel at SIN but with some different features. It has a superconducting solenoid producing a field of 5 T in a 12 cm bore, 6 m long. The cylindrical iron yoke is at room temperature reducing cool-down time to 4.5 K to 30 hours. The coils are cooled by means of a single supercritical heat exchanger built on the side of the refrigerator cold box to simplify the cryostat structure of the solenoid. The solenoid has been operating stably and reliably.

Backward muons are extracted from the solenoid and pass through an achromatic beam transport system. A small beam spot is then possible without collimation. In preliminary tuning a beam spot of 5 cm diameter was obtained. The KEK booster has an unusual time struc-

Layout of the new BOOM pulsed meson facility set up by the Meson Science Laboratory of the University of Tokyo using the KEK 500 MeV Booster.



ture — 50 ns pulses every 50 ms — which gives extraordinarily sharp neson pulses from BOOM. The intensities are 10^5 positive muons per pulse or 2×10^6 per second. The negative muon intensities are a factor of four down. The average intensity is limited by the proton beam intensity in the booster, 6×10^{11} protons per pulse, but is already comparable to muon fluxes at existing meson factories. The instantaneous intensity produced by a booster bunch, corresponding to 10^{11} positive muons per second, is unique.

The pulsed nature of BOOM is well-suited to the study of delayed phenomena over a long timescale since with the sharp muon pulses there is virtually no background. For example a muon to electron decay time spectrum as long as 10 μs can be obtained. This was achieved in a preliminary run without any collimator or shield. Normally such measurements are difficult because of the unavoidable constant background of muons and of various sources of beam-produced electrons.

The importance of slow relaxation of muon spins has been recognized in a series of experiments of the Tokyo group at TRIUMF. The BOOM facility is expected to be ideal for such purposes. Furthermore, due to the extremely small duty factor (10^{-6}) it offers unique opportunities to apply extreme external conditions, such as r.f. fields and laser pulses.

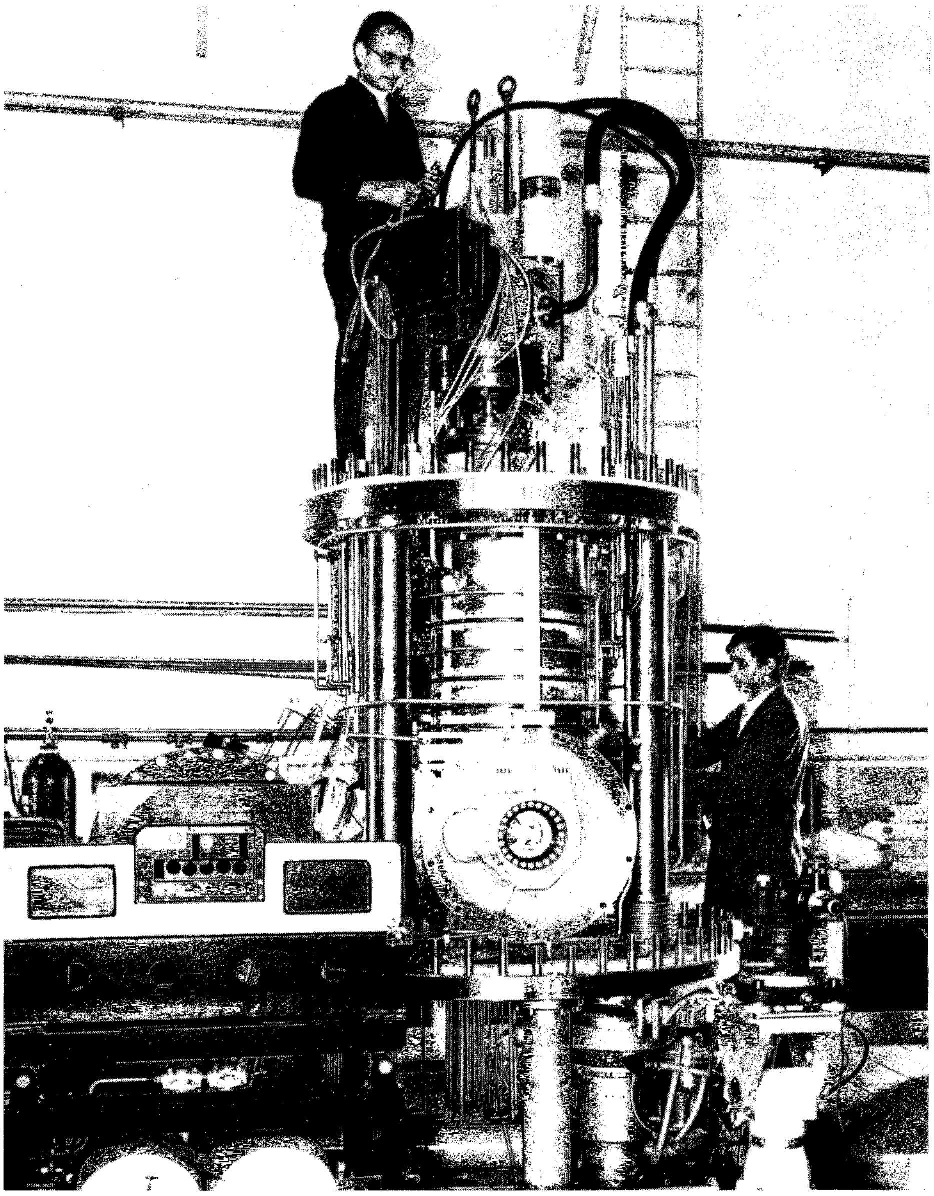
BOOM will be used for experiments after October of this year. It is hoped that it will not only be used by Japanese physicists, but will also complement the world's existing meson factories. Proposals or comments to assure the most effective and productive use of BOOM should be communicated to Toshimitsu Yamazaki, Professor of Physics at the University of Tokyo. The Japanese team is also eager to sustain its present overseas activities using high intensity continuous beams at the meson factories.

CERN
Sigma clocks tick ideally

The experiment carried out at CERN in the HYBUC very high field hydrogen bubble chamber several years ago has yielded another piece of information from its study of sigma particles. It has shown no observable change in the expected lifetime of the sigma despite the particle experiencing average decelerations in the chamber liquid of up to some 10^{15} g. The clock dictating the particle lifetime ticks away 'ideally' regardless of the accelerations

Installation of the HYBUC very high field bubble chamber, where the behaviour of sigma particles has shown that despite strong decelerations, the special theory of relativity holds good.

