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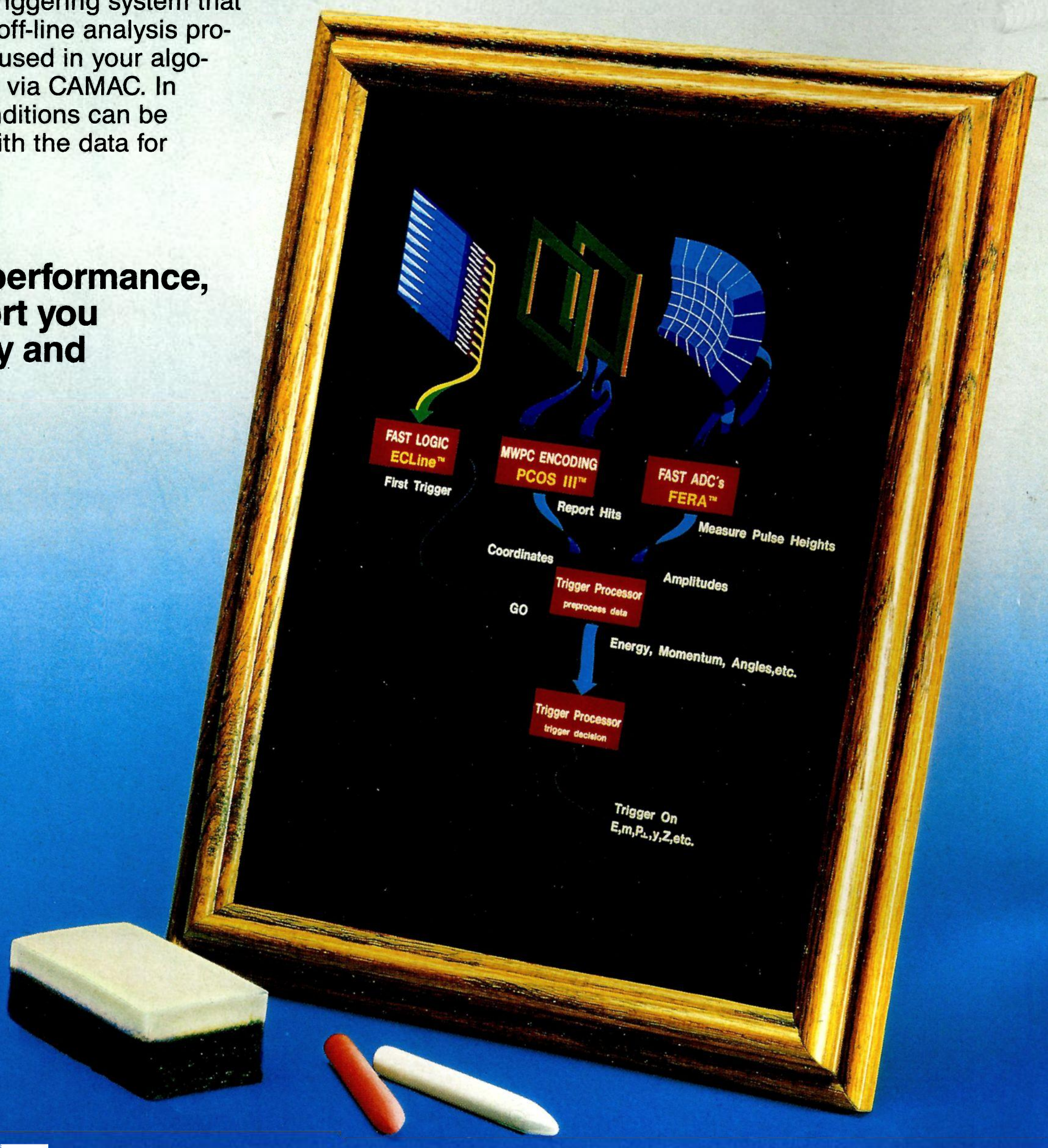

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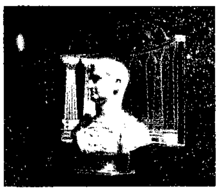

Cover photograph:
The atoms of the Universe move in time and space. This was communicated in a recent CERN exhibition by projecting human history against a background of a distant galaxy. The artwork was prepared by Marcel Sturzinger.

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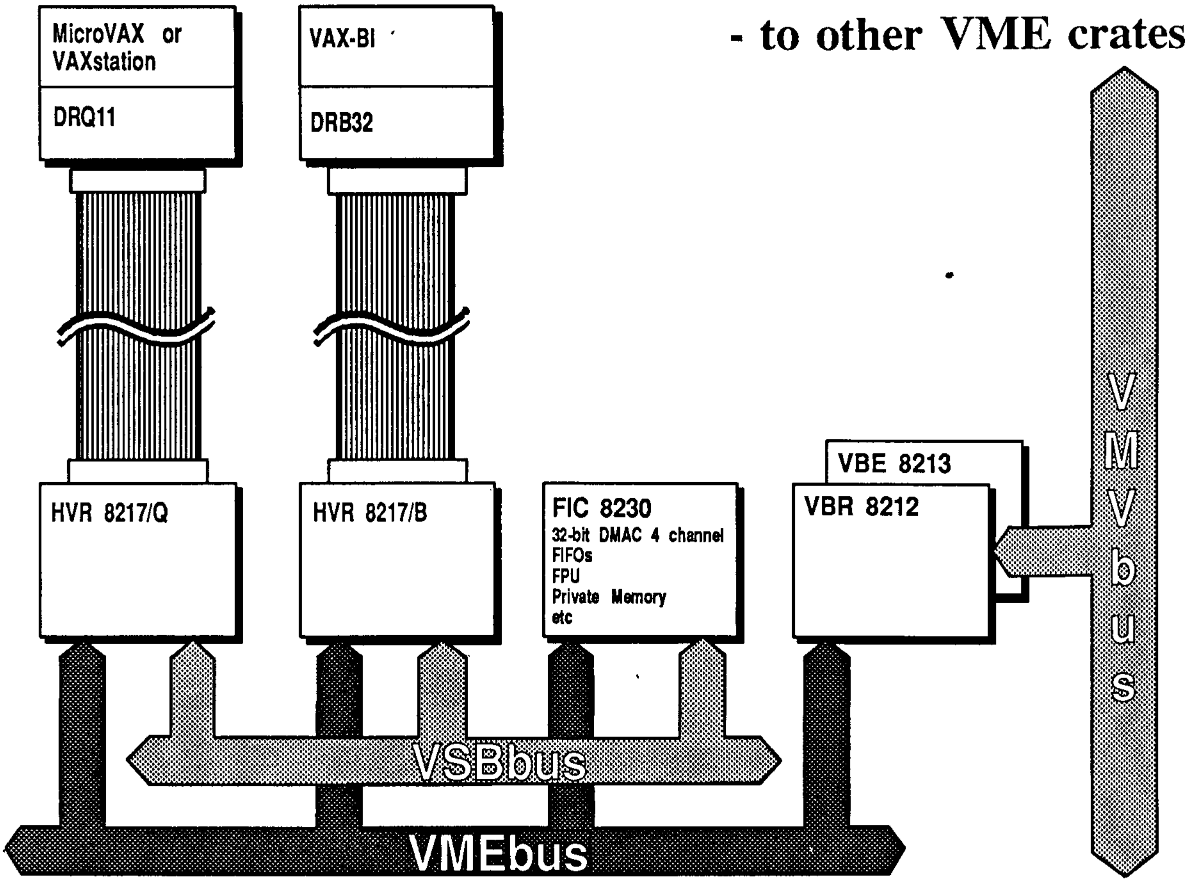

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CREATIVE ELECTRONIC SYSTEMS

Looking to the future

The gavel changes hands. Outgoing President of CERN Council Wolfgang Kummer of Austria (left) with new President Josef Rembser of Germany.

(Photo CERN X400.12.1987)

At its meeting in December, CERN Council 'welcomed with enthusiasm' the nomination of Carlo Rubbia as the Laboratory's next Director General, for five years from January 1989, when he will take over from Herwig Schopper, who took up office in January 1981.

In his report, Schopper illustrated the impressive range of ERN's current activities. The antiproton improvement programme is now completed, with experiments set to profit from the higher antiproton levels of the new ACOL source, including the recently completed AC Antiproton Collector now complementing the AA Antiproton Accumulator. While running-in during the final months of 1987, ACOL supplied a record antiproton stacking rate, promising well for the first real physics run later this year. 1987 also saw important physics results and developments in the supply of nuclear beams at both high and low energies. The all-important preparations for the LEP electron-positron collid- continue to go well, and the challenge of installing the machine and its complicated infrastructure can be faced with confidence.

At the meeting, Carlo Rubbia reported on the findings of his working group on the long-term future of CERN. The preliminary version of this report, published in 1986 (see September 1986 issue, page 17) called for research and development for the technology needed to push CERN's objectives of a linear electron-positron collider (CLIC) and the LHC proton-proton collider in the tunnel now being completed for LEP

With R and D work underway to develop the required high field superconducting magnets, Rubbia underlined the attractiveness of the LHC option, and saw the future as being 'extremely bright', with a wide ongoing European programme in the three collision physics sectors electron-positron (LEP at CERN), electron-proton (HERA at DESY in Hamburg) and proton-antiproton (CERN Collider), complemented by big passive underground experiments.

Council also heard Anatole Abragam present the final version of his committee's review of CERN. The title of its initial chapter 'CERN, a scientific and cultural success' sets the tone for the remainder of the document. A number of detailed recommendations were put forward to safeguard CERN's future interests, and methods of implementation will now be examined by Council and its committees.

Elections and appointments

In addition to Rubbia's nomination as the next Director General, Josef Rembser of West Germany's Ministry of Research and Technology was elected President of CERN Council for one year, succeeding Wolfgang Kummer of Austria. Council Vice-Presidents are Pierre Lehmann (France) and C. Lopez (Spain). Paul Kienle (GSI Darmstadt) was appointed as a new member of the Scientific Policy Committee. At CERN, Georges Michel was named Leader of Personnel Division for three years, while Willem Middelkoop becomes Chairman of the Pensions Board, also for three years.

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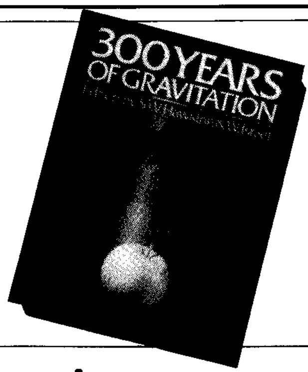

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Around the Laboratories

SOVIET UNION
New dimension

Soviet high energy physics is benefiting from a Central Committee decision to push forward work for the 'Accelerator and Storage Comlex' (better known even in the West by its Russian acronym UNK) for which a 21 kilometre underground ring is being built at the Institute for High Energy Physics at Serpukhov, near Moscow. About 9 km of the 5 metre-diameter tunnel has been cut.

As well as a ring of conventional magnets for 400 GeV proton beams, the plan is to have a superconducting magnet ring in place by 1993 to provide 3 TeV (3000 GeV) proton beams – the highest proton beam energies planned in the world for fixed target experiments. Initial trials with 'warm iron' superconducting magnets gave unacceptable static heat leaks, and attention turned towards a 'cold on' design. Subsequently a second superconducting ring would be added, to provide 6 TeV proton-proton collisions in 1995. The design collision luminosity is 4 x 10^{32}, and the existing 70 GeV proton accelerator will be upgraded to take on a new role as the UNK injector.

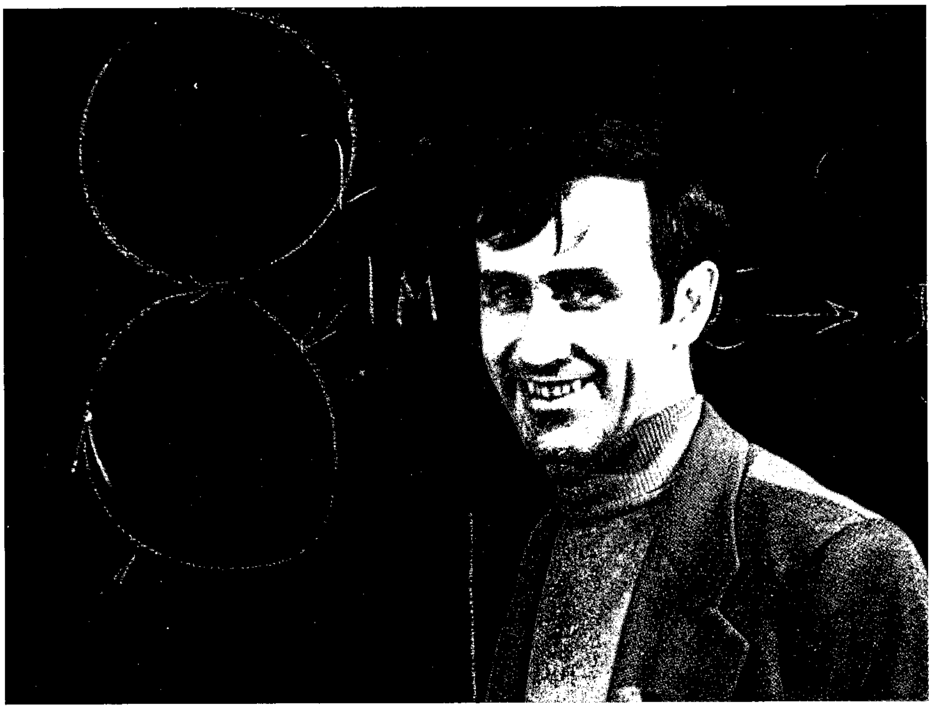
Even by itself, UNK will be one of the world's major particle physics tools, but Soviet particle physics takes on a totally new dimension with the courageous decision to build the VLEPP electron-positron collider also at Serpukhov. The design for this ambitious machine has been nurtured by the Novosibirsk Laboratory with its long tradition of electron-positron physics.

VLEPP looks like being the world's first big truly linear collider, with two five-kilometre electron and positron linacs firing directly towards each other. The plan foresees beam energies of 500 GeV (1 TeV collisions) in 1996, after an initial phase of operation at 150 GeV per beam using the first 1.5 km of the linacs. The ultimate objective is to double the length of the linacs to 10 km to attain 1 TeV per beam. Anticipated collision luminosity is 10^{32}. To push the project along, Novosibirsk is to build a 10 metre model machine to provide 1 GeV. As well as helping VLEPP, this could lead on to a 100 metre version to provide beams for a 5-7 GeV 'B factory' at Novosibirsk for studying particles carrying the 'beauty' quantum number.

Siting UNK and VLEPP next to each other at Serpukhov opens the door to the mouth-watering prospect of electron-proton collisions at up to 3.5 TeV.

