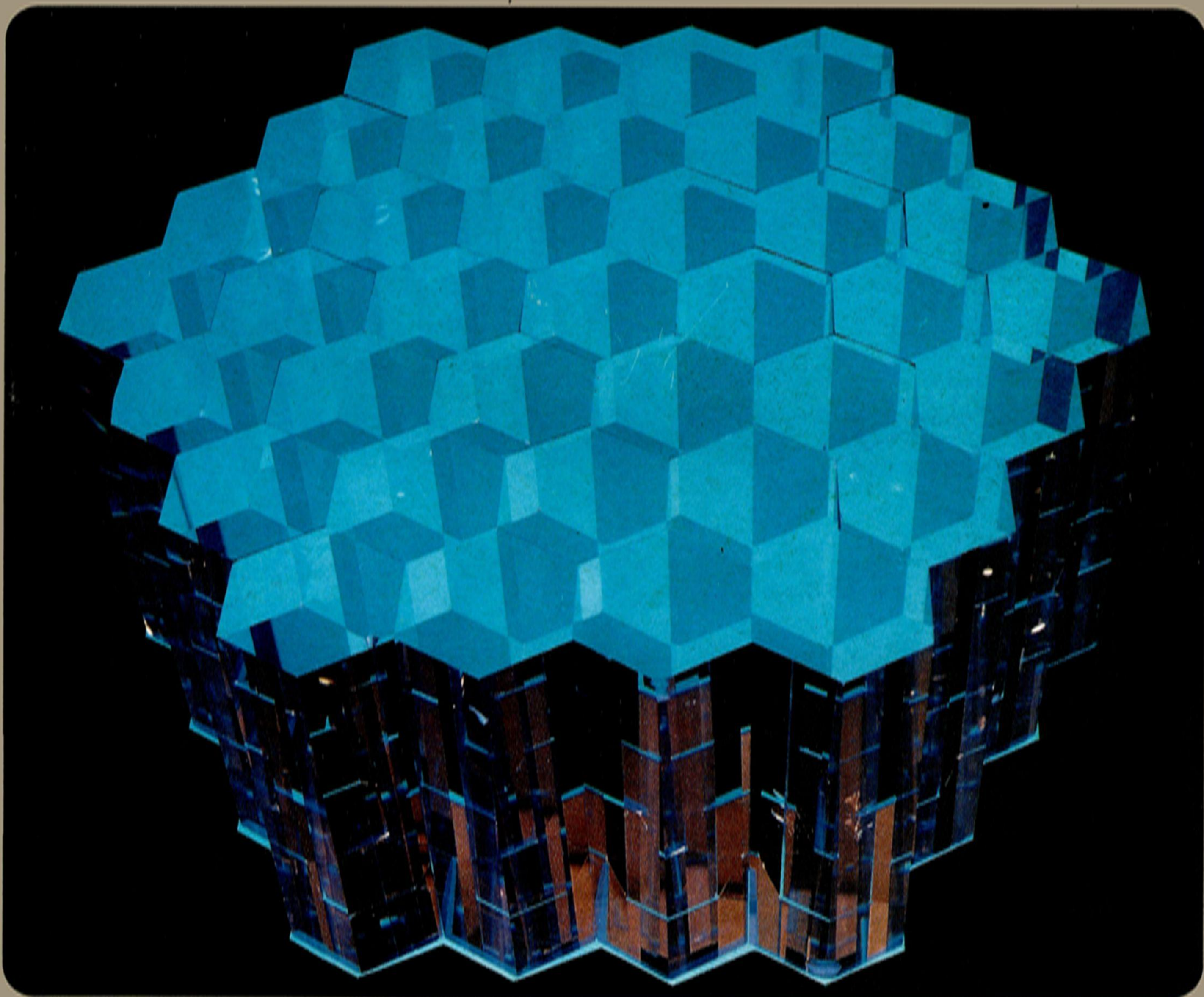
CERN COURIER

International Journal of High Energy Physics



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CERN COURIER

International Journal of High Energy Physics

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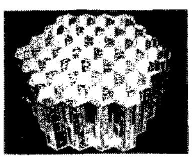

Cover photograph:
An array of barium fluoride crystals exploited by Brookhaven photographer Mort Rosen. For particle physics exploitations, see page 23.

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NORWAY AT
LA NORVEGE AU
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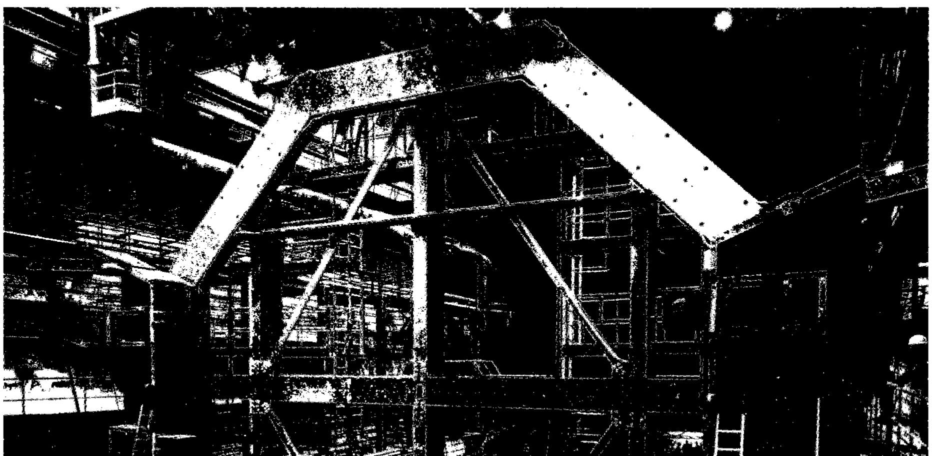
፤ NATIONAL ELEKTRO NORSK KABEL NATIONAL TRANSFORMER DATAKABLER	: Electrical installation work (low and : high voltage)-power-, rectifier and try : type transformers - cables - telecom- : munication equipment - switchbo- ards.
›COM TRONDHEIM ›COM ODDA	: CAD/CAM electronics PCB design. : Manufacture of single- and double sided PCB's.
SK DATA	: Computers with peripheral equipment.
TEREX	: Specialist in high performance graphics. Boards, monitors and software.
SEEM POWER	: Laboratory Supplies, 0-32(64)V, 100 (50)A : Battery Chargers 12-24-48 V, 600 W or larger : Switch-mode AC/DC, DC/DC, DC/AC Converters : Custom built Power Supplies for Industrial and Military Applications.
S T K	: Electrical power cables. Communication cables. 5500 BCS integrated services business communication systems.
STEINSVIK	: Components for jet engines and gas turbines.

EXPORT COUNCIL OF NORWAY: Organizer of the joint presentation.

Around the Laboratories

On 8 February the 27 kilometre LEP tunnel excavation was completed with an explosion clearing away the last rubble from the troublesome section under the Jura. CERN Director General, Herwig Schopper, and LEP Project Leader, Emilio Picasso, cut the symbolic ribbon opening the route to electrons and positrons all around the ring.

(Photo CERN 139.2.88)



CERN LEP progress

With installation work in the first completed section of CERN's LEP electron-positron collider pushing ahead at top speed, the final breakthrough in the 27 kilometre tunnel was made deep under the Jura mountains early in February after more than four years of herculean toil.

Less than two years after the official groundbreaking ceremony by Presidents François Mitterrand of France and Pierre Aubert of Switzerland in September 1983, excavation work for the access shafts and underground caverns was well advanced, and tunnelling machines came into action. Problems with water seepage in the section deep under the Jura mountains slowed down progress in that area, but the impact on the overall schedule was minimized by embarking on machine installation in the completed art of the tunnel, with French Premier Jacques Chirac and Swiss President Pierre Aubert putting the first magnet in place last June (see July/August 1987 issue, page 1). Injection of a beam from the neighbouring SPS synchrotron into the first section of LEP is scheduled for July of this year, and first electron-positron collisions for July 1989.

The pace also quickens for final assembly of the four giant detectors Aleph, Delphi, L3 and Opal for

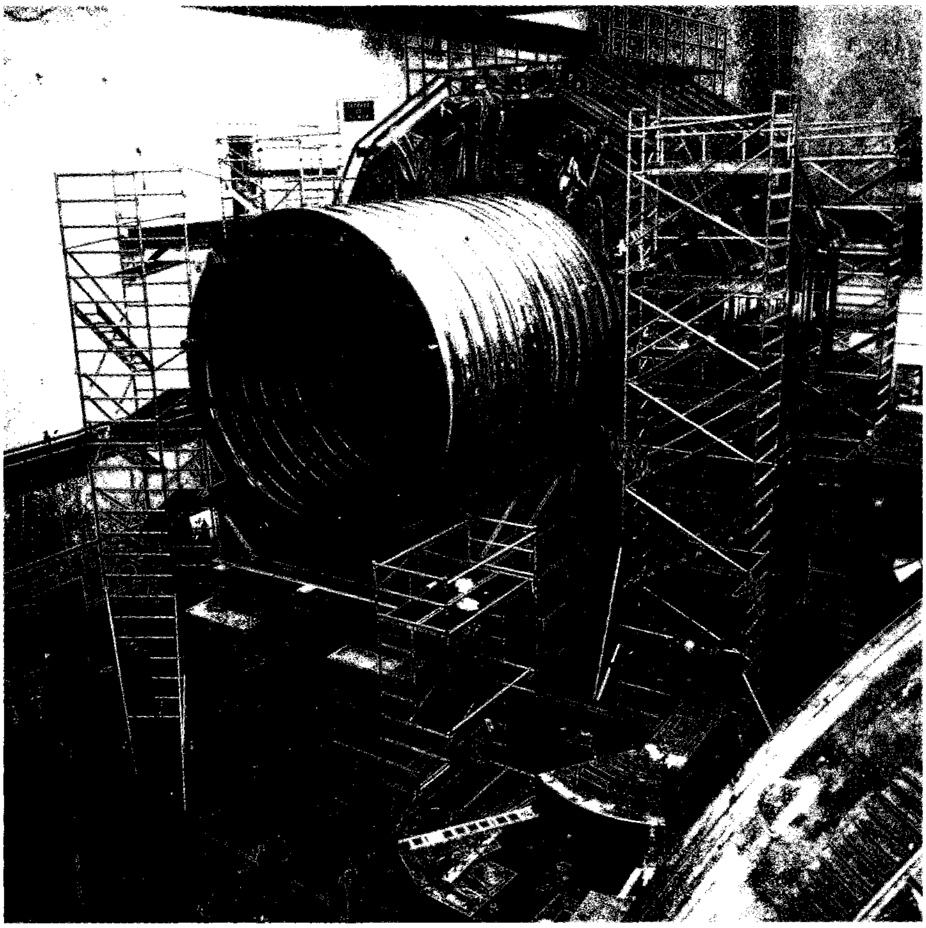
and Delphi and Opal are not far behind.

A notable 1987 milestone was the completion and delivery of the coils for the experiments' huge magnets. Aleph's 5 metre-diameter superconducting coil arrived first, after its overland journey from Saclay (see July/August 1987 issue, page 14). Delphi's superconducting coil, slightly bigger, arrived in December after an epic trip over land and water from the UK Rutherford Appleton Laboratory (see December 1987 issue, page 23).

CERN and Munich's Max Planck Institute developed special instrumentation for measuring the magnetic field inside both these coils, the uniformity of which is important for the central detectors to be mounted inside.

Built at CERN, Opal's 4 metre-diameter conventional magnet coil was put through its paces in December, attaining its nominal power of 5 Mwatts (7000 amps) without mishap.

The 1000 tonnes of octagonal windings for L3's 16 metre-wide 'magnetic cave' have gradually been taking shape at CERN, and installation underground got underway in January.