(Photo CERN 178.10.70)



and is in perfect agreement with the calculation from special relativity.

This result could be anticipated by simply consulting the Particle Data Tables which contain measurements of sigma lifetimes both in 'free flight' and in nuclear emulsion where they experience strong decelerations. The measurements agree to within a few per cent. Also the g-2 experiment at CERN measured muon lifetimes in conditions where the muons were experiencing transverse accelerations, as they orbited the storage ring, of 10^{18} g. Again no change compared with the anticipated lifetimes was detected. Thus both longitudinal and transverse accelerations over the measured range do not measurably affect particle clocks, which tick at a rhythm dictated by their velocity.

The HYBUC result was reported in the 17 July issue of 'Nature'. The experiment observed some 120 000 sigmas subject to decelerations ranging from 0.5 to 5×10^{15} g with instantaneous values as high as 10^{22} g. The sigmas were in the 200–650 MeV momentum range which is appropriate for studying possible deceleration effects since the average lifetime is then a significant fraction (40 per cent in the case of the negative sigmas and 21 per cent in the case of the positive sigmas) of the distance the particles could travel before they came to rest. There was no measurable variation of the lifetimes as a function of the variation of the longitudinal deceleration, to within an accuracy of a few per cent.

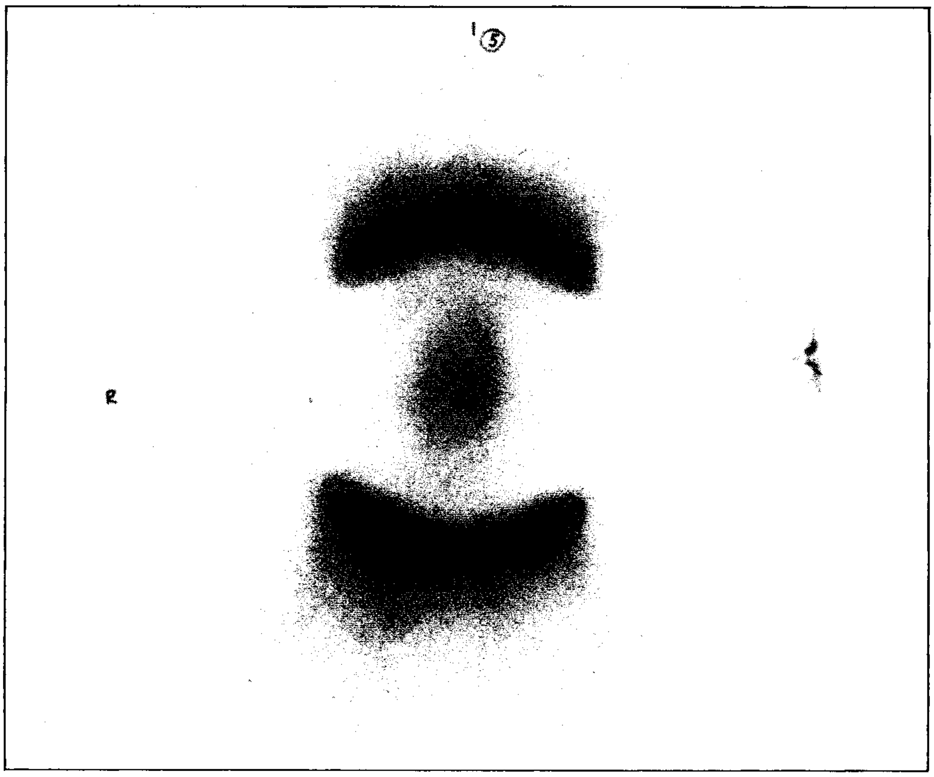
SIN
First beam from medical channel

The first negative pion beam from the SIN Piotron (see September 1977 issue, page 285) was extracted on 22 June. This large acceptance angle superconducting pion channel has been designed and constructed as a dedicated cancer therapy facility.

The initial performance indicates that the beam geometry and intensity already approach design specifications. The unique configuration of sixty pion beams converging to an isocentric 'hotspot' will allow the radiotherapists to treat complex three-dimensional tumour volumes by means of dynamic scanning; either moving the patient (and the tumour volume) about the isocentre (raster scan) or changing beam momentum and operating individual beam slit shutters (ring scan).

Preliminary measurements indicate that the pion dose rate is approximately 140 rads/min for a spot of 44 mm in all dimensions with

Radiograph of two sectors, each of fifteen beams of negative pions, stopping in a lucite cylinder. The central spot is the overlapping of contaminating electrons and muons from the thirty beams. The target material was beryllium, the pion momentum 170 MeV, the diameter of the lucite cylinder 46.7 cm and the diameter of the film 34.8 cm.



a beryllium target of 30 mm length in a water phantom of 46.7 cm diameter. This assures that patient treatment times will be within reasonable limits. Measurements of beam optics to date indicate minor aberrations which are under further study. The performance of the target assembly, the helium cooling system, the magnet coils, and the slit shutters are all satisfactory.

A pion rate meter (the pion 'clock') is also performing well. It will be used as the basis for the delivery of the treatment dose to the patient.

If all proceeds well, it is anticipated that the first patients will be treated before the end of the year. This first clinical phase must be preceded by further dosimetry and by radiobiological experiments. The initial treatments will be given to patients with multiple superficial and subcutaneous tumour metastases, similar to the initial clinical phase of the pion therapy facility at TRIUMF (see July issue, page 200). Thereafter deep-lying advanced malignant tumours will be treated. Potential initial sites include tumours of the bladder, uterus, rectum, pancreas and liver.