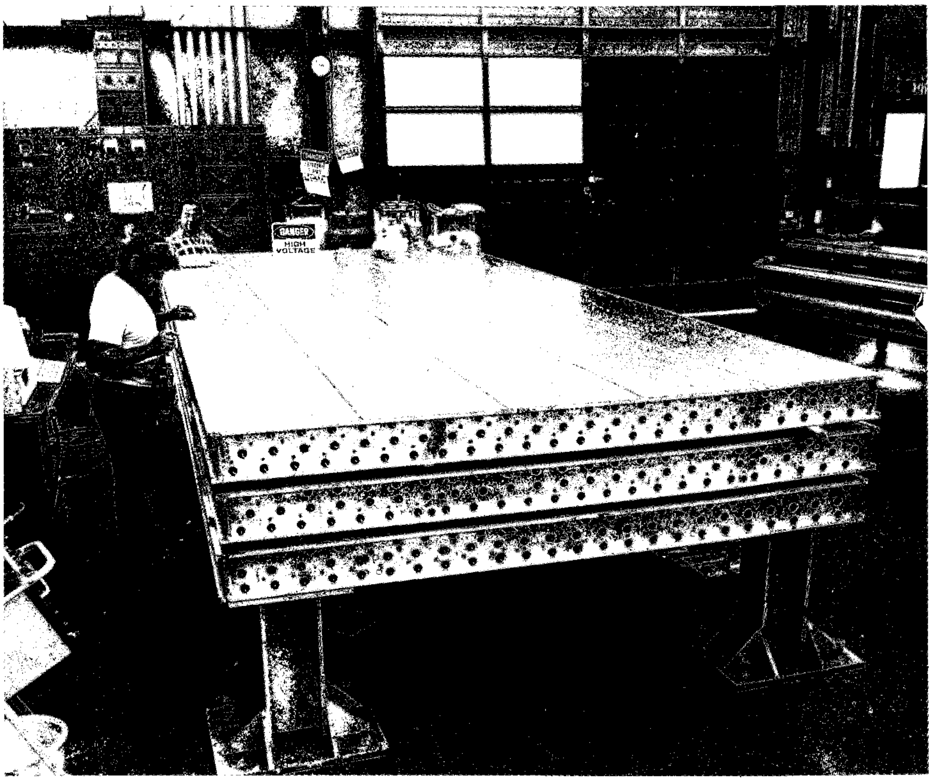
Novosibirsk's idea for a linear electron-positron collider first emerged in 1978 in a paper written for the late Gersh Budker's 60th birthday. At about the same time, the Stanford Linear Accelerator Center in the US began to prepare a scheme to accelerate both electrons and positrons to 50 GeV in the existing two-mile linac, swinging them round in separate arcs to collide.

This Stanford Linear Collider, SLC, is now preparing for its first physics run. With the LEP electron-positron collider at CERN now being fitted out with the equipment to produce (initially) 50 GeV beams in a 27 kilometre ring tunnel, world attention is turning to the next generation of electron-positron machines. In addition to VLEPP, CLIC (CERN LInear Collider) and SC (Stanford Collider), both based on



A.N. Skrinsky of the Soviet Novosibirsk Laboratory - nurturing designs for multi-kilometre linacs to fire electron and positron beams at each other.

A set of 2.5x6.5 m proportional drift chambers for muon detection at the DO experiment now being built for the Fermilab Tevatron proton-antiproton collider. Each chamber produces a line segment through a combination of drift time and cathode pad signal measurements.



semi-conventional ideas with room temperature accelerating cavities operating at high frequencies (see September 1987 issue, page 7), are under study.

FERMILAB
DO takes shape

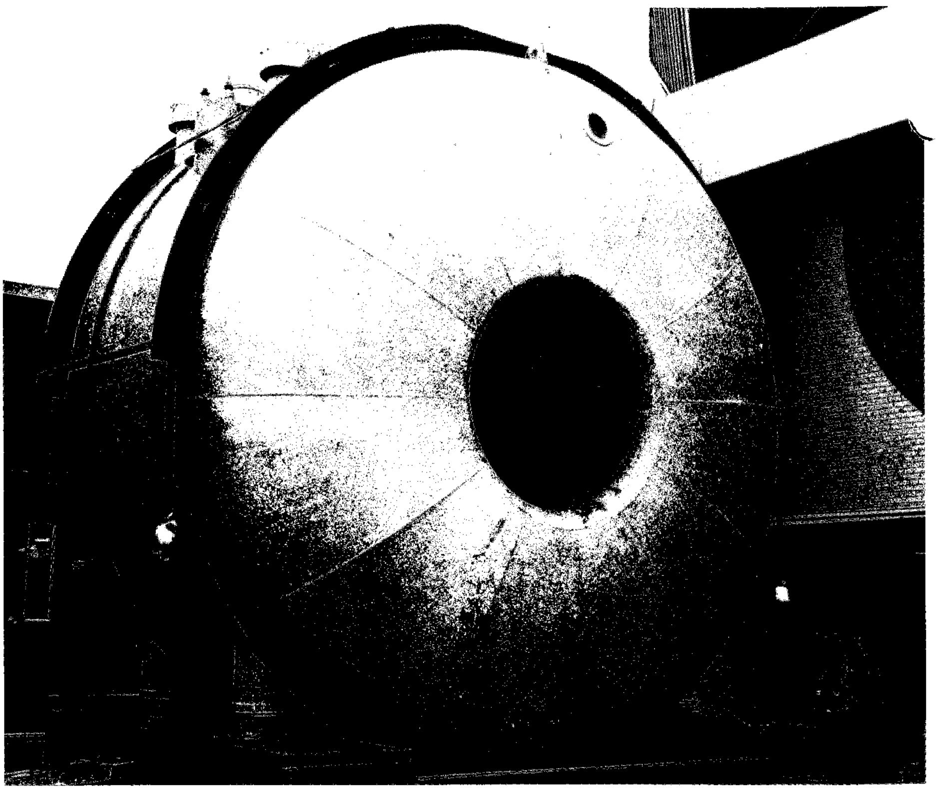
The Fermilab landscape has been changing over the past year with preparations for the upcoming DO experiment for the Tevatron proton-antiproton Collider.

The experiment is designed to exploit many of the important physics signatures of very high energy hadronic collisions in the light of experience from UA1 and UA2 studies at CERN's proton-antiproton collider, and more recently CDF at the Tevatron collider.

To help find new states and rare phenomena, particular attention with DO has been given to electrons and muons. Measurement of 'missing' traverse energy (energy imbalance due to highly penetrating particles flying out of the apparatus undetected) has been stressed in the design of the calorimetry; three uranium-liquid argon calorimeters provide high resolution hermetic coverage, with electrons and hadrons giving equal response in prototype devices.

Eliminating the magnetic field in the tracking region makes the detector compact. Lepton identification is boosted by using transition radiation detectors (TRD) with the tracking chambers to help sift out electrons and by having lots of material (greater than 13 absorption lengths) to catch muons.

In the new DO experimental hall the physical outlines of the detec-



The cryostat for the central DO calorimeter is now being prepared for modules.

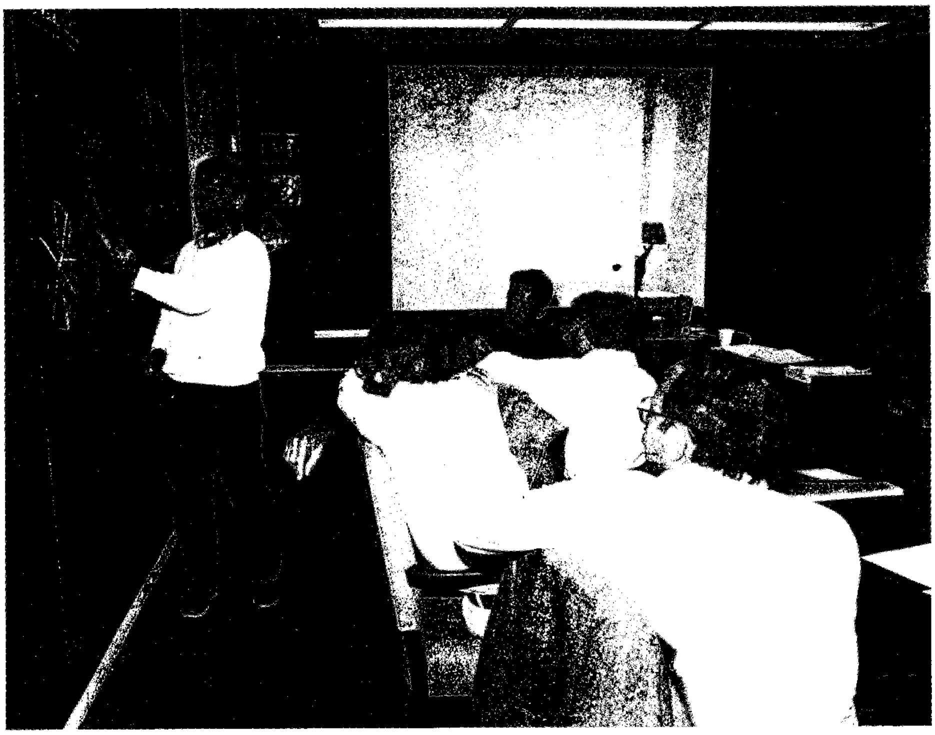
tor are emerging. After completing the detector's moving platform, work is now in progress on the exterior toroidal field magnets to bend the emerging muons. Concurrently, the movable digitizing and trigger electronics house has been completed, as has the cable bridge and the cryogenic, power, gas and water utilities.

DO components taking shape at Fermilab include the large proportional drift tube panels for the muon detector, laminated G-10 signal boards for calorimeter readout, cathode strips for muon chambers, and end calorimeter modules. The large annular cryostat for the central calorimeter has been vacuum and cold-tested and is being prepared to accept its load of 64 individual calorimeter modules.

DO collaborating institutions in DO are equally busy building detectors, electronics and software for shipment to Fermilab. TRD construction is well advanced at Saclay while a unit at Brookhaven is turning out the central calorimeter modules. Berkeley is gearing up for the large electromagnetic sections of the two end calorimeters. Groups from Florida State, Florida, Michigan State, New York, Rochester, Stony Brook and Yale are supplying many of the calorimeter components, while muon chamber effort comes from Indiana, Maryland, and Northern Illinois. Tracking chambers are emerging from Berkeley, Northwestern, and Stony Brook. Electronics for signal shaping, digitization and triggering are being built and tested at Brown, Columbia, Michigan State, New York and Stony Brook. High voltage and monitoring systems are being prepared by Riverside and Fermilab. A team from Serpukhov (USSR) has recently joined the collaboration and will provide both coarse-grained calorimetry and very forward muon detection.

With work so widely dispersed, one of the Tevatron fixed target beamlines has been used to give detector elements a thorough shakedown. As well as demonstrating that many sub-systems integrate successfully, these tests have also led to the continuing evolution of on-line and off-line software.

The DO team looks forward to joining the search for exciting new physics in 1989 using the large angle tracking and TRD, the central calorimeter, and a portion of the muon system, together with the trigger, multiple microprocessor event filter, on-line software and the various support systems. The full detector is expected to be operational in 1990.



Nigel Lockyer (Pennsylvania) describes possible solutions with members of the Collider Architecture Working Group at the recent Fermilab Workshop on Beauty physics.

Beauty workshop

A workshop on 'High Sensitivity Beauty Physics' held at Fermilab from 11-14 November brought together an international group of over 200 people from both hadron and electron-positron machines to look at the possibilities for such experiments at Fermilab, using both collider and fixed target operation. The workshop also gave valuable insights into future experiments with multi-TeV accelerators.

The motivation behind the workshop was the beauty (B) particle production rates at Fermilab, which although they are only a small fraction of the total physics, are nevertheless several orders of magnitude higher than at existing, forthcoming or proposed electron-positron colliders.

Working groups covered five areas. The architecture group was split into two sections, one for col-

liding beam experiments (central solenoid with forward dipoles, large dipoles with forward tracking) and another looking at fixed-target options (remote imaging, open geometry). Members of this group represented collider experiments at Fermilab (CDF and D0), Stanford (Mark II) and CERN (UA1 and UA2). The second working group focused on tracking technologies (silicon strips, pixels, fibres, radial drift chambers and straws) together with tracking and vertexing algorithms and efficiencies. The data acquisition and triggering working group examined such topics as high speed (multi-gigahertz) interaction rates in fixed-target (front-end electronics and massively parallel processing), and collider options ($5x10^{31}$ luminosity and 200 ns crossing rate), on-line impact parameter calculations, lepton and impact parameter triggers, and front-end systems for silicon tracking. The fourth group focused on particle identification, while the final group looked at the physics implications, including CP (combined particle-antiparticle and left-right symmetry) violation.

In colliding beam physics as many as possible of the emerging particles need to be intercepted, but for B physics the 45 degree region was seen to be especially important. This involves bridging between the forward and central detectors, and the collider architecture group suggested using a dipole magnet.

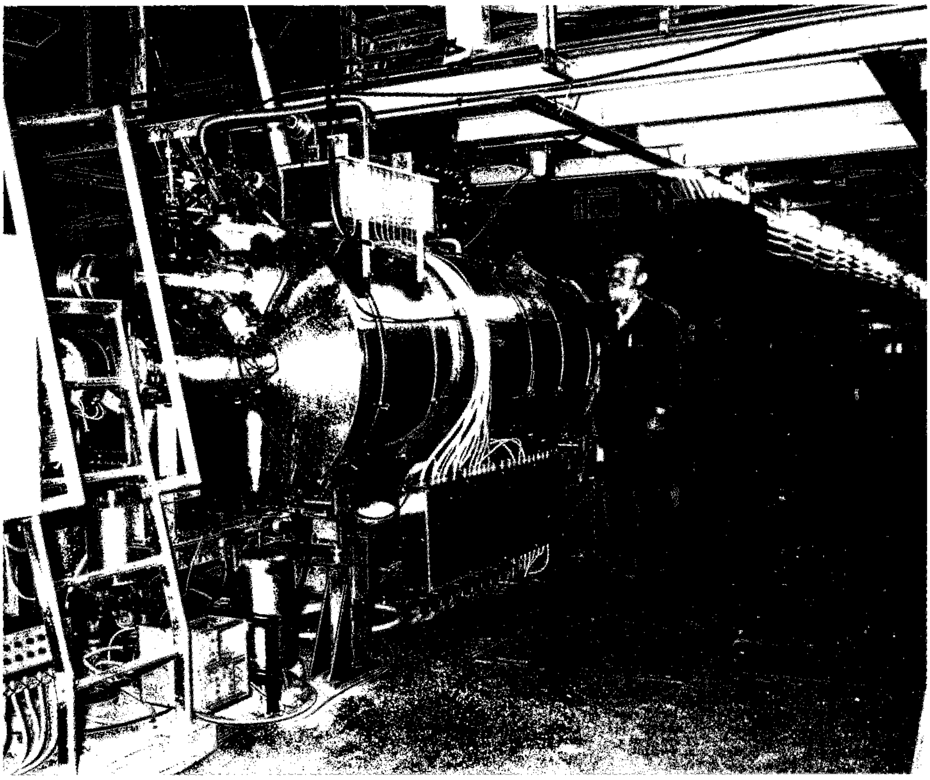
The fixed-target group stressed the efficient use of upgraded existing detectors to study B production at lower rates to prepare for high-rate studies later.

In his talk on fixed-target issues, J.D. Bjorken pointed out that the problems of doing fixed-target B physics at Fermilab are in some ways comparable to those of B physics at the proposed US Superconducting Supercollider (SSC). The B-spectrometer being proposed by Berkeley for the SSC looks in many ways to be a good B physics design for a Fermilab experiment. Also because some of the anticipated problems associated with SSC experiments (luminosity, radiation damage, etc.) are very much the same as those anticipated at B physics fixed-target experiments, the latter can be viewed as the next necessary developmental step.

CERN Superconducting cavity beam tests

Last summer, the SPS Super Proton Synchrotron was the scene of important tests of a prototype superconducting radiofrequency accelerating cavity. After good performance in bench tests, the three objectives of the cavity beam trials were – to study its long-term behaviour in an accelerator, to increase the accelerating voltage for electrons and positrons when the SPS is used as an injector for the neighbouring LEP electron-positron collider (now under construction) and to use a feedback system to decrease the cavity impedance during proton acceleration.