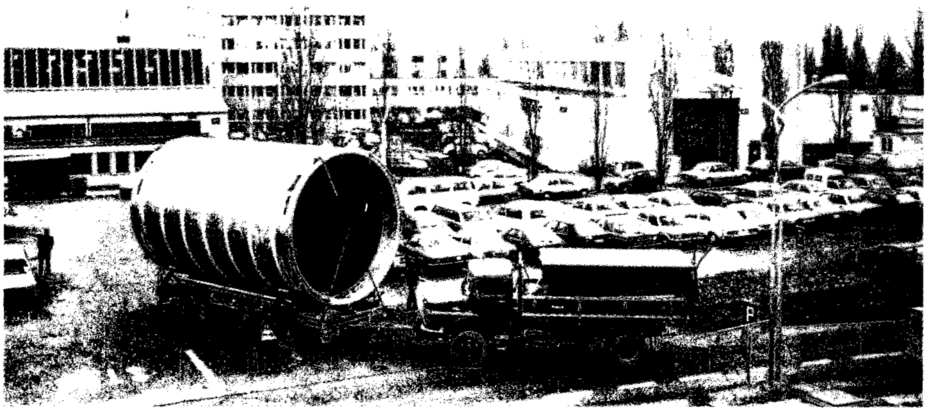


(Top) The 5 metre superconducting coil for the Aleph experiment at CERN's LEP electron-positron collider is eased into its yoke. The coil was built at Saclay and the yoke put together by Italian industry in Milan.

(Photo CERN X481.7.87)

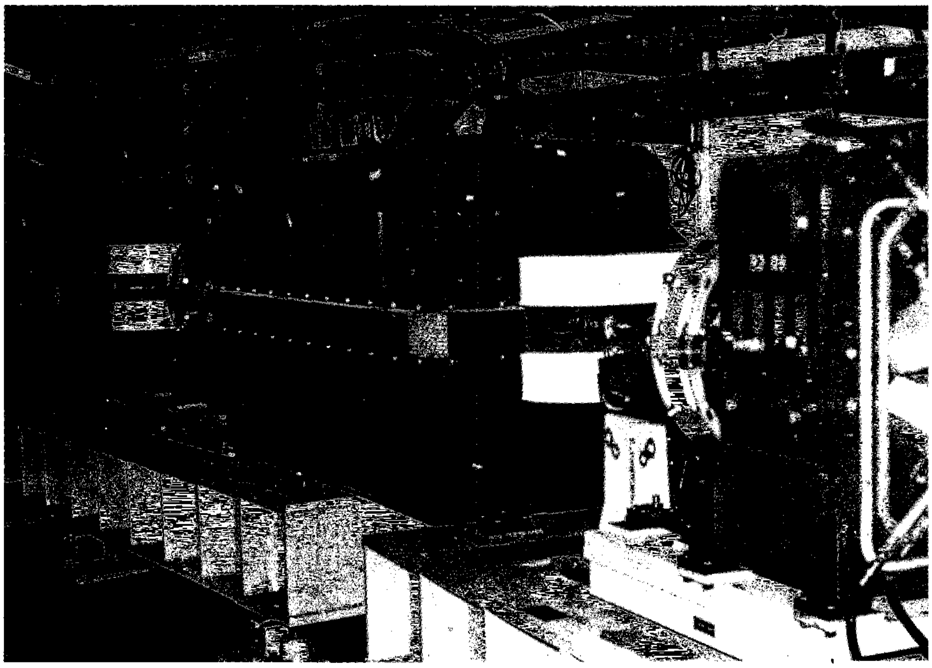
(Middle) Delphi's 6.2 metre diameter superconducting coil, the largest in the world, arrives at CERN from the UK Rutherford Appleton Lab.

(Photo CERN X027.12.87)



(Below) The 4 metre-diameter coil for the OPAL experiment performed well in power tests.

(Photo CERN X235.12.87)



A magnet cell of the new BEPC Beijing Electron-Positron Collider.

CHINA
First circulating particles

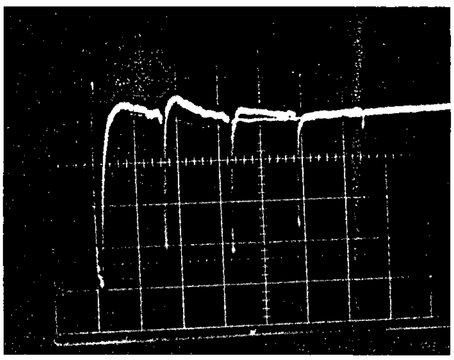
Following production of China's first positrons, the new BEPC Beijing Electron-Positron Collider continues to make good progress, with first beams injected into the 240 metre storage ring.

BEPC is designed to take electron and positron beams to between 2.2 and 2.8 GeV, fed by a 1.6 GeV linac. After a big push last year to install components for the ring, a test was made in December to inject 1.15 GeV beam (pulse current 200 mA) from the linac.

Excitement was high as the monitor showed the beam making five complete turns, although some remaining problems with the radiofrequency system prevented the beam from being stable.

Spurred on by this success, the BEPC team is working to stabilize the energy of the linac beam, improve the storage ring systems (including realigning all the components), and fully commission the radiofrequency. It is hoped to have stable beams stored by the summer, with electron-positron collisions by the autumn.

The monitor shows the first (as yet unstable) circulating beams in BEPC.



FERMILAB
Looking to upgrade

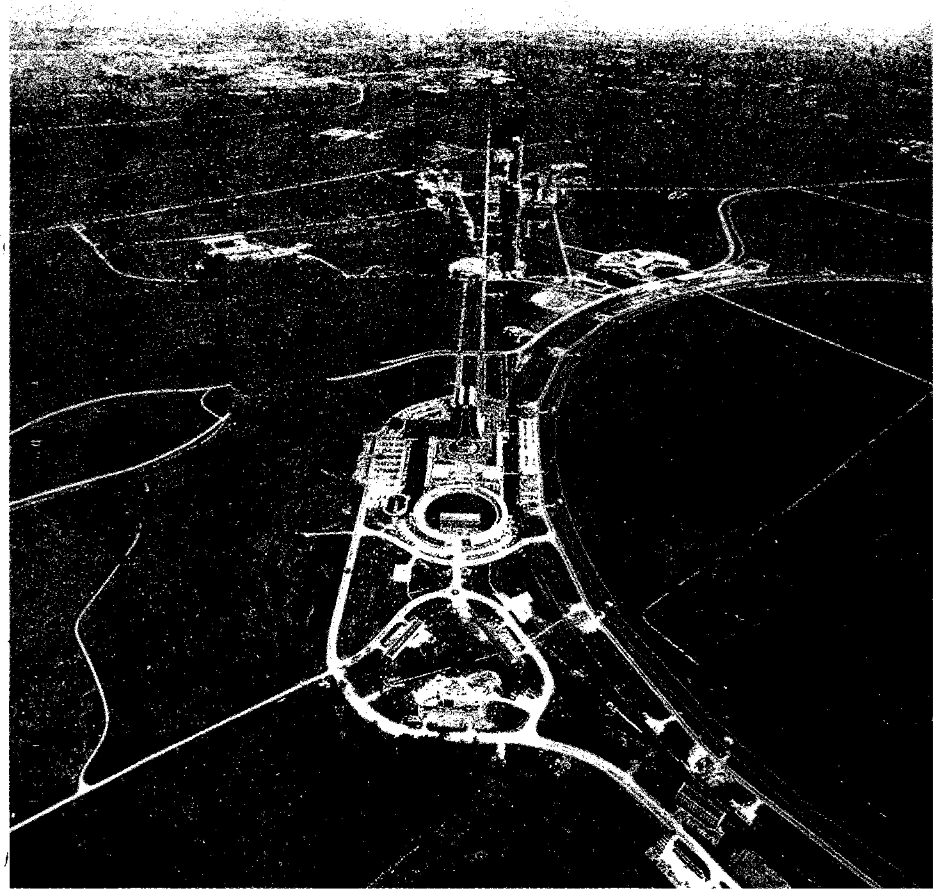
Fermilab is looking to upgrade the Tevatron, already the world's highest energy machine both for fixed target work and for proton-antiproton collisions, the goal being to improve the beams and reach a luminosity of 5 x 10^{31} cm^{-2} s^{-1}. (The luminosity of a colliding beam machine is the number of particles per second circulating in one beam multiplied by the average number of intercepted particles per unit transverse area in the other beam. When multiplied by a specific reaction rate, it gives the average number of events per second for that reaction.)

The initial project to convert the superconducting Tevatron into a collider had a luminosity goal of about 10^{30}. Commissioned for fixed target operation in 1983, the Tevatron's initial 1.6 TeV collision energy events were observed in October 1985 with a luminosity of about 10^{24}. Fermilab Director Leon Lederman described it as 'the world's lowest recorded luminosity'. Since then the figure has climbed five orders of magnitude to 10^{29}. The proposed upgrade goes a factor of 50 above the Tevatron collider's initial goal.

This requires three things – smaller beams (reducing the emittance); going from the present three bunch mode to 'multi-bunch' operation, with about 144 stored bunches; and increasing the number of antiprotons significantly.

Initial steps toward multi-bunch operation have already been made. Studies of helically separated counter-rotating beams are currently in progress, the idea being to install electrostatic separators. The

A view of Fermilab with the circular Booster area and triangular Antiproton Complex in the foreground, and the Main Ring/Tevatron tunnel on the right.



CERN experience with separated beams in the SPS provides valuable guidance.

A second significant step is the proposed upgrade of the linac, boosting its output from 200 MeV to 400 MeV by equipping roughly half of the machine with higher accelerating gradient structures. The higher injection energy would reduce unwanted space charge effects on the beam emittance.

A third step would be the addition of two new 20 GeV rings. The first (called the Post-Booster) would sit between the existing 8 GeV Booster and the Main Ring, taking 8 GeV protons from the Booster and injecting them into the Main Ring at 20 GeV with a significantly smaller beam emittance. Studies predict much improved Main Ring performance resulting from the combination of a smaller beam and better magnetic field quality. The second 20 GeV ring (called the Antiproton Depository) would increase the number of antiprotons by about a factor of ten. In this new scenario, the Accumulator would continue in its present role, cooling and stacking antiprotons, then transferring them to the new Depository for cooling and storage while the Accumulator stacked fresh batches. With a suitable number of antiparticles accumulated, they would be accelerated to 20 GeV and transferred to the Main Ring and ultimately to the Tevatron. Also 'used' antiprotons (emittance diluted by interbeam scattering) could be decelerated in the Tevatron and Main Ring and put back into the Depository for later reuse.

Portions of the project could conceivably be funded in the next US financial year.

New tagged hadron beam

E769 is a new Fermilab fixed target experiment studying the production of charmed particles by hadron beams at the Tagged Photon Spectrometer. It is a collaboration of Centro Brasileiro de Pesquisas Fisicas, Fermilab, Northeastern, Toronto, Tufts, Wisconsin and Yale. During the previous fixed target run, the Tagged Photon Spectrometer was host to experiment E691 (photoproduction of charmed particles) which accumulated the world's largest sample of reconstructed charm decays (see November 1986 issue, page 29).