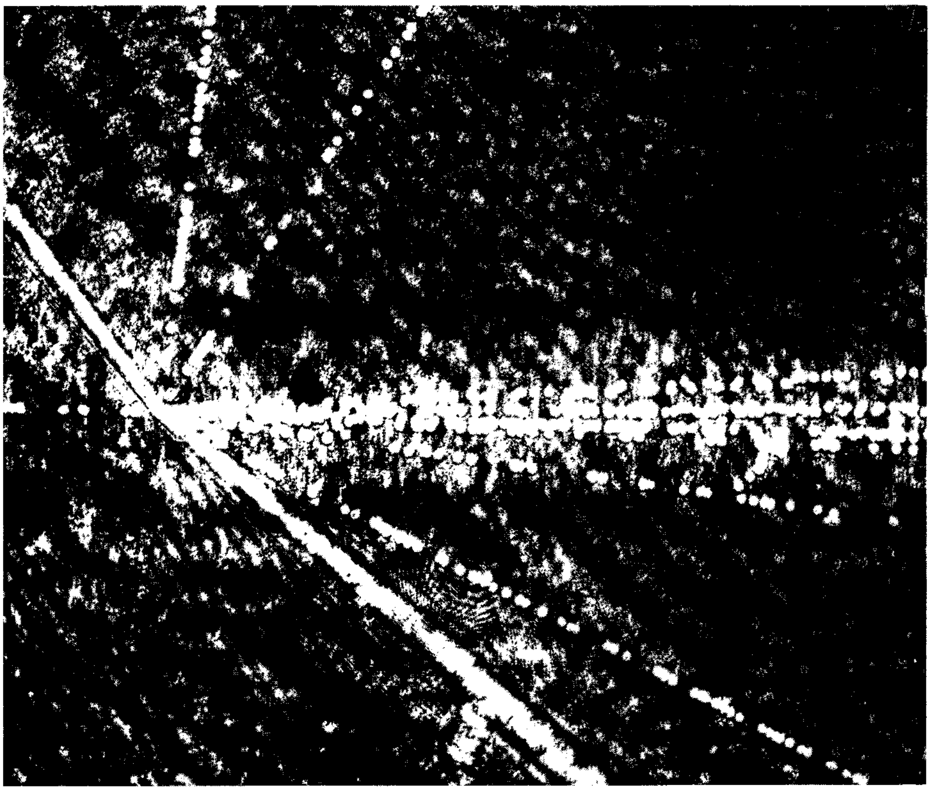
A CAT scanner specially adapted for treatment planning is already operating at the nearby Canton Hospital of Aarau. Patients can be referred from throughout Switzerland as well as from abroad.

Now complete is the 1500 ton magnet for the UA1 experiment at the SPS proton-antiproton collider at CERN.

(Photo CERN 384.7.80)

People and things

As reported in our June issue, page 154, there is new interest in the use of holography for photographing events in bubble chambers. Tests at CERN with the small BIBC bubble chamber have given a most beautiful demonstration of the abilities of the technique. The photograph is just one event picked from a hologram taken with a 140 GeV negative pion beam and BIBC filled with freon. The bubble diameter is only some 8 μm and the total length represented in the picture is only about 1 mm.

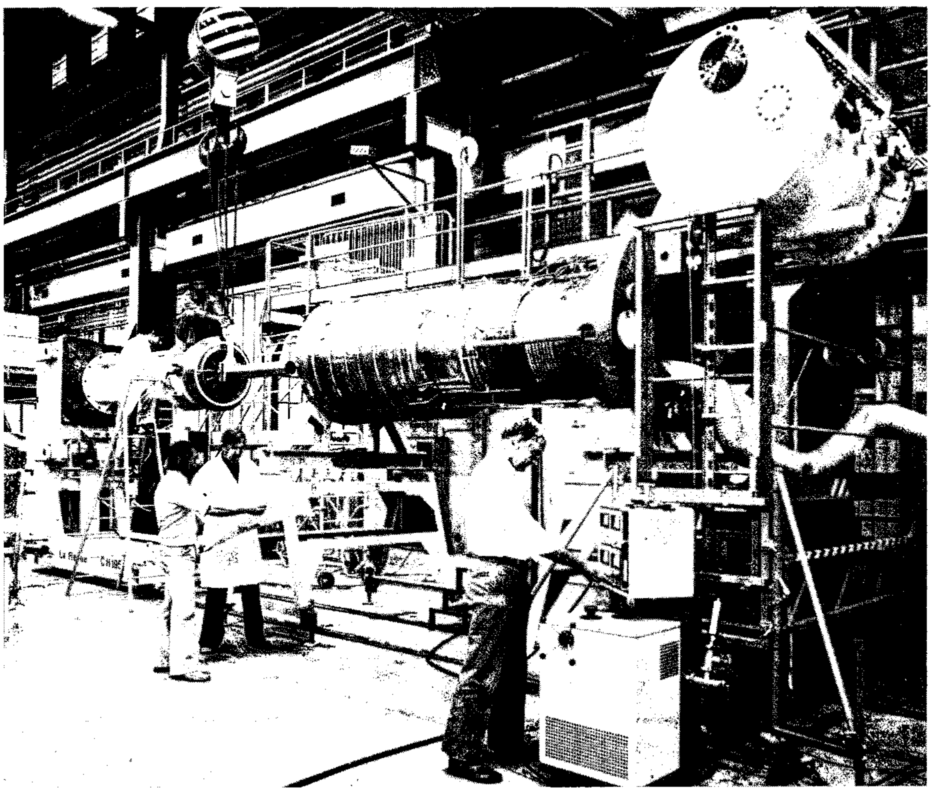


On people

Sidney Drell, deputy director and executive head for theoretical physics at SLAC, has received the 1980 Leo Szilard Award for Physics in the Public Interest from the American Physical Society. The award cites his 'outstanding contribution to the formulation of national policy through the application of physical principles'.

As well as his high energy physics work, Drell has worked for many US government agencies, including the President's Science Advisory Committee, the US Arms Control and Disarmament Agency, the Office of Science and Technology Policy, the Office of Technology Assessment and the National Security Council. After having worked there earlier in his career, Drell rejoined Stanford in 1956, and has since remained there.

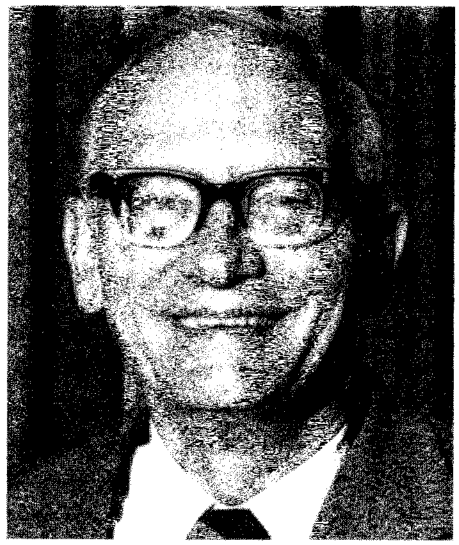
Among the tributes to CERN theorist Rolf Hagedorn on the occasion of his 60th birthday is the dedication of a book entitled 'Hadronic matter of extreme density'. Edited by N. Cabibbo and L. Sertorio, the book reviews a Workshop on this subject held at Erice, Sicily. It is fitting that it should be dedicated to Hagedorn who has done some of his outstanding work on the subject of the study of matter at high density and high temperature.



