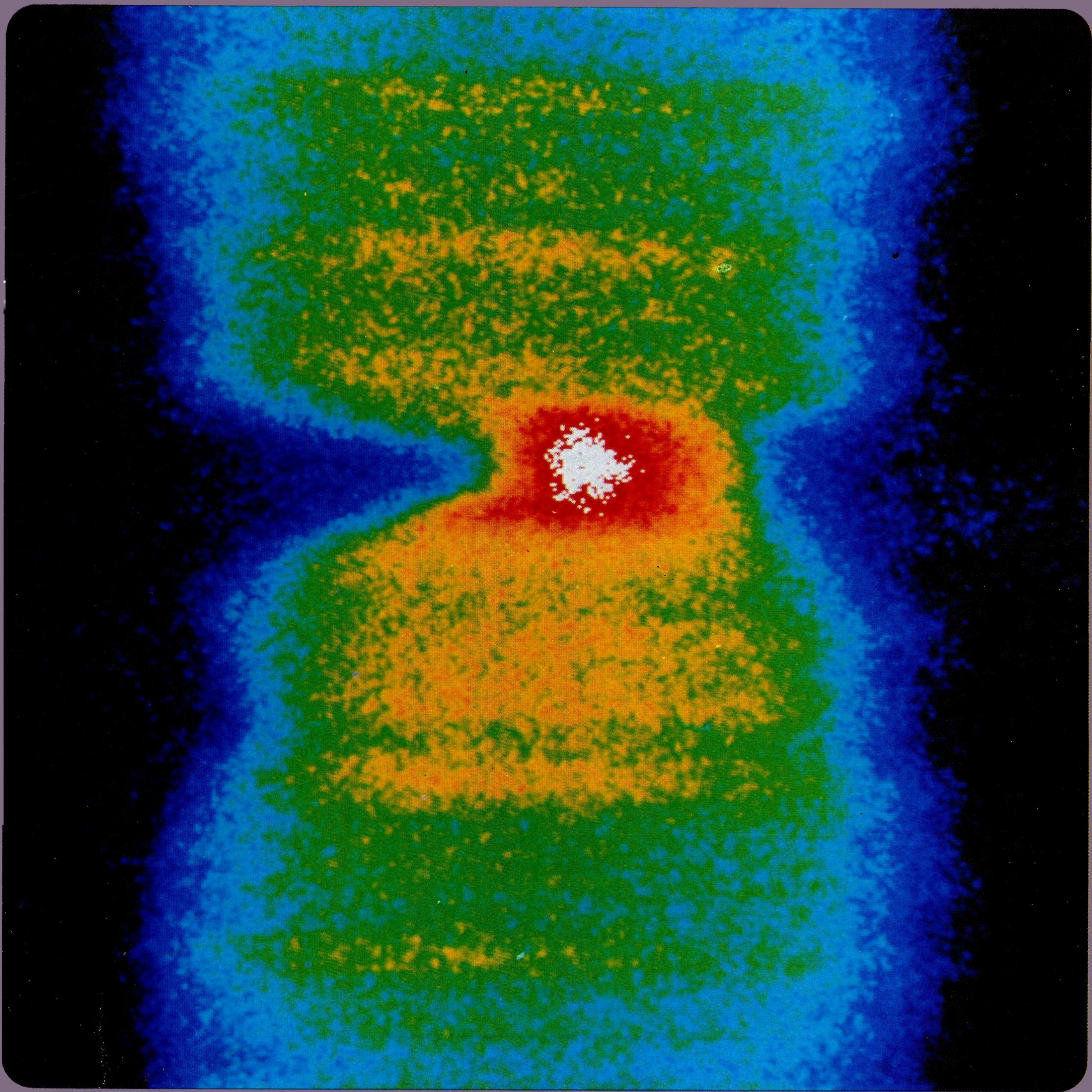
# CERN COURIER

International Journal of High Energy Physics



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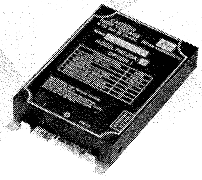

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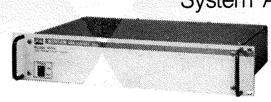

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# CERN COURIER

**Covering current developments in high energy physics and related fields worldwide**

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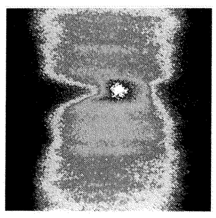

*Cover photograph:*
Plasma compression (z-pinch) of a beam of argon nuclei from the Unilac machine at Darmstadt's GSI heavy ion Laboratory (see page 18).

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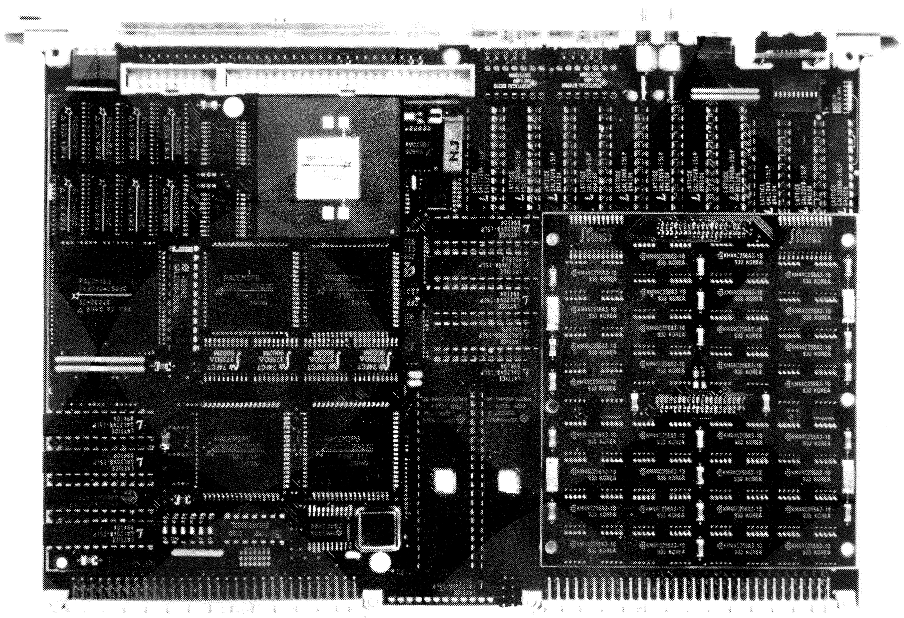

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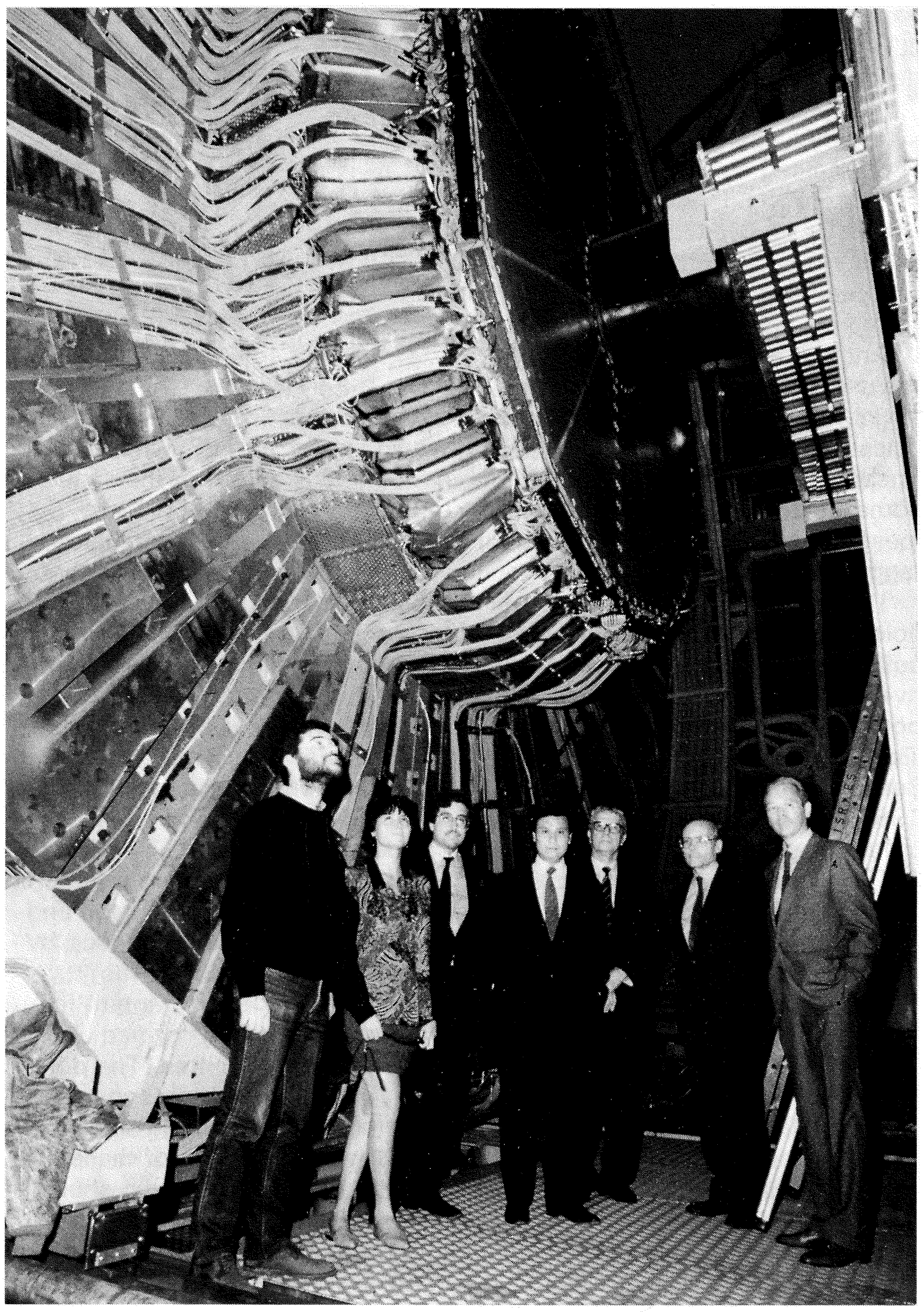
# Delphi

Experiment spokesman Ugo Amaldi (right) shows a party of Portuguese VIPs round the Delphi detector at CERN's LEP electron-positron collider.

(Photo CERN H1/22/86.9.90)



## LEP experiments – ten years of collaboration

*At CERN's new LEP electron-positron collider, the initial year of data-taking by the four big experiments – Aleph, Delphi, L3 and Opal, comes as the result of some ten years of careful preparation. This is the first in a series of four articles which looks at the history and aspirations of each of these mighty collaborations, together involving over 2,000 physicists from CERN's fourteen Member States, plus Brazil, Bulgaria, Canada, China, Finland, East Germany, Hungary, India, Israel, Japan, Poland, the USA and the USSR.*

The ten-year history of Delphi is recorded in several shelves of notebooks and diaries carefully kept up to date by experiment spokesman Ugo Amaldi.

Notebook 1 sets the scene in 1980, when a major meeting at Uppsala, organized by the European Committee for Future Accelerators (ECFA), summarized LEP requirements for a wide range of detector subsystems and instrumentation technologies. However the emphasis at this stage was more on the approach to the problems involved, with plans for experimental groups still at an early stage. Amaldi, for example, spoke at Uppsala on calorimetry for LEP.

But by the end of 1980, a substantial level of potential collaboration had built up in what was known at the time as COLLEPS – Collaboration for LEP Studies.

For LEP, one overriding question was whether to play safe and go for tried and tested detector techniques, or to plan for a detector which looked forward to new horizons. Unsure of which way to play, some physicists hedged their bets and followed both paths for a while.

COLLEPS was looking for something new, and soon found it. Very novel in those days were Tom Ypsilantis' and Jacques Seguinot's ideas (subsequent contributions were to come from Tord Ekelof) for a Ring Imaging Cherenkov (RICH) detector for particle identification. In this technique, the photons radiated by a charged particle passing through a medium are focussed by mirrors to provide a ring image. The ring size is related to the mass and momentum of the particle, and can be used as a means of identifying particles.

Another appealing novelty was the use of silicon strips to reconstruct the tracks of short-lived particles. In those days the fifth ('beauty') quark was still a newcomer, with its lifetime yet to be measured, but the idea of flavour tagging was considered attractive.

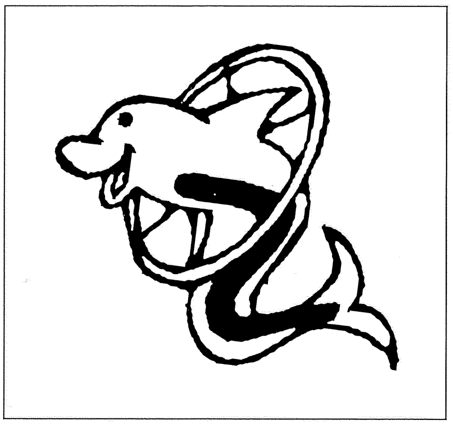
The commitment to new technology helped the final form of the collaboration to crystallize. Alternative ideas for various detector components were examined, but the Time Projection Chamber idea from Berkeley was seized on early in 1981 as a likely candidate for central tracking.

The most unconventional element, the RICH, was obviously at a very early stage in its history, and the schematic design for the whole detector went through several major iterations and a lot of heated discussion until the present 'barrel' solution was adopted in 1982. The original idea had been spherical symmetry and a central magnetic field, but this geometry could not be implemented in the required standard solenoid magnet.