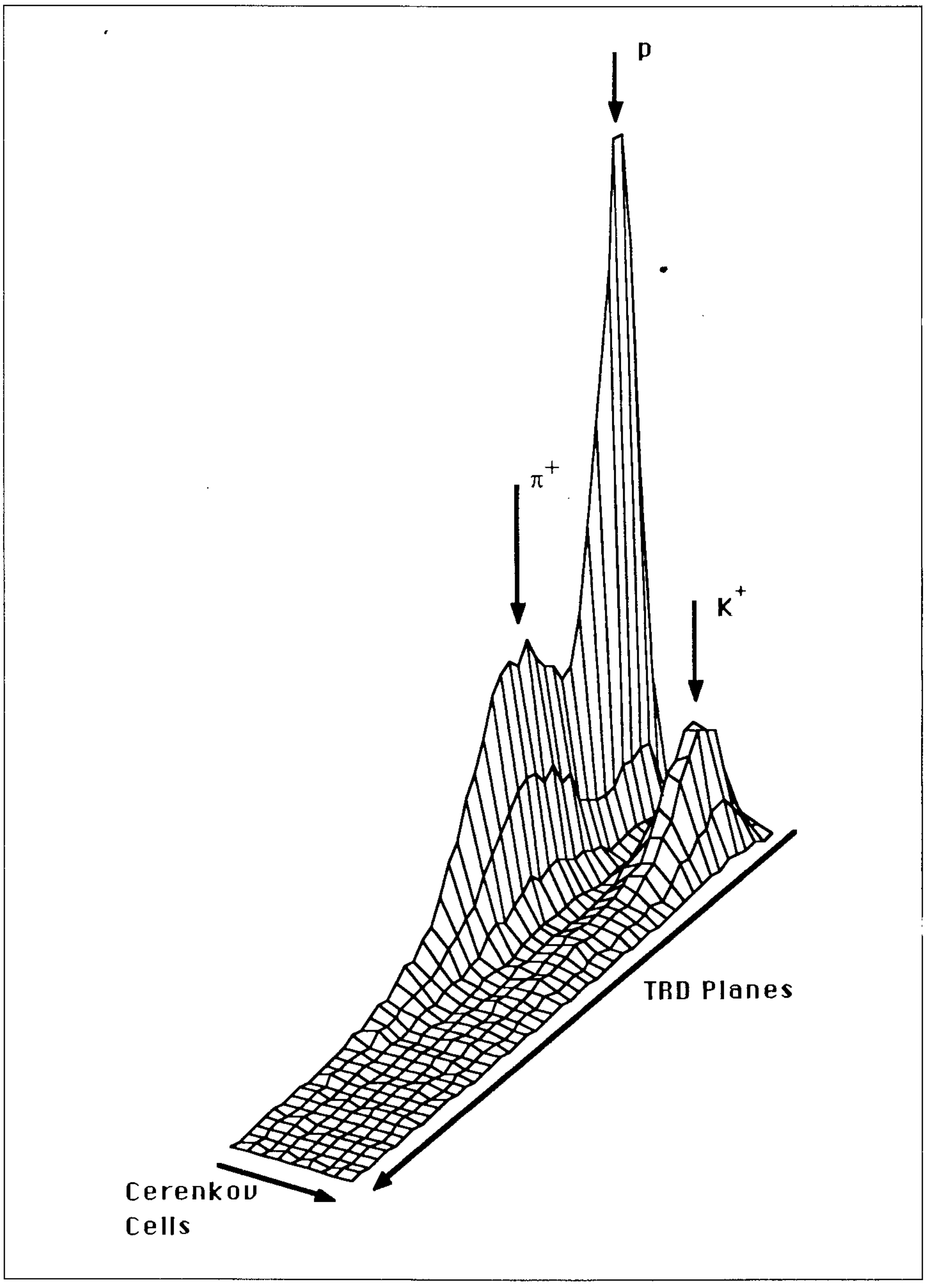
Since then there have been some major additions for the new experiment. The first is the reconfiguration of the beamline leading to the experimental hall. The electron/tagged photon beam has been redesigned to transport instead 250 GeV pions, kaons, and protons to the spectrometer. A new beamline Transition Radiation Detector (TRD) and a Differential Isochronous Self-Focusing Cherenkov Counter (DISC) were a major part of this effort. The DISC is being operated at the upper limit of its useful momentum range to provide a positive tag for charged kaons. Its high quality optics allow the separation of kaons from pions and protons by discriminating among the angles at which these particles produce Cherenkov light, a difference of only 0.069 milliradians for pions and kaons at 250 GeV. The TRD was specially designed for E769 and uses 24 identical chamber-radiator assemblies, with a stack of 200 polypropylene sheets equally spaced over 50 mm making up each radiator. Transition radiation photons produced by beam particles as they pass through this stack are detected in two thin multiwire chambers filled with xenon. As production and detection of these TR photons is more likely when the beam particle is a pion than when it is a proton or kaon, a large number of detector planes firing provides a positive pion tag.

The second major addition is a new data acquisition system partially composed of Fermilab-developed Advanced Computer Program (ACP) modules. An ACP system is a series of single board microprocessor-based computers with large memories. Originally developed for off-line event analysis (see October 1987 issue, page 22), these modules have now been used by E769 for data acquisition as well, in view of the high statistics needed (over 300 events per second with a total data sample of over 300 million events).

The old CAMAC data acquisition system was read out serially by two CAMAC branch highways and a PDP11. This took about 2 microseconds per word. The experiment replaced the CAMAC branch highways with 7 parallel highways to bins of readout buffers and ACP modules. These highways are read out simultaneously at between 1 and 0.6 microseconds per word. By reading the modules at 0.6 microseconds, E769 gains a factor of three in readout speed alone and, combined with the parallel branches, a factor of 20 in readout time.

Because each ACP module has 2 Mbytes of memory and with Tevatron spills twenty seconds long, E769 can store events in the ACP buffers and comfortably write them all to tape. The system can also write data to magnetic tape from the ACP memories directly, without other intervening computers. The experiment is using a 6250 bpi tape drive working at 100 inches per second.

Particle identification by transition radiation detectors (TRD) and Cherenkov cells for a new 250 GeV beam at Fermilab.

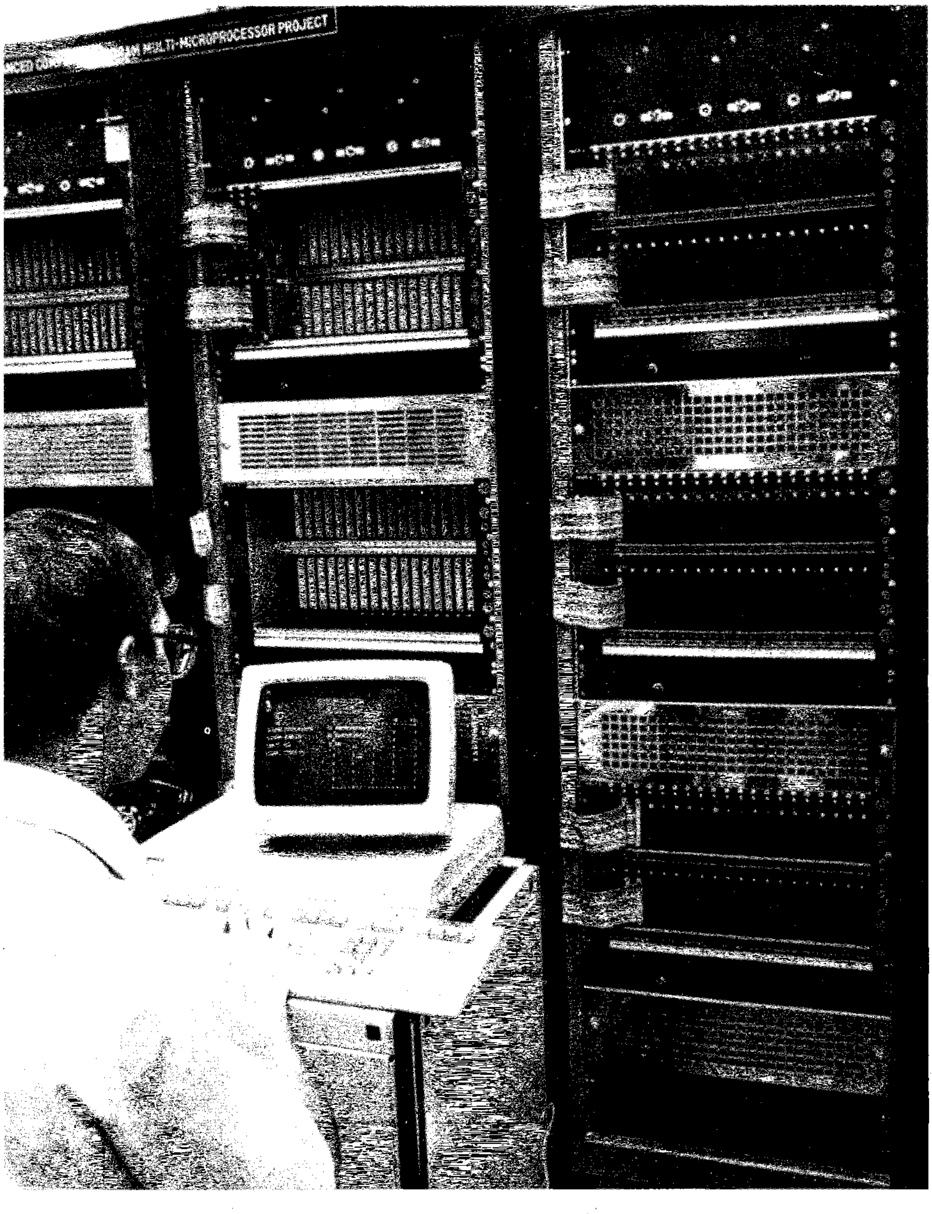


Another major upgrade is in the experiment target region. To track the beam particles, 8 planes of 1 mm wire chambers and 2 planes of silicon microstrips with 25 micron pitch, in conjunction with a target consisting of 26 250-micron foils, will precisely locate the primary interaction.

The experiment has accumulated 300 million events on tape and off-line analysis is underway. An enlarged collaboration is hoping to extend the studies to include particles containing heavier (beauty) quarks.

Fermilab's Advanced Computer Program equipment in use.

(Photos Fermilab)



GRENOBLE European Synchrotron Radiation Facility agreement

One of the biggest research spin-offs from high energy physics is the intense electromagnetic radiation (synchrotron radiation) from circulating electron beams, now used in an extensive range of studies in physics, materials science, chemistry, biology and medicine.

All over the world, laboratories which made their mark with electron beams have been drawn into this work (Stanford and Cornell in the US, DESY in Germany, Novosibirsk in the USSR, Daresbury in the UK, Orsay in France, Frascati in Italy, ...), while special electron machines such as those at the US National Synchrotron Radiation Light Source at Brookhaven and the Photon Factory at the Japanese KEK Laboratory have greatly extended the range of beams available.

Major new projects have been put forward in several countries. Europe took a major step forward with the signing on 22 December of an agreement to start construction of a new European Synchrotron Radiation Facility (ESRF) in Grenoble, France.

Government representatives from France, West Germany, Italy, the UK, Spain, Switzerland and the Nordic Countries (Denmark, Finland, Norway, Sweden) voted to start ESRF construction with a budget for this year of 108 million French francs.

To be built alongside Grenoble's existing Institut Laue-Langevin, with a tradition of materials research using neutron beams from

its high flux reactor, the ESRF will be based on an 850 metre storage ring to work at 6 GeV (mainly X-rays), fed by a 300 metre booster ring taking particles from the linear injector. A ring-shaped experimental hall will accommodate beamlines up to 75 metres long. To improve performance, positron operation is envisaged. A 200 MeV electron preinjector is one of the first items on the shopping list.

Construction will last six and a half years, with first experiments (7 beamlines) scheduled for 1994. Subsequently, the number of beamlines will be increased to 30. Total costs over eleven years are estimated at 3.6 billion French francs, with 2.6 billion earmarked for construction.

Model of the proposed European Synchrotron Radiation Facility to be built at Grenoble. The ring-shaped experimental hall in the foreground houses the beams from the 850 metre storage ring. In the background are the buildings of the existing Institut Laue-Langevin, a multinational laboratory equipped with a high flux reactor for research with neutron beams.

BERKELEY
Another narrow peak

Several years ago, heavy ion experiments at the UNILAC machine at Darmstadt (GSI) reported unexplained narrow peaks in electron-positron spectra, corresponding to the decay of several neutral states in the range 1.6 – 1.9 MeV (see April 1986 issue, page 22).

Subsequently, another GSI experiment found a positron signal corresponding to a 1.5 MeV neutral particle, but searches in other environments found nothing, and theorists admitted to being baffled (see July/August 1987 issue, page 8). However neutral particles decaying into electron-positron pairs might also decay into photons.