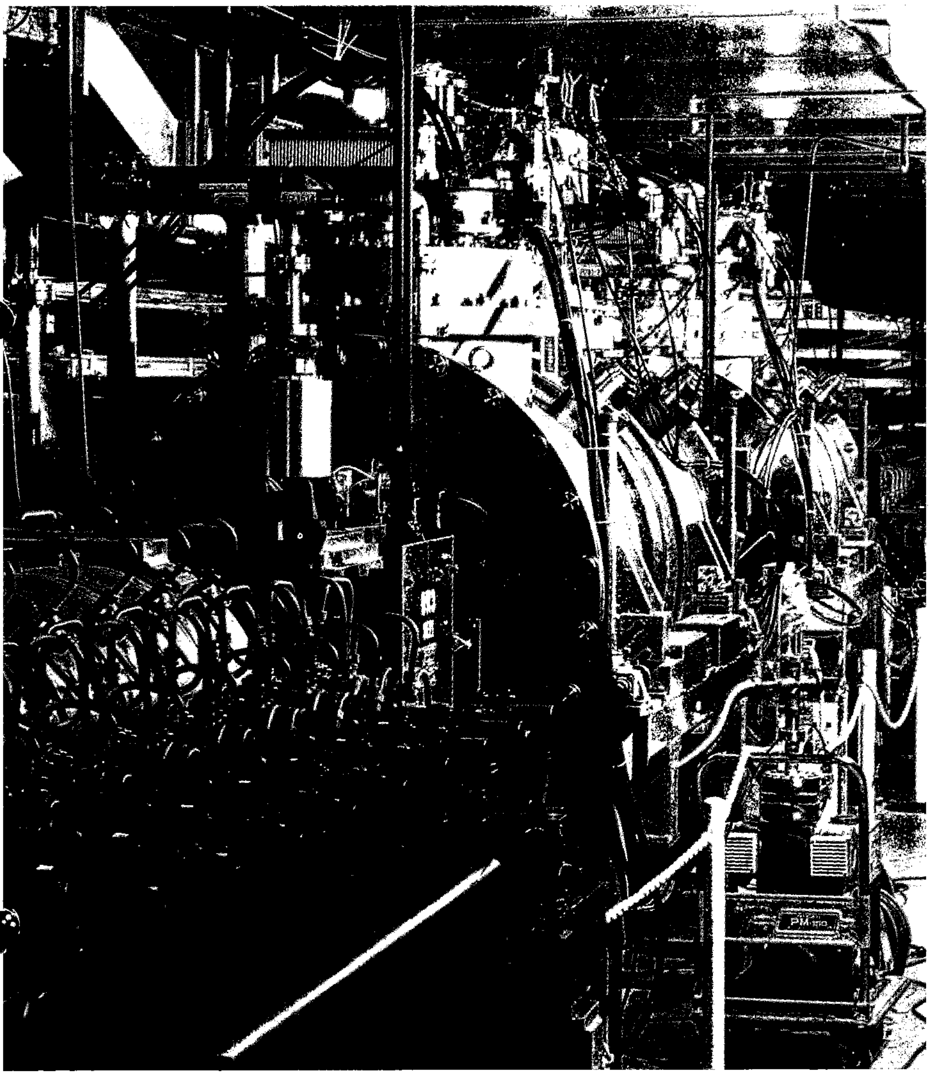
The 350 MHz four-cell niobium cavity, cryostat and ancillary equip-



Prototype superconducting radiofrequency accelerating cavity under test in the SPS Super Proton Synchrotron at CERN.

(Photo CERN X66.8.87)

Aiming to get the most out of electron/positron beams - Superconducting radiofrequency accelerating cavity under test at the Japanese KEK Laboratory.



Multiple effort

Several Laboratories are pushing the development of superconducting radiofrequency cavities to boost electron (positron) beam energies. As well as CERN (for LEP, see this page) and DESY at Hamburg (for the HERA electron-proton collider, see page 15), KEK in Japan is aiming to get the most out of the new TRISTAN electron-positron collider.

Beam tests at KEK have used the small TRISTAN Accumulator Ring. Initial studies used a three-cell cavity, and in November two 500 MHz five-cell cavities from Mitsubishi stored 41 milliamp currents at 2.5 GeV and accelerated 15 mA to 6.5 GeV. Together with conventional cavities, the energy was taken to 7.7 GeV (6 mA). Quality (Q) factors were about 2×10^9 in the beam, with accelerating fields of 4/5 MV/m. In static tests, a number of cavities have achieved 10 MV/m.

ment were designed and manufactured at CERN as a prototype for LEP and equipped with a main r.f. coupler tested up to 40 kW (cw), higher order mode couplers for damping unwanted r.f. modes excited by the beam and a frequency tuner system handling a loaded cavity bandwidth of 100 Hz.

Prior to installation in the SPS, there was only enough time to prepare the cavity up to an accelerating field of 4.4 MV/m rather than its achieved maximum of 7.2 MV/m.

In the first few months of the test, the cavity had to be cooled in the underground ring using dewars on the surface 60 m above, with liquid helium being transferred through a 100 metre flexible line. The test will continue in March, this time using a small refrigerator in the tunnel.

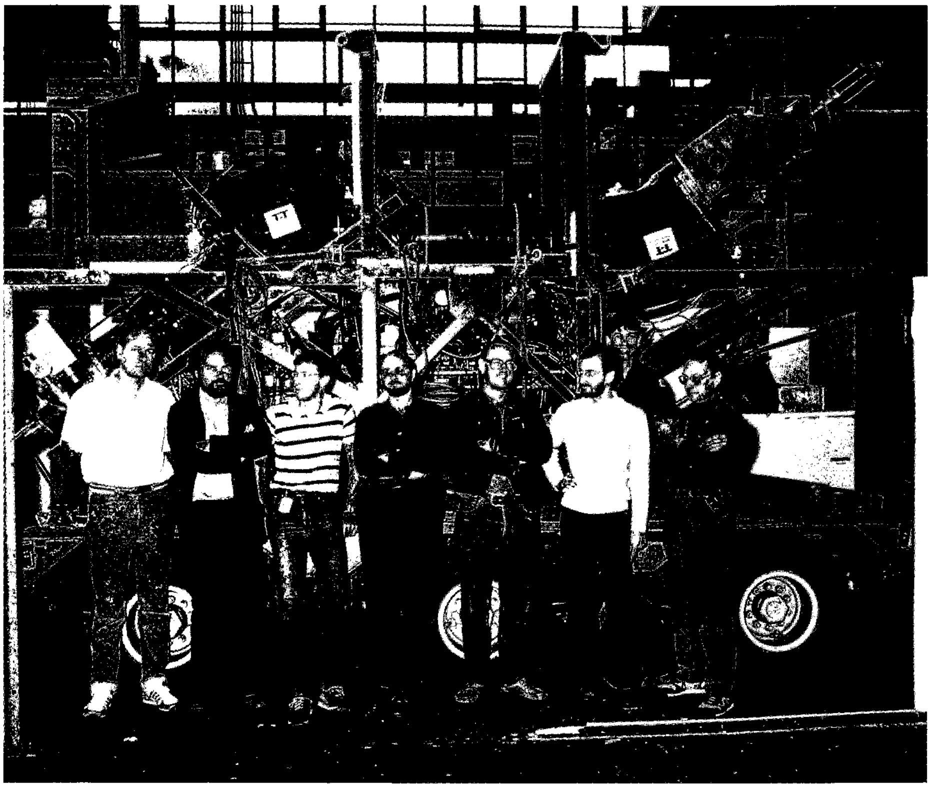
No major failures occurred during the test period (five cooldowns). The accelerating field suffered no adverse effects and the quality factor (Q) was estimated to be greater than 3×10^9. The cavity accelerated a positron beam from 14.6 to 17.4 GeV, and with the 200 MHz copper cavities assisting the energy went to 18 GeV, with 300 microamps in four bunches. Cavity accelerating fields reached 3.2 MV/m (total 5.4 MV/m), with no unexpected higher order modes.

With interleaved proton and positron acceleration, the cavity impedance was damped for the intense proton pulses to suppress beam instabilities. An active r.f. feedback system with a 40 kW tetrode amplifier connected to the cavity minimized the beam induced fields, and worked well with the positrons.

With early installation in LEP in mind, four similar cavities and cryostats are under construction, two at CERN and two in industry.

Electron cooling in LEAR

Members of the CERN/KfK Karlsruhe collaboration pose with the electron cooling system installed on the LEAR storage ring.

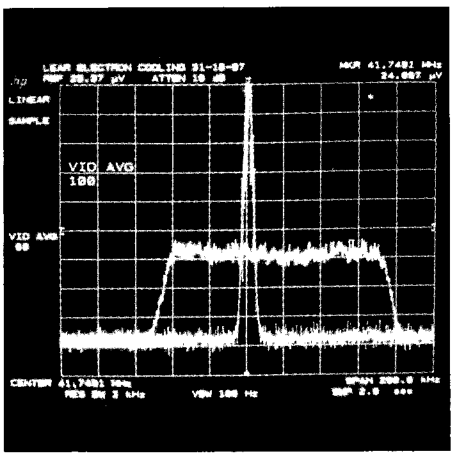


At the end of October, a CERN/Kernforschungzentrum Karlsruhe collaboration, led by H. Haseroth and H. Poth, harvested the fruit of several years of work on the development of an electron cooling system for CERN's LEAR Low Energy Antiproton Ring.

Electron cooling has been in the shadow of the spectacular success of stochastic cooling but was in fact the first beam cooling technique to operate. The idea of using a well-defined electron beam to tame a less well behaved beam was invented at the Soviet Novosibirsk Laboratory and was demonstrated in the NAP-M ring in 1974.

The first pròposed implementation in the West (to cool antiproton beams for CERN's Intersecting Storage Rings) followed a visit of P. Strohlin to Novosibirsk. To test the idea at CERN, the ring used for measuring the anomalous magnetic moment of the muon was converted and rechristened ICE (for Initial Cooling Experiment). Success came in 1980, under F. Krienen and H. Herr, but in the meantime electron cooling had been overtaken by CERN's stochastic method better adapted to high energy beams.

Beam cooling at work. Electron cooling tests in CERN's LEAR Low Energy Antiproton Ring cut an energy spread of $2.4x10^{-3}$ to $19x10^{-5}$ in a few seconds.



A Fermilab team demonstrated electron cooling in 1981, while working on their antiproton source, and retain interest in the technique, both for the source and for cooling stored beams in the Tevatron.

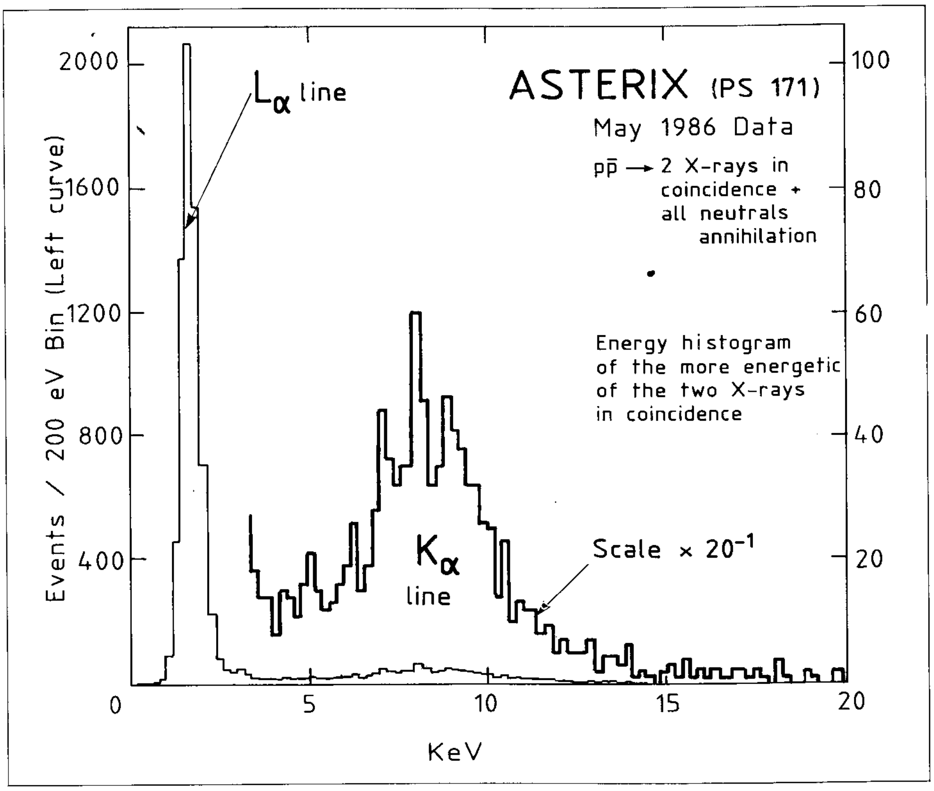
Throughout the world, some ten low energy ion storage rings are constructing, or have proposed, electron cooling systems to improve the quality of their beams. This effort has been considerably stimulated by the decision to go ahead with electron cooling in LEAR.

At LEAR the aim is to complement the stochastic cooling already installed. While the stochastic method works best on high energy ('hot') beams, since it needs to detect deviations from desired values, the electron method works best on low energy ('cold') beams since the interaction between the beam particles and the electrons increases as the two velocities approach.

Though it remains to be convincingly demonstrated, electron cooling should cope better with higher intensity beams since the cooling rate is less dependent on the number of particles to be cooled.

Several experiments, accepted and proposed, for LEAR require very cold beams in the ring. For extraction to external experiments the beam momentum spread has to be increased, diminishing what has been achieved by cooling, though the cooling still provides slimmer

Spectrum of coincident pairs of X-rays from proton-antiproton atoms. Selecting a transition to the first atomic excited state (L line) enables the first ground state transition (K-alpha line) to be unravelled from the other K lines.



beams, and can help the experiments wanting decelerated particles.

The electron gun from the ICE ring was converted for LEAR. The cooling had to be achieved along a shorter interaction length, a 1.5 m straight where the electron beam overlaps with the orbiting particles, compared to 3 m in ICE, and the problem of firing an intense electron beam into the very high vacuum of LEAR (2.5 A into 10^{-11} torr) had to be confronted. Special diagnostics had to be developed, including scattering of laser light on the electron beam, observing the microwave radiation from the spiralling of the electrons in the magnetic field, and observation of the X-rays caused by stray electrons.

In the October tests cooling was observed from the very first injection of a proton beam into LEAR using Schottky scans and the detection of neutral hydrogen. This latter technique can only be applied while working on proton beams – neutral hydrogen atoms emerge from the straight section undeviated by the magnetic fields of the ring or of the electron cooling system. This is a useful tuning aid, since hydrogen production increases as the two beam velocities approach (the ideal condition for cooling). Production rates of a few thousand hydrogen atoms per second were observed and the method still worked with low proton intensities, about 10^6, when Schottky scans were no longer sensitive.

Major achievements included slimming the proton beam from a few centimetres across to a few millimetres in seconds, while the energy spread was pared from several parts per thousand to better than one part in ten thousand. The short time available for the tests saw a number of beam physics experiments. The cooling of a bunched beam was demonstrated and very short bunches were achieved. The electron energy was moved off the optimum value and the proton energy was seen to follow. Too much cooling induced beam instabilities. The equilibrium between the stochastically introduced heating of the proton beam for beam extraction and the electron cooling gave a measure of the cooling power.

Further tests with antiproton beams are eagerly awaited, when the cooling rates can be compared with those of protons. Experiments at Novosibirsk indicate that over a range of parameters electron cooling works more than twice as fast for negatively charged beams (like antiprotons).

Much work remains to convert the system used for these experiments into a reliable system for regular operation of LEAR, however the tests have shown convincingly that electron cooling adds another effective weapon for taming beams of antiprotons and other ions.