Meanwhile the milestone 1981 ECFA LEP meeting at Villars in Switzerland showed how much progress had been made since Uppsala, but plans for coherent experimental teams were still at an early stage, with physicists evaluating many different options.

One thing becoming clear at that time was that no new money would appear for LEP, which would have to be eked out of the annual CERN budget. With CERN's resources limited, the experiments would have to be funded largely by the participating research institutes themselves. At this stage, the first estimates of support were called for, and it was encouraging for Amaldi to find that even in those early days some 57 million Swiss francs had been pledged for a detector whose final price tag would not be too far distant (85 million).

*Delphi's dolphin ('delfino' in Italian) logo. In Greek mythology Apollo was brought to the shore of Delphi by two of these animals, and the logo expressed the hope that many Z particles would be brought to the experiment.*



By early 1982, the name DELPHI (DEtector with Lepton, Photon and Hadron Identification, proposed by Gerald Myatt of Oxford, was adopted, and a letter of intent forwarded to the newly-formed LEP Experiments Committee. The dolphin ('delfino' in Italian) logo came from the Padua group. In ancient Greek mythology, two of these animals brought Apollo to the shore of Delphi, and the Delphi experiment logo expressed the hope that many Z particles would come to the Delphi experiment.

After an initial selection of four LEP experiments, the collaborations had to take on members from unsuccessful bids, and some provisional configurations of detector components had to be revised. There was some concern when the Delphi roll grew to include more than 200 names (it has subsequently gone on to 500!).

A dramatic moment was the decision of the siting of the experiments around the LEP ring. With the conventional magnets of Opal and L3 needing high power, Aleph and Delphi, with their superconducting magnets, had to squabble over pits 4 and 8. Director General Herwig Schopper spun a coin, with Aleph getting pit 4 deep under the Jura, but this fate was not as unkind as it might have appeared, with subsequent events also substantially influencing the progress of the experiments.

Approval in principle was a good time to launch issue No. 1 of the Delphi Bulletin. Delphi was the first major experimental collaboration to have a regular newsletter. Ten years down the line the Bulletin is still going strong, with a print run of nearly 1,000, and issue No. 50 will mark the collaboration's tenth anniversary.

Collaboration needs personal contact, and 'Delphi weeks' have been a regular feature on the calendar. Taking place mostly at CERN (once even at Delphi) the annual rhythm has dropped from six to four, however with the experiment now running, a regular series of seminars has been set up.

A 'parliament' is provided by a Collaboration Board, chaired initially by Bert Diddens of NIKHEF, Amsterdam, and now by George Kalmus of the UK Rutherford Appleton Laboratory. One important job of this forum is to reconcile, if not avoid, potential conflicts between participating group interests on one hand and the need to ensure a good final product on the other. For technical matters, an Executive Committee makes recommendations for ratification by the CB.

The mammoth task of project

Delphi's 6.2 metre diameter superconducting magnet, the largest in the world, arrived at CERN from the UK Rutherford Appleton Laboratory in December 1987.


## LEP polarization

*Major achievement in the final 24 hours of this year's five-month run at CERN's new LEP electron-positron collider was the observation of a significant level of polarization (spin alignment) in the orbiting beams.*

*Circulating electrons behave like tiny magnets which tend to line up with the fields which guide the beams, however this effect is very sensitive to imperfections and there were doubts whether it would ever be seen in LEP.*

*A small collaboration of machine specialists from CERN and experimental physicists from the Ecole Polytechnique, College de France and the Munich Max Planck Institute developed a sensitive polarimeter to look at these effects. In the final hours of the LEP run they were able to detect, then suppress and reestablish several times a beam polarization level of 11 ± 2 per cent. This required the beam orbits in the 27-kilometre machine to be steered to within half a millimetre! As well as highlighting the quality of LEP construction, this opens the door to new physics.*

control fell to Technical Coordinator Hans-Jürgen Hilke. After seven years of development, construction and testing, only thirteen months were available for Delphi installation in the underground pit. This task was ably coordinated by Gregoire Kantardjian in the face of the tight schedule, especially with a decision having been taken to go for as much barrel RICH as possible from the start. As well as more than a dozen major subassemblies, each with a certain level of autonomy, some tasks, notably gas systems and electronics, were grouped together for the whole detector. Here, standardization paid dividends.

Safety requirements and other limiting factors, such as critical dimensions, had to be stipulated at the outset. Scheduling and sequencing all the component tasks included monitoring progress of component construction in many distant institutes to ensure an orderly arrival at CERN. Although the total workload was split between almost forty research centres, for some groups their Delphi contribution was their largest-ever commitment.

Figuring prominently in the Delphi shopping list had been the world's largest superconducting magnet – 7.4 metres long and 6.2 metres in diameter, to supply a 1.2 tesla field over 145 cubic m. Built at the UK Rutherford Appleton Laboratory, the mighty coil eventually embarked on its 1600 kilometre voyage to CERN in October 1987.

In October 1988, just when things were going along nicely, near-disaster struck when the liquid helium system for the big superconducting magnet sprang a leak. This put the installation programme back five months, however some time was clawed back by meanwhile installing the shell of the High Density Projection Chamber of the barrel electromagnetic calorimeter inside the magnet, while heroic work put the magnet to rights.

Mainly as a result of this magnet mishap, Delphi faced LEP commissioning last July with minimal magnetic field measurements and no prior checkout of the detector with cosmic rays. On 14 August, there was a moment of panic when the other three experiments reported their first Z particles, but Delphi had nothing. This was rapidly traced to a misalignment of the colliding beams, and within hours the dolphin had brought Delphi had its first Zs.

The entire collaboration breathed a sigh of relief when the magnet, which had been operating at reduced power for part of the time since the mishap, began routine operation this March at its design field of 1.2 tesla.

To mark the change from con-

# Around the Laboratories

struction to operation and attack what is now the main task – transforming data into physics information – the organizational structure of the collaboration has been modified in a minor perestroika.

The new arrangements reflect a workload split between the underground physics area, the separate computer functions and the physics analysis and interpretation. Half the infrastructure, under one Deputy Spokesman (currently Paul Booth of Liverpool) covers the former, up to the arrival of data at the computing areas. The remaining organization, under a second Deputy Spokesman (founder collaboration member and currently ECFA Chairman Jean Augustin of Orsay) assumes responsibility for analysis and physics.

Egil Lillestol of Bergen, now in a key role in CERN's Particle Physics Experiments (PPE) Division, was for a long time Delphi's Administrative Coordinator. With the accent now on production, there is no further need for such a role. Another founder Delphi member, Jim Allaby, became Leader of CERN's PPE Division. Hilke moves out of the Technical Coordinator seat next March to take on other responsibilities and will hand over to Henrik Foeth.

With a nested data acquisition system with multiple triggering levels capable of handling a substantially increased electron-positron collision rate, Delphi faces the future confidently. First physics results could appear this year from the RICH and from the silicon microvertex (July/August, page 7) subsystems which have already been shown to work close to design levels.

With the physics output only just beginning, fat notebooks will continue to accumulate on the spokesman's shelf.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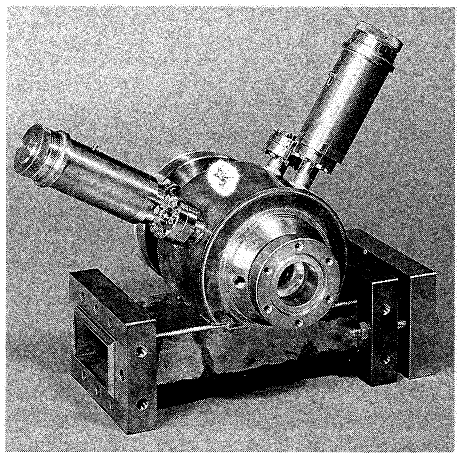
## CERN
## Making CLIC tick

While the Large Hadron Collider (LHC) scheme for counter-rotating proton beams in a new superconducting ring to be built in CERN's existing 27-kilometre LEP tunnel is being pushed as the Laboratory's main construction project for the 1990s, research and development continues in parallel for an eventual complementary attack on new physics frontiers with CERN's Linear Collider – CLIC – firing TeV electron and positron beams at each other.

(Aware of the technological problems involved in producing and handling TeV electron beams, front-line Laboratories all over the world are studying various aspects – see January/February, page 15, the Stanford story in this issue – page 11, and the Cornell superconducting radiofrequency workshop report on page 20.)

The solution proposed for CLIC at CERN uses 30 GHz radiofrequency power, itself generated by a



*The radiofrequency gun for CERN's new linear collider test facility uses a design scaled from that used at Brookhaven's Accelerator Test Facility.*

drive beam of short (millimetre) intense ($10^{12}$) bunches of electrons with ten millimetre spacing driven by superconducting cavities operating at 0.35 GHz.

Work is in progress on 30 GHz structures used to generate 30 GHz power by deceleration of the high-intensity drive beam and on those 30 GHz structures to accelerate the main beam. A complete structure of the latter type has been produced recently and successfully tuned. A test stand has shown that sub-micron remote alignment is possible using industrial equipment.

Further initial efforts concentrate on developing the electron sources and bunch compression techniques needed for such a drive beam, and alongside the LEP Injection Linac (LIL) the new CLIC Test Facility (CTF) uses an r.f. gun working with a spare 35 MW LIL klystron providing 3 GHz, together with a laser-driven photocathode and, possibly, magnetic bunch compressors.

This gun, operating at 10 cm wavelength, cannot attain the centimetre wavetrains for 30 GHz working, but gives a useful idea of the problems encountered in generating compact, intense particle bunches.

The second CTF goal is to provide 30 GHz r.f. power for structure tests, using a spare LIL accelerating section to take 4.5 MeV bunches from the 3 GHz gun beyond 50 MeV. This beam would then interact with a short section of CLIC-type structure to convert beam energy into r.f. power.

Initially, CTF's electrons will be produced from a yttrium or cesium iodide photocathode irradiated by a long-pulse laser not synchronized with the r.f.. Subsequent tests foresee more exotic photocathode materials prepared in situ under vacuum to attain higher quantum efficiencies and a picosecond laser synchronized with the r.f. power.

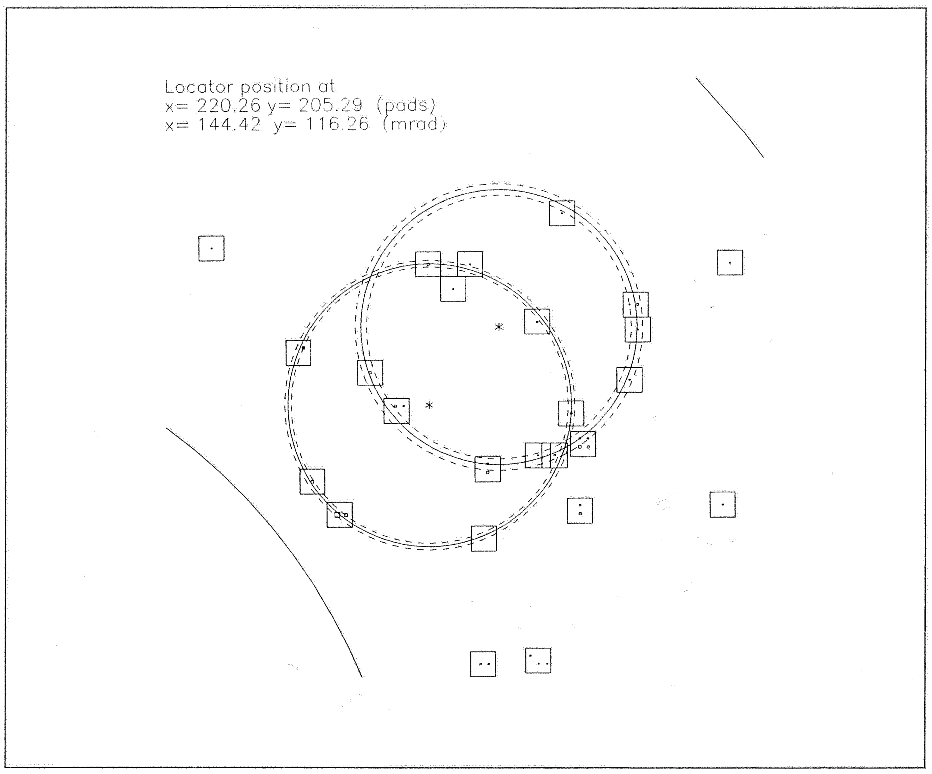
## High energy ion beams

During August, CERN's SPS synchrotron was in action again supplying beams of sulphur ions at 200 GeV/nucleon to a range of experiments, some new, others having their first taste of high energy nuclei since the previous run in 1987.

(As well as supplying the experiments with their largest dose of high energy sulphur ions so far, CERN's accelerator complex continued to act as the injector for the LEP electron-positron collider, which finished its 1990 run with record performances.)

One of the pioneer experiments in CERN's programme of research with high energy heavy ion beams is the NA35 European collaboration using a 2-metre streamer chamber. In earlier runs, this study revealed interesting new behaviour, including evidence for a pion emission region twice as large as the incident

*A double ring seen by the NA45 'CERES' (CErenkov Ring Electron Spectrometer) experiment studying heavy ion interactions at CERN. The signal comes from an electron-positron pair opened by a magnetic field. The rings are fitted from the squares showing individual pulse heights.*



ion projectile, and a change in the relative level of strange particle production.