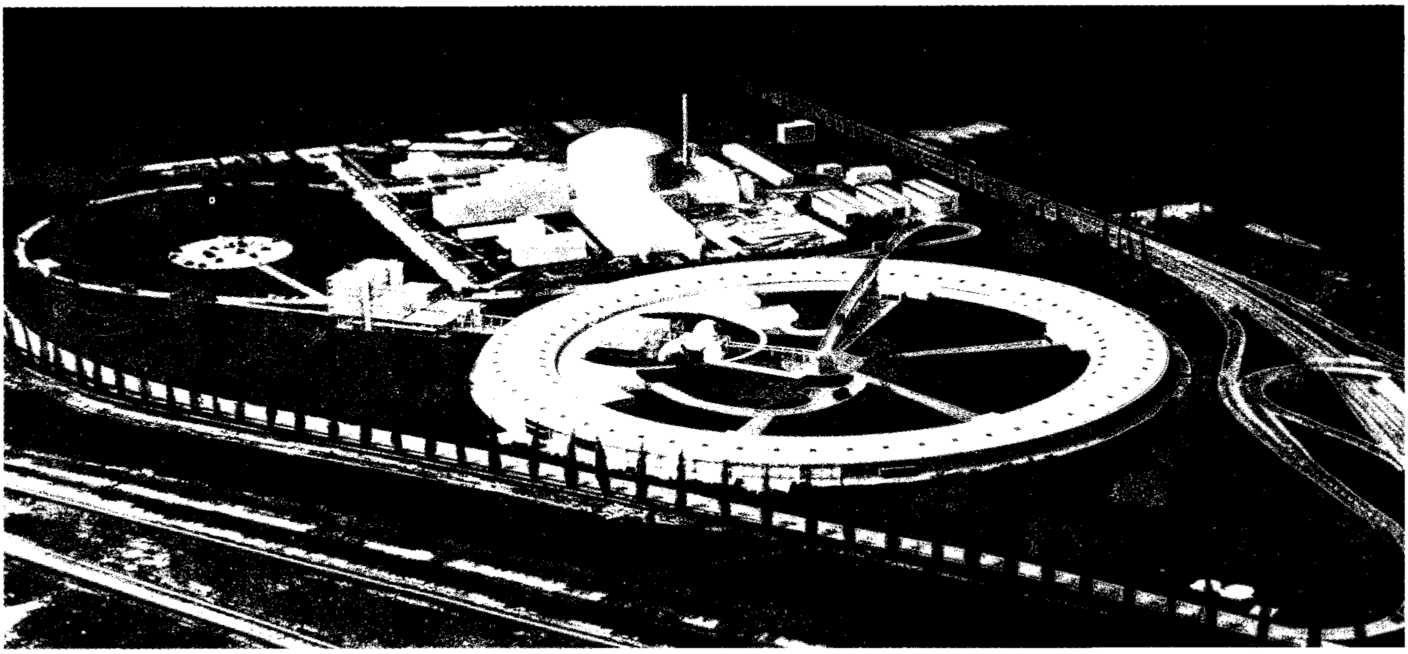
Now a group working at the Berkeley Superhilac has looked carefully at the photons produced when 6 MeV/nucleon beams of uranium hit thorium targets and found pairs of back-to-back photons consistent with the decay of a neutral state just above 1 MeV (1062 keV). Although the region covered extended up to 2 MeV, no other candidates emerged.

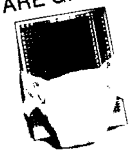
Whatever the explanation for the new states, it now has to cope with a complex structure.

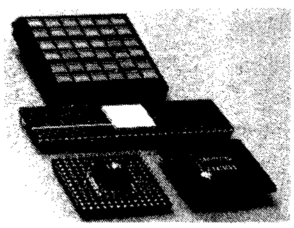
SUPERCOLLIDER
And then there were seven.....

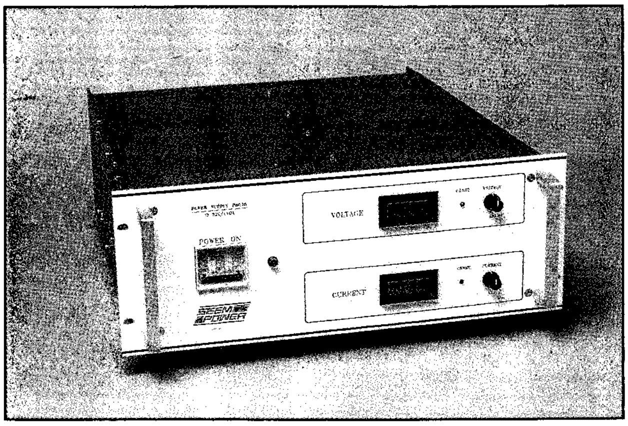
The 43 suggested sites from 25 states for the proposed 84 kilometre US Superconducting Supercollider (SSC, see November 1987 issue, page 17) have been whittled down to seven.

The sites – in Texas, Illinois, North Carolina, Tennessee, Arizona, Michigan and Colorado were selected by a joint committee of the US National Academy of Sciences and the National Academy of Engineering and confirmed








VOLTAGE
POWER ON
CURRENT
SEEM POWER

The seven possible sites selected for the proposed US Superconducting Supercollider – SSC.

by the US Department of Energy (DOE). An eighth site, in New York, had been selected by the committee but was withdrawn after local opposition. Before making a further selection in July, DOE officials will visit each site.

The unranked list of best-qualified sites resulted from applying technical requirements and factors known from experience with large Laboratories as promoting scientific productivity.

Meanwhile the SSC seeks large-scale funding, and the President is expected to seek $363 million for fiscal 1989 to allow construction to get underway. This year DOE got $25 million for ongoing preparatory work, but an additional $10 million for initial construction work was not approved.

The sites selected are Maricopa, southwest of Phoenix, Arizona; northeast of Denver, Colorado; Fermilab, Illinois; Stockbridge, south central Michigan; near Durham and Raleigh, North Carolina; southeast of Nashville, Tennessee; and south of Dallas, Texas.

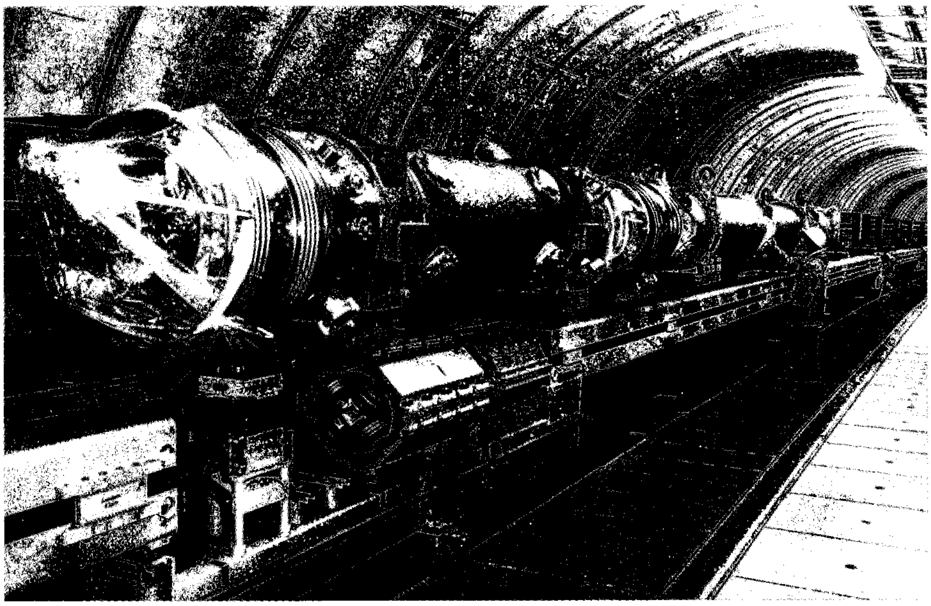
DESY HERA progress

Following successful injection of beam into the first section of the electron ring of the HERA electron-proton collider being built at the German DESY Laboratory in Hamburg (see January/February issue, page 15), about half the required 420 magnet modules for HERA's electron ring have been mounted in the 6.3 kilometre tunnel. The ring is scheduled for testing this year.

Two experiments are being prepared for HERA – Zeus for the South Hall and H1 for the North Hall. Two more halls – East and West – are also being readied. From the latter liquid helium, power and cooling water will be distributed to the ring, while the East Hall will house equipment to measure the electron beam polarization. Spin rotator magnets in the nearby straight sections will switch the direction of the electron spins. Once the techniques have been mastered, spin rotators will be installed for Zeus and H1 to permit experiments using polarized beams.

Meanwhile preparations for HERA's superconducting proton ring push ahead, with first industrial deliveries of the quadrupole magnets (developed at Saclay) and testing of liquid helium transfer lines.

The Zeus and H1 groups are busy perfecting components for their big detectors. CERN beams are used in many tests, including several modules for the Zeus calorimeter from York University, Canada, using depleted uranium and plastic scintillator, and H1's prototype liquid argon calorimeter (Dortmund and Max Planck Institute, Munich).



▲ *Parts of the HERA electron-proton collider being built at the German DESY Laboratory in Hamburg are beginning to look like the real thing. Superconducting magnets for the proton ring are seen here test mounted above the magnets of the electron ring.*

▼ *First industrial delivery of a HERA superconducting quadrupole of Saclay design.*

CERN LAA for new detectors

The LAA project under Antonino Zichichi formally set up last year at CERN (see September 1987 issue, page 11) is an intensive programme to develop new experimental techniques. Its ultimate aim is working prototypes of detector components for a future multi-TeV (1 TeV = 1000 GeV) hadron collider.

To search for rare phenomena at any new hadron collider lots of collisions will be needed. However if the 'missing energy' technique (energy imbalance around the collision point) is to be used to pick up signs of otherwise invisible particles such as neutrinos, only one collision should occur each time the particle bunches cross inside the rings of the collider (most of the particles in the stored bunches simply whizz past each other without interacting). This means that the bunches in the collider have to be less than 100 nanoseconds apart, with implications for detector readout systems. Another vital point is radiation resistance – the detector components have to be able to withstand the hostile environments in the beams for up to years at a stretch.

The LAA effort is divided into nine specialized areas – high precision tracking, calorimetry, large area devices, leading particle detection, special applications of integrated circuits, data acquisition and analysis, supercomputers and simulation studies, high magnetic fields, and high temperature superconductivity.

To track the particles emerging from the collision region, three so-

ADVANCED LIGHT SOURCE OPENINGS

Lawrence Berkeley Laboratory, University of California

OPTICAL SYSTEMS LEAD SCIENTIST
Staff Scientist 3 (A/4522)

Duties: The incumbent will be responsible for the design of x-ray and vacuum-ultraviolet optical systems for synchrotron radiation beamlines. Will report to the Project Deputy Director for Experimental Systems of the Advanced Light Source, a state-of-the-art national facility for scientific research at the Lawrence Berkeley Laboratory. Becoming familiar with the specialized needs of the scientific teams at each beamline, the incumbent will develop beamline design strategies for each. The overall systems will include monochromators, relay optics water-cooled components, condensing mirrors, polarization and harmonic control mechanisms, wavelength-tuning and spectral-resolution control mechanisms, and detection systems. Ray tracing will be an important tool for these activities. The optical systems must satisfy challenging fabrication tolerances and withstand demanding photon beam power loadings. The advanced instrumentation required includes glancing-incidence mirror assemblies, high-resolution grating and crystal monochromators and beam position and intensity sensors.

Requirements: The successful candidate will have considerable experience and a strong record of published original work in the design of x-ray or vacuum-ultraviolet optical systems. Candidates with a background in instrumentation for synchrotron radiation research are encouraged to apply. A Ph.D in a relevant field is preferred.