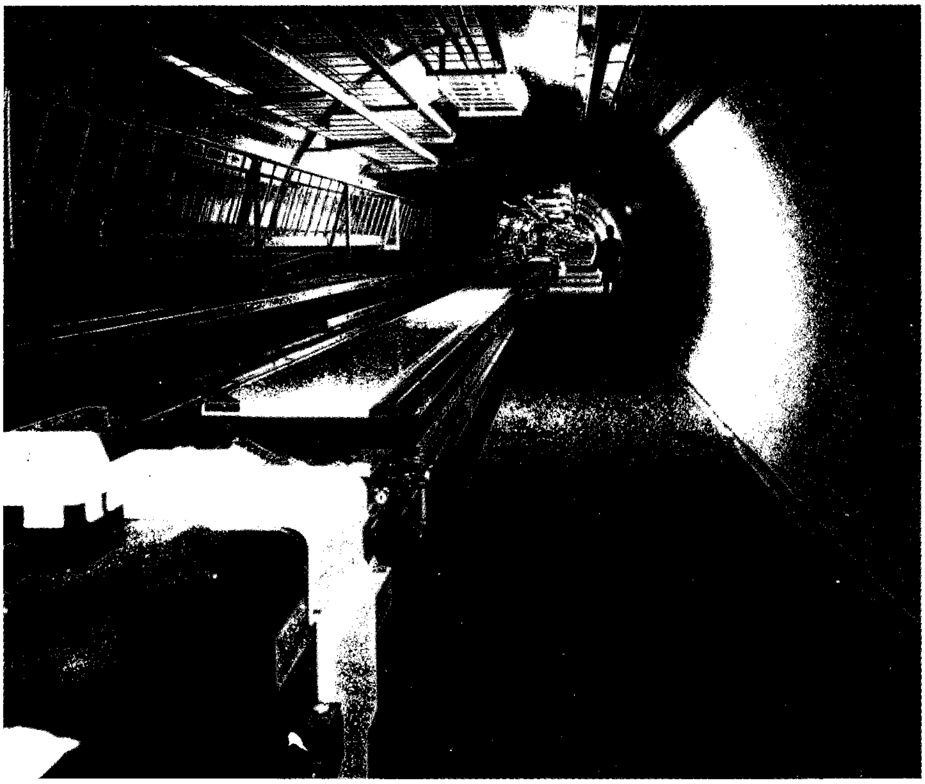
Ground state of protonium

'Exotic atoms' – where everyday orbital electrons are replaced by other negatively charged particles (muons, pions, kaons, antiprotons) provide physicists with another window on the strong nuclear force to supplement what is learned from scattering experiments.

These synthetic atoms have long been a speciality of CERN research, and the availability of intense beams of antiprotons at the LEAR Low Energy Antiproton Ring gave a boost to the study of atoms with orbital antiprotons.

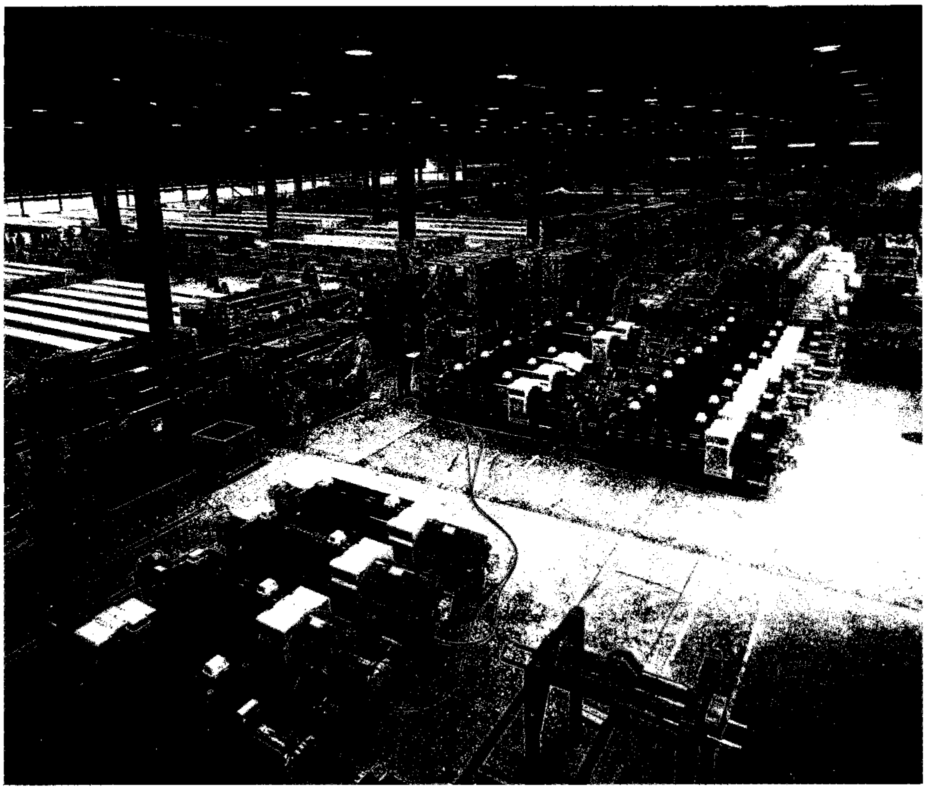
Like everyday electrons, antiprotons are held in their atomic orbits by the electromagnetic attraction of the positively charged nucleus. However because antiprotons are almost 2000 times heavier than electrons, they pass very close to the nucleus, experiencing at close quarters the effect of the nuclear force,

LEP progress



Not a mock-up this time but the real thing. A section of the 27 kilometre LEP electron-positron collider at CERN, where installation work is pushing ahead quickly.

(Photo CERN X312.11.87)



Magnets being readied to go down into the LEP tunnel. At the rear are the 'concrete' dipole elements, with quadrupole and sextupole assemblies in the foreground.

(Photo CERN X340.11.87)

measured through the resulting changes in atomic behaviour.

Because their inner orbits are so small, antiprotons are frequently swallowed by the nucleus before they can reach the ground state orbit, making the corresponding X-ray spectra (K lines) difficult to see. This was overcome in different ways by three experiments at LEAR (see December l986 issue, page 12).

The simplest such atom is 'protonium', or antiprotonic hydrogen,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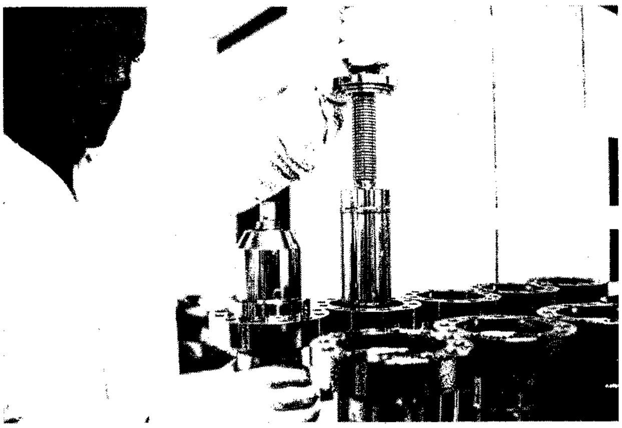


with a lone nuclear proton and an orbital antiproton, giving deep insights into the nuclear interaction between particle and antiparticle. However the individual K lines were difficult to separate or were obscured by large backgrounds. To overcome this, the ASTERIX experiment looked for two or three coincident X-rays due to successive atomic transitions as the orbital antiprotons tumbled from one orbit to the next, landing up in the ground state.

Selecting a particular line (an L transition to the first excited state) in coincidence with a K line selects the first K X-ray line (K-alpha) from the complete pattern of K lines. This requires a detector with good angular coverage, low threshold and good efficiency, as only one K-alpha X-ray is emitted per hundred L lines. Unravelling the K-alpha from its neighbours in this way makes for cleaner nuclear physics information.

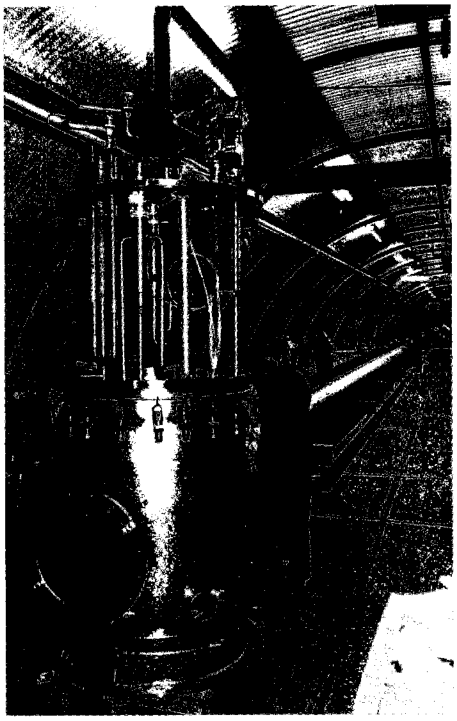
DESY
Accelerators tested

As mentioned briefly in our December 1987 issue, the new chain of electron accelerators at the German DESY Laboratory in Hamburg underwent a 14-day trial. The electron linac, the new DESY II synchrotron and the PETRA ring (previously an electron-positron collider and now used as an intermediate accelerator) injected particles into the first completed section of the electron ring for the HERA electron-proton collider.

On 5 November, single bunches were injected from PETRA into an electron module of HERA at time intervals of 8 seconds using two septum- and three kicker-magnets. Later the beam was transported through 11 HERA modules in 130 metres of tunnel, giving a final particle intensity of 8 x 10^8.

One interesting test involved picking out single bunches from the beam stored in PETRA with the help of very fast ejection kickers, without disturbing the rest of the bunches. The kickers operate faster than the bunch separation of 96 nanoseconds, allowing the injection process to be studied in depth. Video images of the spots produced by single bunches on thin fluorescent screens are stored electronically and analyzed to optimize injection.

PETRA was operated at 7 GeV (in future it will be 14 GeV) for electrons. Throughout the test, a 4-cell superconducting cavity operated in the PETRA ring.



Helium transfer line under test at DESY for the superconducting magnets of the HERA electron-positron collider now under construction.

PETRA beam test of superconducting cavities

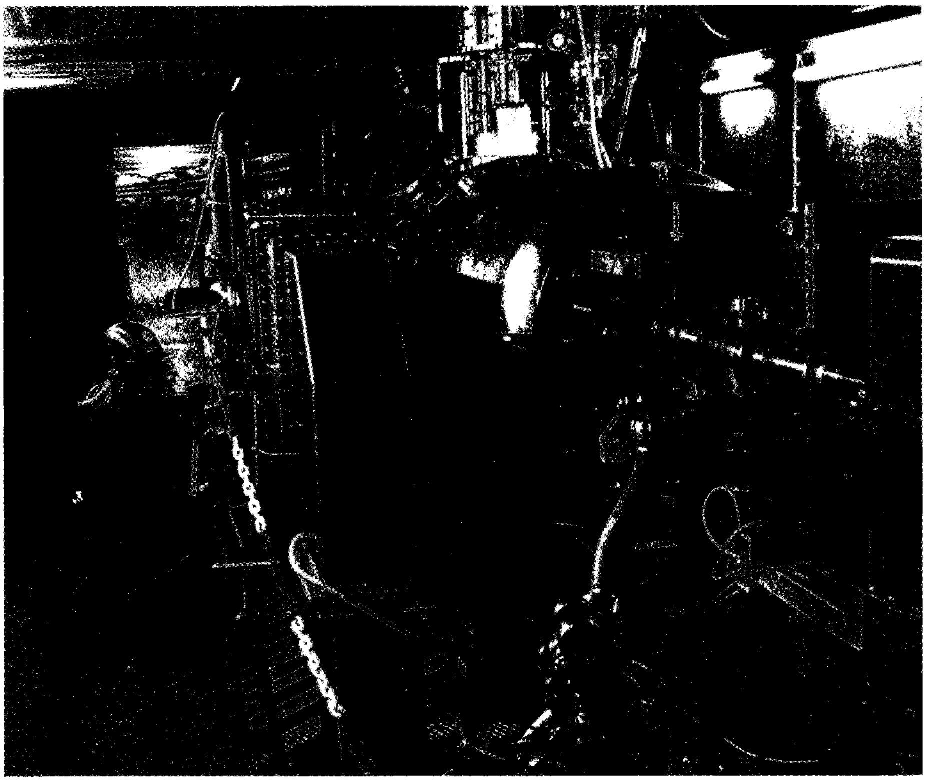
Superconducting 500 MHz cavities have been developed at DESY for increasing the electron beam energy in the HERA storage ring. The basic 4-cell design follows closely the corresponding CERN layout (see page 7). At DESY new higher order mode couplers have been developed to supply enough damping of higher cavity modes at the HERA current of 60 mA. In this design the dominant higher order mode resonances are much more strongly damped than in a normal conducting copper cavity. A tight-fitting helium vessel is welded to the cavity, and the additional use of aluminium fillers reduces the amount of liquid helium required to 100 litres per 4-cell unit, an important safety aspect. The complete assembly, including couplers and helium vessel, is fabricated, chemically cleaned and processed by industry. Two such assemblies will be mounted under dust-free conditions in 4.2 m cryostats supplied by industry.

In the first prototype cryostat with its two 4-cell assemblies a cold leak in one cavity had to be fixed. Subsequently the cavity quenched at 2.5 MV/m at one of the repaired electron beam welds. The other cavity assembly was limited at 200 kW forward power by sparking at the high power input window. At this level the accelerating gradient was 5.1 MV/m. Field emission at this gradient lowered the quality factor (Q-value) to 1.3 x 10^9 (compared to 2 x 10^9 at lower fields).

The main purpose of the test was to explore the behaviour of

Prototype superconducting radiofrequency accelerating cavity under test at the PETRA electron ring at the DESY Laboratory in Hamburg.

(Photo Nick Wall)



the higher order mode couplers. Under single and multibunch conditions with beams on and off axis the higher order mode spectrum was carefully measured while the cavity was tuned over its full range, and the measured data corresponded to the predicted values. The efficient loading of the superconducting cavity will result in only 100 Watt higher order mode power under HERA conditions.

Injection and storage of multibunch (4.4 mA) and single bunch (2.5 mA) currents at 7 GeV with one and two cavities provided valuable experience, and the measured synchrotron frequency confirmed the radiofrequency calibration at 5.1 MV/m.

After this successful test the go-ahead was given for 16 superconducting 4-cell cavity units in 8 cryostats. These will be installed in HERA by the end of 1989.

Theory workshop

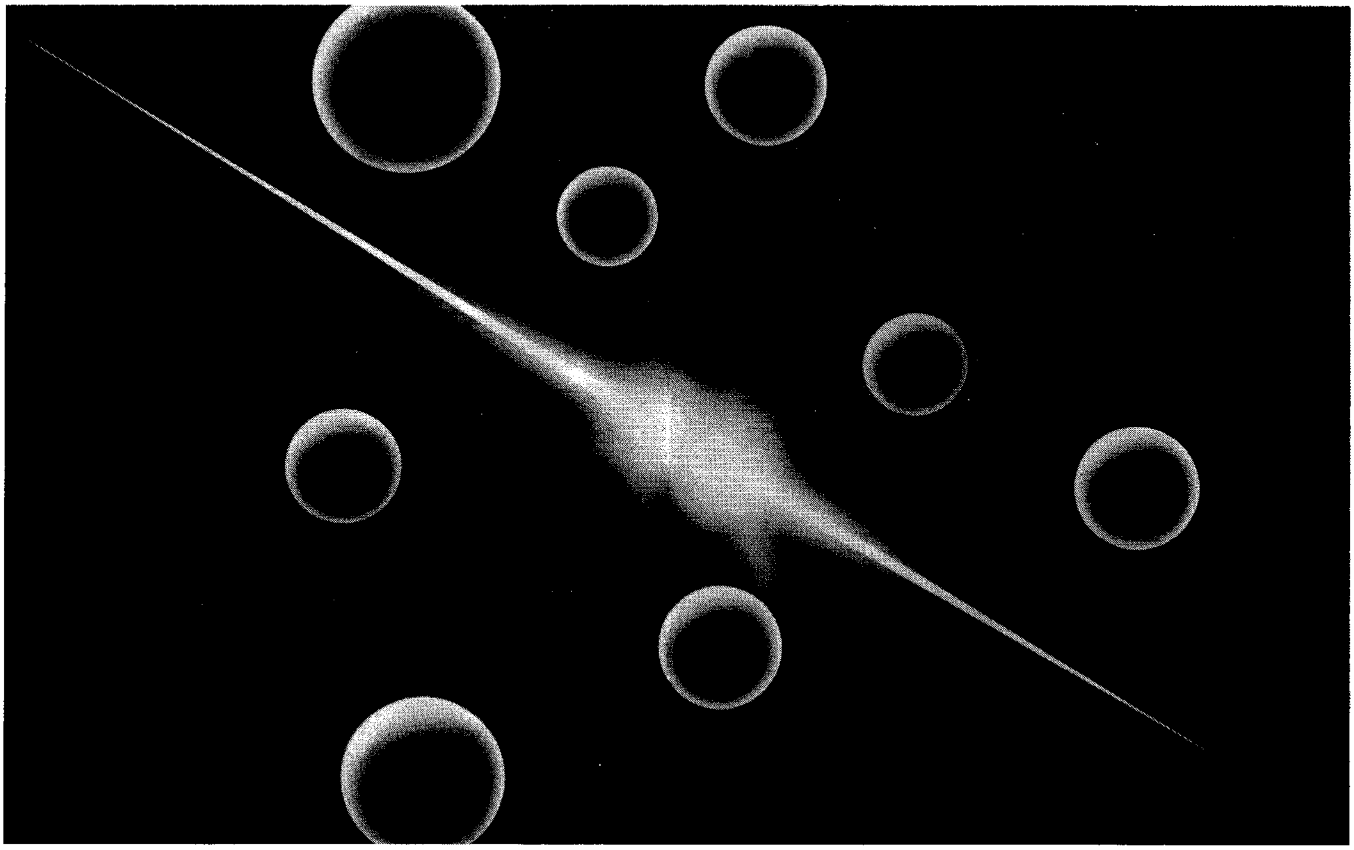
The annual Theory Workshop at the German DESY Laboratory, held last year from 12-14 October, concentrated on the physics potential of the HERA electron-proton collider now under construction at Hambug. After a welcome address by DESY Director Volker Soergel HERA status was reviewed by R. Brinkmann (DESY), and D. Barber (DESY) examined the possibility of having polarized (spin oriented) beams in HERA. This first session ended with reports by P. Steffen (DESY) and D. Saxon (Rutherford Appleton) on the status of the H1 and ZEUS detectors, respectively, now under construction.