The rapid cycling bubble chamber, built at Rutherford, being assembled at CERN where it is to be used with the European Hybrid Spectrometer. Seen here are Ken Quinton of Rutherford (foreground), Ron Newport of Rutherford (background, right) and Alain Hervé of CERN. Working on the piston are Jorge Costa and Jeff Thomas of Rutherford. This major new detection system for the North Experimental Area is scheduled to be ready when the SPS restarts next year after its long shutdown.

(Photo CERN 131.8.80)

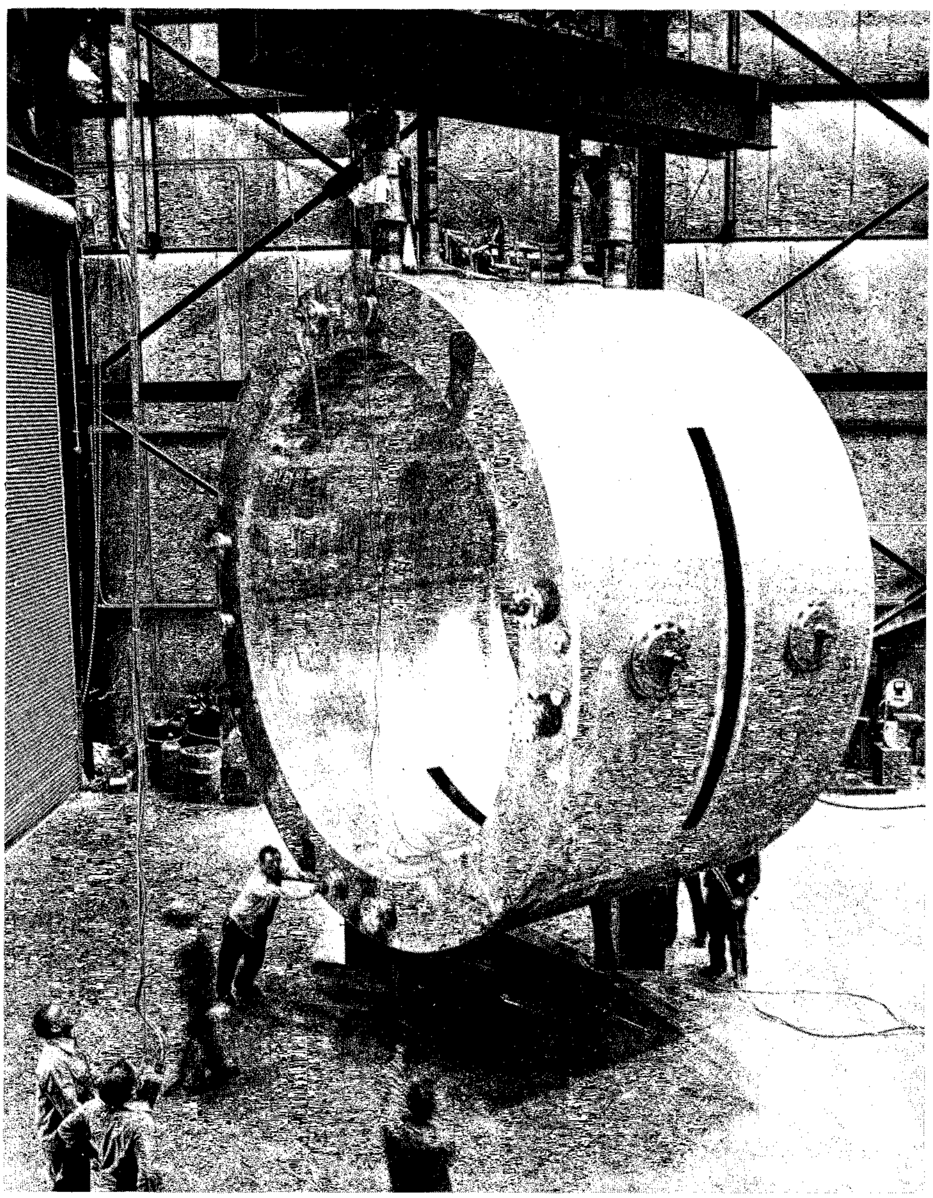
John Warren: from physics to apples



John Warren, first director of the TRIUMF Laboratory, retired this year as physics professor at the University of British Columbia. To mark the occasion, many of his ex-students and colleagues gathered in Vancouver recently at a meeting held in his honour.

After coming to the University British Columbia in 1947, he was responsible for the design and construction of the first accelerator in Western Canada, a 3 MeV Van de Graaff. His efforts to get a higher energy machine succeeded in 1968 when the TRIUMF meson factory was funded.

Although he has retired from teaching, he is still active in the TRIUMF experimental programme and has become involved in the Knowledge Network Institute (TV University) of British Columbia. One sideline activity is apple growing, and among his 30 000 trees are reputed to be a few direct descendants of the tree influential in the formulation of the theory of gravity.

