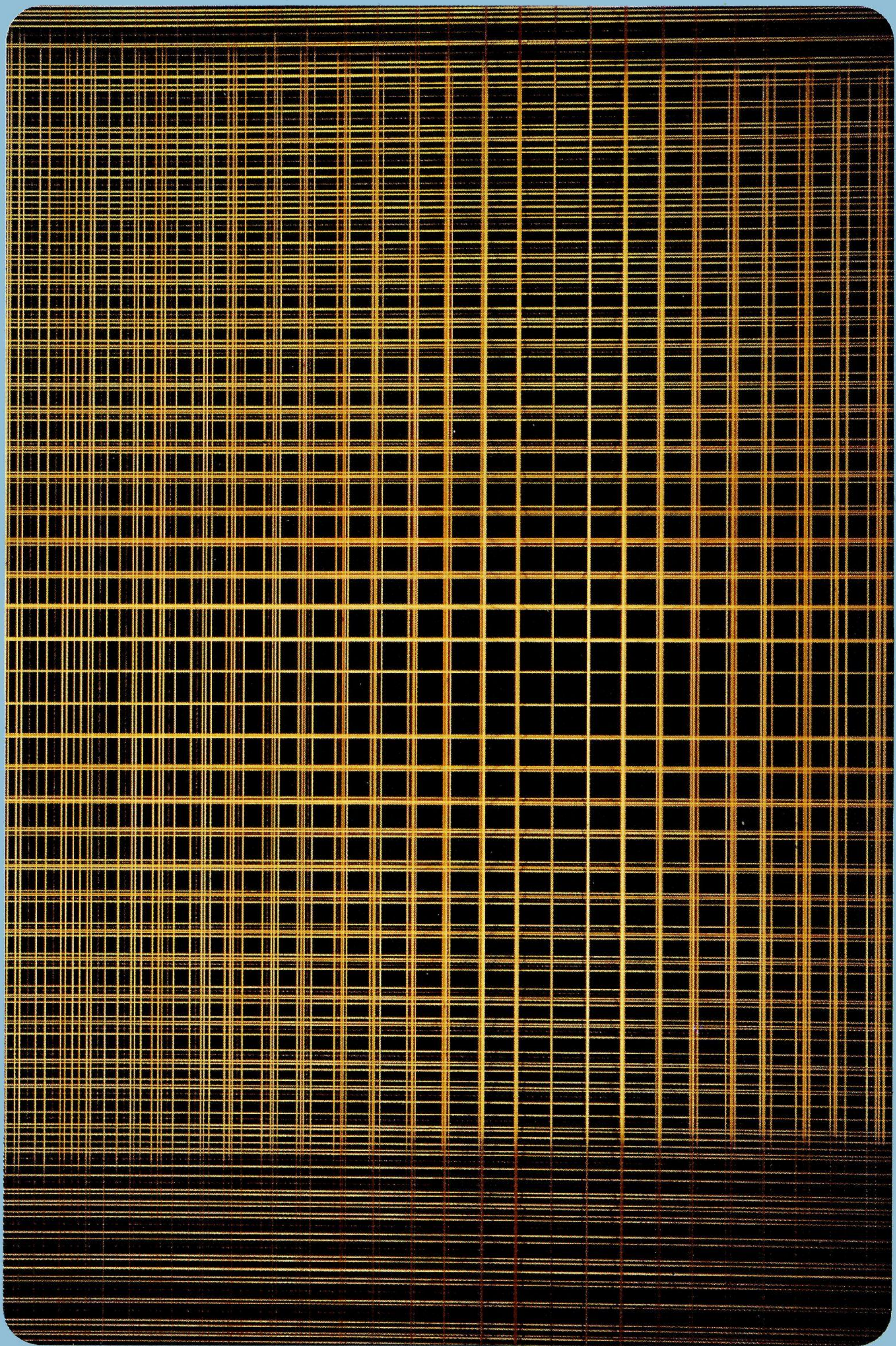
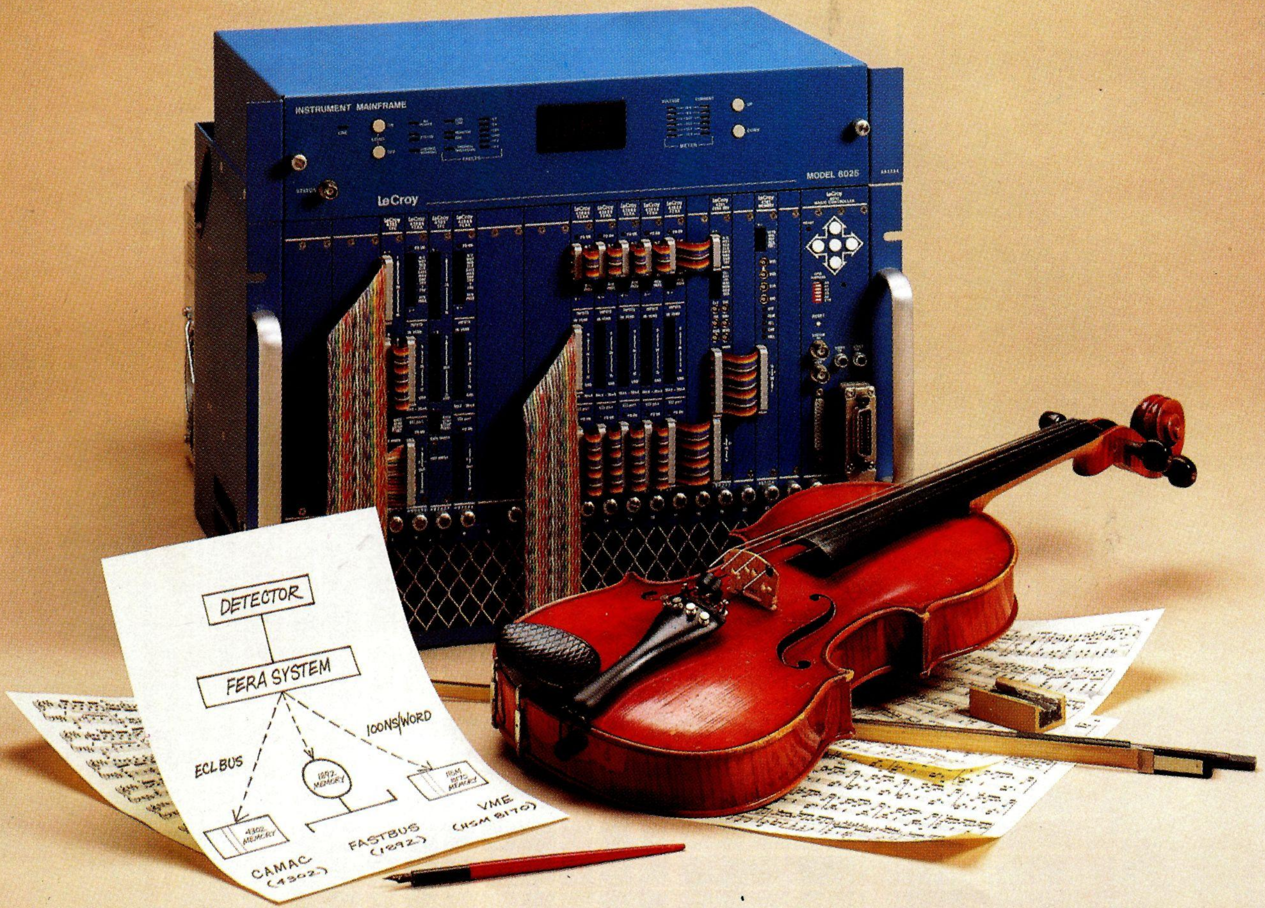
# CERN COURIER