These results suggested the onset of new interaction mechanisms, pointing to a need for further investigations. With the CERN heavy ion programme graduating from oxygen to sulphur, the thick sprays of forward-produced particles become difficult to analyse using streamer chamber pictures alone, despite a tenfold increase in picture-taking speed.

To extend the role of this experiment, the idea was to capitalize on the expertise gained at Munich's Max Planck Institute workshops in construction of the Time Projection Chamber (TPC) for the Aleph experiment at CERN's LEP electron-positron collider, and build a second TPC.

Measuring 2.5 m across the beam direction, 1.2 m high and 1.2 m deep, the TPC is large, with only a third equipped for both tracking and energy loss measurements, the majority being used for tracking only. Another innovation is that no magnetic field is used. The resulting tracks are thus straight lines and simple to analyse.

As well as complementing the coverage of the detector, the TPC also provides event selection capabilities difficult or impossible using the streamer chamber alone. With a major aim being to search for clues of the formation of quark-gluon plasma – when quarks and gluons become liberated from their confinement inside nucleons to form a new type of matter – the new setup enables experimenters to filter out interesting events for rapid analysis. It also provides a fuller comparison of proton-nucleus and nucleus-nucleus reactions.

Also using a TPC for tracking the results of the heavy ion collisions was NA36, a Europe/US/India collaboration. They added the TPC to the comprehensive detection system developed by the European Hybrid Spectrometer group which ran at the SPS for many years. This experiment has now been completed.

Making its debut in the recent heavy ion run was the NA45 CERES (CErenkov Electron Ring Spectrometer) experiment – a Brookhaven/CERN/Heidelberg/Milan/Weizmann Inst collaboration using Ring-Imaging Cherenkov detectors (RICHs) to pick up electron-positron pairs.

These electron-positron spectra, showing the production of resonances like rho, omega and phi mesons superimposed on a steeply-falling continuum are a powerful probe of the early stages of heavy ion interactions and the possible creation of quark-gluon plasma. As well as ion beams, CERES will also collect data using high energy protons.

In a RICH, the photons radiated by a traversing charged particle are focused by a spherical mirror into a ring, whose diameter depends on the mass and momentum of the radiating particle. The two CERES RICHs, separated by a superconducting solenoid to give the particles an azimuthal 'kick', are operated with a radiator gas (methane) whose low refractive index suppresses signals due to pions and other hadrons, isolating the very light electrons and positrons. The experiment is essentially 'hadron-blind'.

Novel RICH features include gated two-step parallel plate counters, 60,000-channel pad readout, and a 1 mm-thick self-supporting carbon fibre mirror.

In the August heavy-ion run, the RICHs were only partially instrumented, but the functioning portion clearly showed electron rings.

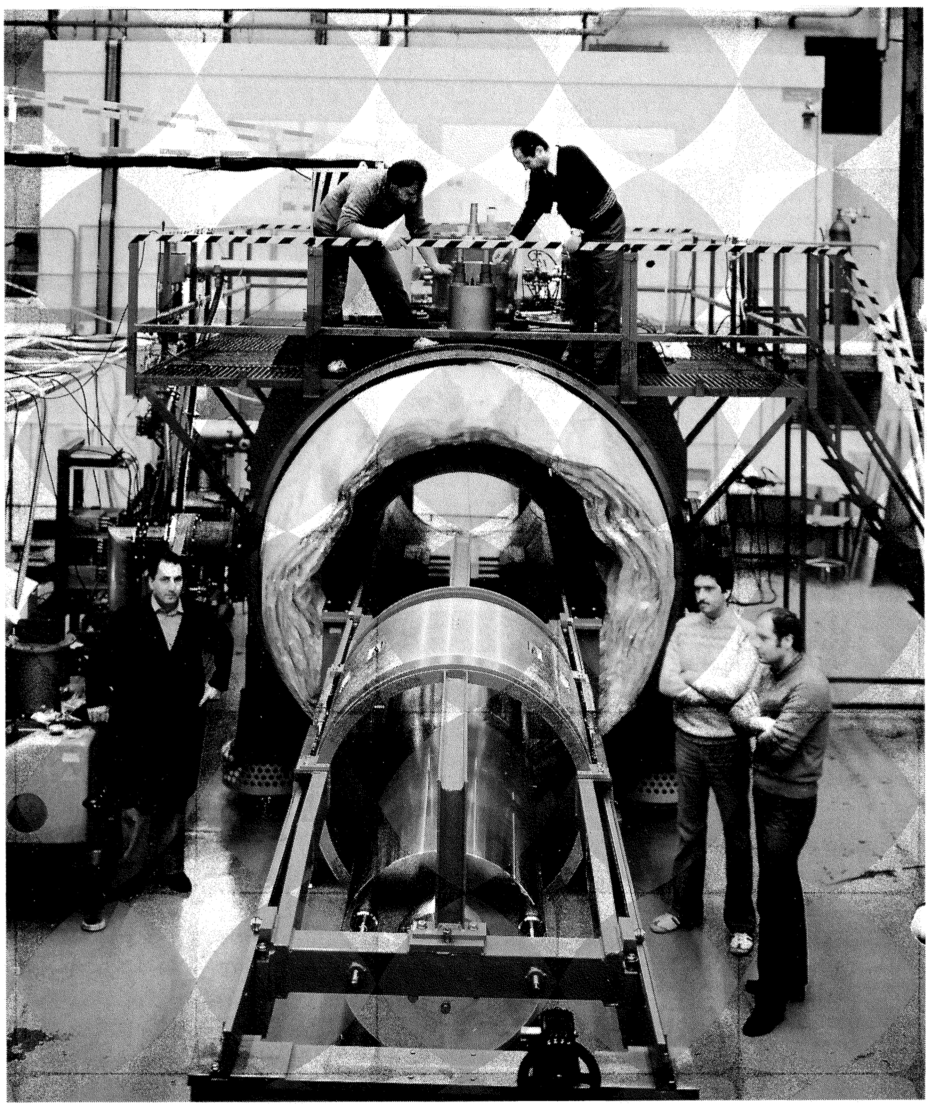
Another new experiment is NA44, a US/Europe/Japan collaboration using a focusing spectrometer based on a superconducting quadrupole salvaged from the old CERN Intersecting Storage Rings (ISR) to study two-particle correlations. The idea is to use interference effects to look at what happens deep inside the extended interaction region. While NA44 is advertised as an ion experiment, initial data taken earlier this year used proton beams, and the first ion data will come from the next run, probably next year but yet to be scheduled.

A 'veteran' of CERN heavy ion beam running is the NA34 'Helios' experiment, now looking at muon pairs. Also looking at muon pairs is the ongoing NA38 experiment, where 1987 data on suppression of J/psi resonance production suggested that quark-gluon plasma formation may not be far away and provided a valuable boost to this work.

Experiments in the West Area using the sulphur beams included the pioneer WA80 'Plastic Ball' study, augmented this year with a large finely-segmented lead-glass array to pick up neutral mesons and direct photons.

Alongside WA80 was the WA85 group using the modified Omega spectrometer with a downstream 'butterfly' detector arrangement to look for increases in the production rate of strange particles.

Complementing this extensive range of studies with CERN's high energy nuclear beams is a range of smaller experiments using emulsion targets. These emulsion studies alone include groups from Europe, America, Asia and Africa.



*It took ten years to build the 3m long, 2.3 ton Explorer gravitational wave antenna. Operated by a Rome group at CERN, it is now operational in the continuing quest for signs of gravitational radiation.*

*(Photo CERN 577.12.82)*

# Looking for gravitational waves

Gravitational waves were predicted by Albert Einstein in 1916 in his theory of General Relativity. They can be thought as gravitational forces which propagate with the velocity of light, just like electromagnetic forces. However while electromagnetic waves are generated by accelerations of electrical charges, gravitational waves come from the acceleration of masses.

Due to the weakness of the gravitational pull compared to electromagnetic strengths, all conceivable gravitational wave sources turn out to be very feeble. The strongest would be astrophysical phenomena like supernovae and pulsars, in spite of their remoteness. Another consequence of the weakness of the gravitational interaction is that the waves are very penetrating, losing only a tiny fraction of their energy when passing through a solid.

The search for gravitational waves started in the sixties with the work of Joe Weber at Maryland. His experiment tried to detect the very small vibrations induced in a cylindrical aluminium bar 1.5 m long and weighing 1.5 ton by waves coming, for example, from a distant supernova.

Because of the tiny interactions involved, these vibrations are expected to be much smaller even than atomic nuclei! Detecting them is naturally very difficult and, after 30 years of efforts in various laboratories, there is still no definite result.

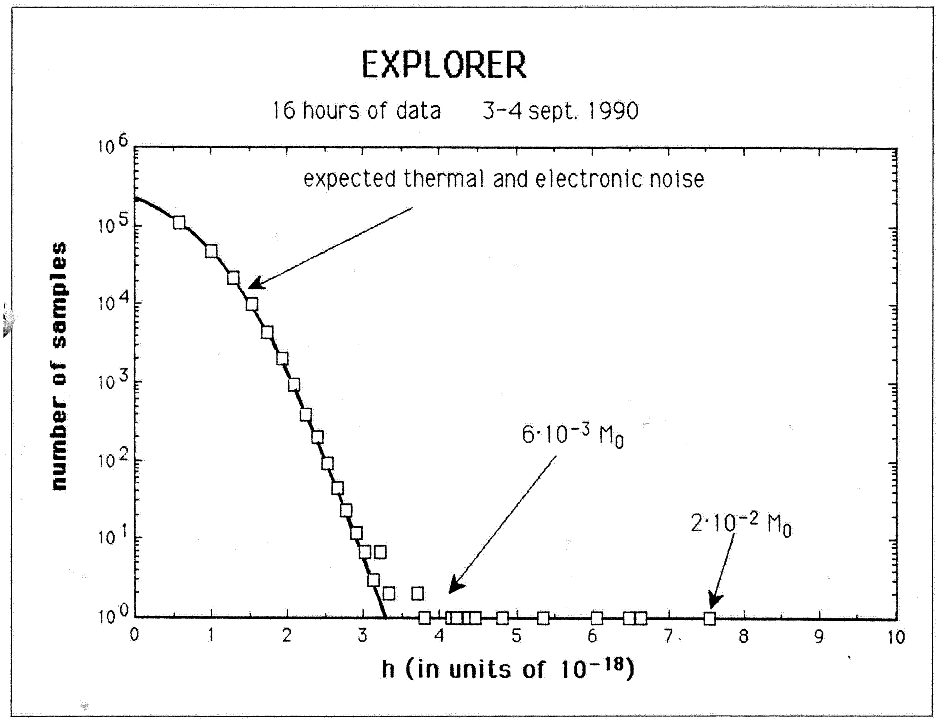
At CERN, a Rome group, financed by the Italian INFN, has come to the end of the ten-year construction programme for an antenna originally named Explorer by the late Edoardo Amaldi. The instrument was commissioned in June. Even more difficult than attaining the planned sensitivity was the need to maintain steady performance over long and continuous periods.

The detector consists of an aluminium cylinder, 3 m long weighing 2.3 ton, cooled with superfluid helium to reduce thermal noise. The vibrations are detected by a capacitive transducer with a very low noise superconducting (SQUID) amplifier.

Sensitivity can be expressed by the ratio of the minimum observable bar vibration to the bar length. According to calculations, waves producing effects of the order of $8 \times 10^{-19}$ should be produced by a conversion of a solar mass star at a distance of 0.6 megaparsec (2 million light years) or, for a supernova, by the conversion of 1% of a solar mass from a distance of 60 kpc (the distance of the Large Magellanic Cloud).

Such a sensitivity has never been reached by an antenna oper-

*Exploring with the Explorer antenna. The curve on the left is the classic Boltzmann distribution of background thermal and electronic noise. The sensitive detector could pick up additional signals, equivalent to the gravitational waves which would be produced by small fractions of a solar mass. But in this case, with no confirmation from other detectors, these signals must be attributed to unknown local noise, probably of electrical origin.*




ating continuously and for long periods of time. However to pick up gravitational wave signals and rule out spurious effects with confidence means looking at the same vent simultaneously with at least two different antennas some distance apart.

Explorer should stay in operation for years, looking for correlations with neutrino detectors and, in future, with similar or different antennas being developed elsewhere (Maryland, Stanford, Louisiana, Caltech, MIT, Glasgow, Munich, Orsay, Pisa, Legnaro, Frascati, Moscow, Tokyo, Canton, Perth). Explorer's data is analysed in real time by a digital computer linked to a world network so that other experimenters can look at the data on-line.

However Explorer is only the first stage of the Rome experiment. The next step is to extend coverage up to the Virgo cluster at about 15 Mpc, where thousands of galaxies are available as Supernovae sources. With only at best about one supernova explosion per decade in each galaxy, lots of galaxies are needed if frequent signals are to be seen.

To reach this goal the Rome group has constructed and installed at CERN another antenna, called Nautilus. This will be cooled to less than 100 mK by a dilution refrigerator, decreasing thermal noise to a minimum. The first test at this ultralow temperature, never before attained for a body weighing 2.3 ton, will be done soon at CERN. For the planned sensitivity of 3 x $10^{-21}$, the large aluminium bar will behave as a quantum oscillator, requiring improved transducer performance. Many years of work are still ahead in the gravitational wave hunt, the stakes and the motivation are high.

*From Guido Pizzella*

# STANFORD
## Looking for a beam in a needle

A major challenge for the next generation of linear colliders, known generically as the Next Linear Collider (NLC), is to make extremely narrow electron and positron beams.