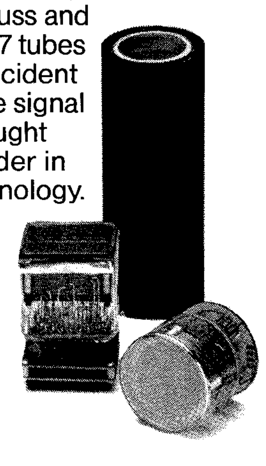
The remainder of the Workshop was given over to detailed presentations by seven working groups, comprising about 200 physicists, who had spent nine months looking into different aspects of HERA physics. G. Ingelman (DESY), J. Feltesse (Saclay) and M. Klein (Berlin-Zeuthen) presented the conclusions of the working group looking at 'deep inelastic' collisions (where the electron penetrates deep into the proton), in particular the ability to extract precision values for the proton quark/gluon content (structure functions).

The working group studying the implications for HERA of quantum chromodynamics (QCD), the field theory of quarks and gluons, had a new analysis of structure functions by Richard Roberts (Rutherford Appleton), a discussion by W. J. Stirling (Durham) and A. M. Cooper-Sarkar (Rutherford Appleton) of ways to measure gluon content, and detailed studies of QCD effects by G. Ingelman (DESY) and P. Burrows (Oxford).

The third working group concentrated on aspects of high energy photoproduction to be tested at HERA. L. Suszyzki (DESY) discussed a photon tagging system, while D. Diokmann (Bonn) and C. de Jong (NIKHEF) looked, respectively, at diffractive meson production and at hard processes initiated by (quasi) real photons. This working group, as well as the heavy quark working group, emphasized that heavy flavour production will be very abundant at HERA.

Detailed predictions of the working group for heavy quark (charm, bottom and top) production were presented by G. Schuler (DESY) and Z. Kunszt (ETH Zurich). In particular, Schuler indicated that HERA could see top quark effects up to 85/90 GeV. R. Marshall (Rutherford Appleton) and F. Barreiro (Madrid) presented the 'experimental' conclusions of this working group, with Marshall describing possible





DESY Theory Workshop 1987 – Willibald Jentschke (right) with Harry Lehmann.

strategies for digging the top signal out of the background and Barreiro discussing ways to study the large B meson sample (over 10^5 events/year), which will be produced at HERA.

A rather thorough discussion of the results of the radiative corrections working group at HERA was presented by W. Hollik (Hamburg) and M. Spiesberger (Würzburg). There is now agreement between all calculations and, as J. Kripfganz (Leipzig) emphasized, the dominant electromagnetic origin of some of the larger corrections is now understood. The implementation of these radiative corrections in a simulation programme was described by C. Kiesling (Max Planck).

Much more speculative were the reports of the 'exotic' working group, looking for new physics possibilities at HERA. J. Bartels (Hamburg) and L. Stanco (Padua) described, respectively, the theoretical expectations and the experimental strategies for detecting supersymmetric signals. H. U. Martyn and C. Berger (both from Aachen) looked at the implications of as-yet undiscovered compositeness, providing new interactions or excited leptons. The potentially spectacular signals associated with resonances carrying electron-quark or electron-gluon quantum numbers were discussed by N. Harnew (Oxford), while J. Bijnens (Munich) put these excitations in theoretical perspective. Perhaps the most exotic report of all came from G. Grindhammer (Max Planck), who highlighted the consequences of quarks with appetite being liberated at HERA, munching their way through ZEUS or H1!

The last working group dealt with electroweak phenomena and a summary was presented by R. Rückl (DESY). This was followed by reports by G. Cozzika (Saclay) and G. Heath (Oxford) on the prospects for precision measurements of various electroweak parameters at HERA, while M. Treichel (Wuppertal) and J. van der Horst (NIKHEF) described, respectively, the rather restricted possibilities available at HERA for measuring the parameters of the six-quark (Kobayashi Maskawa) picture and detecting W, Z and Higgs bosons directly. F. Cornet (Max Planck), finally, reported on the potential for discovering new weak bosons and currents.

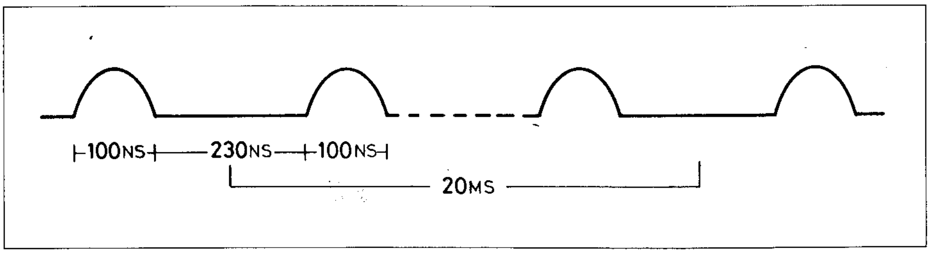
A summary by P. Langacker (Penn./DESY) captured nicely some of the excitement felt in the Workshop about the prospects for HERA physics, stressing the complementary role that HERA will play to the electron-positron and proton-antiproton colliders coming into operation.

Next year's Workshop – 'Physics of Flavour' – will be held from 28-30 September in Hamburg. P. Zerwas (Aachen) is the chairman of the organizing committee.

From Roberto Peccei

Roberto Peccei

Pulsed protons from ISIS at the UK Rutherford Appleton Laboratory.



RUTHERFORD APPLETON
Pulsed muons

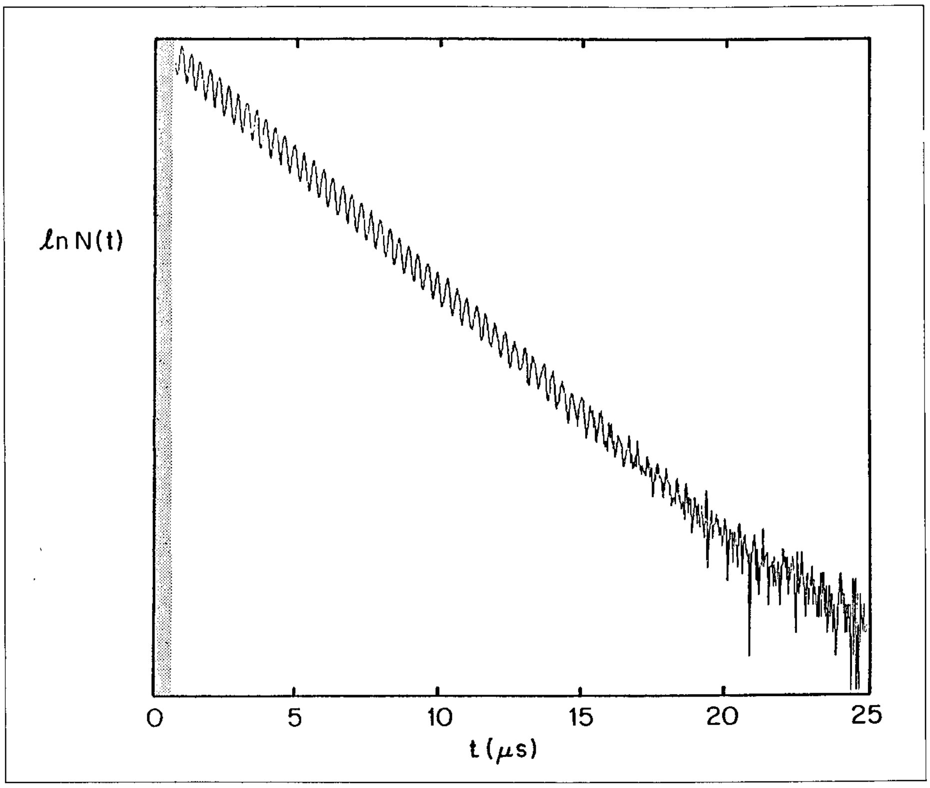
As well as being used in particle physics and nuclear structure research, beams of low energy muons also provide tools in condensed matter research and as a catalyst for thermonuclear fusion. Their long (2.2 microsecond) lifetime provides many advantages but also problems for the continuous beams of the 'pion factories' that have taken up the running after pioneering work at CERN's 30-year-old Synchro-Cyclotron. In order to avoid pile-up, many experiments are forced to handle one muon at a time; this limits beam intensities to 10^4 per second, while ten thousand times this number are available. Also the long 'live time' of the apparatus magnifies the backgrounds from the accelerator and from cosmic rays. Using a pulsed beam, measurements can start with a lot of muons after the machine background has died and with a narrow time slot reducing the effect of cosmic rays. However adding a pulsed proton source onto an existing facility would cost more than fifty million dollars, so an alternative approach was necessary.

ISIS at the UK Rutherford Appleton Laboratory uses an 800 MeV proton synchrotron to produce spallation neutrons for condensed matter research. The protons are pulsed, so that neutron energies can be determined by 'time of flight' from the spallation target. Additional suggested uses for the pulsed beam included experiments with neutrinos from the spallation target (the KARMEN project – see January 1986 issue, page 13). A Birmingham group proposed pulsed muon physics, including muon spin rotation, using an intermediate production target in the proton beam. Beamline components were obtained from many sources – parts of old UK beams were rescued from the scrapheap, while other units were borrowed from other Laboratories.

Construction was funded by the rapidly growing muon spin rotation community using contributions from France, Sweden, Germany, Italy and Japan together with a European Economic Community grant for international research.

Muon spin rotation is a very powerful method for measuring magnetic and hyperfine fields within condensed matter. The weak interaction forces the muon (from the decay of a pion) to be formed with its spin always pointing the same way, and to decay preferen-

The characteristic oscillations due to muon spin rotation give information on local magnetic fields. Using the pulsed muon beams at ISIS, low backgrounds and high beam intensities enable the signals to be followed over ten average muon lifetimes (log scale).



tially along its spin direction. So the number of electrons from muon decay observed in a given direction oscillates as the muon magnetic moment precesses around the local field where the muon is stopped.

Using a pulsed beam of positive muons at ISIS, the absence of background and the high beam intensity enables the characteristic oscillation of the precession signal to be followed across ten average muon lifetimes! The only price to pay is a small loss in time resolution.

A very wide scientific programme has already begun, which to date includes studies of metals, metal hydrides, magnetic materials and, of course, high-temperature superconductors. Also considerable interest is placed on the study of the muonium atom (an electron bound to a positive muon) both for its fundamental properties as well as the subtle isotope effects revealed in a comparison with hydrogen. A Birmingham / Bologna / Delft / RAL / US group is measuring the fraction of muons sticking to the alpha-particle following catalysed deuterium-tritium fusion.

This pulsed muon facility complements the work using continuous beams. With further funding, a kicker magnet can be added to separate the two muon pulses into different experimental areas, with the option of time-slicing pulses down to 10 ns. Also there is space for decay and superconducting channels off the same graphite target.

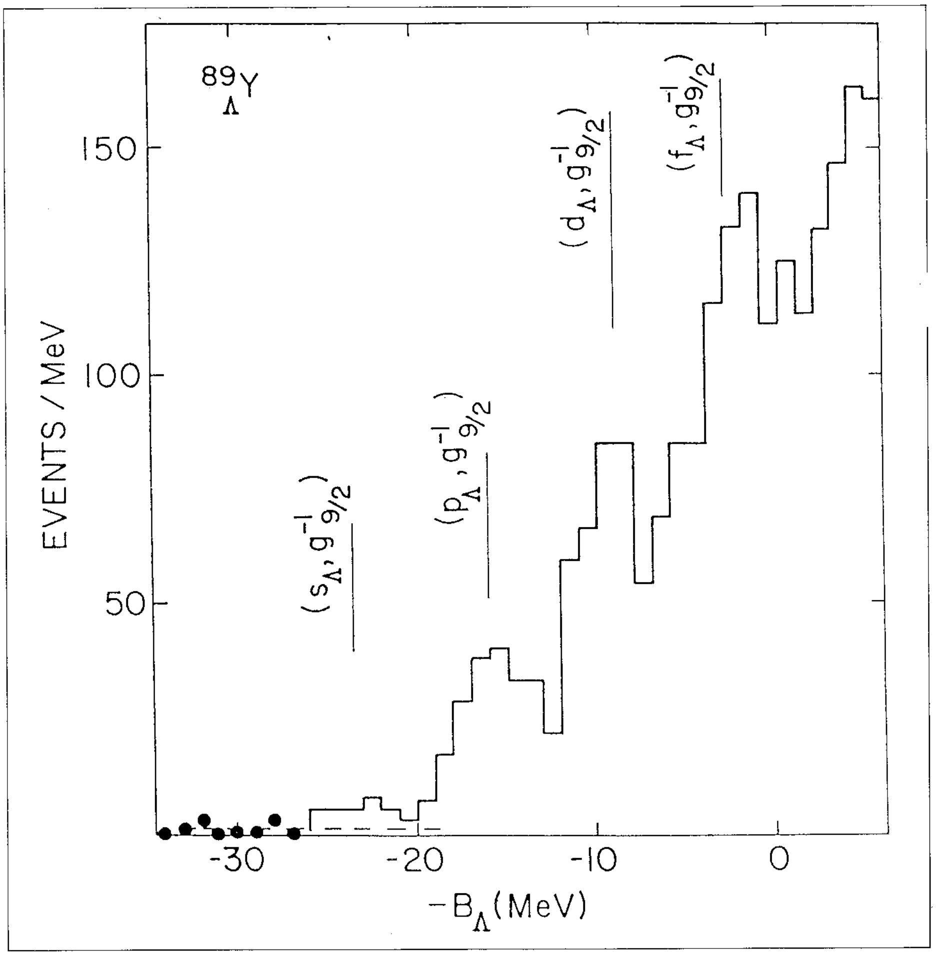
A hypernuclear ladder - a portion of the spectrum from positive kaon production by positive pions on yttrium 89, from Experiment 798 at the Brookhaven Alternating Gradient Synchrotron, showing the bound single particle states of a lambda particle in a nucleus.

BROOKHAVEN Deeply-bound hypernuclei

In a major step forward in research on hypernuclei, a team (Experiment 798) at the Brookhaven Alternating Gradient Synchrotron (AGS) has found a nuclear spectrum of lambda single-particle bound states well-defined even when the lambda is deeply bound. This shows that the nuclear shell model picture is valid for deeply lying states as well as surface excitations.