International Journal of High Energy Physics



VOLUME 31 6 JULY/AUGUST 1991

# A Classic Performer




# The FERA™ ADC/TDC Ensemble

The LeCroy Fast Encoding and Readout ADC System is a classic. For more than five years, FERA has been performing all over the world. Applications include high rate analog data acquisition, real time systems, colliding beam diagnostics and energy based triggers in both heavy ion and particle beam experiments. Today, the FERA ensemble gives the best performance at the lowest price.

♪♪♪

**The FERA quintet includes:**

**4300B/600** 10-Bit, 16-channel charge sensitive ADC 4.8 μsec conversion time

**4300B/610** 11-Bit, 16-channel charge sensitive ADC 8.9 μsec conversion time

**4301** FERA calibration, fanout, and ECL bus driver

**4302** FERA multiport CAMAC memory

**4303** Time-to-FERA converter, 50 psec resolution (used with 4300B)



- **Performs at Over 50 Institutions**
- **High Fidelity with 10-Bit or 11-Bit Resolution**
- **Fast Conversion and High Speed ECL Bus Output For Minimal Deadtime (Highest Throughput)**
- **Fast On-board Zero Suppression and Pedestal Subtraction for Readout of Compact Data**
- **Compatible With LeCroy Series ECLine Trigger Process Modules**
- **Direct Connection to High Speed FIFO Memories in FASTBUS, VME, and CAMAC**
- **Wide Dynamic Range to Cover Most Applications**
- **Fast Delivery**

**Call or write today for more FERA product information and a LeCroy Research Instrumentation Catalog.**

700 Chestnut Ridge Road, Chestnut Ridge, NY 10977-6499 USA Tel: (914) 578-6013
2, chemin Pre-de-la-Fontaine, 1217 Meyrin 1-Geneva, Switzerland Tel: (022) 719 21 11

LeCroy

*Innovators in Instrumentation*

## Advertising enquiries

### Europe

Micheline Falciola
Advertising Manager
CERN
CH-1211 Geneva 23, Switzerland
Tel.: +41 (22) 767 4103
Fax: +41 (22) 782 1906

### Rest of the world

Yvette M. Perez
Gordon and Breach Science Publishers
Frankford Arsenal, Bldg 110
5301 Tacony Street, Box 330
Philadelphia, PA 19137
Tel.: +1 (215) 537 7262
Fax: +1 (215) 537 0711


*Distributed to Member State governments, institutes and laboratories affiliated with CERN, and to their personnel.*


## General distribution

Monika Wilson (MONIKA at CERNVM)*
CERN, 1211 Geneva 23, Switzerland

In certain countries, copies are available on request from:

### China

Dr. Qian Ke-Qin
Institute of High Energy Physics
P.O. Box 918, Beijing,
People's Republic of China

### Federal Republic of Germany

Gabriela Heessel
DESY, Notkestr. 85, 2000 Hamburg 52

### Italy

Mrs. Pieri or Mrs. Montanari
INFN, Casella Postale 56
00044 Frascati, Roma

### United Kingdom

Su Lockley
Rutherford Appleton Laboratory,
Chilton, Didcot, Oxfordshire OX11 0QX

### USA/Canada

Cyndi Rathbun (B90904 at FNALVM)
Fermilab, P.O. Box 500, Batavia
Illinois 60510



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

Printed by: Presses Centrales S.A.
1002 Lausanne, Switzerland

Published by:
European Laboratory for Particle Physics
CERN, 1211 Geneva 23, Switzerland
tel. +41 (22) 767 61 11,
telex 419 000 CERN CH,
telefax +41 (22) 767 65 55

CERN COURIER only:
tel. +41 (22) 767 41 03,
telefax +41 (22) 782 19 06

USA: Controlled Circulation
Postage paid at Batavia, Illinois



**Volume 31**
**No. 6**
**July/**
**August 1991**

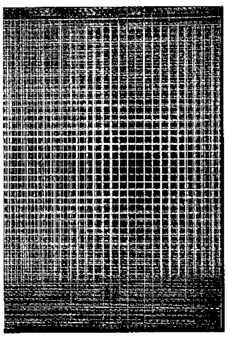
# CERN COURIER

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

*Editor:* Gordon Fraser (COURIER at CERNVM)*
*French edition:* Henri-Luc Felder
*Production and Advertisements:*
Micheline Falciola (FAL at CERNVM)*
*Advisory Panel:* P. Darriulat (Chairman), H. Bøggild,
H. Lengeler, A. Martin

* *(Full electronic mail address... at CERNVM.CERN.CH)*



*Cover photograph:*
Inside a crossed-wire drift chamber module for a Brookhaven experiment (see page 15).

# San Francisco Accelerator Conference

*The superconducting proton ring (top) at the HERA electron-proton collider now being commissioned at the DESY Laboratory in Hamburg could give the world's highest energy proton beams.*

'Where are today's challenges in accelerator physics?' was the theme of the open session at the San Francisco meeting, the largest-ever gathering of accelerator physicists and engineers. There were over 1500 participants at this, the 14th Conference in the IEEE series, held in the USA every alternate year, confronting this time well over a thousand invited and contributed papers (an increase of 50% compared to the previous Conference). This was an impressive sign of the health of the field, spearheaded by the demands of particle physics but fleshed out by the bulk of activity in other areas of science and in practical applications.

*Linear colliders*

The most difficult challenge is to continue the steady climb in peak energies for physics with lepton (electron) beams; as with hadrons (protons), this has climbed by a factor of ten about every twelve years. The tradition with colliding proton beams is being sustained by the US Superconducting Supercollider (SSC) and CERN's Large Hadron Collider (LHC) projects, but, since both size and cost of lepton rings increase as the square of the energy, CERN's existing LEP machine, with its coming 90 GeV per beam for colliding electrons and positrons, looks like the last of its kind.

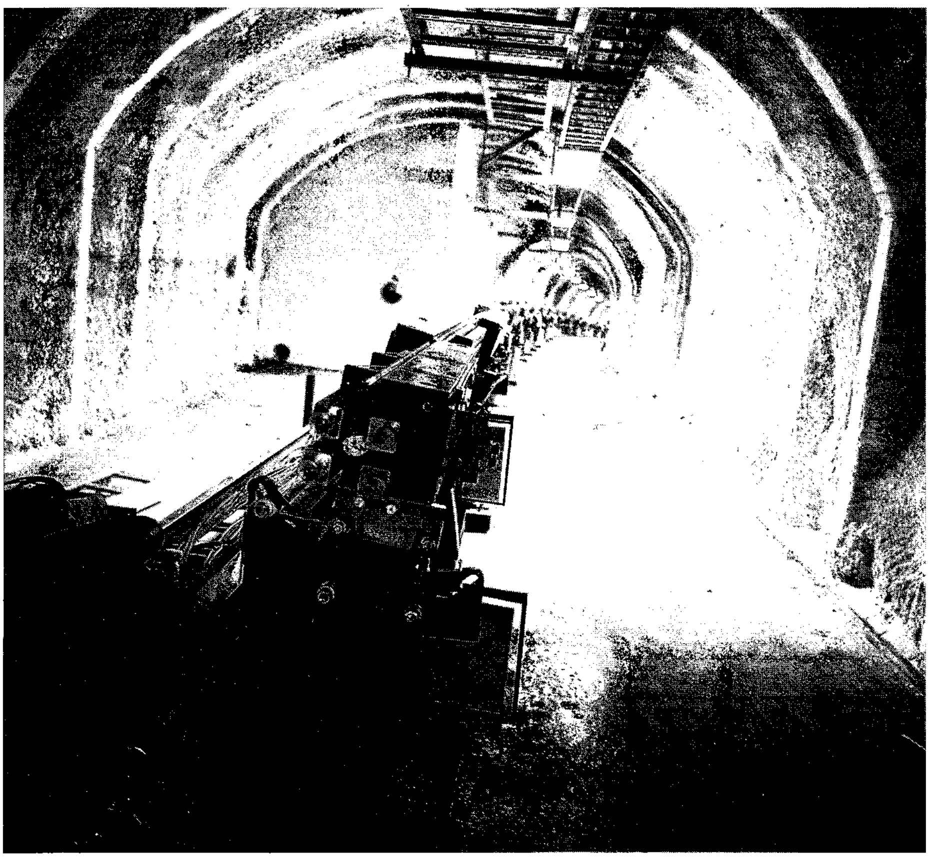
Physics needs 1 TeV lepton beams with luminosities of $10^{33}$ per sq cm per s and the route must be linear colliders where costs are proportional to the energy. The problems are to provide efficient high frequency sources of radiofrequency accelerating power, to cope with the wakefields caused by the interaction of the intense beams with accelerator structures, and to handle micron-size beams involving extreme precision in structure alignment and compensation for random ground motion.