Whereas particle bunches in the Stanford Linear Collider (SLC) are millimetre-long needles 4-5 microns across, NLC's will have to be ten times shorter and up to a thousand times narrower! These tiny beams are needed to produce the required high collision rates – luminosities of $10^{33-34}$ per sq cm per s – as the collision energy climbs toward 1 TeV and the reaction rates for interesting physical processes drop.

The Final Focus Test Beam facility now under construction at Stanford aims to study the necessary optics and the alignment, control and measurement systems to achieve such tiny beams.

The final focus of a linear collider which sharpens the beams and keeps them in collision requires careful control and stabilization of its magnetic elements, as well as accurate measurements of the beam itself. Much has been learned at SLC, but NLC would need to achieve tighter mechanical and electrical tolerances. Precision measurement techniques and tuning mechanisms also need to be developed.

In collaboration with teams of physicists and engineers from the Soviet Union, Germany, France, and Japan, the Stanford Linear Accelerator Center (SLAC) has recently begun to build and instrument a prototype magnetic system capa-

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Organized visits take place only on Saturdays, at 9.30 a.m., and/or 2.30 p.m. The visits last about three hours and are free. The minimum age limit is 16 years.

Les visites commentées ont lieu seulement le samedi à 9 h. 30 et/ou 14 h. 30. Elles durent environ trois heures et sont gratuites. La limite d'âge minimum imposée est de seize ans.

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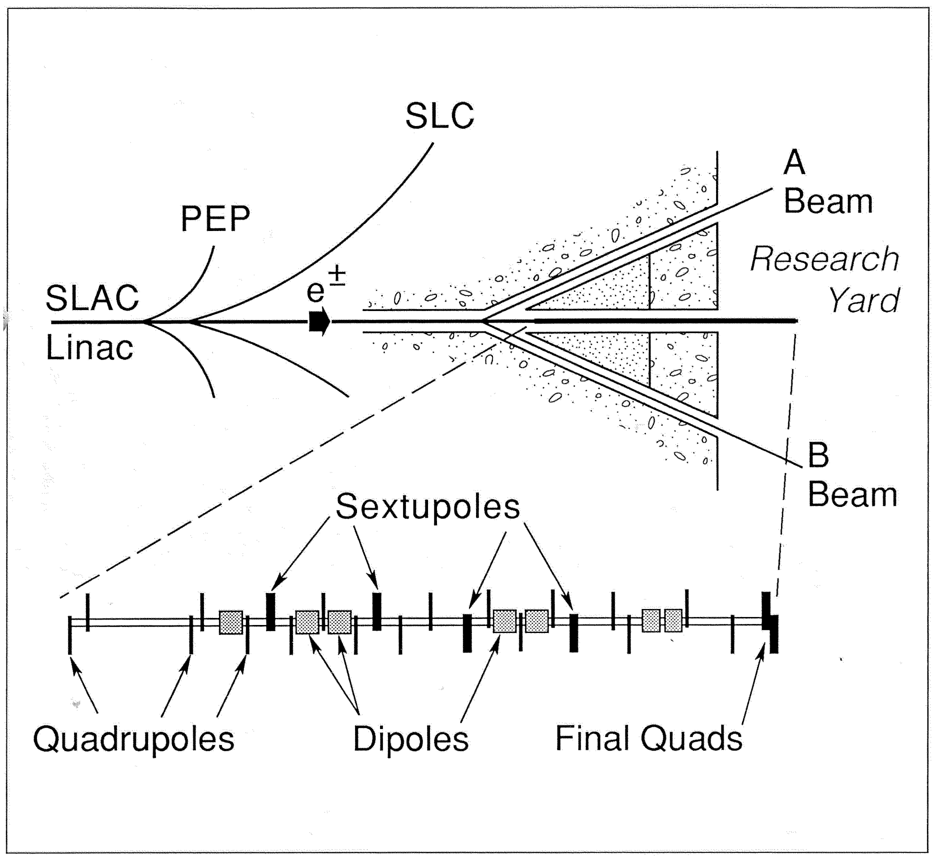
Layout of the principal elements of the Final Focus Test Beam in the straight-ahead channel at the end of the two-mile Stanford linac.




ble of producing the small beam spots required for NLC. This Final Focus Test Beam (FFTB) will occupy some 150 metres at the end of SLAC's two-mile linac, with the final elements extending into the Research Yard, and will be fed by the small emittance SLC electron (or positron) beam.

The optics of this beam will be corrected to third order for geometric and chromatic aberrations to produce a focal point at which the beam height will be reduced by a factor of 300 to less than 100 nanometres. Just such a compression factor will be required for the final focus of a TeV-scale linear collider.

The major final focus problem is to achieve a large geometric beam demagnification while controlling chromatic aberrations. The position of the focal point along the axis depends upon momentum, so the transverse size of the beam at the nominal focal point will be degraded because a high-gradient linac beam is not monochromatic. This degradation, or chromatic aberration, becomes more severe at higher demagnification and as the momentum spread of the beam increases.

This can be controlled by sextupole magnets, which have quadrupole moments varying linearly with transverse position. Paired with bending magnets that disperse the beam they can introduce momentum-dependent focusing.

The FFTB is an international effort. The optical design principles were developed by accelerator physicists from around the world - KEK (Japan), Orsay (France), and SLAC have contributed to detailed design, error analysis, and development of precise tuning techniques. The main magnets were designed and are being fabricated at the Soviet Institute for Nuclear Physics, Novosibirsk, and those for the final lens pair are being designed there and in Japan. State-of-the-art mechanical stabilization of these critical components will be done by KEK. Improvements, and in some cases completely new directions, in instrumentation are needed to measure beam properties. Measurement of the final spot size is a particularly challenging problem, as the intense beam will destroy any material in its path. Beam position monitors and associated electronics are being designed to provide resolutions of 1-2 microns. Wire scanners will be used to measure beam profiles away from the focal point, while techniques are being developed to measure the focused spot by observing the interaction of the beam with gas-jet or renewable solid targets.

Precise mechanical alignment and stabilization are necessary also for the remainder of the magnetic elements and electronic monitors. They must be aligned to better than 30 microns along the entire beam, and their position must be stable to 1-2 microns. Groups from DESY (Germany) and SLAC are studying how to achieve these goals.

These problems of accelerator alignment were highlighted in a recent workshop held at the DESY Laboratory in Hamburg. Components can be expected to creep a few hundred microns, even if solidly mounted. For the FFTB, initial adjustment gives a precision of 100 microns horizontally and 30 microns vertically, but the objective is to reduce these figures substantially, and to carry out these adjustments within a few minutes.

Current work is fast approaching the feasibility limits using mechanical systems, and the nanometre precision ultimately needed will probably call for magnetic control.

Component positioning is checked at SLAC using a laser beam, but alignment along stretched wires is also being studied, with fast optical and electronic readout for continuous feedback from mechanical (and ultimately magnetic) correction devices.

SLAC's Final Focus Test Beam is well underway. All participating groups have received the necessary funding, and the US Department of Energy has given the go-ahead for its construction at SLAC. Completion is expected in late 1992, and successful commissioning of the test beam will be a major step in the world-wide effort to design and build a TeV-scale linear collider.

# DESY
# All superconducting magnets in place for HERA

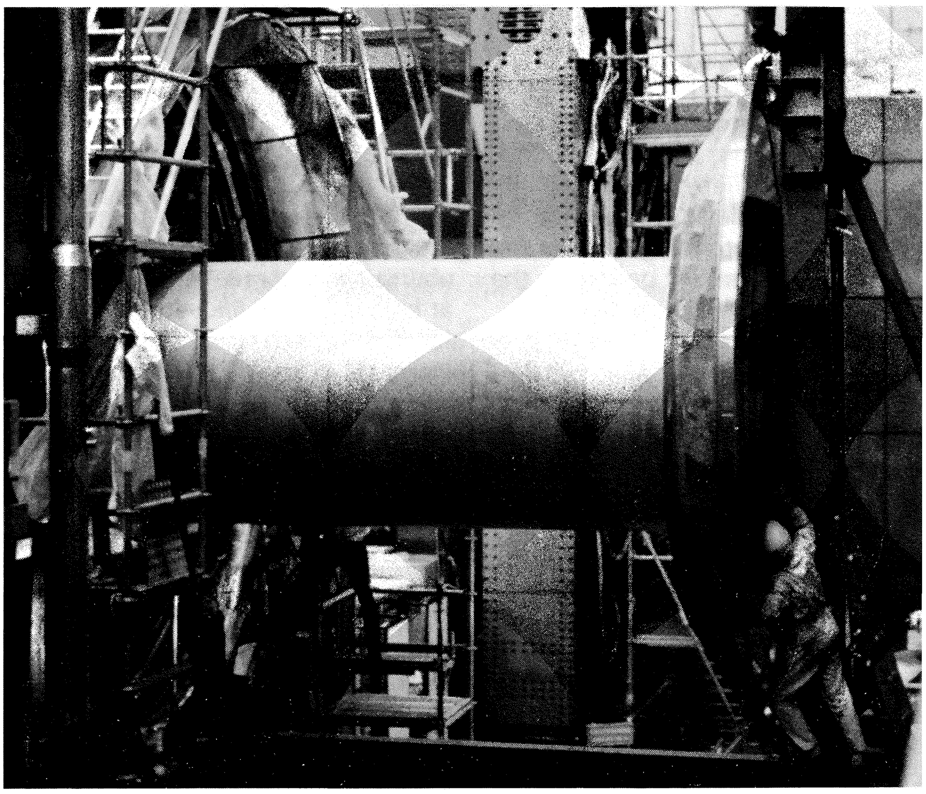
On 19 September the last of the 646 superconducting magnets for the proton ring of the HERA electron-proton collider was placed in position in the 6.4 kilometre tunnel at the German DESY Laboratory in Hamburg.

The different sections of the cryogenic ring are being cooled down, and all magnet connections should be complete by 8 November for the official ceremony marking the end of HERA construction and installation.

▲ *19 September – DESY Director Volker Soergel watches as the last of the 646 superconducting magnets moves into position in the proton ring of the 6.4 kilometre HERA electron-proton collider.*

▼ *The inner wall of the liquid argon cryostat slides inside the calorimeter of the H1 experiment being readied to exploit HERA beams from the middle of next year.*

*(Photos P. Waloschek)*



The installation spotlight now moves towards the two big experiments, H1 and Zeus, preparing to exploit HERA's colliding beams from the middle of next year. In September, H1 finished mounting most of the 'wheels' of the liquid argon calorimeter and its inner cylindrical cryostat wall could be slid into place. The wire chambers for H1 tracking now await installation inside the calorimeter.

For Zeus, the forward muon toroid and the experiment's compensating solenoid have been installed, the next step being installation of muon chambers, all these components being Italian contributions.

## SUPERCOLLIDER Groundwork

The Program Advisory Committee of the proposed US Superconducting Supercollider (SSC) met at Snowmass, Colorado, in July to consider 15 initial expressions of interest in SSC research. This resulted in a call for letters of intent for major detectors to look at high transverse momentum processes, and the committee will meet again from 13-15 December to consider the letters received. While promising ideas will benefit from support for the preparation of complete technical proposals during the next year, any group can still submit a later proposal.

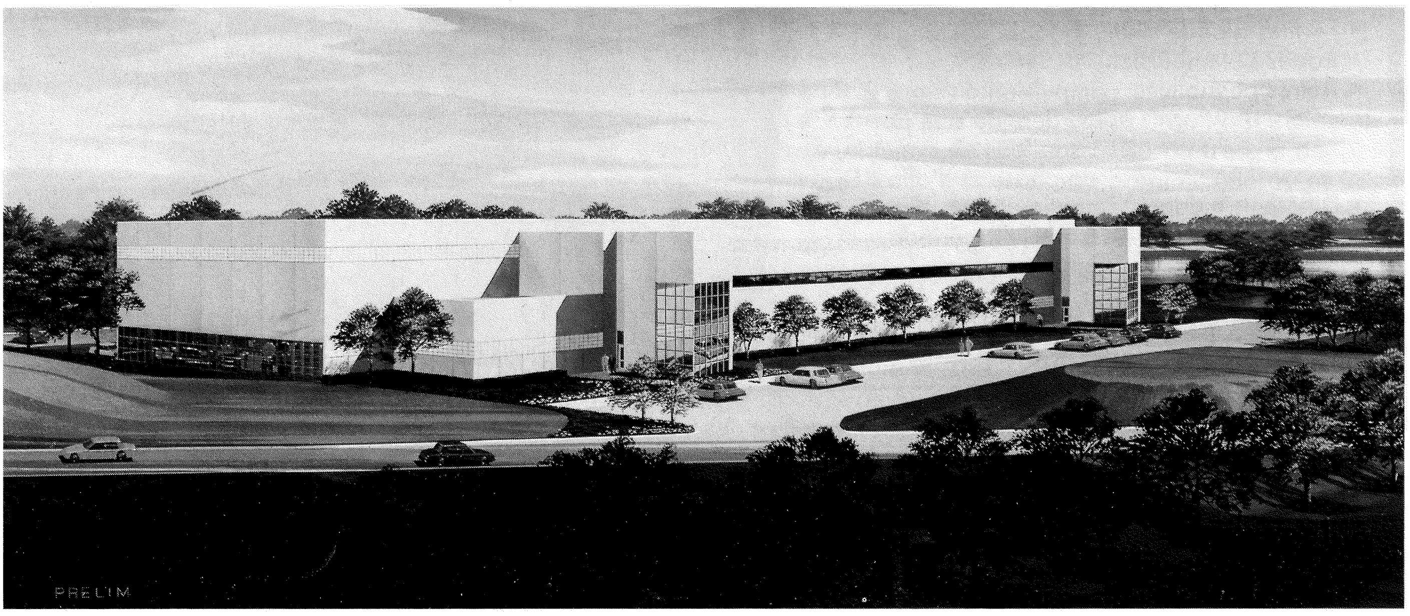
For the eight thousand superconducting dipole magnets needed to steer the proton beams round the SSC's 87-kilometre ring, a supplier is being selected to develop the design and produce the first prototype and preproduction units. After testing, two companies will compete for the production of the dipoles.