In hypernuclei, one or more nucleons have been replaced by hyperons (lambdas, sigmas, etc.). Usually they are made using the strangeness of a beam of negative kaons to transform neutrons into lambda hyperons. This reaction is useful mainly for nuclear valence states as it is difficult to implant the lambda deep inside the nucleus because of the strong absorption of negative kaons and unfavourable kinematics.

Another way of making hypernuclei is to look for the production of positive kaons from a positive pion beam, where the emergent positive kaon is more likely to escape the nucleus and be counted. In addition, the large momentum transfer is better for producing high spin hypernuclei.



The Pauli Exclusion Principle stops more nucleons being added to an already full nuclear shell. However a distinguishable lambda is able to fit in anywhere. A beautiful and regular spectroscopic ladder can be seen with the lambda in successive levels.

In E 798, positive incoming pions of momentum 1050 MeV were measured in coincidence with outgoing positive kaons, using the Moby Dick spectrometer at the LESB-1 beamline and a series of eight targets - beryllium 9, carbon 12, carbon 13, oxygen 16, silicon 28, calcium 40, vanadium 51 and yttrium 89. For the lighter targets the observed spectra were similar to those previously obtained in experiments using negative kaon beams. For the heavier targets, the low-lying bound hypernuclear states, including the ground state, were observed for the first time.

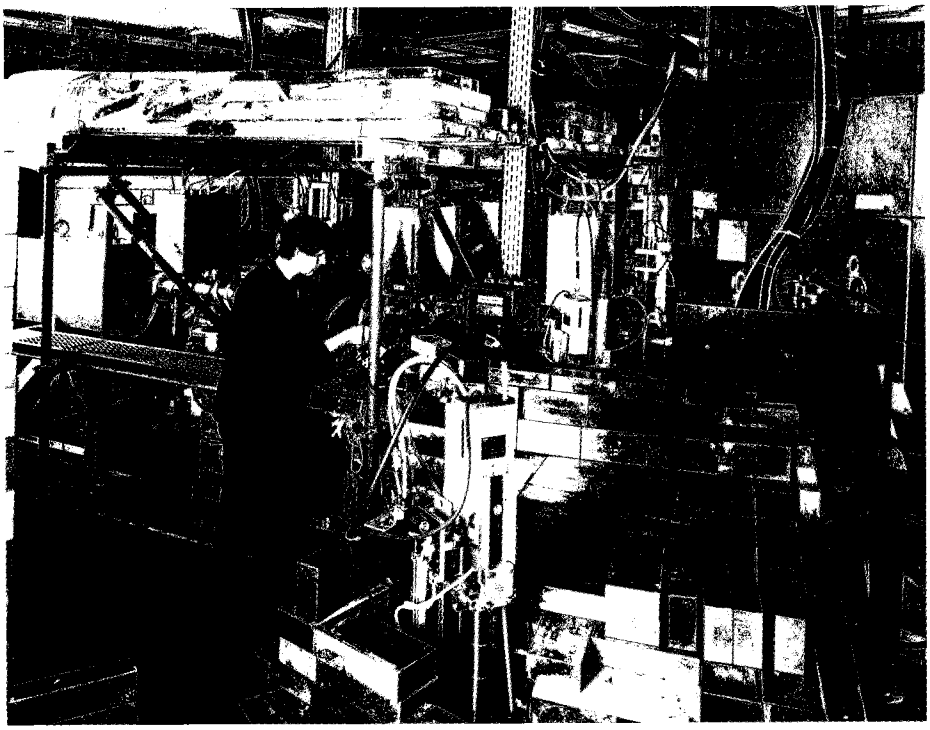
In principle the two non-strange quarks in the lambda should lead to a 'Pauli pressure' due to effects (anti-symmetrization) at the quark level, shifting the lambda spacings from the predictions of the simple potential model. However this is not evident from the data.

Higher energy resolution measurements on nuclei with mass number greater than 100 could probe the subtle quark effects in hypernuclei.

These experiments with pion beams have revived interest in heavy hypernuclei. Lambda particles should shrink the nuclear core, modifying its vibrational and rotational frequencies. Other insights would follow from improvements in the experimental techniques.

E 798 included scientists from Brookhaven, Los Alamos, Houston, Tohoku, TRIUMF, Vassar, Carnegie-Mellon, Florida State, and Mississippi.

Small is beautiful – the COSY compact synchrotron light source being developed at BESSY in Berlin has a circumference of less than 10 metres.



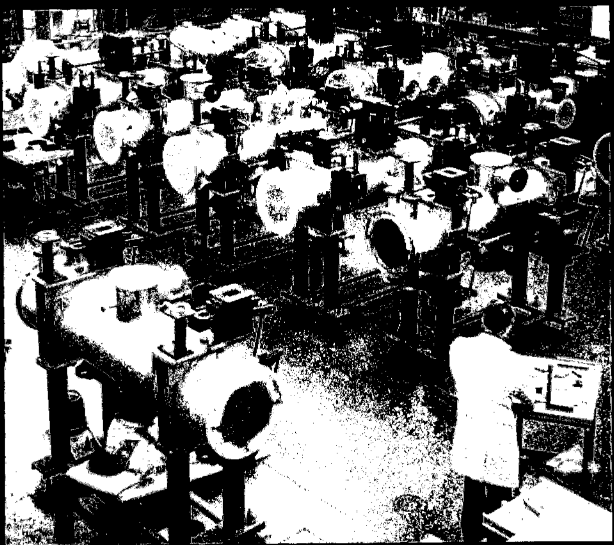
BESSY COSY commissioning

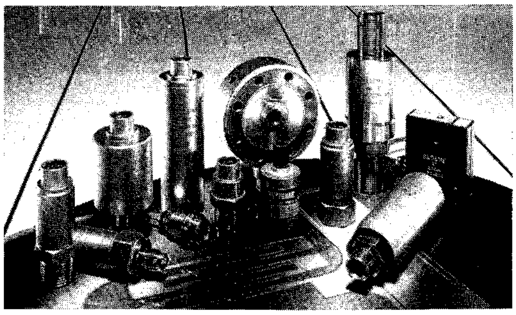
In November the compact electron storage ring COSY, a dedicated synchrotron light source for X-ray lithography under development at the BESSY synchrotron radiation Laboratory in Berlin, passed an important milestone with electron currents up to 75 mA stored at 50 MeV injection energy using normal conducting dipole magnets. Now the next step – to fit superconducting dipoles and increase the energy – can be attacked with confidence.

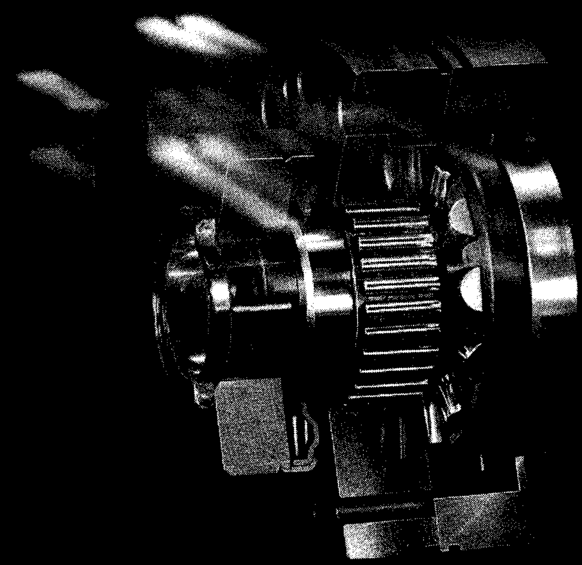
The development of the COSY machine results from the need for compact high intensity soft X-ray sources for sub-micron technologies in highly integrated electronics. These techniques have been studied for several years at the Fraunhofer Institut fuer Mikrostrukturtechnik (IMT) in Berlin using vacuum ultra-violet synchrotron radiation from the BESSY 800 MeV storage ring. As an integral part of a submicron pilot processing line for X-ray lithography, IMT has contracted the development of an advanced compact light source to BESSY. At least five similar projects are underway elsewhere.

Starting in 1984 with a feasibility study, the BESSY machine group worked out the present COSY design for a critical wavelength of 1.2 nm at 600 MeV based on two superconducting 180 degree dipoles and four normal conducting quadrupole magnets with a total circumference of only 9.6 m.

The compactness has some inherent risks because of the need to inject electrons at low energies. It also requires the development of superconducting 180 degree dipole magnets (4.5 T) with a very small bending radius (0.44 m).



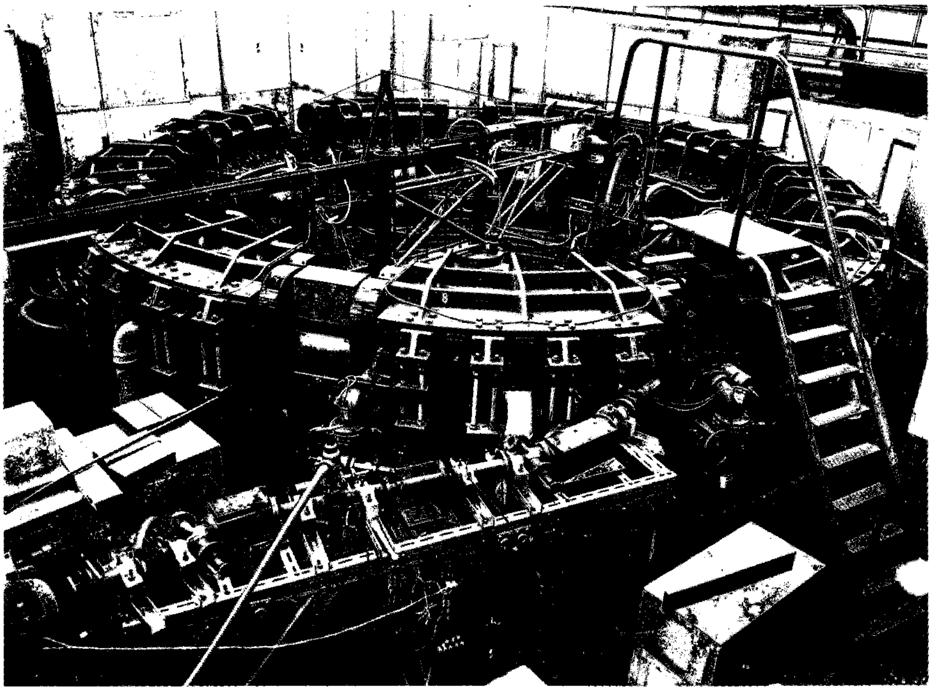




With the present set-up, using two normal conducting dipoles prior to the installation of the superconducting magnets, the injection process has been studied in detail. Electrons from a 50 MeV racetrack microtron, constructed by Scanditronix in Sweden, are injected vertically by a pulsed septum and three kicker magnets. So far, maximum currents of 75 mA have been accumulated in three minutes.

The next challenge is to store electrons with the superconducting dipoles. These magnets, built by Siemens/Interatom, have already reached at the manufacturers the design field of 4.5 T and ramped at 1.2 T/min. The first electrons stored at final energy are expected in 1988.

The Bonn 500 MeV electron synchrotron, the first accelerator in Europe to use the strong focusing technique, started operating in 1958. It is to be moved to the Deutsches Museum in Munich.



BONN
Continuous electron beams from ELSA

In October the new Bonn Electron-Stretcher-Accelerator, ELSA, was inaugurated by the Minister of Science and Research of North-Rhine Westfalia, Frau Anke Brunn. The Federal Government was represented by P. Dallinger and J. Rembser. The accelerator and the three main experiments SAPHIR, PHOENICS and the Electron Scattering Facility were presented at a symposium.

ELSA is the third electron machine built at the Physikalisches Institut in Bonn with strong student participation. The 500 MeV electron accelerator, the first in Europe with strong focusing magnets, started operation in 1958. After more than 100 000 hours it was removed to liberate space for ELSA. The 'Deutsches Museum' in Munich will preserve this unique machine as a milestone of the European accelerator development.

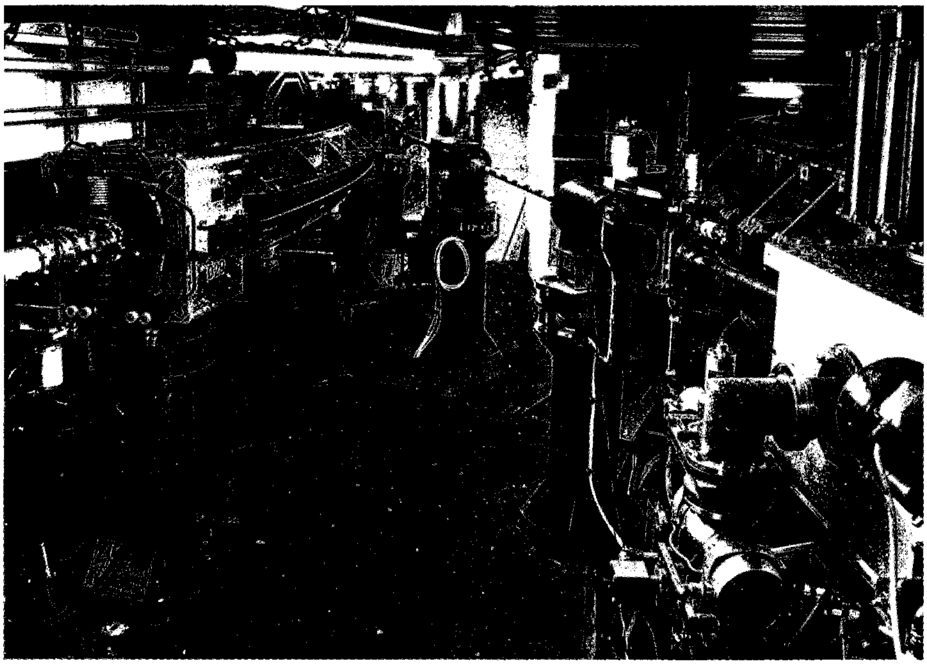
The second accelerator, the 2.5 GeV electron synchrotron, came into operation in 1967. The scientific programme at the accelerators was devoted mainly to studies of the structure of the nucleons and light nuclei, photo-induced production of mesons and baryons, new quark systems (dibaryons) and the development of new experimental techniques (such as the use of polarized electrons, photons and targets to study spin dependent effects). Since 1962 synchrotron radiation experiments, covering the vacuum ultraviolet and the X-ray region were performed with both machines.

ELSA is a separated function machine, using the 2.5 GeV electron synchrotron as injector. It can be operated in two modes. Up to 2 GeV it serves as a storage ring, stretching the pulsed beam to a continuous one to give a duty cycle of nearly 100%. The energy loss by synchrotron radiation is compensated by a single 500 MHz resonator (DORIS-type). In the second mode, the magnets can be ramped to a flat top field corresponding to 3.5 GeV. Two 5-cell 500 MHz resonators (PETRA-type) are then needed. Depending on the length of the flat top and the time for injection, the duty cycle is between 6% and 95%. The beam current can reach 0.5 microamps.

Tests with ELSA started last spring at 1 GeV and no major difficulties were encountered. The first external beam was achieved in September and the ramping up to 2 GeV worked well. 3.5 GeV operation is scheduled for this spring.

The physics will concentrate on photo-induced reactions on nucleons and light nuclei with two

The beam transfer region where electrons from the 2.5 GeV injector synchrotron, on the right, are sent into Bonn's new 165 m ELSA ring.



or more particles in the final state. The optimum system in this case is a tagged photon beam and large solid angle detectors. Another speciality at Bonn will be electron scattering using polarization techniques. The use of transversally polarized photons and polarized targets is foreseen. The relatively low intensity of ELSA is ideally matched to these types of experiments. Many of today's nuclear physics studies call for continuous GeV electron beams. ELSA is the first continuous electron beam accelerator in the GeV range, promising exciting new particle and nuclear physics. The ambitious US CEBAF project should continue the work in the same energy range with higher intensity beams.