A guiding light in thinking about such machines has been the experience at the hybrid Stanford Linear Collider. Though the SLC physics programme may have been drowned by the flood of data from LEP, it has been brilliantly successful in revealing and mastering some of the accelerator physics problems for linear colliders. Much has been learned about beam dynamics in such machines and about handling micron-size beams with huge peak currents.

Stanford Linear Accelerator Center (SLAC) Director Burt Richter reviewed present approaches to linear colliders involving close collaboration between many Laboratories. At SLAC the project is called NLC (Next Linear Collider) proposing mode-damped structures operating at around 12 GHz with up to 100 MV per m accelerating gradients. Prototype work (together with DESY in Germany, KEK in Japan, Novosibirsk in the USSR and Orsay in France) includes a Final Focus Test Beam on the 50 GeV SLAC linac to study beam spot sizes down to 1 x 0.06 microns (November 1990, page 11).

The most advanced work in terms of hardware is the construction of the Accelerator Test Facility at KEK with completion scheduled for 1993 in preparation for the JLC, Japan Linear Collider. The ATF has a source, linac, damping ring (for studies of low emittances down to 3 x $10^{-8}$ m.rad), a mode-damped 1 GeV X-band linac with 100 MV gradients, and a final focus configuration focusing down to 0.03 microns in the vertical plane. Beam monitors are being developed to cope with nanometre beam sizes. An example of the meticulous engineering involved is a prototype quadrupole for the final focus with pole profiles accurate to better than 2 microns.

At Cornell the emphasis is on the use of superconducting r.f. structures. This could be an expensive route, requiring a much longer machine, but would relax many of the fierce challenges of other schemes, since it would require lower peak power, field gradient, *Stanford's SLC Linear Collider – physics output so far eclipsed by CERN's LEP, but brilliantly successful in exploring and mastering linear accelerator problems.*



and operating frequency. It would also tolerate greater beam sizes and less stringent structure alignment. The scheme is known as TESLA for TeV Energy Superconducting Linear Accelerator (November 1990, page 20). Sets of parameters for progressively increasing energies (a superconducting machine should be easily adaptable), from 0.1 to 1.5 TeV in the centre of mass, have been drawn up with the expectation of field gradients of 15 MV in the near future and maybe as high as 40 MV in ten years (single cell cavities now regularly reach 25 MV).

This work rides on the back of the successful operation of superconducting cavities in accelerator conditions. Y. Kojima listed major contributions, particularly from KEK where 32 five-cell niobium cavities have operated for many thousands of hours in TRISTAN with no deterioration in performance. Other large-scale use is at DESY, CEBAF (series production started last October at the rate of twelve cavities per month) and CERN (where the technique of niobium sputtering on copper has brought a significant reduction in cost – very important for the LEP upgrade which will ultimately have three times CEBAF in superconducting r.f. power).

A more conventional technique for linear colliders is proposed at DESY (April, page 15). At the other end of the spectrum, the most technologically difficult is the CLIC, CERN LInear Collider, proposal using intense drive beams in a superconducting linac alongside the main linac. It would be a 25 km machine providing 1 TeV beams. A test facility is scheduled for completion at the end of 1992. Very tight structure and alignment tolerances are involved, down to 1 micron for the quadrupoles, which could be exceeded by normal ground motion. A dynamic alignment system, using signals taken from the beam to drive micro-movers sustaining components in position, is giving encouraging results.

Gyroklystrons have moved to the fore among possible power sources for linear colliders particularly following work at the University of Maryland. They have operated a two-cavity X-band gyroklystron at 9.85 GHz and achieved output power in excess of 8 MW. There are plans for a new tube to operate near 20 GHz with similar output.

None of these far-reaching plans for linear colliders will come to fruition before well into the next century but they are provoking still more refined mastery of charged particle beams which has been the way ahead for decades, leaving a multitude of other applications in their wake.

In the meantime, LEP carries the lepton energy flag forward. Jean-Pierre Koutchouk, reporting LEP performance and plans, announced a new interpretation of its acronym to describe the work ahead – Luminosity, Energy and Polarization. The luminosity upgrade involves a pretzel scheme with an increase in the number of orbiting bunches (see page 5). The energy upgrade will be complete in 1994 taking the machine beyond the threshold for the production of W pairs. Polarization studies are underway; significant values will not be trivial to achieve but they could improve the accuracy of the present Z mass measurement by a factor of ten compared to its present value of

± 20 MeV. Operation with polarized beams is anticipated in 1996.