Conceptual planning and programming is underway for the SSC Laboratory's West Campus to house the injector complex, half the interaction regions, the test beam area, and office and laboratory space. The idea is to have a compact 'walking campus' where two- or three-story buildings in harmony with the prairie setting would be only a few minutes' walk apart.

The first ten acres of land for the Laboratory were acquired by the State of Texas on July 6. A total of 1,261 parcels, 16,553 acres in all, will be acquired from 707 different landowners within the next two years. About 60 percent will be purchased outright, and the rest 'in subsurface fee', with the current owner retaining title to the surface and continuing to use it as before.

The first building to be erected will be the Magnet Development Laboratory for assembly of in-house magnets. Groundwork has begun and construction should be complete next Spring. A separate Magnet Test Lab will be built later.

*Artist's impression of the Magnet Development Laboratory, soon to be constructed on the Ellis County, Texas, site of the US Superconducting Supercollider (SSC).*



Argonne Director Alan Schriesheim addresses the groundbreaking ceremony for the 7 GeV Advanced Photon Source to be built at the US Laboratory.

# ARGONNE Advanced Photon Source on the way

June 4 saw groundbreaking for the Advanced Photon Source (APS), the US 7 GeV entry into high brilliance synchrotron radiation x-ray research.

Budgeted at $456 million for construction, the AFS is scheduled for completion in 1995, roughly a year after the 6 GeV European Synchrotron Radiation Facility (ESRF) at Grenoble, France (September/October, page 13), and somewhat ahead of the 8 GeV Super Photon Ring (SPring-8) at Nishiharima Technopolis near Osaka, Japan.

The APS groundbreaking marked the culmination of an effort begun in 1983 with the report of the Eisenberger-Knotek Committee convened by the US Department of Energy to evaluate future opportunities and technical needs for synchrotron radiation-based research. A concerted effort by the US materials science community communicated the need for a high-energy low-emittance storage ring for extremely brilliant x-rays in the energy range up to several hundred keV.

In 1986 a conceptual design report spearheaded by Yanglai Cho outlined plans for a 6 GeV machine to be built at Argonne. A DOE Design Review Committee, in an otherwise favourable evaluation, recommended another look at energy. A National Task Group was formed to reconsider the photon energy tunability of undulator beams in the light of user needs, and settled on two principal recommendations: that an undulator at the new machine should provide radiation tunable over the 7 to 14 keV range for the initial phase of operation, and that at mature operation the minimum gap and the ring energy should allow the first undulator to be tunable over the 4.7 to 14 keV interval, with 20 keV radiation from at least the fundamental of a second undulator. Thus a revised conceptual design report upgraded the storage ring energy to nominal operation at 7 GeV with 7.7 GeV capability.

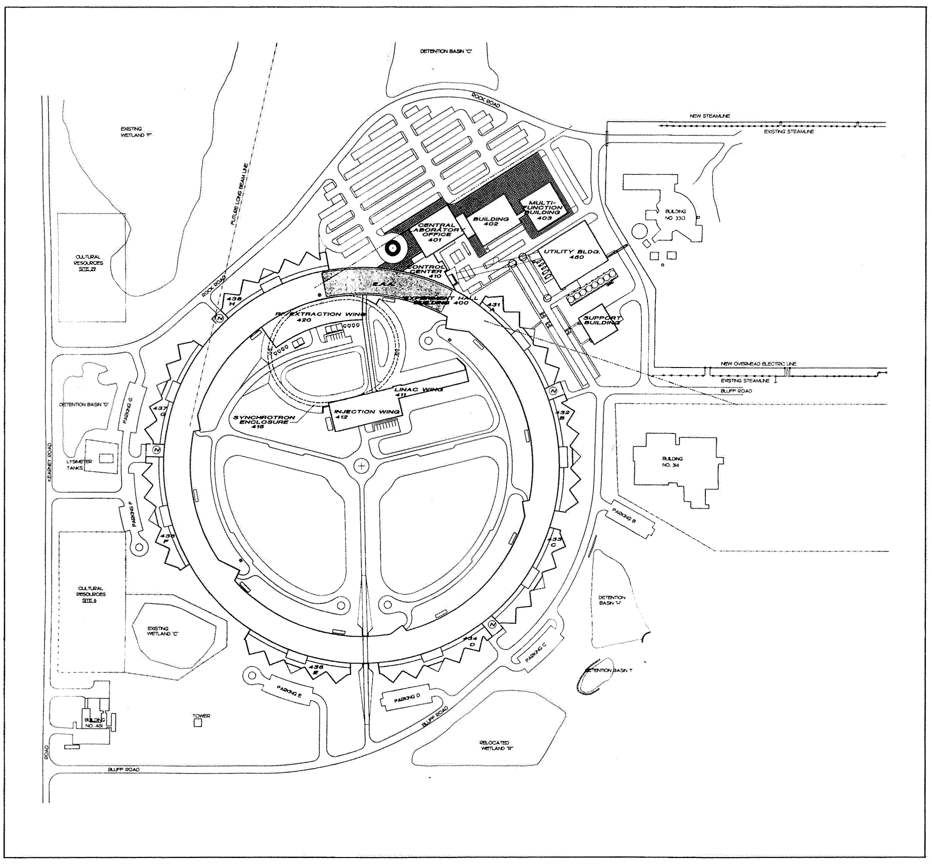
The APS will accelerate electrons to 200 MeV at a 60 Hz rate along the first third of the linac. Focused to a 3 mm spot on a 7 mm-thick tungsten positron production target, these electrons will 'each' yield 0.0083 positrons within a solid angle of 0. 1 5 sr in an energy range of $8 \pm 1.5$ MeV. A high-field pulsed solenoid will focus the positrons, then accelerated to 450 MeV in the positron linear accelerator over the remaining two-thirds of the linac's total 40 m length.

On injection into the 30m 450 MeV positron accumulator ring (PAR), as many as 24 successive pulses, or $3.6 \times 10^{10}$ positrons, from the linac will be accumulated as a single bunch each 0.5 second period. Bunch length compression in PAR will make the beam more compact and allow pulses from the linac to be accumulated as the booster synchrotron ramps the previous set of pulses.

After injection into the 367 m booster/injector synchrotron, positrons will be ramped from 450 MeV to 7 GeV in approximately one-third of a second. Because it cycles back down to 450 MeV to pick up the subsequent pulse, the booster performs two cycles per second.

The storage ring, with a circumference of 1104 metres, is designed for a nominal energy of 7 GeV and the capacity to attain 8.5 GeV. However all calculations of undulator spectra indicate an optimal energy range between 7 and 7.5 GeV. APS will fill some 30 of the 1296 available r.f. buckets with positron bunches, each carrying of the order of 5 milliamps. The ring is designed for currents in the 100-300 mA range. Up to 60 of the available r.f. buckets will be filled with positron bunches each carrying of the order of 5 milliamps. An-

*Schematic of Argonne's 1104-metre Advanced Photon Source, which should be providing high brillance x-rays for synchrotron radiation research from 1995.*




ticipated filling time for 100 mA is one minute.

The ring's 40 sectors will each include a straight section. R.f. cavities and injection apparatus will take up six of these, leaving 34 for experiments. Each will contain one insertion device – either a wiggler (for very intense x-rays over a wide band of energies) or an undulator (for radiation of selected energy at high spectral brilliance). One of the two bending magnets in each sector will be available to extract radiation.

These insertion devices continue to be a primary R&D focus. In 1988 a prototype undulator fabricated in collaboration with industry was installed in Cornell's CESR electron ring where it performed according to design calculations . A prototype ultraviolet undulator is now undergoing tests at Brookhaven's Vacuum Ultraviolet ring and a wiggler device to produce polarized radiation is foreseen.

Because of the materials science community's early involvement in overall facility design, the APS will provide considerable space for research – two laboratory areas each of several hundred square feet are planned for each sector of the machine.

A call for letters of intent from prospective collaborations by 1 May brought 30 replies, representing some 300 scientists and engineers from 9 national laboratories, 16 industrial concerns and 47 universities. Review is the responsibility of the APS Proposal Evaluation Board, which in its first meeting in May completed a preliminary screening. Recommendations to APS management include invitations to submit formal proposals (due in December), suggestions for consolidation of collaborations, and comments.

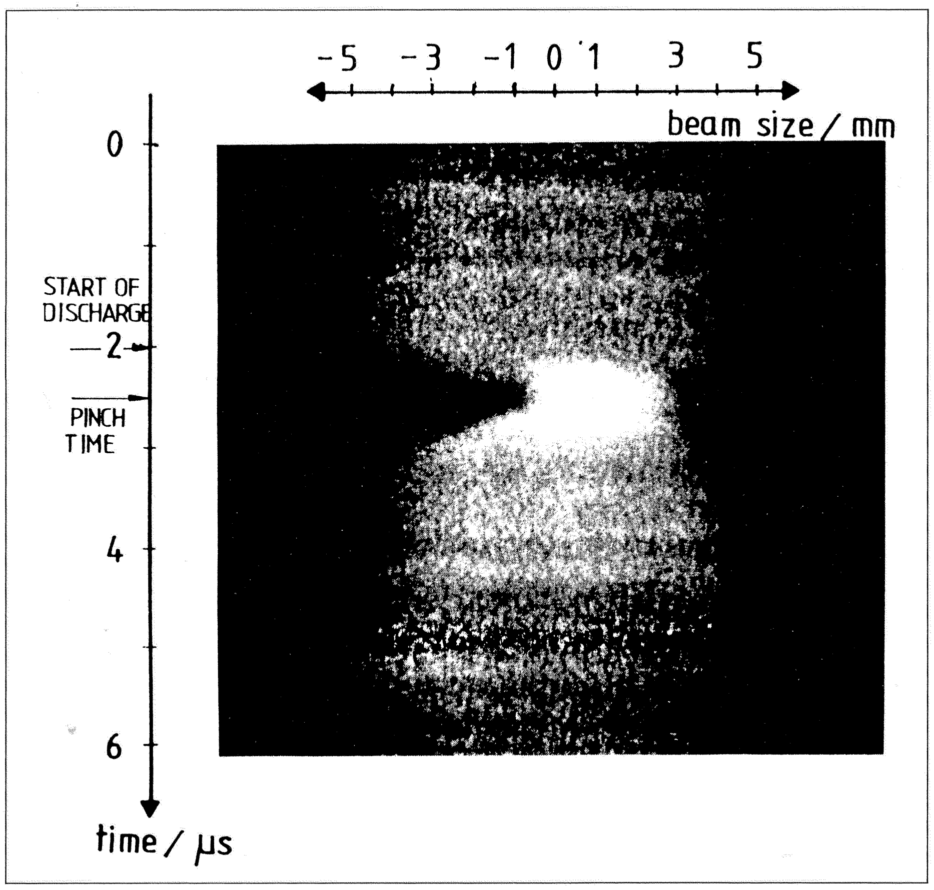
Speaking at the groundbreaking, APS Users' Association Vice-Chairman Steve Durbin (Purdue) recalled that the APS users' group held its first workshop back in 1985. 'While it might seem remarkable that a user group can function productively for a decade before the first x-rays arrive, that is the clearest possible signal that (the APS) will be a users' facility, fully optimized to meet the needs of a wide and diverse scientific community. When this project is commissioned, it will be the centre of unparalleled scientific productivity.'

## DARMSTADT
## Pinching beams

In recent experiments at the Unilac linac at Darmstadt's GSI heavy-ion Laboratory in collaboration with laser specialists from Aachen's RWTH (Rheinisch-Westfälische Technische Hochschule), a heavy ion beam has been successfully focused by a 'z-pinch' plasma lens.

The magnetic field in a cylindrical column of current-carrying plasma can focus charged particles in the axial (z) direction – hence z-pinch – providing a potentially useful method to complement conventional focusing techniques such as quadrupoles, magnetic horns and 'wire' lenses (cylindrical conductors carrying an axial current). However the effect has only rarely been demonstrated, the pioneer experiment having been at Brookhaven in 1965.

In the GSI success, a collimated 10mm-diameter 11.4 MeV/nucleon




▲ Streak image of a 10mm 11.4 MeV/nucleon argon beam from the Unilac machine at Darmstadt's GSI heavy ion Laboratory, showing the compression (z-pinch) on ignition of a surrounding cylinder of plasma (see front cover photograph).

argon beam was fired along the pinched plasma column. Light from a plastic scintillator mounted just behind the pinch was recorded with a fast streak camera. After plasma ignition using a 32.5 kV discharge in hydrogen at 2.5 mbar, the z-pinch shrinks the beam diameter from 10 to 2-3 mm, at the same time tripling the beam intensity.