NOVOSIBIRSK Comparing electron and positron magnetic moments

Electrically charged particles that spin behave as tiny magnets, and classical (relativistic) quantum mechanics relates this spin and the resulting magnetic moment. However delicate additional quantum effects due to the continual emission and absorption of particles also come into play, slightly changing this magnetic moment and in turn rotating the spin direction of a particle circulating in a magnetic field (spin precession).

One of the great achievements of modern physics is the highly accurate (quantum electrodynamics) prediction of the magnetic moment of particles like electrons and its verification to nine parts per million in a series of precision measurements at CERN (the g-2 experiments).

Further insight comes from comparisons of the magnetic moments of electrons and their antimatter counterparts (positrons). Any difference would signal some important asymmetry between matter and antimatter, with immediate consequences for physics.

New information comes from comparisons at Novosibirsk of the behaviour of polarized (spin oriented) beams of electrons and positrons circulating in a storage ring in the same magnetic fields.

In previous experiments at the Novosibirsk VEPP-2M ring, electron and positron magnetic moments were compared using the resonant depolarization technique to find the spin precession rates. Its accuracy was limited by the stability of the accelerating frequency and by the uncontrollable drift of the magnetic field in the storage ring.

This can be avoided using an alternative method. Because of radiative polarization, the spin directions of electrons and positrons circulating in a storage ring line up with the guiding magnetic field. These spins can be made to point horizontally by applying a radiofrequency field in resonance with the spin frequency. After switching off the resonant action, and provided there are no electric fields, the electron and positron spins rotate around the guide field direction and any differences in their magnetic moments give a turn-by-turn accumulated phase difference.

After a certain number of spin revolutions the r.f. field is applied again to restore the polarization. Although the polarization levels of the beams are now arbitrary, their correlation contains the complete information on any phase difference gained during the free precession.

As in the previous experiments, the VEPP-2M beam polarizations were measured using the intrabeam scattering of the particles. In

routine 650 MeV studies, the radiatively polarized electron and positron beam currents were 5 mA. Ten runs were made, with free precession lasting 0.1 s (3×10^6 spin revolutions). The number of spin turns could not be increased any further due to the polarization smearing, relatively rapid during spin precession in the horizontal plane.

From the measured phase difference, the magnetic moments of electrons and positrons were found to be the same to within one part in a hundred million. Check measurements using an electric field to deliberately separate the electron and positron beam spin precession frequencies underlined the sensitivity of the method.

Looking far into the future – Antonino Zichichi at last year's INFN Eloisatron workshop, flanked (left) by Luigi Granelli, then Italian Minister for Science, and Ahmed Ali.

Beyond 2000

With several major schemes for future hadron and electron-positron colliders being mooted around the world, particle physicists are eager to coordinate their activities to optimize the inevitably lengthy development work for these new machines. (See, for example, the report of the recent 'Future Perspectives' meeting organized by ICFA – the International Committee for Future Accelerators – in the December 1987 issue, page 1).

These machines would provide the research arena towards the turn of the century, but last year a meeting of bold physicists in Erice, Sicily, attempted to look even further into the future. The workshop provided a scientific forum for new avenues in very high energy hadronic physics, with special emphasis on the European scene.

The physics talks assessed the current status of the field, and looked forward to what could be expected from future colliders, as judged by insights from ongoing experiments and by theoretical ideas. A series of illuminating talks looked at the physics possibilities and the attendant technological requirements using multi-TeV (thousands of GeV) proton beams.

Reviewing the HERA electron-proton collider now under construction at the German DESY Laboratory in Hamburg, DESY Director Volker Soergel pointed out that the machine will be able to supply proton beams at up to 1 TeV.

CERN Director General Herwig Schopper stressed the need for world-wide collaboration to avoid costly duplication of resources, and submitted that tenfold increases in hadron collision energy (such as CERN's step from the Intersecting Storage Rings to the proton-antiproton collider at the SPS) are a good way of tackling new research ground.

The LHC Large Hadron Collider idea to install a proton-proton collider in the tunnel now being completed at CERN for the LEP electron-positron collider would provide just such an energy increase, pointed out Schopper (LHC's high field superconducting magnets are aimed at around 8 TeV proton beams, compared with the 1 TeV beams now available from the Fermilab Tevatron). The US SSC Superconducting Supercollider project to provide 20 TeV colliding proton beams involves a 20-fold energy increase – 'a large jump into unknown territory', according to Schopper.

Continuing with this rule of thumb, the following generation machine should pitch for 100 TeV beams. Such an idea – the Eloisatron – has been groomed by Anto-

Physics monitor

nino Zichichi for several years. At the Erice workshop, Zichichi underlined that an initial ten per cent version of such a European machine is needed to pave the way, and at optimal outlay. LHC appears to fit the bill. Zichichi also highlighted European successes in developing techniques for superconducting proton rings, such as that intended for HERA. This view was shared by Luigi Granelli, Italian Minister of Scientific Research at the time of the Erice workshop.

As a small beginning towards the goal of setting up the research and development infrastructure for such an ambitious project, an Eloisatron Institute will be held at Erice's Ettore Majorana Centre this June. Those interested are invited to contact Ahmed Ali at DESY.

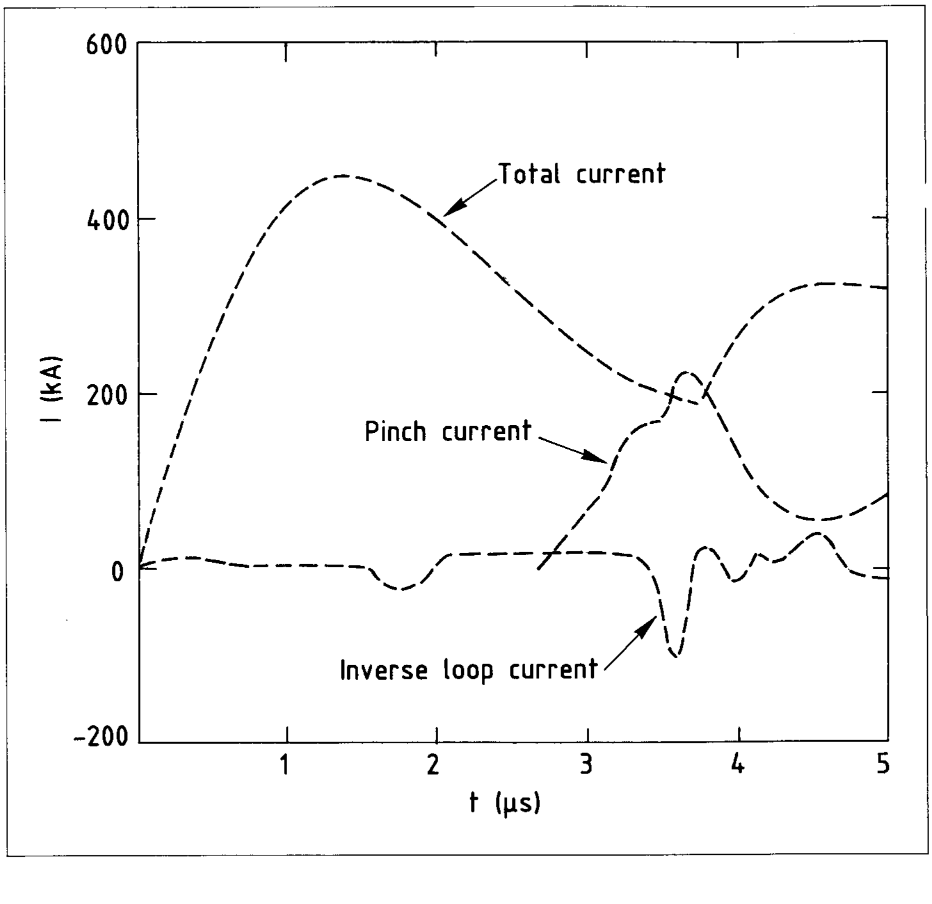
PLASMA/ ACCELERATORS Working together

The quest for ever higher performances in particle accelerators has made accelerator and plasma experts get together. The status of this interdisciplinary effort was the topic of the April 87 issue of the IEEE Transactions on Plasma Science devoted to plasma-based high energy accelerators.

At CERN, a plasma lens has been developed to collect divergent antiproton beams for the ACOL Antiproton Collector project. More generally, a plasma lens could replace magnetic horns and lithium lenses employed for the same purpose. In 1984, a collaboration started with the Universities of Erlangen and Naples, and the results and problems encountered were discussed in a Plasma Lens Workshop held at CERN in September 1986.

In the meantime, the University of Naples extended its interests to the plasma perturbations excited by microwave radiations of slightly different frequencies, the so-called beat-wave techniques, and a new workshop on Plasma Focusing was organized in Capri last October. Gathered in this small paradise favoured by Roman emperors were physicists of six American and European Laboratories.

Two classes of phenomena were discussed: the magnetic focusing due to the azimuthal field produced



Inverse skin effect in the plasma lens developed for CERN's ACOL Antiproton Collector. When a cylindrical conductor has a radius of the order of the skin depth, the current density, and therefore the magnetic field gradient, may increase near the axis. In that case, the pinch current exceeds the total current and current conservation is provided by inverse currents in loops between the pinch and the wall.

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Interested graduate students should write to the address below for applications.

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SRRC

1.3 GeV Synchrotron Light Source

The Synchrotron Radiation Research Center (SRRC) project, ROC government funded, the first of its kind to construct and operate an up-to-date 1.3 GeV electron storage ring for dedicated use of synchrotron radiation research in Taiwan, ROC, has a number of positions available:

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SENIOR ELECTRONIC ENGINEERS
SENIOR COMPUTER SCIENCE ENGINEERS
Preferably Ph.D. with a minimum of two years' experience in accelerator computer control systems.

ELECTRICAL ENGINEERS
Requires MS with experience in magnetic field measurement or RF systems.

MECHANICAL ENGINEERS
Requires MS with experience in ultrahigh vacuum systems.

Knowledge of Chinese is not required. Proficiency in English is essential. Interested applicants may forward complete curriculum vitae with three professional references to

Dr. T.S. Lu
Synchrotron Radiation Research Center
8th Fl., No. 6, Roosevelt Road, Sec. 1
Taipei, Taiwan 10757
Republic of China

in a plasma column of quasi-uniform density and the electric focusing associated with the charge density variations induced either by high power lasers or by high intensity particle beams. Besides acceleration techniques like beat-wave or wake-field accelerators outside the scope of the workshop, applications are foreseen in collecting lenses, final focusing for future linear colliders or heavy ion fusion, wigglers with a short period of beam undulation and self focusing of intense beams in a plasma loaded channel.

Faced with challenges and stimulated by the excellent spirit of the meeting, the participants unanimously agreed to go ahead with a new series of workshops named CAPRI (Common Accelerator and Plasma Research Initiatives) as tribute to the blessed island. An organizing committee composed of B. Autin and H. Riege (CERN), J. Christiansen (Erlangen), A. Dangor (London), U. De Angelis and L. De Menna (Naples), J. L. Bobin (Paris); R. Bingham (Rutherford Appleton Lab.), T. Katsouleas (UCLA) will meet in Paris in November to prepare the next workshop which will take place at Rutherford Appleton Laboratory (UK) in April 1989.

From B. Autin

Double beta decay

Steve Elliott, Alan Hahn and Michael Moe, working at the University of California at Irvine, have seen a new kind of radioactivity – double beta decay – expected for more than half a century but only observed after nearly 40 years of painstaking investigation.

In ordinary single beta decay, a nuclear neutron decays into a proton, releasing an electron and an antineutrino. The resulting nucleus, lighter but containing an extra proton, moves up a rung in the periodic table.

Soon after the formulation by Fermi of the classic theory of beta decay, it was realized that double beta decay could be possible between suitable parent and daughter nuclei two rungs apart in the periodic table. However even if the daughter nucleus were much stabler than the parent, the process would take about 10^{17} years. Here was a challenge for experimentalists.

Excitement mounted in 1948 when one of the first searches reported hints of an effect in the beta decay of tin 124 to tellurium 124, however this was soon attributed to impurities in the source which can easily mask any tiny double beta decay signal.

Experiments then turned to geochemical searches, hoping that ores rich in the parent nucleus would have accumulated observable amounts of daughter nuclei. While this method gave some evidence for double beta decay, it cannot see the decays directly.

In 1974, Moe began looking for the decay of selenium 82 into krypton 82, using 14 grams of the rare selenium isotope, initially with no success. However the development of the time projection chamber provided a new way of tracking the beta decay electrons. After several years patient work to reduce background, the team eventually isolated the tell-tale two electron signature.

With events being seen every few days, the half-life for the decay comes out as about 10^{20} years, in accord with earlier estimates from geochemical measurements.

With this new kind of radioactivity now in the bag, the search goes on for an even more exotic form of beta decay – the so-called neutrinoless type, first suggested by Furry in 1939, where the two neutrinos swallow each other up and are not emitted. This requires a special kind of neutrino behaviour, with important implications for this still mysterious particle. The search continues.

From one surprise to another

In 1973 physicists were surprised to find that the total proton-proton reaction rate rose in the energy range (20-63 GeV) opened up by the CERN Intersecting Storage Rings (ISR). Previously, it had been widely believed that the reaction rate was approaching some fixed value, about 40 millibarns.

The total reaction rate (cross-section) is proportional to the imaginary part of the forward scattering amplitude, a complex number whose real part can be related to the imaginary part. In 1965, N. N. Khuri and T. Kinoshita had predicted that if the total cross-section becomes infinite at infinite energy, the real part should eventually become positive.

The real part of the scattering amplitude was measured at the ISR by looking at the interference of nuclear and electromagnetic effects and found to be positive. Combined measurements of the cross-section and of rho, the ratio of the real and imaginary parts, led to rather tight predictions at higher energies. The total proton-proton and proton-antiproton cross-sections were predicted to be about 62 millibarns at 500 GeV collision energy.

Later, when antiprotons were available in large quantities at CERN, physicists first compared proton-proton and proton-antiproton collisions at the ISR, discovering that the proton-antiproton cross-section also rose. However the most important measurement came from the SPS proton-antiproton collider at 546 GeV collision energy, when the UA4 group found that the reaction rate was behaving as predicted. However, by measuring the real part at 546 GeV, one hoped to get some insight into the total cross-section at much higher energies to gauge the total collision rate of other proton colliders like Fermilab's Tevatron, now operating at 1800 GeV, proposals like CERN's LHC at 14 TeV (14 000 GeV), or the US Superconducting Supercollider (SSC). The surprise was that rho turned out to be about twice the predicted value.

At the second International Conference on Elastic and Diffractive Scattering, organized by R. Cool, K. Goulianos and N. N. Khuri recently at Rockefeller University, Giorgio Matthiae's detailed account of the UA4 results was followed by an intense debate between theorists. Some argued that the result was an illusion due to the differential cross-section deviating from a simple exponential behaviour, but this was not well accepted. Others maintained that the usual assumption of proton-proton and proton-antiproton cross-section equality at high energies might be wrong. However a calculation giving the low energy proton-antiproton reaction rate, recently measured at the LEAR (Low Energy Antiproton Ring) at CERN, as an integral over the difference between the proton-proton and proton-antiproton cross-section, is consistent with no such difference at high energies.

There remains the possibility that above a certain energy, the reaction rate suddenly rises, with observable consequences even for the Fermilab collider. The rise might be due to conventional physics or it could be something new.

This modest experiment in an unglamorous field, deserted by many experimentalists and abandoned by most theoreticians because of calculational difficulties, might be a pointer to new physics, accessible at CERN and at Fermilab.

From André Martin

People and things

Yakov Borisovich Zeldovich 1914-1987

Soviet theorist Yakov Zeldovich died in Moscow in December. From 1931, he made fundamental contributions to the theories of adsorption and catalysis, of combustion kinetics, of detonation and shock waves and of fission chain reactions. His particle physics work began in the 1950s and included the formulation of several fundamental concepts. He also proposed looking for parity violation in atoms to trap ultracold neutrons. While continuing his particle physics work, in the 1960s he went on to become a world authority on cosmology and astrophysics. Until the last day of his life this generous man continued to be a source of ideas and inspiration. As well as the highest accolades of the USSR, he also received important recognition in the US, the UK, East Germany, Hungary and in the international sphere.