*Factory fever*

Stepping back from the high energy frontier, many Laboratories are proposing machines for specific tasks. As M. Zisman brought out in his review of Beauty Factories, these machines attack the luminosity frontier because they want to accumulate massive statistics of particular interactions, much beyond what can be achieved at existing facilities.

A long-standing contender is the KAON Factory project at TRIUMF in Vancouver, Canada. After encouraging initial support from the provincial British Columbia administration (December 1990, page 29), recent developments had been less encouraging. However news of fresh political support came through during the Conference.

Beauty Factories are comparatively new on the scene, prompted by the prospect of fresh information on the two-decade-old problem of charge-parity violation, which could be seen with B mesons as with kaons. Though the B pairs are produced at comparatively low energies, production rates and the need for high statistics requires machines of very high luminosity – about 3 x $10^{33}$ per sq cm per s, thirty times higher than currently achieved at Cornell's CESR in this energy range. Extracting the physics is also helped by having a moving centre-of-mass and the Factories involve either dual storage rings or storage ring and linac of asymmetric energy. Since beam-beam interactions would limit luminosities, many bunches and small beam sizes are necessary. (The word 'micron', hardly ever heard at accelerator conferences as recently as a few years ago, cropped up repeatedly in San Francisco.)

Beauty Factory schemes are being developed at Cornell (see page 8), Stanford/Berkeley (June, page 8), KEK (January/February, page 21), DESY (adding a ring to PETRA) and Novosibirsk (6.5 on 4.3 GeV). There has even been thought of using the vacated ISR tunnel at CERN (June 1990, page 10).

First money for construction of a Phi Factory at Frascati was liberated a year ago for a five-year construction project (September/October 1990, page 43) to give a luminosity of $10^{33}$ with intense electron and positron beams at 1 GeV centre-of-mass. Other phi factory schemes are under study at UCLA (superconducting single-ring with 1 A beams) and at KEK (double-ring with 9 A total current). A Tau-Charm Factory is proposed for Seville (see page 13).

*The Superconducting Proton Rings*

The big machine talk which excited most interest came from Bjorn Wiik reporting progress on commissioning the HERA collider at DESY. To bring this pioneering high energy electron-proton machine into action within budget and on schedule is a very impressive achievement.

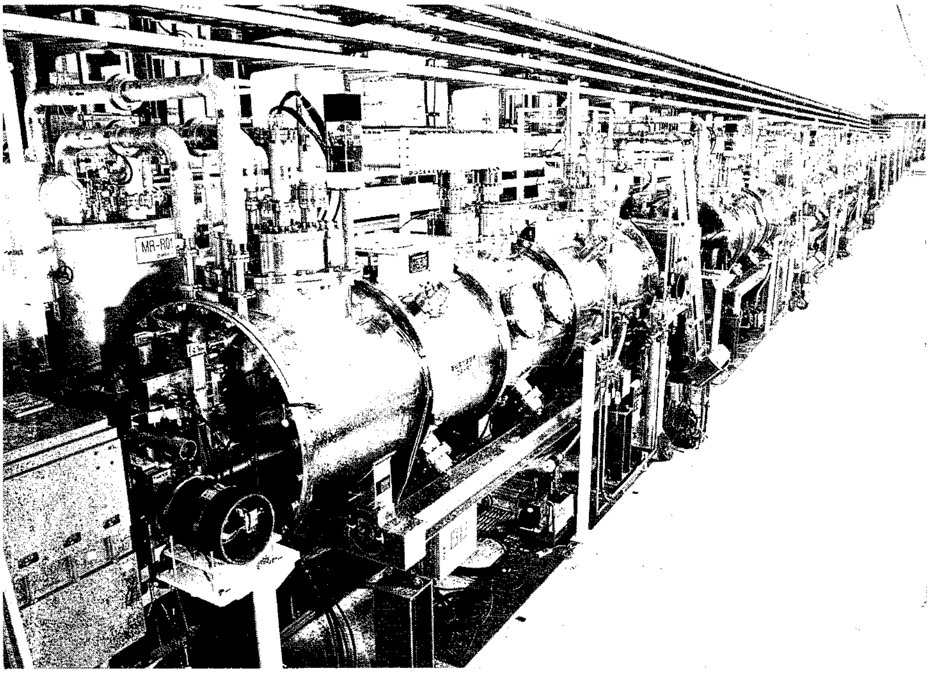
The industrial production of the 1820 superconducting magnets for the proton ring has gone very well – none quenched below the design field of 4.7 T and 98% of them required only two quenches to reach their stable fields. The achievable current gives over 30% safety margin compared to the design value (corresponding to 820 GeV operation) with good field quality and will make it possible for the ring to exceed the energy of Fermilab's Tevatron, currently the world's highest energy proton machine.

The worry about persistent currents affecting injection conditions in an unpredictable way is receding as the fields are reproducible and can therefore be compensated. The cryogenic system seems well up to its job – when a single magnet goes normal, it can be brought back into action in a few minutes.