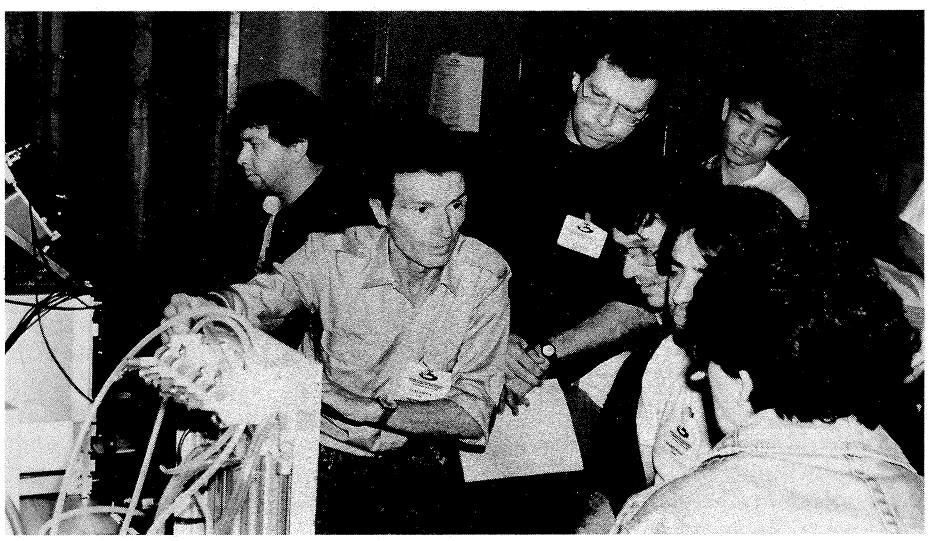
GSI is now looking at the possibility of such a plasma lens as part of a fine focusing system for the Laboratory's SIS heavy ion synchrotron, the aim being to pump more than ten Terawatts into each gram of target for fusion (inertial confinement) research.

At CERN a plasma lens development programme was started several years ago with the aim of improving the capture rate of antiprotons (May 1989, page 7). A promising new lens, achieving 5 tesla and a gradient of 300 tesla/m in bench tests, will be tried out at CERN's antiproton production target next year.

## RIO DE JANEIRO Instrumentation school

Students from Latin America were able to get hands-on experience in state-of-the-art physics instrumentation in this year's School on Instrumentation for High Energy Physics organized by the active Instrumentation Panel of ICFA (the International Committee for Future Accelerators) at the Centro Brasileiro de Pesquicas Fisicas (CBPF), Rio de Janeiro, in July.

*Yuri Zanewski from the Joint Institute for Nuclear Research, Dubna, near Moscow, explains a demonstration of imaging detectors for x-ray radiography to students at the recent ICFA School on Instrumentation in Elementary Particle Physics, held in Rio de Janeiro, Brazil, in July.*



While the two previous schools in this series had been held at the International Centre for Theoretical Physics in Trieste, Italy, the Brazilian proposal to move the venue succeeded in its aims – a large participation from Latin American students, 50 out of a total of 80.

The ICFA school is unique in offering specially designed hands-on laboratory experiments in addition to the standard fare of courses and specialized seminars. Basic courses included in the earlier schools and repeated in Brazil included studies of drift and proportional chambers and silicon detectors, plus a complete table-top measurement of the muon lifetime, while students also had the opportunity to participate in two courses on specialized applications of wire chambers – an x-ray imaging chamber for low-dose medical diagnostics, and a small photosensitive drift chamber capable of detecting and localizing single ultra-violet photons.

The laboratory sessions were as international as the student participation. One experiment had been prepared by a team of Brazilian physicists from the University of São Paulo and the Federal University of Rio de Janeiro. The others were flown in from Guanajuato (Mexico), Fermilab and Cornell (US), Uppsala (Sweden), JINR Dubna (USSR), and London's Imperial College, and the excellent support and cooperation from the CBPF high energy physics group greatly facilitated the task of getting these experiments going in a new environment.

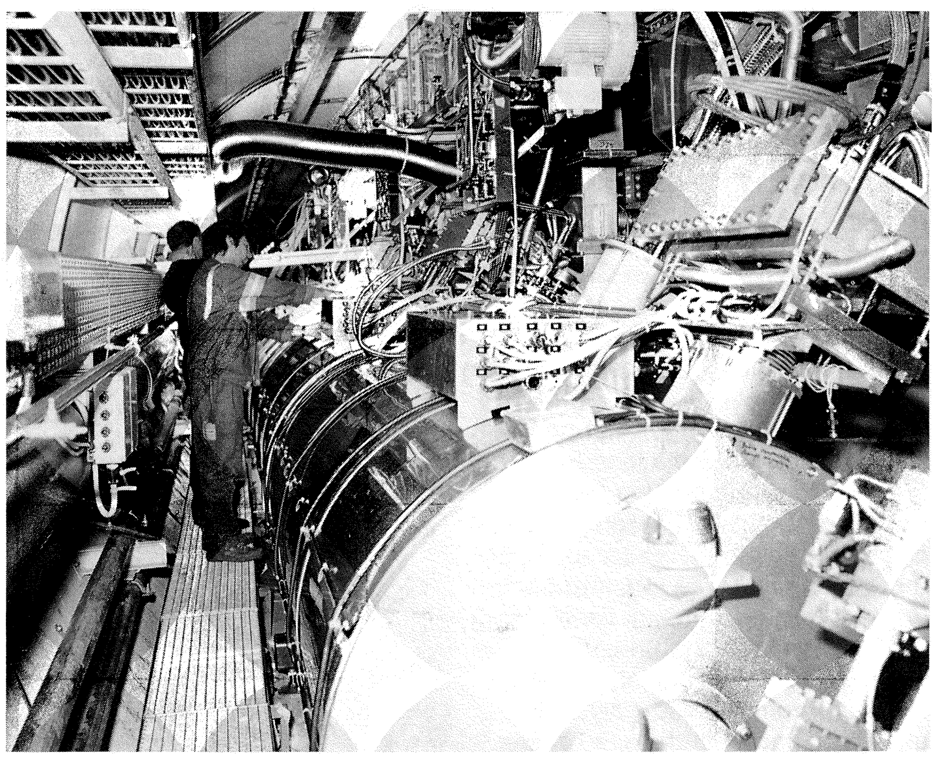
The organizers were Joao dos Anjos (CBPF – chairman), Don Hartill (Cornell), Fabio Sauli (CERN) and Marleigh Sheaff (Wisconsin). Questionnaire feedback awarded the school high marks, and suggestions serve as input to next year's school, which returns to Trieste, under the direction of Fabio Sauli and Paolo Poropat (INFN Trieste).

# Physics monitor

## Superconducting linear colliders

The advantages of superconducting radiofrequency (SRF) for particle accelerators have been demonstrated by successful operation of systems in the TRISTAN and LEP electron-positron collider rings respectively at the Japanese KEK Laboratory and at CERN. If performance continues to improve and costs can be lowered, this would open an attractive option for a high luminosity TeV (1000 GeV) linear collider.

A four-day workshop on a TeV Energy Superconducting Linear Accelerator (TESLA) held at Cornell from 23-26 July aimed at defining parameters and exploring ideas for improving gradients and lowering


*Superconducting radiofrequency systems, such as this one at CERN's new LEP electron-positron collider, are being increasingly used for accelerating beams to high energy.*

cost. About 70 scientists participated from Laboratories in the US, Europe, the USSR, and Japan.

In the first day's plenary talks M. Yoshioka from KEK reviewed the KEK Linear Collider Workshop held earlier this year, while Ugo Amaldi from CERN promoted new parameter strategies which helped guide the working group sessions. These talks were followed by progress reports from working groups, with the remaining three days devoted to working groups and final summaries.

A staged approach to TESLA was considered reasonable. The starting energy will depend on physics motivations and on progress in achieving higher gradients. Linear colliders have the advantage that, if a suitable site is selected, they can be extended.

Parameters for five machines were generated, with collision energies from 0.1 TeV (a Z-factory) to 1.5 TeV, using gradients from 15 MeV/m to 40 MeV/m. In contrast to ongoing applications, such as those for high energy storage rings, TESLA r.f. must be pulsed to keep cryogenic costs down.

However a few percent duty cycle retains the many attractive features, stemming from the $10^5$ times lower losses compared with a conventional copper linac, including a much lower r.f. peak power (say 40 Kwatts/metre), and a low r.f. frequency (1.5 – 3 GHz) that curtails wakefields and relaxes tolerances on alignment and injection jitter. The energy spread is small, so that final focus systems can be greatly simplified. The r.f. pulse length (of the order of milliseconds) is many thousand times longer than for copper cavities, so many hundreds of bunches can be accelerated. Conversion efficiencies as high as 20% from AC to beam power can be reached, twenty times higher than normal conducting machines. Bunches are then spaced very far apart, so multi-bunch instabilities can be avoided even if quality factors (Q) of dangerous modes are as high as $10^6$.

The guiding philosophy for TESLA beam parameters was to make the most of the high beam power available. Thus it was possible to reach high luminosities of $5 \times 10^{33}$ per sq cm per s at 1 TeV, with the final focus spot size going to about 1000 angstroms from the miniscule 20 angstrom beam envisioned for a conventional TeV collider.

The major challenges for TESLA are to increase gradients and lower costs. Gradients around 5 MeV/m are achieved with superconducting cavities handling electrons in TRISTAN and LEP, while acceptance tests on more than 70 metres of industrially produced structures average close to 9 MeV/m, and progress continues to be made. Recently, at 1.5-3 GHz, several centres (CEBAF, Cornell, Saclay and Wuppertal) have suggested gradients above 15 MeV/m in full scale structures.

Field emission is the dominant obstacle to reaching higher fields. Basic studies continue to improve understanding of this pernicious phenomenon which plagues both normal and superconducting r.f., and cures are being developed. With specially developed heat treatment techniques at 1400-1500°C, single cell 1.5 GHz niobium cavities at Cornell reach fields corresponding to 25 MeV/m. When the new heat treatment was applied to a five-cell 3 GHz structure at Wuppertal, it reached surface fields corresponding to 32 MeV/m. In a specially designed test cavity at Cornell (November 1989, page 10) and in a radiofrequency-quadrupole-type cavity at Argonne, CW surface fields of 145 MV/m were demonstrated without breakdown, and a 1 msec pulsed field of 210 MV/m was reached at Argonne.

Many ideas were put forward at the workshop for lowering costs. Since a Q of $10^6$ appears sufficient for damping higher modes, the number of cells can be increased from the customary four or five to ten. By polarizing individual cells, deflecting modes can be oriented so that one coupler can do the job of two. Economical cryostat designs were sketched that improve the filling factor from 0.5 to 0.75, and reduce static heat losses to below 1 watt/m.

The parameters worked out for TESLA need to be cost-optimized, and this will be attempted in future workshops. To continue progress on gradient and cost issues, needs for increased funding and manpower were stressed. There was intense discussion on strengthening existing collaborations. The next TESLA workshop will be held at the German DESY Laboratory, Hamburg, in conjunction with the 5th International Workshop on r.f. Superconductivity, to be held next July/August.

## Scintillating fibres

In the search for new detector techniques, scintillating fibre technology has already gained a firm foothold, and is a strong contender for the extreme experimental conditions of tomorrow's machines.

Organized by a group from the Institute of High Energy Physics, Berlin-Zeuthen, a workshop held from 3-5 September in the nearby village of Blossin brought together experts from East and West, and from science and industry.

Experience in building and testing fibre detectors was illustrated by report from the WA84 group at CERN using a fibre target to look for beauty particles, from the L3 experiment at CERN's LEP electron-positron collider (where a subgroup uses a fibre calibration system for the tracking detectors), and from the 'spaghetti calorimeter' being leveloped in the Italian-funded LAA project at CERN and aiming for improved energy resolution in hadron calorimetry.

In addition, many proposals testified to the confidence in this technology. Fibre tracking and fibre calorimetry are a possibility for the next generation of hadron colliders, while fibre targets of up to 25 tonnes could be constructed for neutrino physics.

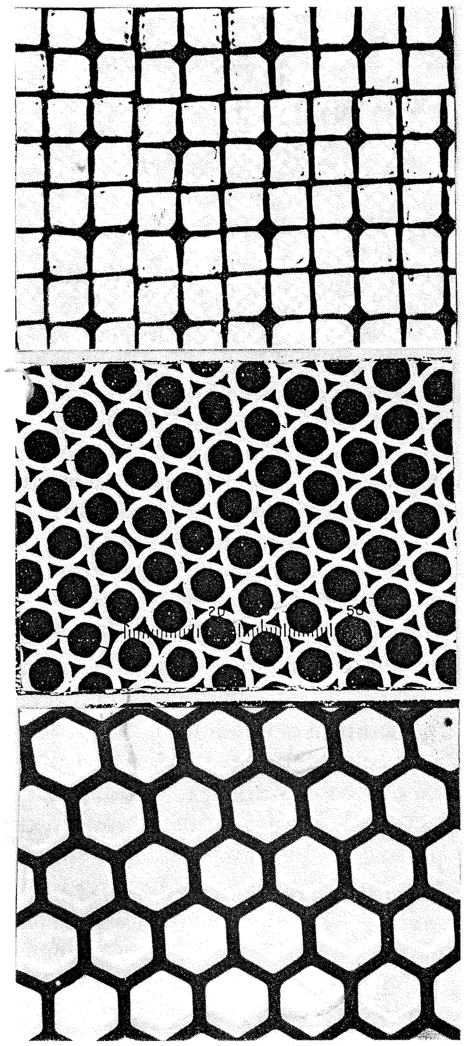
The second day of the meeting was given over to production possibilities and the characteristics of different products. Three different variants can be used in principle – plastic or glass fibres, and glass capillaries filled with scintillating liquids, and the advantages and disadvantages of each have to be carefully considered.