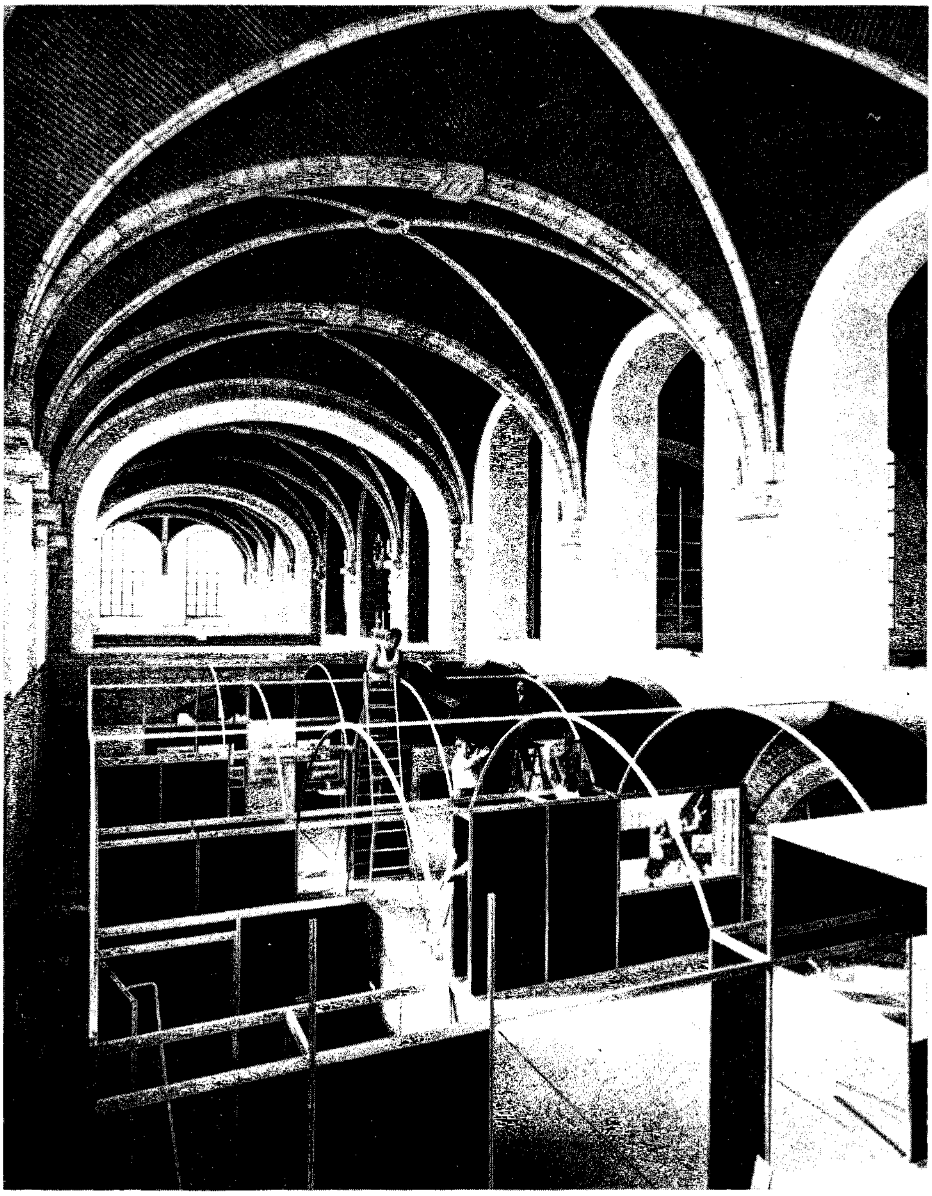


Seen here being manoeuvred into position in interaction region 6 at PEP is the 100 ton superconducting magnet coil trucked overland from Argonne (see April issue, page 57). The magnet has now been installed inside its iron yoke and instrumentation is being added for the High Resolution Spectrometer Experiment at PEP.

(Photo Joe Faust)

Letters from Pauli

Now available is the first volume to be published of Pauli's scientific correspondence. It contains some 240 letters written to or by Wolfgang Pauli during the years 1919–1929. It is based on the Pauli Letter Collection of over 2000 originals or copies gathered together largely through the initiative of Mrs. Pauli, with the support of colleagues, and which is now held at CERN. The period covered by this volume covers what is frequently considered to be the 'golden period of physics', and two subsequent volumes now in preparation will cover the years 1930–1939 and*



Preparing the CERN exhibition in the splendid Gothic Hall of the University Centre at Louvain.

(Photo CERN 249.8.80)

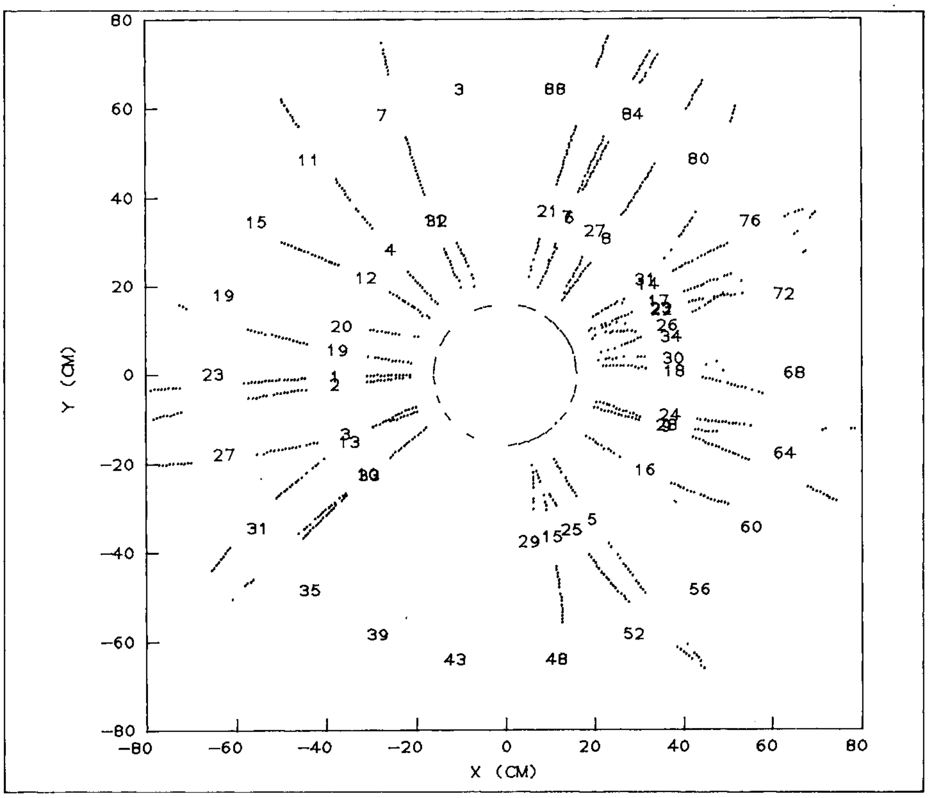
1940–1949 respectively, with all correspondence arranged chronologically. This collection of letters well illustrates the motivation and thinking of a scientist whose achievements and qualities cannot be gauged from his published papers alone. The correspondence displays to the full Pauli's stimulating ideas, his clear guidance and his famed critical powers.