Steve Holmes described the improvement programme at the Fermilab Tevatron, pioneer of superconducting rings. As Leon Lederman pointed out in one of his usual elegant talks, the machine has an important piece of physics within its grasp since the top quark is predicted to have a mass between 80 and 220 GeV, and upgraded performance should make the top easier to find. Present machine luminosity reaches to 2 x $10^{30}$ (twice the design figure) and the intention is to push this to over 5 x $10^{31}$ in a phased improvement programme. This is starting with installation of electrostatic separators, a linac upgrade to double the injection energy into the Booster to 400 GeV, improvements to the antiproton source and finally the construction of a new ring (the Main Injector – June, page 13) to replace the existing Main Ring, where beam transmission is the present major limitation on Tevatron performance. The whole programme should be complete early in 1996 and give several years of extended physics potential in the USA pre-SSC.

The success story of the development of high current niobium-titanium superconductor, which lies behind the achievements at the Tevatron and HERA and the plans for the SSC and LHC projects, was reviewed by David Larbalestier. Critical currents now exceed 3200 A per sq mm in superconductor avail-

*Superconducting radiofrequency cavities at the TRISTAN electron-positron collider at the Japanese KEK Laboratory have operated reliably for thousands of hours.*



able from industry and 3700 A per sq mm when produced in laboratory conditions. An example is the current density achieved in the latest focusing quadrupoles for the collision regions of the Tevatron; they reach 3100 A per sq mm, almost twice that in the original ring dipoles. As the control of extrinsic effects, like sausaging of the conductor strands, and intrinsic effects, improving flux pinning, are taken still further, it could be possible to push these figures even higher – a 50% improvement may be a realistic figure.

The Superconducting Super Collider requires 8000 superconducting dipole magnets in its two 20 TeV proton rings. The Laboratory is now tackling the magnet design change to accommodate the dipole aperture increase from 4 to 5 cm, which prudence dictated following massive simulations of particle loss over millions of turns. Bob Palmer described the work analysing quench behaviour which points to individual strand movement as being the major culprit. Conductor reconfiguration, with a larger copper to superconductor ratio to take more heat away prior to a quench, has given better performance in the short 5 cm aperture magnets tested so far; they all exceeded design field prior to the first quench and had good field quality with the exception of one multipole.

Roy Schwitters and Don Edwards also reported SSC progress. The parameters of the injectors are being finalized so that civil engineering for the machine can start; all the necessary land acquisitions will be completed in autumn and it is intended to place the first tunnelling contracts by the end of the year. Staff are moving into a huge building on the Laboratory campus near Waxahachie. The Magnet Test Facility is almost complete and a major milestone will be the operation of a half-cell of five dipoles and a quadrupole next summer. First full energy collisions are scheduled for autumn 1999.

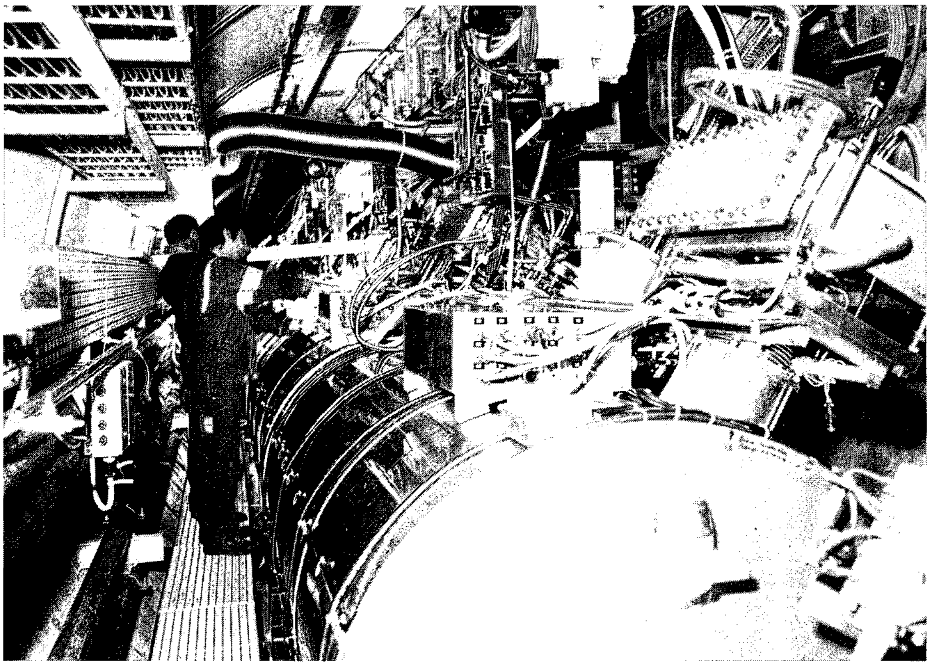
The most challenging work on superconducting magnets is being confronted in preparation for the Large Hadron Collider project at CERN. This was covered by Carlo Rubbia in his talk on the broad research programme at CERN which caters for half of the world particle physics community. Given the requirement that the LHC will sit above the LEP ring, there is need for the highest possible magnetic fields to give 8 TeV proton beams. Also space restrictions in the LEP tunnel, plus potential cost savings, point to the use of magnets with two apertures for the counter-rotating beams in a single cryostat. Thus CERN has to aim for the higher fields than yet achieved, plus 'two-in-one' magnets operating at 1.8 K rather than the usual 4.2 K. This ambitious programme has a milestone of testing a string of magnets in June 1992. Authorization of the project is anticipated at that time, with first collisions anticipated in March 1998.