OPTICAL SYSTEMS SPECIALIST
Staff Scientist 2 (A/4525)

Duties: The incumbent will participate in the design, implementation, and commissioning of optical systems for one or more synchrotron radiation beamlines of the Advanced Light Source, a state-of-the-art national facility for scientific research at the Lawrence Berkeley Laboratory. The design process will involve consultations with the intended user groups, development of optimized optical schemes by analytical methods, and evaluation of the schemes by computer modeling procedures, including exact geometrical ray tracing. The optical systems are for the vacuum-ultraviolet and soft x-ray regions of the spectrum, involve both relay and spectroscopic technologies, and must satisfy challenging fabrication tolerances and withstand demanding photon beam power loadings. The advanced instrumentation required includes glancing-incidence mirror assemblies, high-resolution grating and crystal monochomators, and beam position and intensity sensors.

Requirements: The successful candidate will have working experience and a record of published original work in the design of optical systems, either for synchrotron radiation or for applications in other parts of the electromagnetic spectrum. Applications from graduates of universities that specialize in optics are particularly welcome. Expertise in vacuum-ultraviolet or soft x-ray systems is available in the existing group to complement those who do not have it. A Ph.D. in a relevant field is preferred.

OPTICAL SYSTEMS STABILITY SPECIALIST
Staff Scientist 3 (A/4523)

Duties: The incumbent will be responsible for assuring the stability of the overall optical system of the Advanced Light Source, a state-of-the-art national facility for scientific research at the Lawrence Berkeley Laboratory. Involving instrumentation for the control of near-diffraction-limited radiation to very short wavelengths in the vacuum-ultraviolet and x-ray regions of the spectrum. The work will require a stability analysis for the overall system and the development of such photon detection interface, feedback, and control systems as may be necessary to provide optical systems with stable aiming, focusing, and positioning controls. The advanced beamlines will include glancing-incidence mirror assemblies, high-resolution grating and crystal monochromators, and beam position and intensity sensors. The above tasks will require close collaboration with accelerator physics and instrumentation teams on the development of complementary electron-beam diagnostic and control systems.

Requirements: The successful candidate will have substantial experience and a strong record of published original work in the design and implementation of optical stabilization systems. Expertise in the geometrical stability of large optical systems would be a plus. The candidate must have working experience at visible wavelengths and may rely on colleagues at the Advanced Light Source for complementary expertise at vacuum-ultraviolet and x-ray wavelengths. Applications from graduates of universities that specialize in optics are particularly welcome, although candidates with a background in instrumentation for synchrotron radiation research are also encouraged to apply. A Ph.D in a relevant field is preferred.

OPTICAL COMPONENTS METROLOGY
Staff Scientist 2 (A/4524)

Duties: The incumbent will be responsible for the metrology of optical components of the Advanced Light Source, a state-of-the-art synchrotron radiation facility. In addition to studies of surface finish, assessments of optical surface figure, and measurements of reflecting optics (particularly mirrors and gratings), the incumbent will conduct R&D in new areas of optical component fabrication, such as electroforming. The incumbent may also be responsible for the implementation of one or more beamlines. The beamline optical systems, which involve both relay and spectroscopic technologies, must satisfy challenging fabrication tolerances and withstand demanding photon beam power loadings. The state-of-the-art instrumentation required includes glancing-incidence mirror assemblies and high-resolution grating and crystal monochromators.

Requirements: The successful candidate will have demonstrated experience and a strong record of published original work in the design of optical systems and in optical metrology. Although the Advanced Light Source will generate vacuum-ultraviolet, soft x-ray, and hard x-ray synchrotron radiation, the candidate may have experience at either visible or at the shorter wavelengths. It is expected that optical measurements will primarily be done in the visible even for ultraviolet and x-ray optics, and, if required, colleagues at the Advanced Light Source may provide complementary short-wavelength expertise. Applications from graduates of universities that specialize in optics are particularly welcome, although candidates with a background in instrumentation for synchrotron radiation research are also encouraged to apply. A Ph.D in a relevant field is preferred.

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lutions are being studied. The UA2 detector at CERN's proton-antiproton collider has developed a scintillating fibre tracker to follow the particles emerging from the collision point (see June 1987 issue, page 9). For LAA, tracking by scintillating fibres in a high magnetic field is being looked at by Heinrich Leutz at CERN. The other potential techniques are the compact units using the multidrift tubes of Fabio Sauli's group at CERN (see November 1987 issue, page 4) and semiconductor (gallium arsenide) microstrips and associated electronics (Carlo del Papa at Bologna – see also May 1986 issue, page 5).

For calorimetry, the two avenues being explored are Georges Charpak's barium fluoride scintillator at CERN (see May 1984 issue, page 141), and scintillating fibres embedded in lead to provide equal response for electromagnetic and hadronic energy (R. Wigmans, CERN).

Detectors for future hadron colliders will be big, and the outer layers, for muon work, will cover large areas. The associated production problems are being tackled by Giancarlo Susinno of Cosenza (Italy) at CERN. Alignment and calibration of large drift chambers for muons is the concern of Ulrich Becker of MIT.

The 'leading effect' – the study of particles produced in the forward direction – was enthusiastically followed by Antonino Zichichi's groups at CERN's Intersecting Storage Rings, closed in 1984. According to Zichichi, this type of particle production has not been sufficiently emphasized, and could go on to play an important role at higher energy colliders. T. Massam of Bologna is investigating the implications, at CERN.

Semiconductor detectors have already made their particle physics debut (see May 1986 issue, page 3). For ongoing work, Erik Heinje at CERN is working on the required microelectronics, in collaboration with European microelectronics centres.

Data handling with such high performance machines is a special challenge, being investigated for LAA by Rudy Bock of CERN. data processing. A close watch is being kept on developments in industry.

T.D. Lee of Columbia leads an effort to develop a supercomputer based on the Intel 80286 microprocessor and able to take care of big quark/gluon field theory calculations on lattices. In addition, programs will be written for specific physics predictions, particularly the production of particles containing heavy quarks.

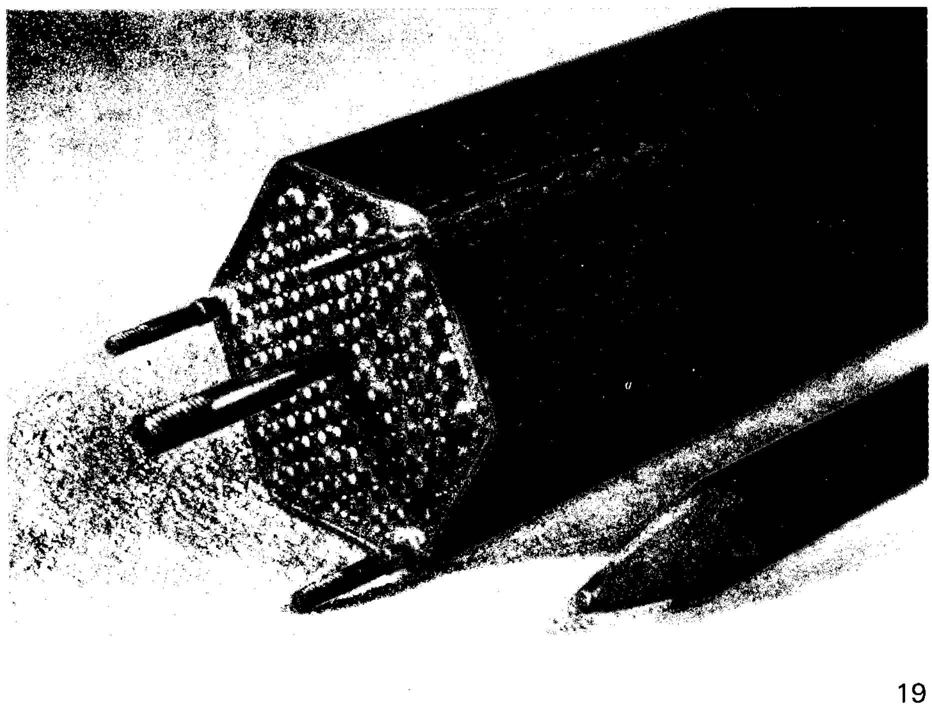
To reduce the size of the detectors at big hadron colliders, powerful magnets could minimize tracking volumes. Using present technology, such a detector would need 30 metres along the beam direction, with a total weight of 30,000 tonnes. Rather than attempt to develop the technology in a physics laboratory, the job has been given to Italian industrial specialists Ansaldo. Increasing the tracking field also has implications for tracking precision.

Finally, the Italian firm LMI has been commissioned to look into the implications of the new high temperature superconductors for detectors and for magnets.

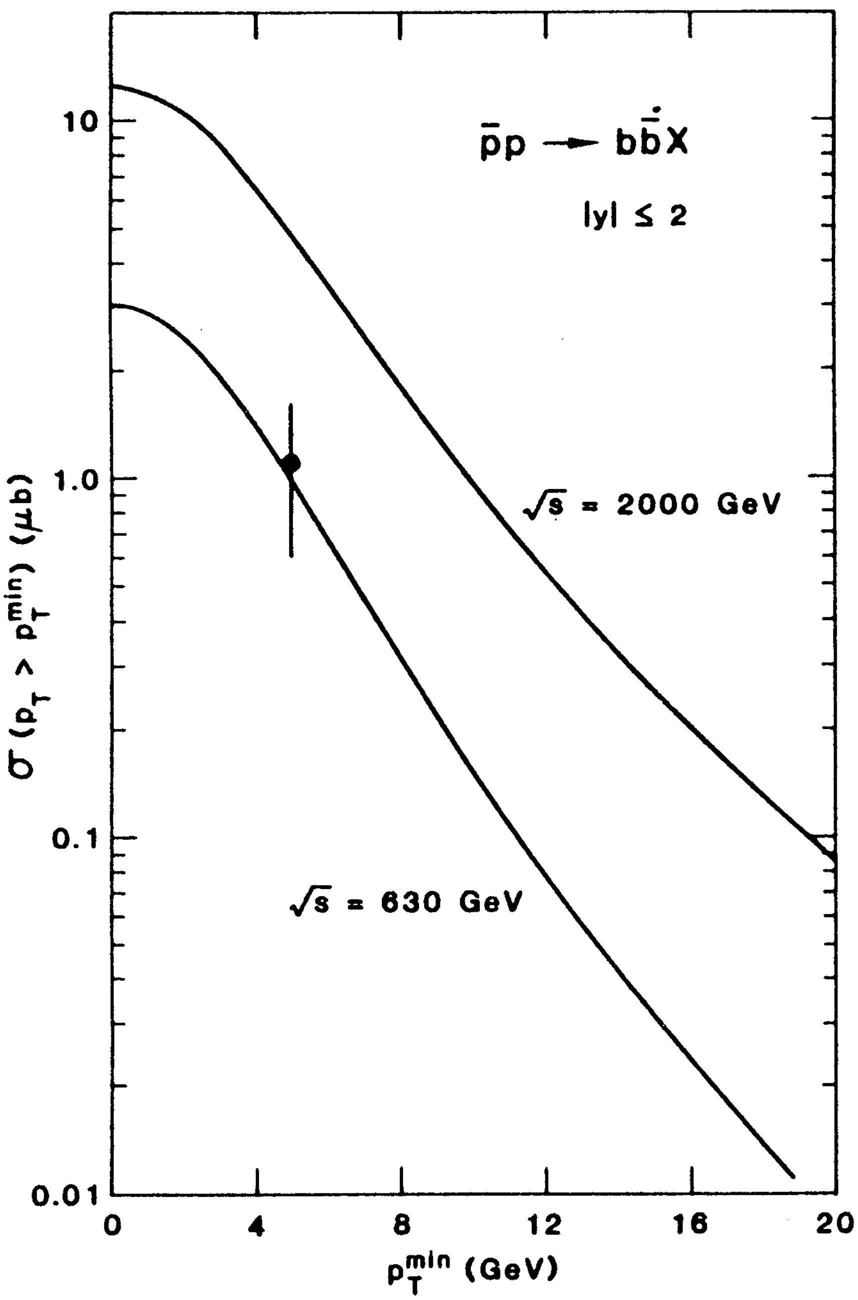
With ambitious new hadron collider schemes being proposed in Europe, the US and the USSR, the detector problems of these new frontiers are continually being highlighted. The LAA scheme provides a useful focus for this work, and already involves specialists from Europe, the US, the USSR and China.