** Wolfgang Pauli — Scientific Correspondence with Bohr, Einstein, Heisenberg etc. Volume I: 1019–1929, Edited by A. Hermann, K. v. Meyenn, V.F. Weisskopf, Published by Springer-Verlag (in German).*

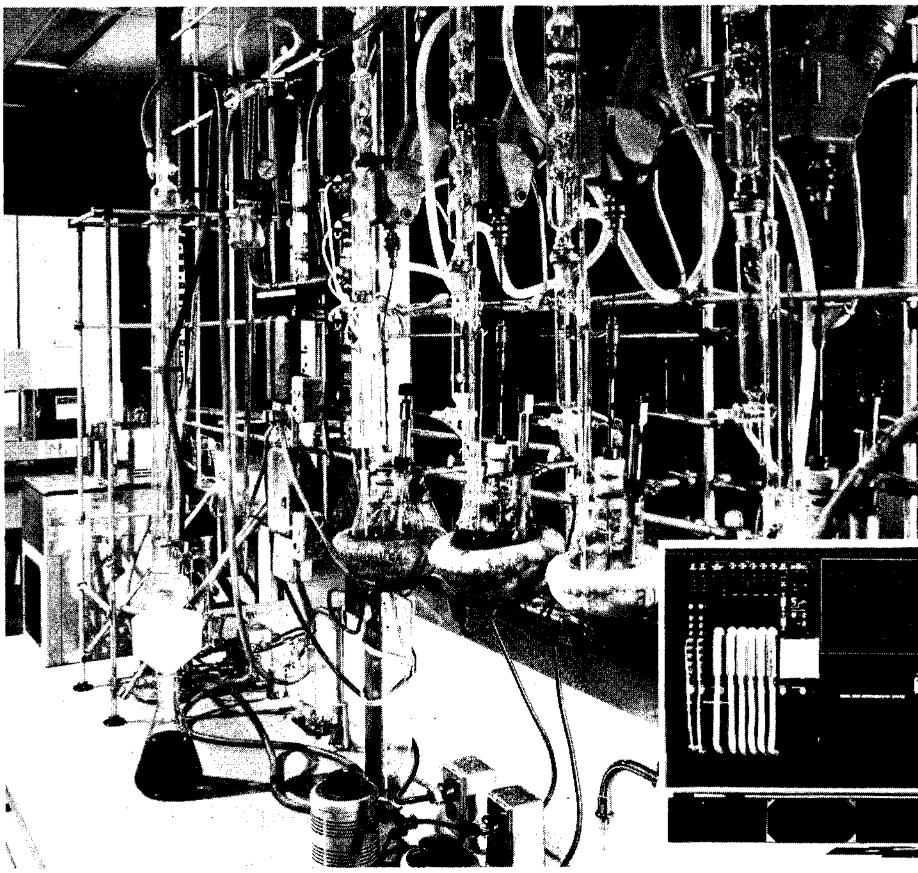
Physics in Belgium

In the July/August edition of 'Europhysics News', J. Lemonne, past President of the Belgian Physical Society and Belgian delegate to the CERN Council, reviews physics activities in Belgium to mark the fiftieth anniversary of the Society.

CERN has a presence in Belgium for six weeks from the beginning of September. On the initiative of R. Gastmans of the Instituut voor Theoretische Fysica at the Katholieke Universiteit Leuven, an exhibition of CERN's work is taking place at the University.



Particles emerging from a collision of two alpha particles (with a combined collision energy of 126 GeV) as seen by the drift chambers of the Axial Field Spectrometer at the CERN Intersecting Storage Rings. The alpha particle run at the end of July went well, as would be expected at the ISR, but what is striking is the high multiplicity of the emerging particles. A large number of events, like the one shown here, record over forty particles emerging from a collision.



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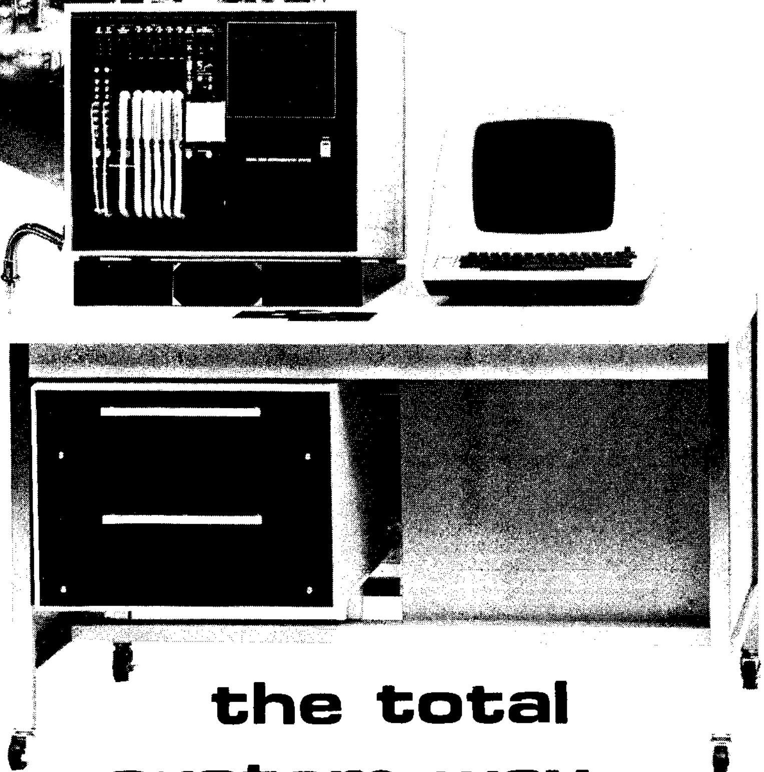

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XP2202	44	bialkali	10	1	1	200	7,4
XP2212	44	bialkali	12	1	1	250	7,5
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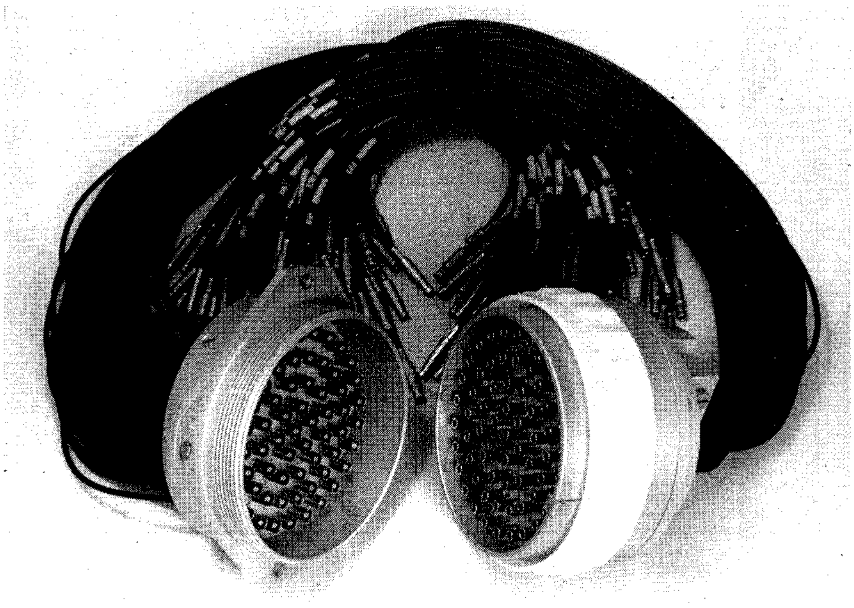