Viktor Yarba reported on UNK construction progress at Serpukhov. Tunnelling is essentially complete, about half the components for the 400 GeV conventional ring are ready and serial production of the 5 T HERA-style superconducting magnets for the 3 TeV ring has started. The initial intention is to operate this ring for fixed-target physics at beam intensities of 5 x $10^{12}$ protons per second with commissioning in 1995.

To complete the superconducting ring stories, 374 low field (3.45 T) dipoles are needed for the RHIC ion storage ring at Brookhaven. After development at the Laboratory, magnet fabrication is being placed in industry. Completion is scheduled for 1996. KEK have also been looking at the design of an ion machine with two superconducting rings, able to collide gold

CERN's LEP electron-positron collider now spells Luminosity, Energy and Polarization. Superconducting radiofrequency will boost the machine's beams from about 50 to 90 GeV.

(Photo CERN 359.1.90)



ions at energies up to 7 GeV per nucleon, using the existing 12 GeV machine as injector.

*Applications*

The use of accelerators and storage rings in synchrotron radiation sources and free electron lasers is now so widespread that the field calls its own large conferences, and every year sees new facilities under construction. It is a pleasing feature of this field that the construction and operation of these radiation sources, for basic and applied research, is also within the reach of countries who do not yet have much experience in accelerator technology. Examples reported at the Conference were synchrotron radiation sources in Korea and Taiwan.

Stan Krinsky reviewed the challenges of still brighter sources. Here again the monitoring of micron-size beams is becoming standard and is essential to maintain the necessary orbit stability. These sources bring the problem of high power densities impinging on optical components. Solutions range from water-jet cooling at Brookhaven to cryogenic cooling or liquid gallium cooling planned at the European ESRF machine in Grenoble and Argonne's APS respectively. Free Electron Lasers, packing great power into a small wavelength band, still have much unrealized potential for taking photon fluxes higher. National FELs are under discussion using linacs or storage rings.

Commercial use of compact synchrotron radiation sources for X-ray lithography in the production of microchips is imminent. Their ability to etch patterns on silicon chips with a resolution already down to near a tenth of a micron could make it possible to pack a megabyte of memory onto a full-stop within the next ten years. IBM has calculated that a single machine could produce six times the computer memory capacity used worldwide last year.

A superconducting compact synchrotron from Oxford Instruments is coming into action at IBM's East Fishkill research centre and will be the first to start commercial chip production. Sumitomo in Japan has a superconducting ring commissioning since August of last year.

At the US National Synchrotron Light Source, Brookhaven has a two-phase programme, SXLS – Superconducting X-ray Lithography Source, involving Grumman Corporation and General Dynamics. They are beginning with a conventional ring using low field (1.1 T) magnets, now being commissioned at 200 MeV with average currents of 720 mA well above design value, and will build a superconducting version (3.87T) for 700 MeV operation by 1993. The Texas Accelerator Center are also developing a design based on superferric 3 T magnets. This could prove one of the most important practical applications of accelerator technology.

The use of accelerators and storage rings in fusion reactors was reviewed by Stan Humphries. They range from neutral particle injectors into Tokomaks (the next goal is the ITER - International Thermonuclear Experimental Reactor – involving Europe, Japan, USSR and USA) to high power ion beams focused onto deuterium pellets in inertial fusion systems. Sandia and Karlsruhe lead the light ion beam work, while Berkeley, Livermore and Darmstadt concentrate on the use of heavy ion beams. The construction of a heavy ion test facility at Berkeley has been recommended by the USA Fusion Policy Advisory Committee.

New medical applications of accelerators are illustrated by the cancer therapy facility now in use at the Loma Linda hospital in California. Jim Slater reported that treatments began on the 250 MeV proton synchrotron (designed and built at Fermilab) in October of last year. Beams can be guided eventually into four treatment rooms at variable energies. Eye, head and neck tumours are presently treated at the rate of ten per day. Whole-body radiations will start soon and the aim is to be able to treat a hundred patients a day. Ion Beam Applications in Belgium have funding for design work on a cyclotron for proton therapy. A deuterium machine for neutron radiography is being built at Argonne.

Among topics covered in other papers were the use of accelerators for the transformation of radioactive waste, for energy production bombarding thorium or uranium, for tritium production, for angiography using superconducting wigglers to achieve adequate radiation intensities, and for geophysical prospecting in boreholes producing gamma rays to measure the Compton density of rock strata.

The Conference was held in the refurbished Palace Sheraton Hotel, one of the first stately hotels to be built in America. One or two refurbishment bugs were still to be ironed out and the proceedings were occasionally interrupted by a loudspeaker message: 'We have a minor alarm situation. There is no reason for concern. Everything is normal.' The fact that everything stayed normal throughout the meeting was a credit to organizer Matt Allen and his colleagues. Hopefully his successor in two years' time will confront yet another 50% rise in activity in this thriving field.