Tracking using the compact multidrift tube modules being developed at CERN by Fabio Sauli's group is one of the projects in the LAA detector development programme at CERN.

(Photo CERN 476.12.85)



Predictions from quantum chromodynamics (QCD) by Ed Berger for beauty quark production in proton-antiproton collisions at CERN (630 GeV), showing the result from the UA1 experiment, and Fermilab (2000 GeV).



CERN
Looking at beauty

The production of particles containing heavy quarks such as charm or beauty is a good way of studying quark dynamics, in particular for testing quantum chromodynamics QCD), the candidate field theory of interactions between quarks and the gluons carrying the inter-quark forces.

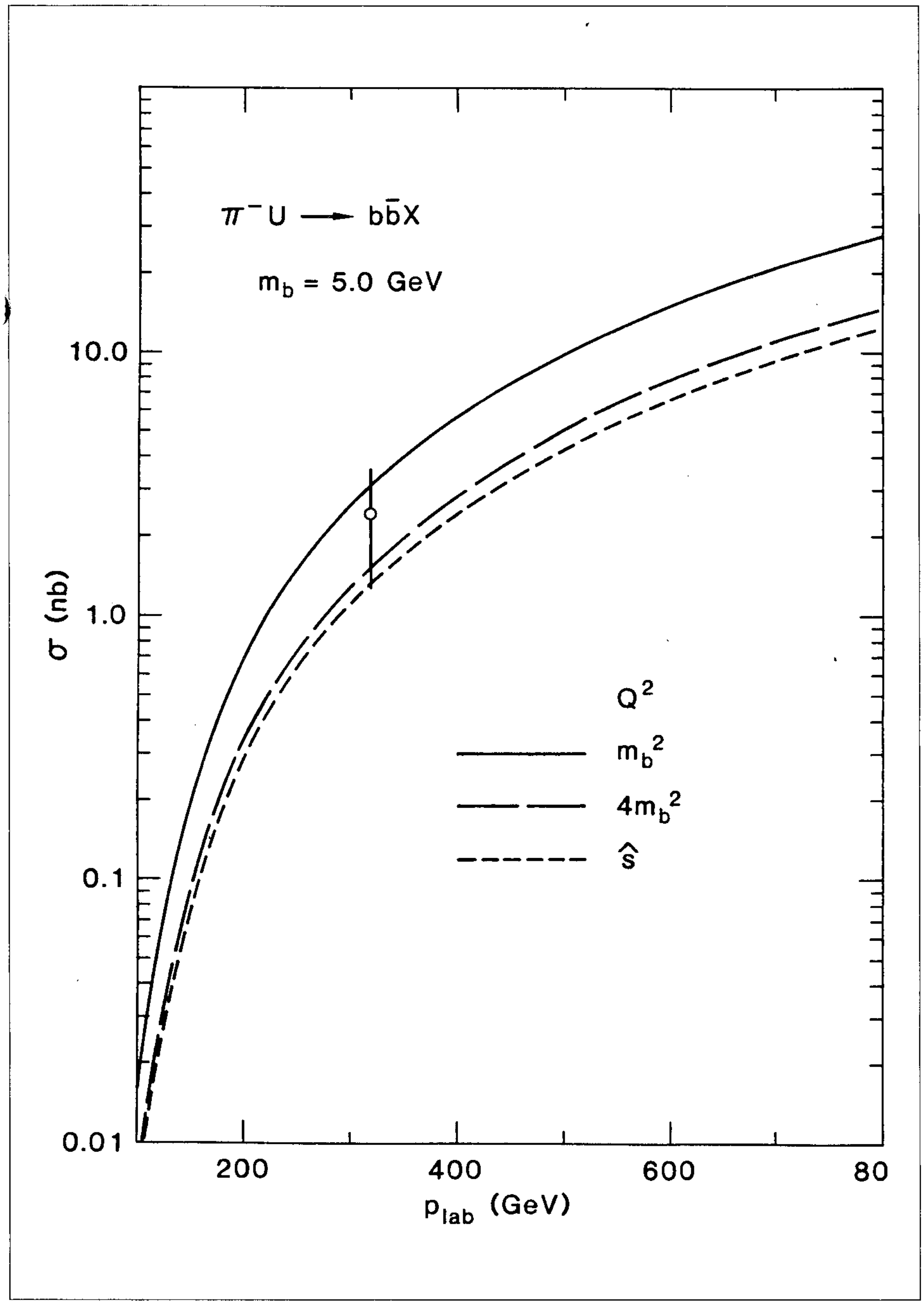
The production rate of particles with charm produced in proton-proton collisions measured at CERN's Intersecting Storage Rings (ISR, closed in 1984) was puzzlingly higher than expected from the simplest theoretical predictions. In addition, the Italian/CERN collaboration working at the Split Field Magnet provided evidence for baryons carrying beauty, produced moreover in the forward direction (the 'leading effect').

Because the beauty quark is considerably heavier than the charm quark, theorists expect QCD predictions for beauty production to be more reliable.

First evidence for the production of beauty particles (B mesons) in a fixed target experiment came from an emulsion study at CERN in 1985 (see July/August 1985 issue, page 238). More recently, additional information on the production of B mesons in fixed target experiments has come from the NA10 study of muon pairs produced by high intensity beams, and from WA78 using the muon spectrometer of the 1985 emulsion experiment together with a specially designed target calorimeter.

Different conditions are found in high energy proton-antiproton annihilation, where the big UA1 experiment gives interesting insights by

Berger's calculations for beauty production from high energy negative pion beams on a heavy target, showing the result reported by the WA78 experiment at CERN.



selecting events containing a muon and one or more narrow jets of hadrons. The observed level of single muons shows that additional quark/gluon mechanisms following the initial particle-antiparticle annihilation are important and have to be included in the calculations.

Once this is done, the observed spectra involving the fourth (charm) and fifth (beauty) quarks tie in well with QCD-based calculations, and show that the sixth ('top') quark has yet to put in an appearance at these collision energies (630 GeV). The production levels of B mesons measured by the WA78 study also tie in with QCD predictions.

The inclusion of additional quark-gluon mechanisms also helps to explain the high production rates of heavy quarks at the ISR, although their liking for the forward direction remains a puzzle. At the proton-antiproton collider, the observed particles emerge broadside to the beams.

The production of leading particles is earmarked for further study and detector development work in the context of the LAA project (see page 16).

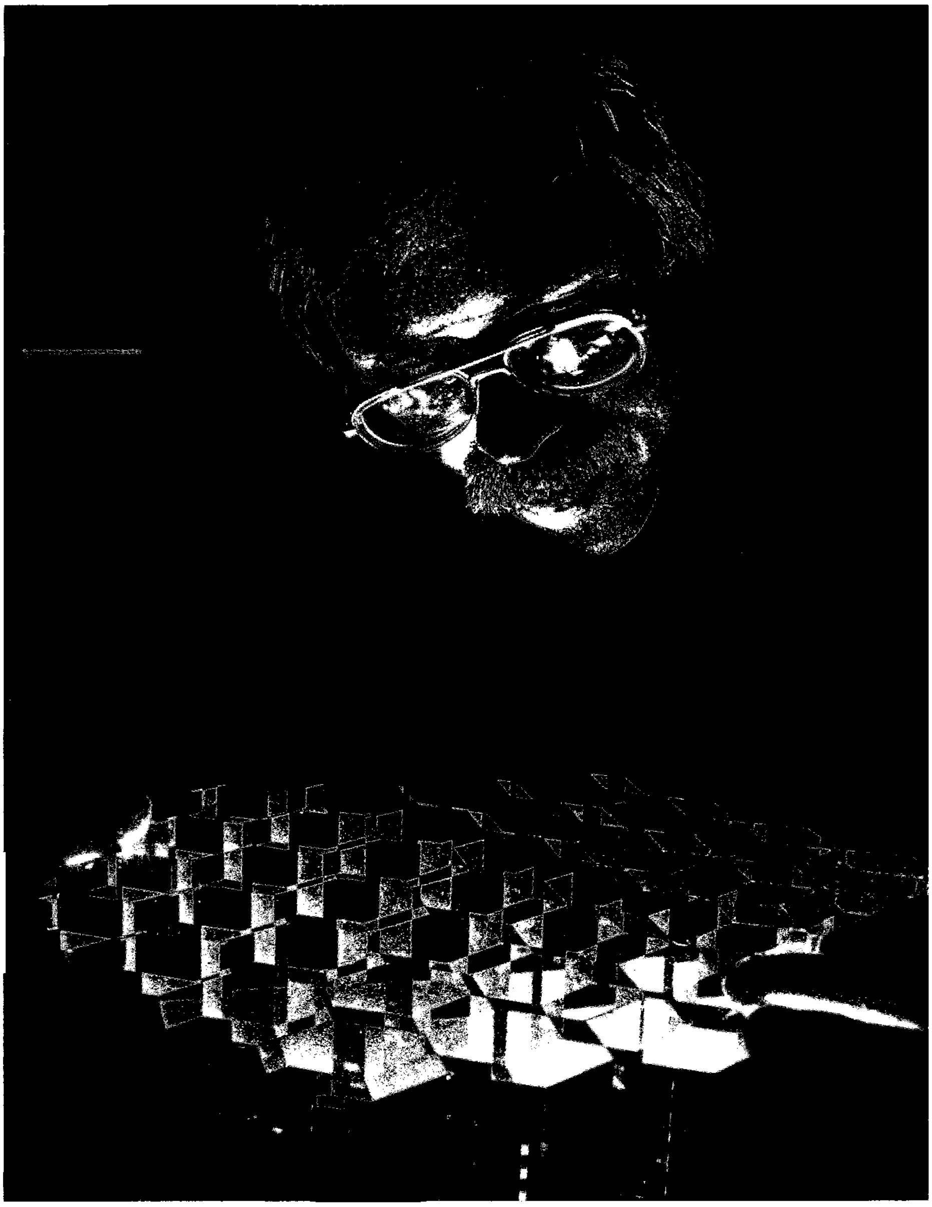
With the indications of neutral B meson mixing from UA1 and from the ARGUS experiment at the German DESY Laboratory, interest is now focusing on the additional possibilities opened up by B meson physics (see, for example, January/February issue, page 5).

DETECTORS
Fast calorimetry with barium fluoride

To study rare processes, many of today's high energy and nuclear physics experiments require extremely high beam intensities. This will be important at future hadron colliders, such as the Superconducting Supercollider (SSC) proposed in the US and the Large Hadron Collider (LHC) in Europe.

To operate at these high rates, a detector must respond very quickly and withstand high levels of radiation. Barium fluoride is a scintillating crystal emitting ultra-violet light with a decay time of less than one nanosecond. In addition, the pure substance is the most radiation resistant scintillator known, showing

Barium fluoride crystals for a photon detector at Brookhaven. See also front cover.



little radiation damage with doses of up to 10^8 rads. These two unique properties make it extremely attractive for fast calorimetry in high radiation environments.

In fact, the scintillation light from barium fluoride has two emission components, a fast one at 220 nm with a decay time of 0.6 ns, and a slow one at 320 nm with a decay time of 625 ns. About 20 % of the total light output appears in the fast component (the useful one for fast calorimetry), ample for high energy applications. However for use at high rates, the slow component must be eliminated or reduced to avoid pileup due to close events.