An example of technological progress is the one-metre attenuation lengths now achievable using coherent bundles of 20-micron fibres, bringing good light transmission with fine resolution.

A final topic was readout, hitherto dominated by image intensifier chains and CCDs. With future detectors probably having to handle at least ten million channels, new solutions are needed not only to build, but to pay for these devices!

The meeting was sponsored by Nuclear Enterprises and Schott Fiber Optics.

*From R. Nahnhauer (IHEP Zeuthen)*



*Scintillating fibres have attractions for detector specialists. Seen here are three cross-sections of bundled coherent light guides – top, 20 micron scintillating fibres from Schott (Mainz); centre, 20 micron capillaries from US Schott; and bottom, 30 micron plastic fibres from Kyowa Gas in Japan.*

# People and things

## *IUPAP elections*

*At the General Assembly of the International Union of Pure and Applied Physics (IUPAP) held in Dresden, Germany, in September, Yoshio Yamaguchi, currently Chairman of the International Committee for Future Accelerators (ICFA), was elected IUPAP's President Designate, to take over from current Chairman Yu. Ossipyan of the USSR Academy of Sciences in 1993.*

*IUPAP's C11 Commission on Particles and Fields consists of – T. Fujii (Tokyo, Chairman), F. Gudden (Siemens, Vice-Chairman), J. Haissinski (Orsay, Secretary), M. Baldeo-Ceolin (Padua), B. Barish (Caltech), P. Markov (Sofia), W.K.H. Panofsky (Stanford), V. Rubakov (Moscow), J. Sacton (Brussels), V. Singh (Tata, Bombay), V. Soergel (DESY), N. Tyurin (Serpukhov), Z.P. Zheng (Beijing).*

## *On people*

*CERN Director General Carlo Rubbia has received the prestigious Umberto Biancamano European Prize, awarded annually for distinguished contributions towards the consolidation of European unity. Established in 1962 as a national Italian award, the prize was extended in 1971 to European personalities, the first such recipient being the artist Marc Chagall.*

*William J. Willis becomes Head of Brookhaven's Center for Accelerator Physics.*

*Denis McWhan has become Chairman of the US National Synchrotron Light Source at Brookhaven. Sam Krinsky, previously Acting Chairman, is his deputy.*

# ARGONNE NATIONAL LABORATORY

Argonne National Laboratory (ANL) is currently seeking several professionals for its 7-GeV Advanced Photon Source (APS) Project. The APS Project will be a national user facility producing extremely brilliant x-rays for applications in a broad range of scientific disciplines.

### ELECTRONICS ENGINEER

A Master's or Ph.D. in E.E. or Physics and 1-5 years experience with low-level microwave design techniques or particle beam applications are necessary. **(Box# 37995)**

### RF ENGINEER

A Ph.D. in E.E., 5 years experience and considerable knowledge of electromagnetic theory and high frequency RF design and analysis techniques are required. **(Box# 82984)**

### ELECTRICAL ENGINEER

A B.S.E.E. and 5-10 years experience with RF circuitry and techniques are necessary. **(Box# 36626)**

### ASSISTANT ELECTRICAL ENGINEER

An advanced degree in E.E. and at least 4 years work experience are imperative. Knowledge and experience with the design and operation of pulsed and steady-state high current power supply systems is important. **(Box# 82717)**

### MECHANICAL ENGINEER

A B.S. or M.S. in M.E. and approximately 10 years experience in vacuum technology and the fabrication and machining of materials. **(Box# 36620)**

### OPTO-MECHANICAL DESIGN ENGINEER

M.S./Ph.D. or equivalent plus 5-10 years experience and considerable knowledge and experience in opto-mechanical design are required. **(Box# 82976)**

### SURVEY ENGINEER

Leads APS Survey and Alignment Team. Develops field procedures to position accelerator and storage ring components at proper location and orientation to a high degree of accuracy. **(Box# 82723)**

### ASSISTANT PHYSICISTS

Requires a Ph.D. in Physics and 1-5 years experience with various accelerator systems. **(Box# 81203)**

The second position requires a Ph.D. and a background in radiofrequency systems including sources, waveguides and cavities. **(Box# 82894)**

Each of these positions commands an excellent salary and benefits package. Confidential consideration can be obtained by sending your resume, indicating position of interest, to: **Walter D. McFall, Box J-APS-(Box#)-88, Employment and Placement, ARGONNE NATIONAL LABORATORY, 9700 South Cass Avenue, Argonne, IL 60439, USA.** Argonne is an equal opportunity/affirmative action employer.

(Use your PC to learn more about ANL and other available opportunities. Dial (508) 263-3857 and key in the password ARGON.)

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## BUCY CHAIR IN PHYSICS
## TEXAS TECH UNIVERSITY

Applications and nominations are invited for a new chair in physics (experimental partical physics) endowed by J. Fred Bucy and Odetta Greer Bucy. The appointment will be at the rank of professor with tenure in the Department of Physics. Criteria for selection include distinguished research in experimental particle physics with an interest in Superconducting Super Collider collaboration and a commitment to physics teaching. The Department of Physics is developing a program in particle physics to augment existing programs in atomic-molecular-optical physics, condensed matter, chemical physics, biophysics, nuclear physics, and pulsed power. The department has 17 regular faculty members and approximately 50 graduate students who are pursuing Ph.D. and M.S. degrees in Physics or in Applied Physics. Applicants should submit a resume, list of publications, and statement of research and teaching plans, as well as the name of five references to :

Professor Walter L. Borst, Chairman,
Department of Physics
Texas Tech University
Lubbock, Texas 79409-1051
USA

The deadline for receipt of application materials is 1 March 1991.

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## FACULTY POSITION
## EXPERIMENTAL PARTICLE PHYSICS AT THE SSC
## PENN STATE UNIVERSITY

The experimental particle physics group at Penn State University is planning a significant increase in its involvement at the Superconducting Super Collider (SSC). Applications are invited for a faculty position. The level of the appointment will be commensurate with the experience of the candidate. Major facilities, including a VAX cluster, electronics laboratories and shop, on-line data acquisition facility, and mechanical shop and assembly areas are in-place and available for SSC-related research. Applicants should have a Ph.D. degree in physics and at least two years of postdoctoral experience. An on-going presence and/or experience at an existing high energy collider facility is desirable. Send application, curriculum vitae and names of four references to

Professor Howard Grotch,
Head, Department of Physics
104 Davey Laboratory
Penn State University
University Park, PA 16802
USA

Applications received by 15 January 1991 will be assured of consideration. However, applications will be considered until the position is filled.

*An affirmative action/equal opportunity employer*
*Women and minorities are encouraged to apply*

*At Los Alamos, Ed Knapp takes on the combined posts of Division Leader (administration) and Scientific Director of the Los Alamos Meson Physics Facility (LAMPF) following the retirement of Don Hagerman. Former LAMPF Director Gerald Garvey becomes Senior Laboratory Fellow.*

## *John Stewart Bell 1928-1990*

*While quantum physics is one of the greatest scientific achievements of the twentieth century, it is also notorious, even among physicists, for being difficult to understand. CERN theorist John Stewart Bell, who died unexpectedly on 1 October, did much to remove these obstacles and unravel the paradoxes which riddle quantum theory and had led some early thinkers, notably Einstein, to be sceptical. Never fearing to enter intellectual territory where few others dared to tread, John Bell helped put the unfamiliar dogma of quantum mechanics on a firmer footing.*

*He moved from the UK to CERN in November 1960 for an active and prominent career. His famous 1964 Inequality specified how results of simultaneous measurements on separated physical systems can be correlated, and has been described as 'the most important recent advance in physics'. (With characteristic modesty, he described it himself as a 'dilemma'.) The Adler-Bell-Jackiw anomaly, found in 1969, pointed out profound questions in field theory.*

*Despite (or perhaps because of) his depth of understanding, he was also sympathetic with those he called the 'why bother?ers', agreeing with them that 'ordinary quantum mechanics is just fine for all practical purposes'. Putting this approach into practice in the mid-60s, notably with Jack Steinberger, he helped cast the definitive formalism for the violation of CP symmetry. He also took a deep interest in accelerator physics, with contributions co-authored with his wife Mary. He was a Fellow of the Royal Society (UK) and in 1989 was awarded the coveted Dannie Heinemann Prize for his contributions to mathematical physics.*

*John S. Bell 1928–1990.*

## *EPS-8*

*Called 'Trends in Physics', the Eighth General Conference of the European Physical Society (hence EPS-8), held in Amsterdam from 4-8 September (in collaboration with the Netherlands Physical Society) saw strong representation from particle physics and particle physicists.*

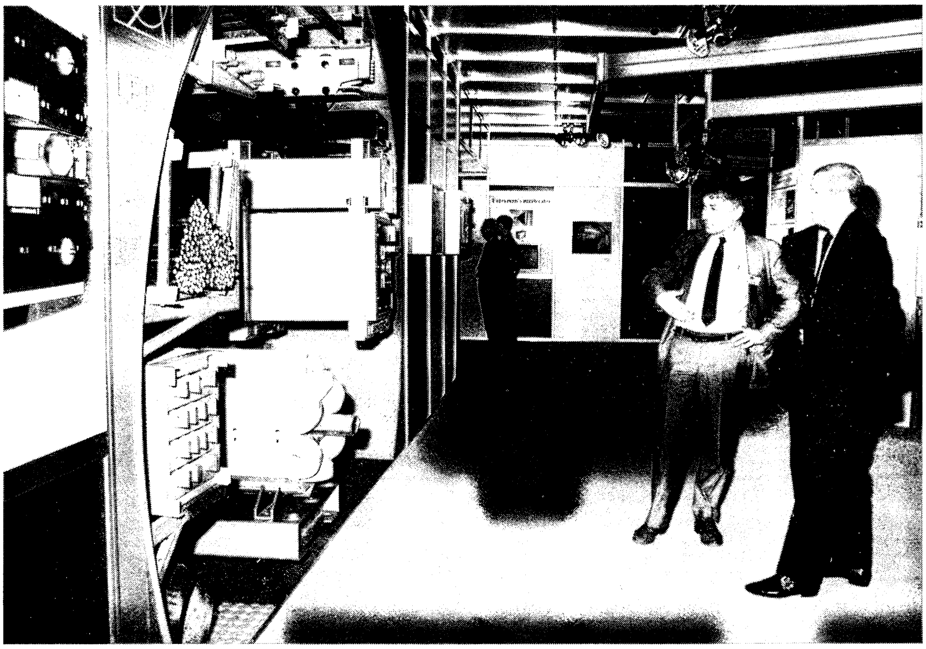
*Plenary sessions included former CERN Director General Herwig Schopper with first results from CERN's LEP electron-positron collider, Gerard 't Hooft of Utrecht with prospects for the Theory of Everything, 1989 Nobel prize-winner Norman Ramsey on experiments on time reversal symmetry and parity, and Reinhard Stock of Frankfurt on nuclear matter under extreme conditions.*

*High energy matters merited two parallel sessions. Oxford's Roger Cashmore chaired one stream including physics from LEP together with news and prospects for existing and proposed hadron colliders, while CERN Director Walter Hoogland presided over sessions on accelerator technology and control.*


*CERN Director General Carlo Rubbia (right) meets Israel's Minister of Science and Technology (and distinguished particle physicist) Yuval Ne'eman in Jerusalem on 8 September to sign an agreement covering future cooperation between Israel and CERN. This extends CERN's policy of setting up bilateral agreements to put ongoing collaboration with non-member states on a firmer footing.*

## *Meetings*

*Particles and Fields '91, sponsored by the Division of Particles and Fields of the American Physical Society and the Division of Particle Physics, Canadian Association of Physicists, will be held from 19-22 August 1991 at the University of British Columbia, Vancouver. Contact PF91 Secretariat, TRIUMF, 4004 Wesbrook Mall, Vancouver, BC, Canada V6T2A3, tel (604) 222-1047, fax (604) 222-1074, bitnet pf91 at triumfcl*



*Prince Claus of the Netherlands (right) inaugurated the CERN exhibition at NIKHEF in September. The Prince, who chairs a national committee for the promotion of science, is seen here viewing a model of CERN's LEP tunnel with CERN Director Walter Hoogland. The exhibition was open throughout the week of the General Conference of the European Physical Society in Amsterdam and coincided with a NIKHEF Open Day.*

*(Photo J.S.E. Schäfer, NIKHEF-H)*

## *US Particle Accelerator School*

*At the Snowmass Summer Study on High Energy Physics in the 1990s, sponsored by the American Physical Society, the US Particle Accelerator School awarded its prizes for this year to Donald Prosnitz of Livermore and Matthew Sands of Santa Cruz.*

*Prosnitz was cited for his contributions to the development of free electron laser amplifiers while Sands received his award for a lifetime of contributions to the science of beams and accelerators.*

*The US Particle Accelerator School's 1990 prizes went to (left) Donald Prosnitz of Livermore and to Matthew Sands of Santa Cruz.*

## Books

*Salam on Dirac*

*Published by Cambridge University Press is 'Unification of Fundamental Forces' by Abdus Salam, taken from the 1988 Dirac Memorial Lectures at Cambridge (ISBN 0 521 37140 6). As well as tracing the increasing motivation of theorists to synthesize all the forces of Nature (where he has made vital contributions), Salam, with characteristic humility, expresses his admiration for the late Paul Dirac, the architect of modern quantum theory. As well as Salam's own address at Cambridge, the book includes the intriguing personal recollections given by Dirac and by another monumental twentieth-century intellect – Werner Heisenberg – at a 1968 symposium organized by the International Centre for Theoretical Physics in Trieste (of which Salam is founder and Director).*