He had accepted an invitation to visit the CERN Theory Division in the spring.

Yakov Borisovich Zeldovich 1914-1987

FELLOWS IN ACCELERATOR TECHNOLOGY

Brookhaven National Laboratory

Applications are invited from individuals with a Ph.D. degree and/or major training in the physical sciences or engineering who wish to launch careers in accelerator design and development.

Successful candidates will be appointed Fellows in Accelerator Technology through the Center for Accelerator Physics, in Brookhaven National Laboratory (BNL) accelerator physics organizations. Appointments are for a period of one year, renewable for a second year. Fellows are expected to select their investigations from among the general objectives of the accelerator physics program at BNL.

The Alternating Gradient Synchrotron (AGS) Department is responsible for the operation of a 200 MeV proton linac, and the 30 GeV AGS which provide proton, polarized proton and heavy ion beams. New BNL initiatives are underway in: the acceleration of heavy ions in the AGS; the construction of a 1.5 GeV booster synchrotron for protons and heavy ions; a proposal to build a relativistic heavy ion collider (RHIC); a study of a high intensity upgrade of the AGS (AGS II); and, research and development effort directed towards the Superconducting Superior Collider (SSC).

The National Synchrotron Light Source (NSLS) Department is responsible for the operation of two electron storage rings, with energy of 0.75 and 2.5 GeV, for the production of synchrotron radiation. The NSLS development program is directed toward improving the ring performance, new undulator and wiggler insertion devices, and coherent radiation sources.

The Center for Accelerator Physics promotes R&D in all areas of accelerator physics and is building the Accelerator Test Facility, consisting of a 50 MeV linac, a NdYag laser, and a high power CO_2 picosecond laser to study laser acceleration of particles and coherent radiation sources.

Scientists and engineers of any nationality are eligible to apply. Salaries are competitive, and Fellows are eligible for comprehensive employee benefits and relocation allowances. Candidates should send a detailed resume to: C. Pellegrini, National Synchrotron Light Source Department, Building 725B, Brookhaven National Laboratory, Associated Universities, Inc., Upton, L.I., NY 11973. Equal Opportunity Employer m/f.

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Research Scientists

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Applicants should submit a curriculum vitae, a list of publications, and three professional references to: **Employment Manager, CEBAF, 12070 Jefferson Avenue, Newport News, VA 23606.**

CEBAF

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On people

The prestigious Enrico Fermi Award of the US Department of Energy 'for exceptional and altogether outstanding scientific and technical achievement in the development, use or control of atomic energy', went in 1987 to Gerald F. Tape and to Luis W. Alvarez.

Tape, former Deputy Director of Brookhaven National Laboratory, President of Associated Universities Inc. (the Brookhaven operating organization), member of the US Atomic Energy Commission and US Representative to the International Atomic Energy Agency, was cited for his 'distinguished career in the administration, development and advancement of US and international atomic energy, as well as contributions to the nonproliferation of atomic weapons, with special recognition for his integrity'.

Alvarez, who won the Nobel Physics Prize outright in 1968, received his Fermi Award for 'the importance and breadth of his pioneering contributions in the physical sciences and their application to high energy physics, nuclear accelerators, instrumentation, paleontology, archaeology and astronomy'.

Accelerator and plasma physics specialist John Lawson recently retired from the Rutherford Appleton Laboratory, UK. After early work with UK synchrotrons, he went on to make major contributions to accelerator theory. In 1955, plasma physics and the problem of fusion power came under his fruitful attention, the result being the famed 'Lawson Criteria'. In later years his broad knowledge and deep insight have been solicited frequently throughout the world. His book 'Physics of Charged Particle Beams' remains a classic.

Hans C. Sens of NIKHEF, Amsterdam, and the University of Utrecht has been appointed a member of the Netherlands Royal Academy of Sciences.

Phil Livdahl retires

Fermilab Deputy Director Phil Livdahl has retired after twenty years of participation in the life of the Laboratory. He was amongst the first recruits for the construction of the Fermilab accelerator having responsibility for the linac construction and then participation in completion of the main ring.

Phil Livdahl took over as Acting Director at that difficult transitional phase when Bob Wilson left and has remained in the top management ever since. He is highly respected for his accelerator expertise, for his reliability and conscientiousness in management and for his human qualities.

Phil Livdahl will not be lost to the accelerator community because his retirement takes him to the West Coast where he will continue work on the proton medical accelerator at the Loma Linda Medical Center.

Pierre Amiot

Pierre Amiot, who died last year, should have been credited in the CERN Courier as one of the driving forces behind CERN's first bubble chamber. We regret the error.

Making history

The CERN history project yielded its first fruits a year ago with the publication of a volume covering the years of the creation of CERN (see March 1987 issue, page 27). 17 November brought together many of the leading figures from the second period under study – covering the construction and first operation of the proton synchrotron through to the end of 1965 when the intersecting storage rings were authorized. The historians presented their findings for comment before preparing the second volume.

Chris Quigg, formerly head of the Fermilab theory group and now Deputy Director of Operations for the Central Design Group of the proposed US Superconducting Supercollider (SSC), gave the third Bernard Gregory Lecture (in English) at CERN and (in French) in Paris in November. The title was 'To explore the 1 TeV level'.

President of the Chinese Academy of Sciences Zhou Guangzhao (left) visited CERN on 27 November to discuss continuing collaboration with scientists from China. An agreement prolonging the existing Protocol was signed with CERN Director General Herwig Schopper.

ESO/CERN Symposium

The 3rd ESO/CERN Symposium on Cosmology, Astronomy and Fundamental Physics will be held at the Palazzo Re Enzo, Bologna (Italy) from 16 to 20 May. The preliminary programme covers: First results from new colliders – Ultrarelativistic nuclear collisions – Standard model of fundamental interactions – Supernova 1987a: observations and interpretations – Dark matter: evidence, candidates and detection – Large scale structure of the universe – Microwave background radiation – High redshift objects – Dynamical parameters of the universe – Underground laboratories – Perspectives for high energy physics – Beyond the standard model, while invited speakers include A. Dressler (MWLCO, Pasadena), M. Geller (CfA, Cambridge, MA), W. Hildebrandt (MPPA, Munich), M. Koshiba (CERN, Geneva), R. G. Kron (Yerkes Observ., Chicago), L. M. Lederman (Fermilab), D. Lynden-Bell (Cambridge), S. Ozaki* (KEK, Japan), F. Pacini (Florence), R. B. Partridge (Haverford College, USA), R. D. Peccei (DESY), C. Rubbia (CERN), M. Satz (Bielefeld), Y. Tanaka* (ISAS, Tokyo), M. S. Turner (Chicago/Fermilab), N. Vittorio (Rome, 'La Sapienza'), L. Woltjer (ESO); (* to be confirmed).

The symposium's aim is to establish the status of knowledge and provide a forum for interdisciplinary discussions, with equal time for formal lectures and general discussions. A poster session is also foreseen. The audience, mainly of astrophysicists and particle physicists in roughly equal numbers, will be limited to about 250. Participation is by invitation only. Those definitely interested should write as soon as possible to: Scientific Secretariat, 3rd ESO/CERN Symposium, Istituto di Fisica 'A. Righi', Via Irnerio 46, I-40126 Bologna, Italy. Tel. 051/24 44 90 – Telex 52 06 34 – Telefax 24 72 44.

Books

Quantum Field Theory and Quantum Statistics is the title of an impressive two-volume collection of 64 essays from 83 contributors, mainly from the USSR, Europe and the US, marking the sixtieth birthday (1984) of Soviet theorist Efim Samoilovich Fradkin. Edited by I.A. Batalin and G.A. Vilkovisky of the Lebedev Institute, Moscow, and C.J. Isham of London, and published by Adam Hilger in the UK, this valuable 'encyclopedia' of modern theory reflects Fradkin's wide interests and numerous important contributions.

'Frontiers of Physics', published by Adam Hilger, contains the lectures given at the seventh UK Institute for High Energy Physics, held at Imperial College, London, in August 1986, covering string and lattice theory. Lecturers were asked specifically to be 'provocative and stimulating to an experienced and/or jaded audience'. Editor is Ian Halliday of Imperial College.

'La matière première', a new book by Michel Crozon from the College de France, traces the history, the major discoveries, and the experimental techniques of high energy physics research. It is published by Editions du Seuil, Paris.

Fortran, the main programming language for scientific and numerical work, continues to evolve to meet emerging needs. The latest form, Fortran 8x, looks ahead to the supercomputer era. 'Fortran 8x Explained' is a new book by Michael Metcalf of CERN and J. K.

Reid of Harwell, UK, published by Oxford University Press. Both Metcalf and Reid are members of the X3J3 Fortran standards committee.

CERN Computing School 1988

Now an annual event, the next CERN Computing School will be in Oxford, UK, from 14-27 August, organized in collaboration with the Rutherford Appleton Laboratory. The school aims to attract about 80 postgraduate students and research workers in physics and computing, mostly from CERN Member States or research centres working in close contact with CERN, and perhaps some from further afield. The programme covers software engineering, document preparation, communications and networks, hardware, data acquisition, computer-aided electronics design etc. Information from Mrs. Ingrid Barnett, Secretary, CERN School of Computing, CERN, 1211 Geneva 23, Switzerland.

Meetings

The XXIV International Conference on High Energy Physics ('Rochester' Conference) sponsored by the International Union of Pure and Applied Physics (IUPAP), will be held in Munich, West Germany, from 4-10 August. Attendance is by invitation only. Further information from K. Bacherer, Max-Planck-Institut fuer Physik und Astrophysik, PO Box 40 12 12, Foehringer Ring 6, D-8000 Munich 40, West Germany. Earn/bitnet KAB AT DMOMPI11.

The International Symposium on Weak and Electromagnetic Interactions in Nuclei (WEIN-89) will be held in Montreal from 15-19 May 1989. Further information from Pierre Depommier, Nuclear Physics Laboratory, University of Montreal, P.O. Box 6128, Station A, Montreal, Quebec, Canada H3C 3J7 or via bitnet at WEIN at UMTLVR, PIERRE at TRIUMFCL, or POM at CERNVM.

Chinese beams

At the new Beijing electron-positron collider ring (BEPC), 1.15 GeV particles from the linac made a few turns just before Christmas. Higher energies await commissioning of the ring's radiofrequency system.

Electronic Mail

The CERN Courier editorial desk can be contacted through electronic mail using the EARN/BITNET communications network. The Editor's address is

COURIER@CERNVM

For subscriptions (free!), changes of address, etc. the contact is

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Lyndon Evans described CERN's proton-antiproton collider for the third in the series of John Adams Memorial Lectures.

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Los Alamos National Laboratory is an innovative leader in scientific research and applications for national security.

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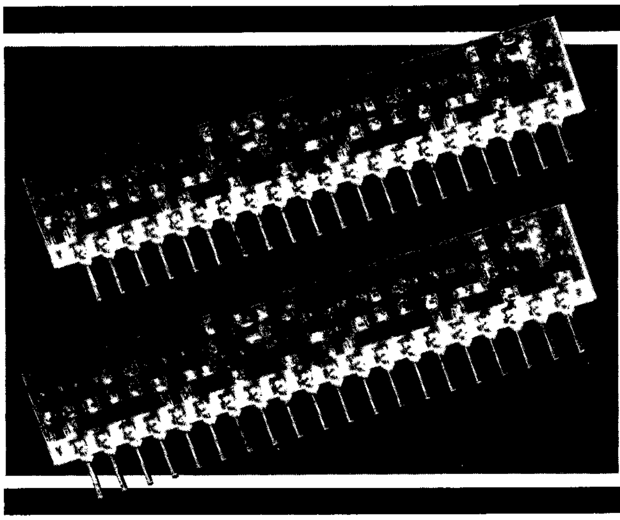

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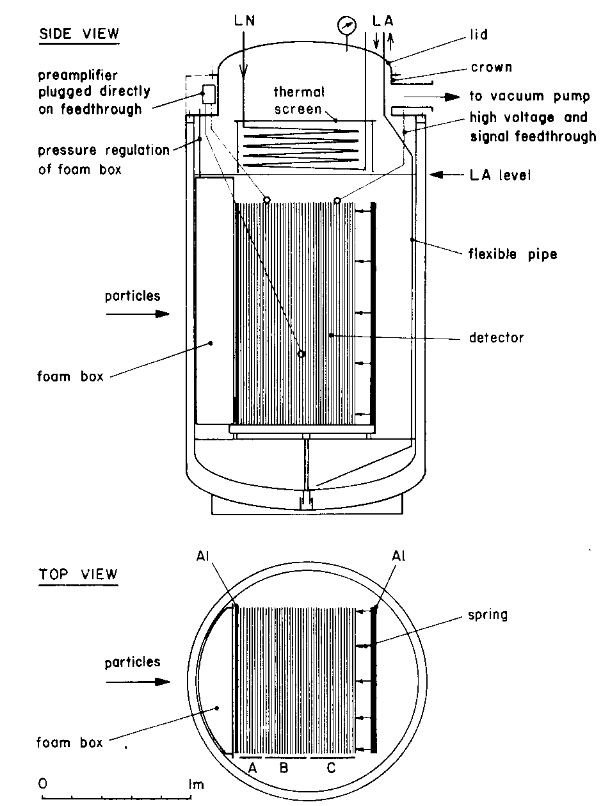
Techniques for Nuclear and Particle Physics Experiments

1987. 384 pages. Hard cover DM 80,-.
ISBN 3-540-17386-2



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K. Pretzl, N. Schmitz, L. Stodolsky (Eds.)

Low Temperature Detectors for Neutrinos and Dark Matter

Proceedings of a Workshop.
Schloss Ringberg, Tegernsee, FRG
May 12-13, 1987

1987. X, 159 pages. Hard cover DM 58,-.
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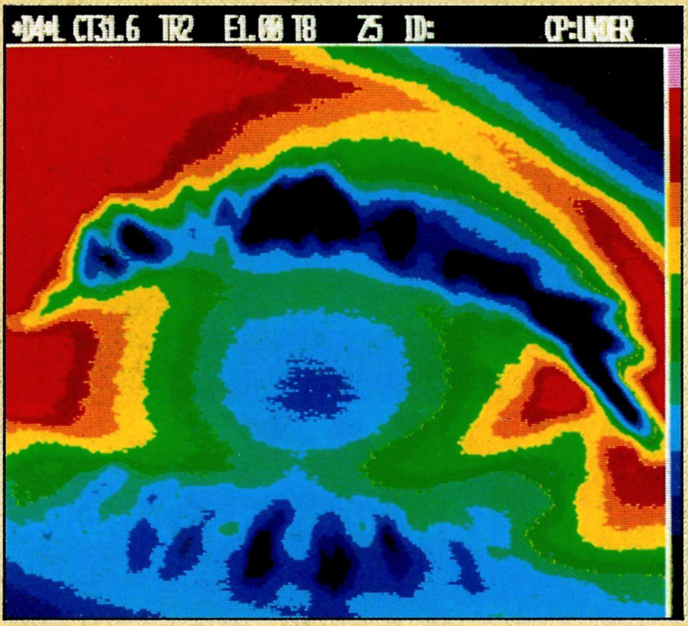
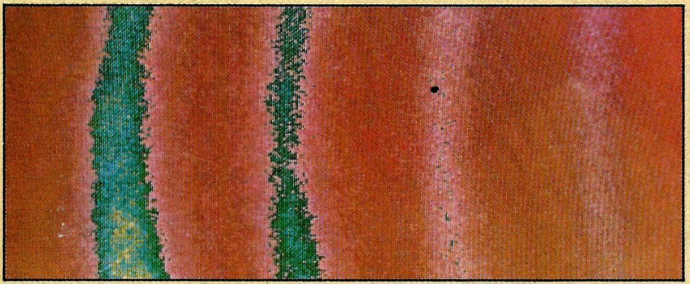


Thermal image of a human eye.



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