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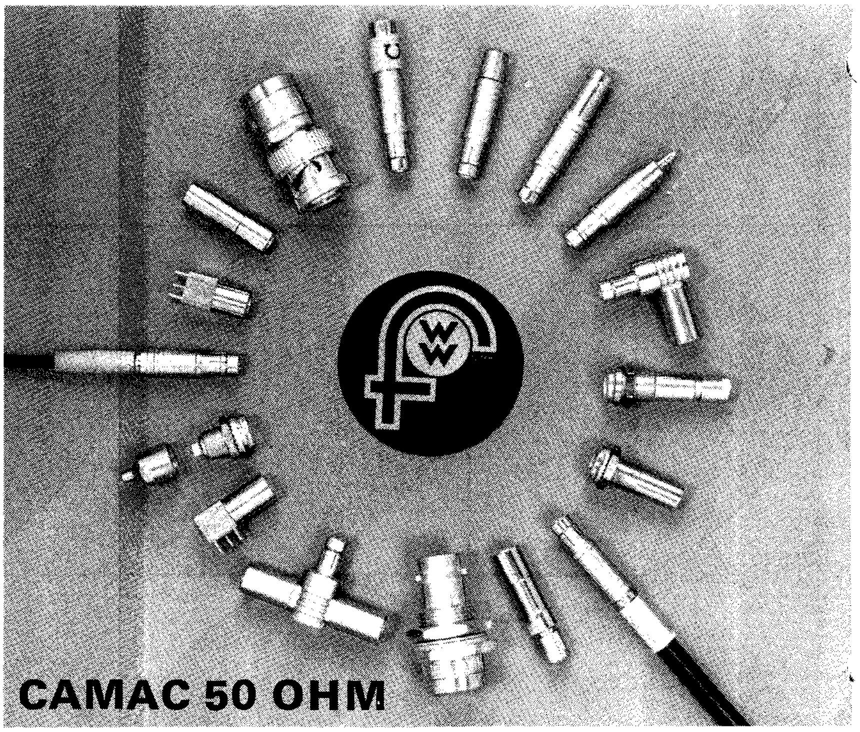

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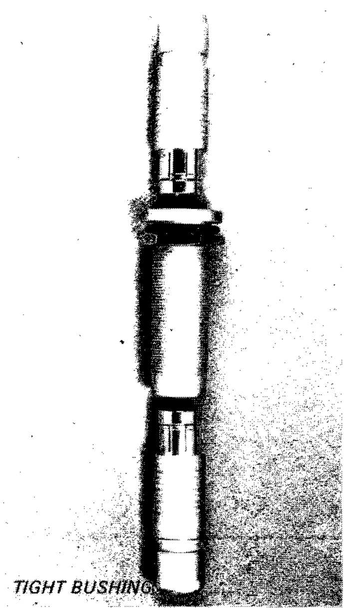

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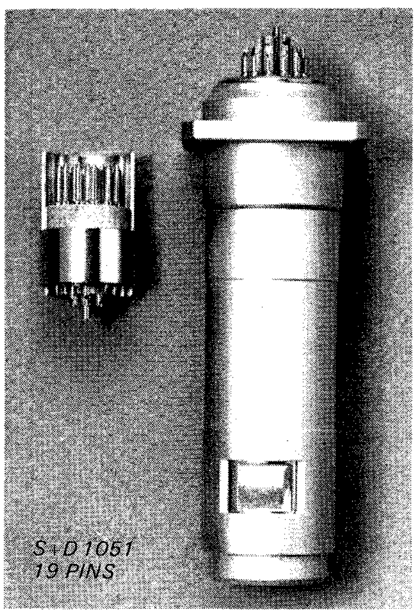