(At lower counting rates, the slow component is useful for good energy resolution while the fast component gives fast timing. These advantages over slower scintillators such as sodium iodide or BGO have been exploited in nuclear physics to detect low energy photons with backgrounds – such as neutrons – suppressed by the precise timing.)

The simplest method is to read out the crystals by photomultiplier tubes with 'solar blind' photocathodes, most sensitive to the fast ultra-violet component but relatively insensitive to the longer wavelength slow component. This considerably reduces the slow component, but a significant amount is still detectable by the phototube.

A second approach is to heat the crystals. The slow component is less intense at higher temperatures, while the fast component is independent of temperature. At about 100C, the slow component becomes less significant than the fast, but still not low enough for many applications.

A third technique, initially tried by a group from Delft University in the Netherlands, is to add a dopant to the crystals. This suppresses the slow component by actually altering the scintillation mechanism of the crystal. This offers a potentially elegant solution if the other benefits, such as radiation hardness, are preserved. As yet this question is not resolved, and a group at Brookhaven is looking at doped crystals with the help of Merck Inc. A combination of all three approaches may be necessary.

An alternative and completely different approach for reading out barium fluoride was discovered several years ago by D. Anderson, working with Georges Charpak's group at CERN (see May 1984 issue, page 141). This technique

uses the photosensitive gas TMAE in a low pressure wire chamber which amplifies and collects the photoelectrons produced by the fast ultra-violet light.

This type of readout offers many advantages over phototubes. First, TMAE is totally blind to the slow component and only picks up the fast light output. Second, low pressure wire chambers are very fast and work well at high rates. In addition, they are essentially blind to charged particles which can act as a source of background and lead to poorer energy resolution. Finally, the wire chamber readout makes for easy segmentation, giving tracking capability, and will work inside a magnetic field.

This technique has undergone considerable development in recent years. A Brookhaven group was mainly interested in using a detector of this kind as photon veto in a high intensity rare kaon decay experiment and developed a detector using large (15 cm long) crystals read out with cathode pads. Fast electronics and pulse shaping gave an output pulse from the wire chamber with a baseline width of 20 ns and rates up to 10^7 Hz per readout element. Even narrower pulses, as short as 10 ns, should be possible at higher energies.

At CERN, a barium fluoride and TMAE detector with good longitudinal and transverse segmentation has been tested with electrons at energies up to 10 GeV. It achieved good energy (1.5 per cent), time (0.5 nanosecond) and position (few millimetres) resolution. The next step is to build a large detector using a few thousand crystals and study its performance in a real physics environment (see page 16).

TMAE is to be used in several large Ring Imaging Cherenkov (RICH) detectors in a number of new experiments, and increased understanding of its basic properties could pay dividends.

Could there be better materials than barium fluoride and TMAE for fast calorimetry? So far barium fluoride is unique for its fast light emission and radiation hardness, and is the only scintillator emitting ultra-violet light energetic enough to photoionize TMAE. However it would not be surprising if other crystals showed similar properties. Work has really just begun toward improving our understanding of the underlying physical mechanisms for scintillation and radiation damage in these materials.

Other substances could also be better than TMAE with barium fluoride or with other crystals. Research in both areas will lead to new and better detectors for future experiments.

From Craig Woody

People and things

Isidor Isaac Rabi 1898-1988

Isidor Isaac Rabi died in January. In addition to his significant scientific contributions, he was an eloquent communicator of the values of science and played a leading role in the creation of major scientific Laboratories.

Born in Galicia and educated in America, his postgraduate studies took him back to Europe, where he worked with Bohr, Pauli and Heisenberg. Following this period came his best known scientific contribution – the invention of the beam resonance method for measuring the magnetic properties of nuclei. This led to greatly improved precision and opened up a deeper interpretation of nuclear behaviour. Rabi was awarded the Nobel Prize in 1944 for this work.

After the war he was among the first to realize the need for larger collaborations in nuclear and particle physics. He promoted the establishment of the Brookhaven National Laboratory in the US and, from this experience, went on to play a seminal role in the creation of CERN.

At the 5th General Conference of UNESCO in Florence in June 1950, Rabi put forward a resolution which gained unanimous support. It authorized the UNESCO Director General 'to assist and encourage the formation of regional centres and laboratories in order to increase and make more fruitful the international collaboration in the search for new knowledge in fields where the effort of any one country

The revamped UA2 detector performed creditably in the proton-antiproton collider run at CERN at the end of last year. The detector was redesigned to exploit the increased antiproton levels expected from the new ACOL antiproton source, including the AC Antiproton Collector ring. One feature is the square metre of silicon pads wrapped inside the inner detector. Admiring the unwrapped silicon are (left to right) George Sanier, Bogdan Lisowksi, Claus Gossling and Trivan Pal.

(Photo CERN X164.8.87)

Isidor Isaac Rabi, 1898-1988.

in the region is insufficient for the task.'

The importance of this resolution in the evolution of CERN was well appreciated by Europe's scientists. When CERN formally came into being several years later, a letter to Rabi from representatives of European States said, 'We have just signed the Agreement which constitutes the official birth of the project you fathered in Florence. Mother and child are doing well, and the doctors send you their greetings.'

It was because of this vital contribution to European science that Rabi was one of the invited speakers at CERN's 30th anniversary ceremony in 1984.

Another Rabi incident which has become part of science history is his legendary remark 'who ever ordered that?' on hearing of the discovery of the muon.

CERN Research Director Pierre Darriulat (who is also the Chairman of the CERN Courier Advisory Panel) receives the degree of doctor honoris causa of the University of Pavia from the rector. Looking on (left) is G.Goggi of Pavia and CERN.

On people

Cosmologists Stephen Hawking of Cambridge and Roger Penrose of Oxford receive the Wolf Prize. Their joint work twenty years ago showed the existence of gravitational singularities – black holes – in general relativity.

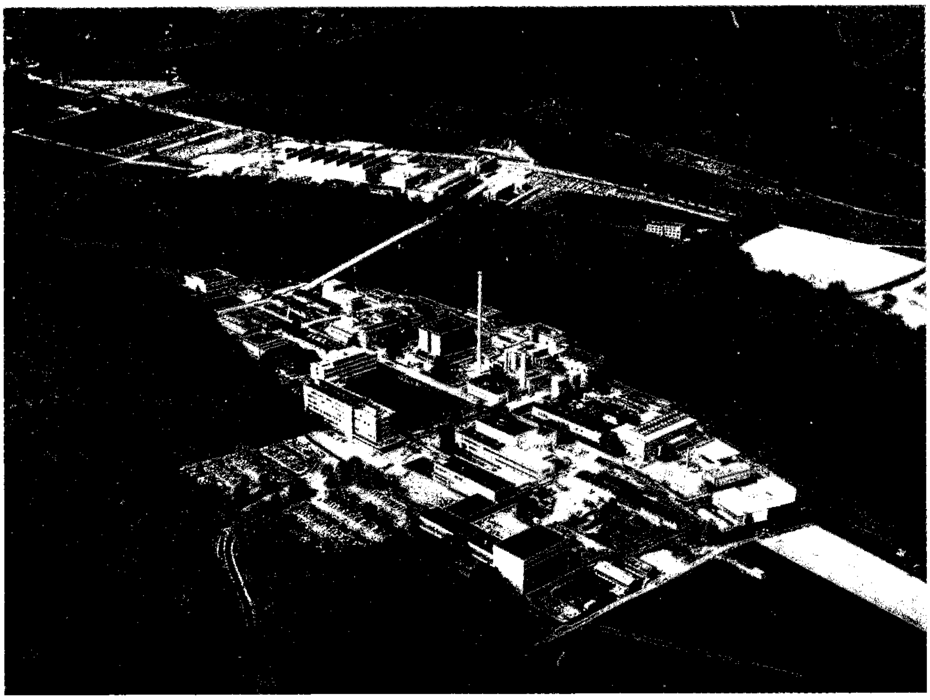
Retirements

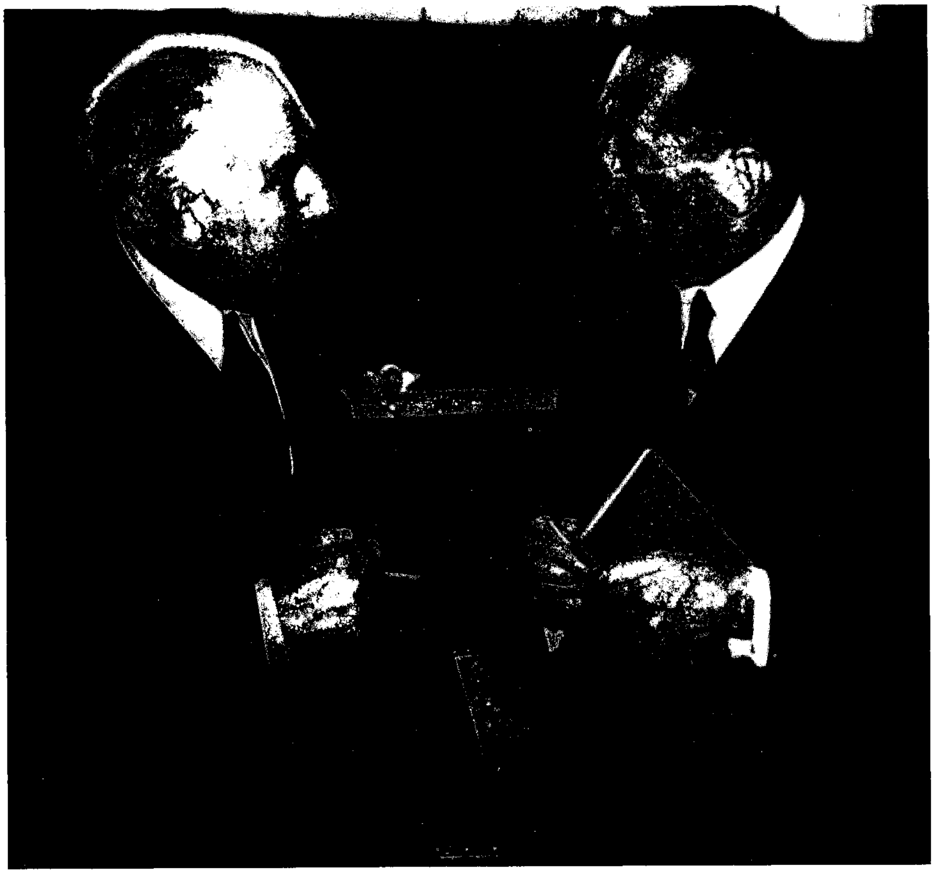
The CERN accelerator physicist who might well be called Mr. Magnets passes a retirement milestone. Lorenzo Resegotti came into the spotlight as the leader of the group that built the remarkable magnets of the Intersecting Storage Rings. Never before had over 400 magnets been strung together to such a peak of perfection, paving the way for the ISR's success as the world's first proton-proton collider.

He also supervised the design and construction of superconducting quadrupoles to squeeze the colliding ISR beams, the first industry-built superconducting magnets to operate in an accelerator environment. More recently, he had the brainwave of pouring concrete around the widely spaced laminations of the magnets to bend the beams in CERN's new LEP electron-positron collider, making for substantial savings. Throughout his distinguished career, his knowledge and thoroughness have contributed substantially to CERN's acknowledged accelerator prowess.