*In a field where many authors continually use and reuse the same material, Salam has a flair for digging out something fresh. To illustrate Dirac's character he quotes from a reporter who went to see Dirac when the physicist visited the University of Wisconsin in 1934:*

*'I have been hearing about a fellow they have up at the University this Spring. A mathematical physicist or something they call him, who has been pushing Sir Isaac Newton, Albert Einstein and all the others off the front pages. His name is Dirac and he is an Englishman. So the other afternoon I knocks on the door of his office and a pleasant voice says 'Come in'.*

*And I want to say that this sentence 'Come in' was one of the longest emitted during our interview. The minute I sees the twinkle in his eyes I knew I was going to like him. He did not seem to be at all busy. When I want to interview an American scientist of his class, he would blow in carrying a big briefcase, and while he talked he would be pulling lecture notes, proofs, books, reprints, manuscripts and what-have-you out of his bag.*

*Dirac is different. He seems to have all the time in the world and his heaviest work is looking out of the window.*

*'Professor,' says I, 'I notice you have quite a few letters in front of your name. Do they stand for anything in particular?' 'No,' says he.*

*'Fine,' says I, 'now will you give me the lowdown on your investigations?' 'No,' says he.*

*I went on. 'Do you go to the movies?'*

*'Yes.'*

*'When?'*

*'In 1920.'*

*Directions in High Energy Physics*

*Published by World Scientific, Singapore, under the personal supervision of Editor-in-Chief K.K. Phua, is the series 'Directions in High Energy Physics'. These books provide a valuable introduction for students, being more accessible than original literature and better organized than conference material. Each volume has its own editors, who commission contributors to provide individual chapters. The series so far consists of:*
*Volume 1 – High Energy Electron-Positron Physics (1988), edited by A. Ali and P. Söding;*
*Volume 2 – Hadronic Multiparticle Production (1988), edited by P. Carruthers;*
*Volume 3 – CP Violation (1989), edited by C. Jarlskog;*
*Volume 4 – Proton-Antiproton Collider Physics (1989), edited by G. Altarelli and L. Di Lella;*
*Volume 5 – Perturbative Quantum Chromodynamics (1989), edited by A.H. Mueller.*
*Forthcoming in the series are:*
*Volume 6 – Quark-Gluon Plasma, edited by R.C. Hwa;*
*Volume 7 – Quantum Electrodynamics, edited by T. Kinoshita;*
*Volume 8 – Interactions Between Elementary Particle Physics and Cosmology, edited by E. Kolb.*

*Future volumes under consideration include: Skyrmions, edited by A. Goldhaber; Quantum Group, Conformal Field Theories and Knot Theory, edited by L. Alvarez-Gaume and C. Gomez; Computing for High Energy Physics, edited by S.C. Loken; Quantum Field Theory and Statistical Mechanics, edited by J.L. Cardy; and Physics and Geometry by R. Jackiw.*

*CERN 'Yellow' reports 1989/1990*

*The following reports have been issued in the official CERN Reports series, since the last list in CERN Courier in December 1989:*

**CERN 89-09**; Wilson, A; Henke, H
The LEP main ring accelerating structure
CERN, 8 Nov 1989. – 42 p

**CERN 89-10 v.1**; Fernandez, E; Jarlskog, G *(eds)*
Proceedings, v.1, ECFA study week on instrumentation technology at high-luminosity hadron colliders, Barcelona, 14–21 Sep 1989
CERN, 24 Nov 1989. – 392 p

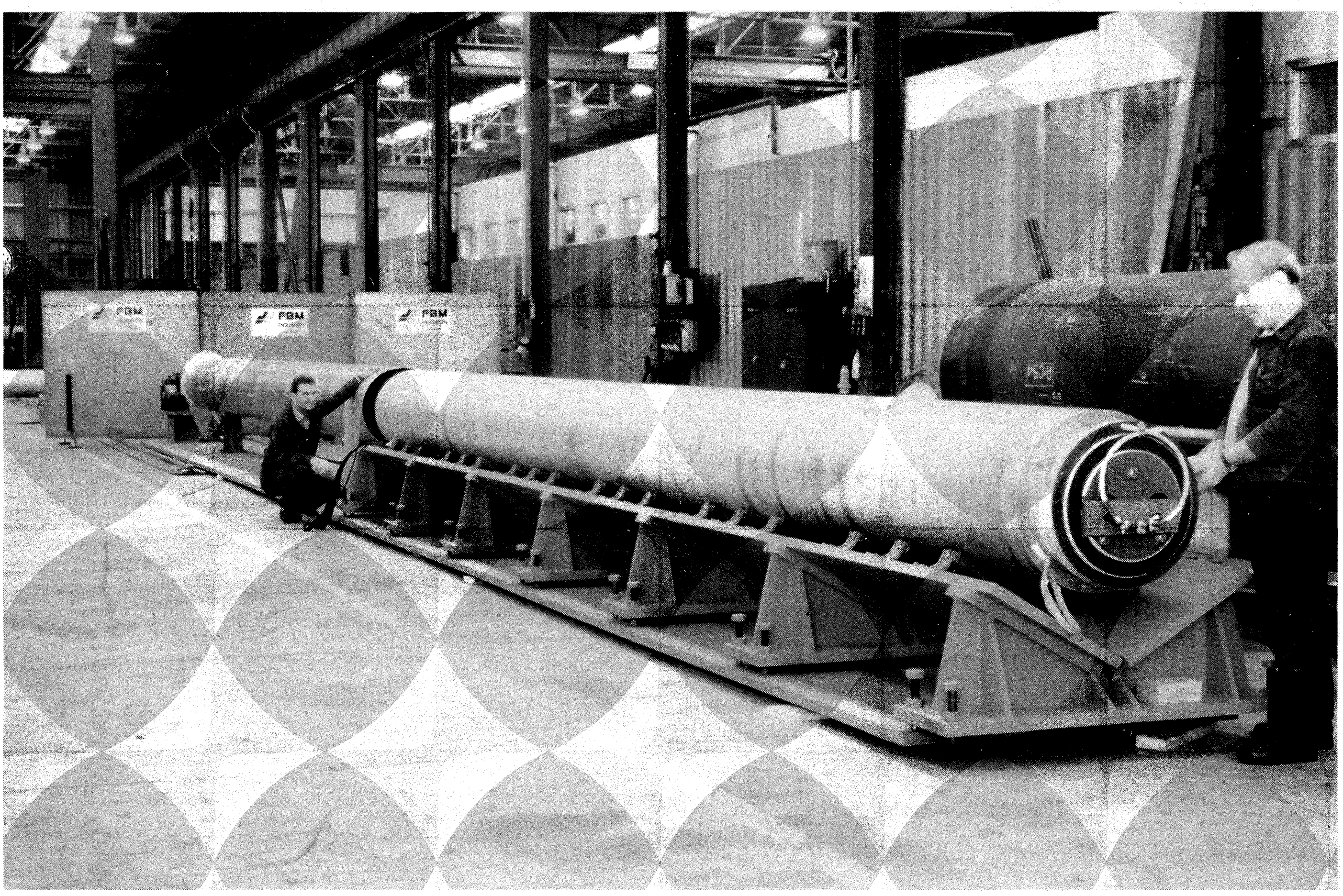
**CERN 89-10 v.2**; Fernandez, E; Jarlskog, G *(eds)*
Proceedings, v.2, ECFA study week on instrumentation technology at high-luminosity hadron colliders, Barcelona, 14–21 Sep 1989
CERN, 24 Nov 1989. – 400 p

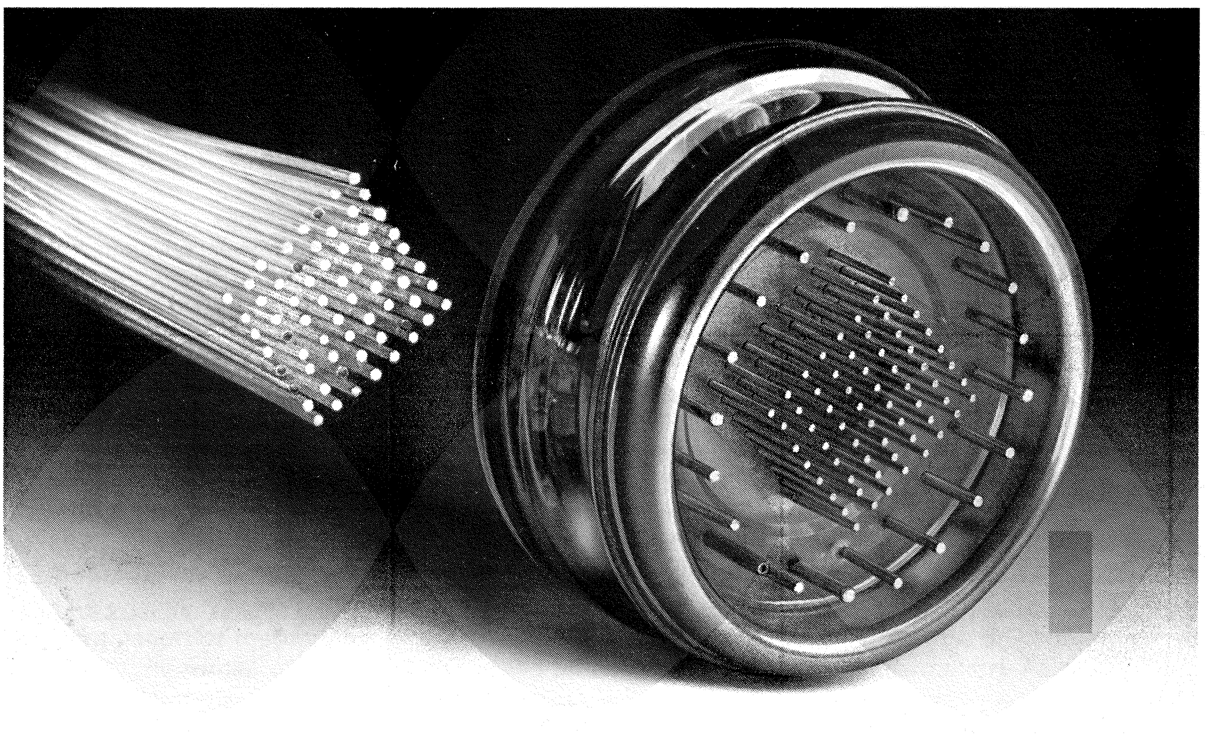
**CERN 89-11**; Quigg, C
The third Bernard Gregory Lectures
CERN, 31 Dec 1989. – 117 p
**CERN 89-12**; Schönbacher, H; Tavlet, M
Compilation of radiation damage test data ; Part 1, 2nd ed., Halogen-free cable-insulating materials = Index des résultats d'essais de radiorésistance ; 1re partie, 2e éd., Matériaux d'isolation de câbles exempts d'halogène.
CERN, 31 Dec 1989. – 217 p
**CERN 90-01**; Billinge, R; Boltezar, E; Boussard, D: *et al.*
Concept for a lead-ion accelerating facility at CERN
CERN, 28 Feb 1990. – 40 p
**CERN 90-02**; Nakada, T *[ed]*
Feasibility study for a B-meson factory in the CERN ISR tunnel
CERN, 30 Mar 1990. – 96 p
**CERN 90-03**; CERN, Genève
Turner, S *[ed]*
Proceedings, CAS - CERN Accelerator school ; Synchrotron radiation and free electron lasers, Chester, UK, 6–13 Apr 1989
CERN, 2 Apr 1990. – 482 p
**CERN 90-04**; CERN, Genève
Turner, S *[ed]*
Proceedings, CAS - CERN Accelerator school ; Third advanced accelerator physics course, Uppsala, Sweden, 18–29 Sep 1989
CERN, 24 Apr 1990. – 227 p
**CERN 90-05**; CERN. Genève
Wilson, E J N
Accelerators for the twenty-first century – a review
CERN, 29 May 1990. – 28 p
Lectures in the Academic Training Programme
**CERN 90-06**; CERN. Genève
Verkerk, C *[ed]*
Proceedings, 1989 CERN school of computing, Bad Herrenalb, 20 Aug – 2 Sep 1989
CERN, 29 May 1990. – 347 p
**CERN 90-07;** CERN, Genève
Turner, S *[ed]*
Proceedings, CAS - CERN Accelerator school ; Power converters for particle accelerators, Montreux, 26 – 30 Mar 1990
CERN, 23 Jul 1990. – 381 p

*Copies may be obtained, while stocks last, by writing to:*
*Scientific Information Service, CERN, CH-1211 GENEVA 23, Switzerland,*
*or by e-mail to:*
*LIBDESK@CERNVM.CERN.CH*

*The first full-length (10 metre) pre-prototype twin aperture superconducting dipole designed with the proposed LHC proton collider for CERN's LEP tunnel in mind was recently put into its cryostat at the FBM factory, Bergamo, Italy. Wound at ABB, Mannheim, Germany, and built with tooling developed for the superconducting ring at the HERA collider at DESY in Hamburg, the dipole is being sent to the French Saclay Laboratory for testing.*

*(Photo CERN AC002.10.90)*





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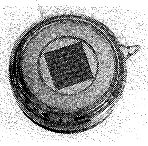

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