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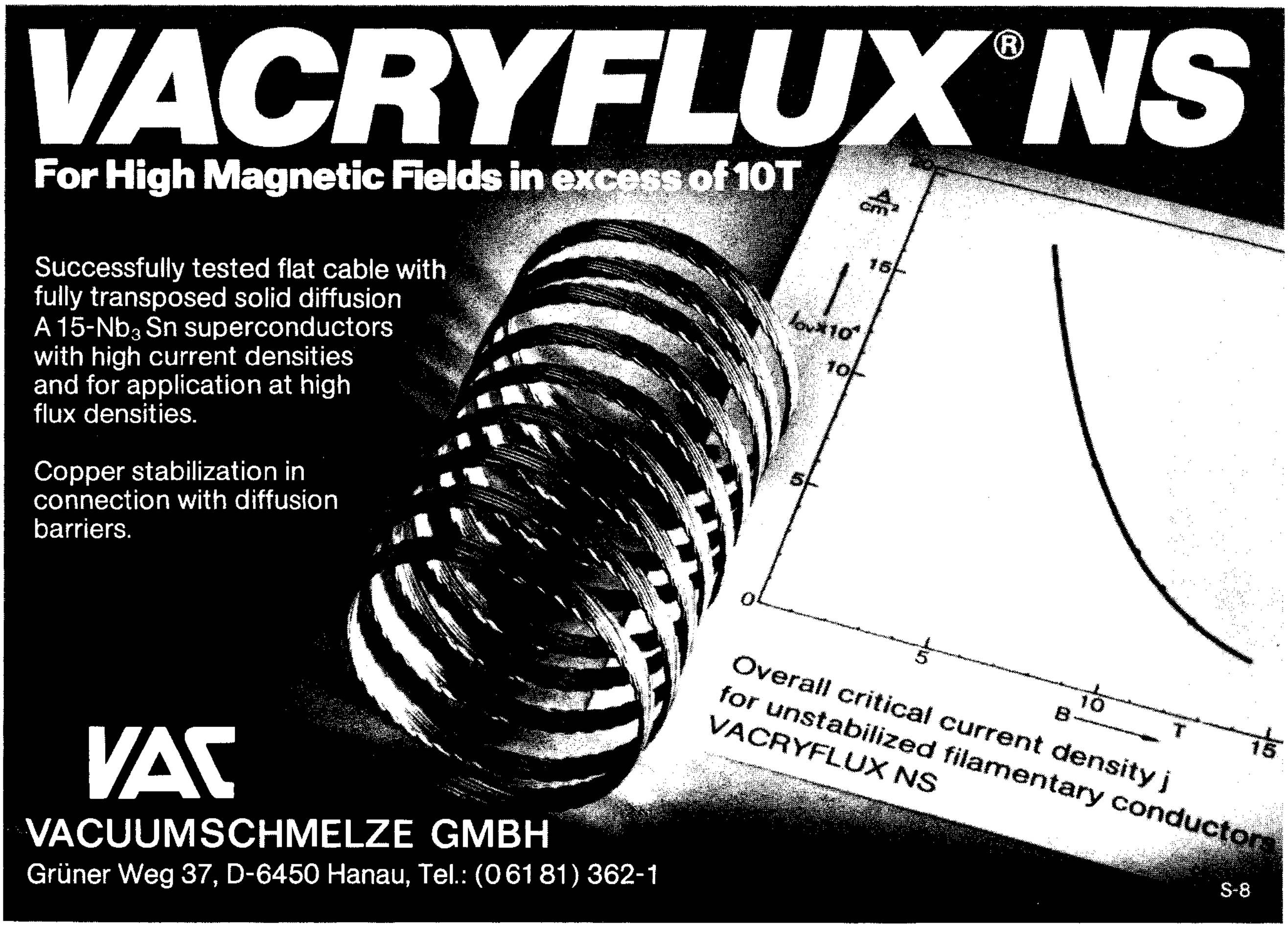
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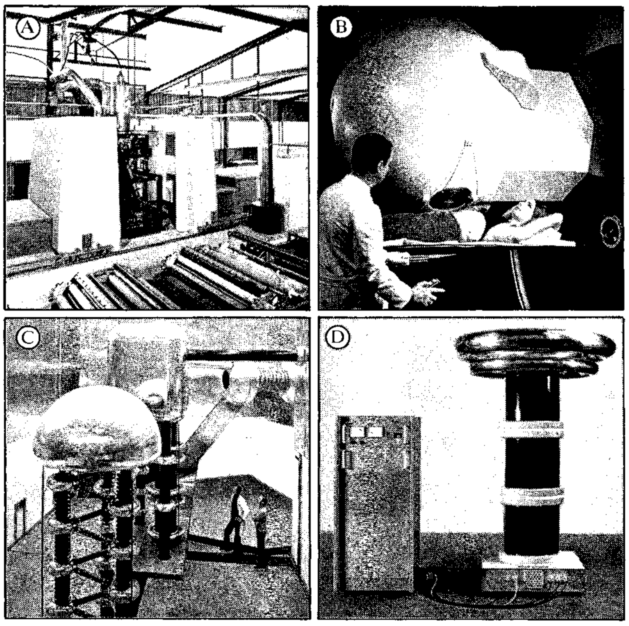

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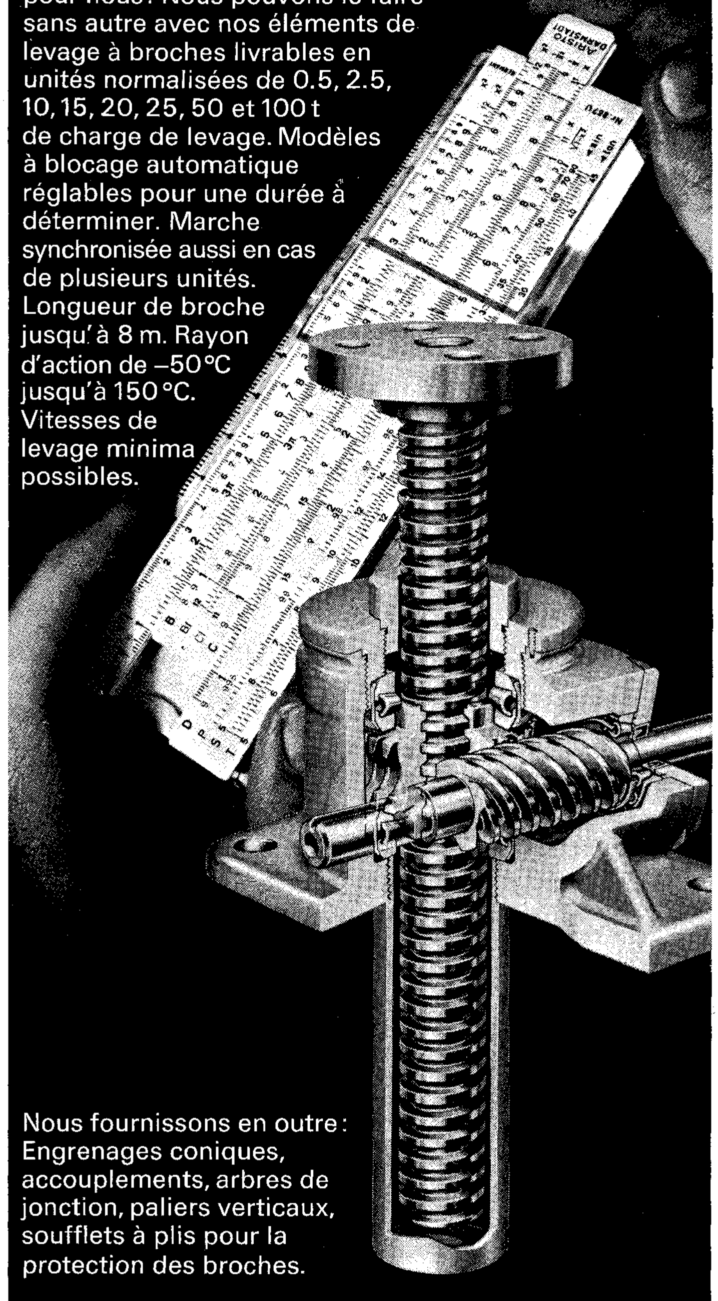

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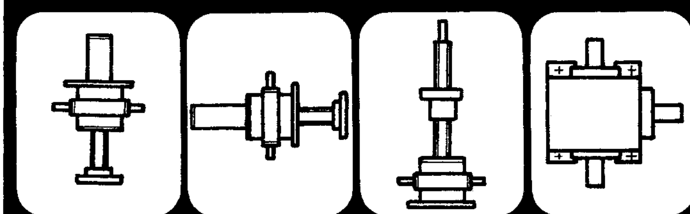

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