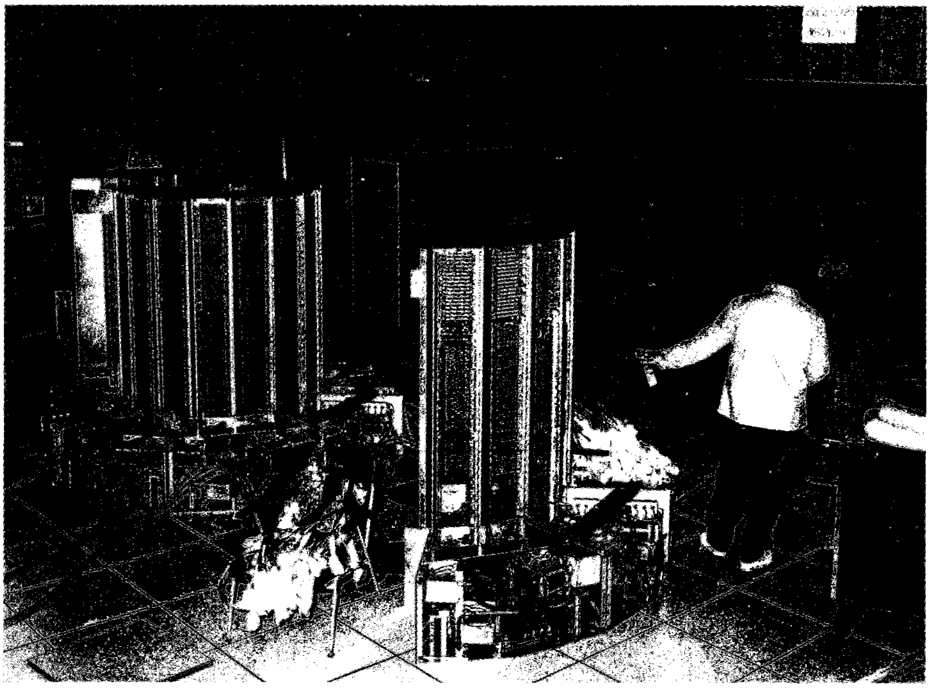
Robert Levy-Mandel is formally retiring from CERN after sixteen years. When he arrived in the early 1970s to join the team building the

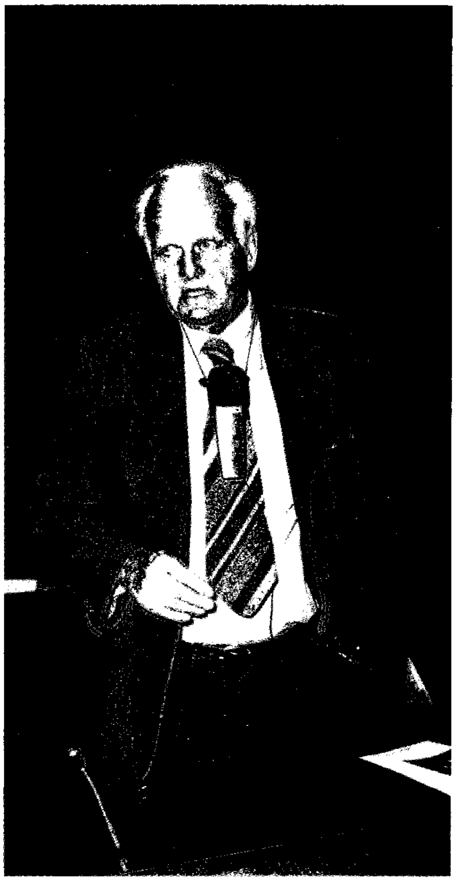
On the bonny banks of the River Aare in Switzerland. In the foreground is what used to be called the Eidgenössiches Institut für Reaktorforschung (Swiss Federal Institute for Nuclear Research), with the former Schweizerisches Institut für Nuklearforschung (SIN) on the far bank. The two research centres have been amalgamated under the name Paul Scherrer Institute, in honour of the distinguished Swiss physicist Paul Scherrer (1890-1969) who signed the 1952 provisional agreement for the establishment of CERN on behalf of Switzerland. Below, Scherrer is seen (right) with Niels Bohr.





CERN's new Cray X-MP/48 supercomputer arrives.





SPS Super Proton Synchrotron, he was already well known in the field of accelerators, having played a key role at Saclay on the Saturne synchrotron. He oversaw SPS civil engineering (ranging from tunnel construction to buildings, electricity supplies and water cooling). There followed a period in the CERN Directorate and he has made important contributions to getting LEP off the ground with the preparation of the huge environmental impact study and in handling relations between CERN and its host States, France and Switzerland.

Books

'Alpha, beta, gamma.....Z, A Primer in Particle Physics' by L.B. Okun of Moscow's Institute of Theoretical and Experimental Physics from Harwood Academic Publishers (translated from Russian) is the result of the author's numerous popular physics lectures, and describes the present state of the subject rather than its history. 'The money spent on high energy physics is like the money spent on our children: neither is the best investment for immediate financial return. Nevertheless, the world is unthinkable without children and the future of science is unthinkable without particle physics', writes Okun.

Another useful new Harwood book, this time in the Contemporary Concepts in Physics series, is 'Gauge Fields and Strings' by A.M. Polyakov of Moscow's Landau Institute for Theoretical Physics. In many cases, the book goes into areas which have never been completely understood, this in the hope to stimulate deeper study.

In January, a series of lectures at CERN by Carl-Friedrich von Weizsäcker on the philosophy of science and the meaning of quantum theory drew large audiences.

Meetings

The third conference on Intersections between Particle and Nuclear Physics will be held in Rockport, Maine, US, from 14-19 May. As with previous meetings in the series, it will stress cooperation between particle and nuclear physics in science, technology and facilities. Further information from Terry Murphy, TRIUMF, 4004 Wesbrook Mall, Vancouver, BC, Canada V6T 2A3.

The 7th Topical Workshop on Proton-Antiproton Collider Physics will be held at Fermilab from 20-24 June. Further information from Phyllis Hale, Fermilab Users Office, PO Box 500, MS 103, Batavia, Illinois 60510. Telex 910-230-3233, fax 312-840-4343, earn/bitnet PBARP7 at FNAL.

Mike Green of London's Queen Mary College talks on the theory of superstrings at the annual UK particle theory get-together at the Rutherford Appleton Laboratory.

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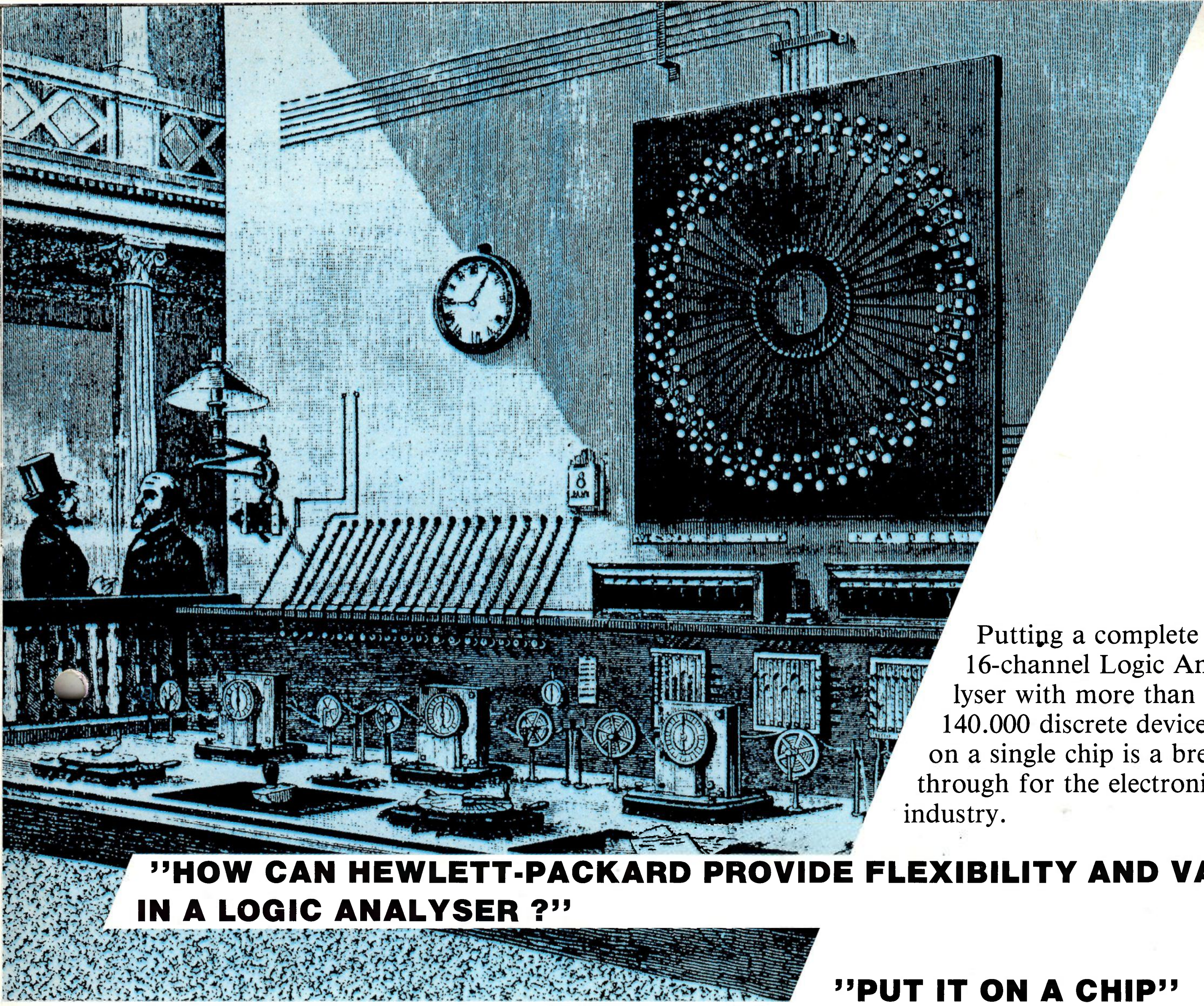

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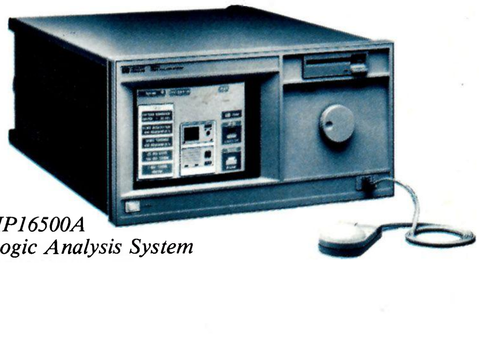

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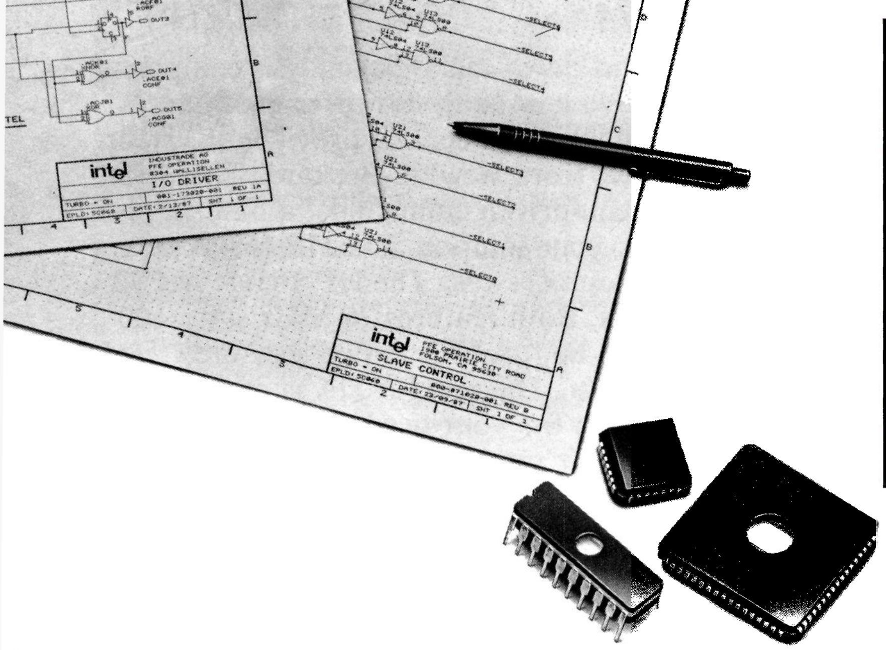

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