*By Brian Southworth*

## Accelerator awards

*During the San Francisco Particle Accelerator Conference, several awards were presented in recognition of contributions to accelerator physics and technology:*

- *The 1991 IEEE Particle Accelerator Conference Technology Award to Zoltan Farkas and Perry Wilson, SLAC, 'for their invention and implementation of the SLED scheme for doubling SLAC energy' and to David Larbalestier, University of Wisconsin, and Ron Scanlon, Lawrence Berkeley Laboratory (LBL), 'for the development of niobium-titanium material for high current density application in high field superconducting magnets'.*
- *The US Particle Accelerator School Prize to Wolfgang Schnell, CERN, 'for the development of accelerating systems and diagnostic systems for high energy accelerators' and Glen Lambertson, LBL, 'for the development of injection/extraction technology, accelerator instrumentation and microwave devices'.*
- *The US Particle Accelerator School Special Recognition to Rolf Wideroe 'for the invention of radiofrequency acceleration'.*
- *The Robert R. Wilson Prize to Reg Richardson 'for his original contributions to the invention of cyclotrons, including the first demonstration of phase stability, the first synchrotron and the first sector-focused cyclotron. This work is the basis of numerous cyclotrons that have major impact on nuclear physics, solid state physics, chemistry and medicine'.*
- *1991 Award for outstanding doctoral thesis to Jeffrey Calame, University of Maryland, 'for research which led to operation of a 10 GHz gyroklystron with 20 MW peak output power in a pulse of one microsecond, a factor of 400 increase compared with previous experiments, establishing the gyroklystron as a candidate for driving future electron-positron colliders'.*

# Around the Laboratories

## CERN
## LEP back in action

At the beginning of April, 1991 operations at CERN's LEP electron-positron collider got underway, with a run scheduled through to November.

The lion's share of running time (over 60 per cent) goes to the four big LEP experiments – Aleph, Delphi, L3 and Opal – looking to build up data at and around the Z particle resonance at 91 GeV. So far, the accumulated collision score is running at several times the 1990 level.

As well as looking to improve current performance, machine development work also covers longer term goals – polarization studies (November 1990, page 3), the energy upgrade (May 1990, page 1), and the 'pretzl' scheme to boost the collision rate by going from four to eight bunches per beam.

So far, virtually all LEP design parameters have been achieved. However beam-beam effects came in sooner than expected and reduced the achievable luminosity (the benchmark of the particle collision rate) from 16 to about 7 $\times 10^{30}$ per sq cm per s. A variety of vertical-horizontal tune combinations have been tried to avoid betatron coupling problems also limiting performance, and a promising combination found. Luminosity has now reached $10^{31}$, with beams regularly squeezed tightly by the 'low-beta' (5 cm) magnets.

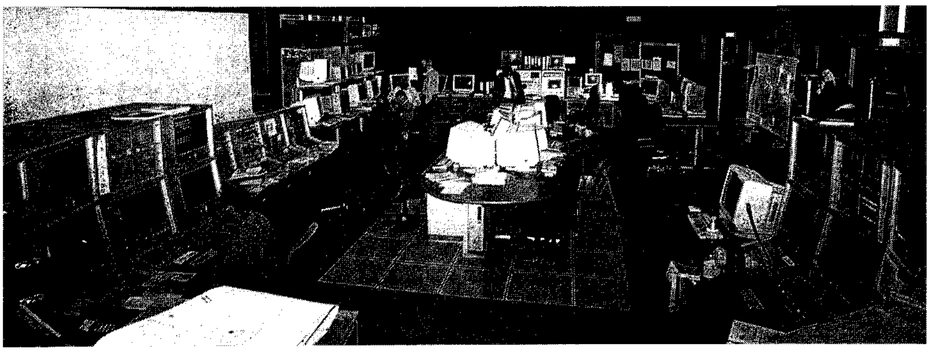
A substantial effort goes into preparing LEP for higher energies. Some 20 buildings have been constructed and major cooling systems are being prepared. The superconducting radiofrequency cavities required are equivalent to a DC linear accelerator giving 5 mA at a few GeV – no mean feat.

Another goal is to adapt the machine for eight – rather than four – bunches per beam. Normally LEP beams collide at eight points – the four even-numbered experimental areas and the four intervening odd-numbered sites. With eight bunches the beams would also collide in the eight intervening ring arcs. These unwanted collisions can be suppressed using electrostatic separators to keep the beams apart. Four such units are now in position and have been activated, with satisfactory results. The full complement of separators will follow next year, while ongoing studies ascertain the optimal beam optics for this scheme and the additional equipment needed.

For polarization studies, additional 'wiggler' magnets have been installed to increase LEP's inherent polarization capabilities and the measuring systems enhanced.

Meanwhile two small LEP experiments – LEP5 by an Italian group using a bremsstrahlung monitor to LEP luminosity, and the MODAL (Monopole Detector at LEP) particle search by a Bologna/Harvard/Weizmann Institute group – end this summer.

*The control room – nerve centre of operations at CERN's LEP electron-positron collider.*



## SUPERCOLLIDER
## Quadrupole magnets

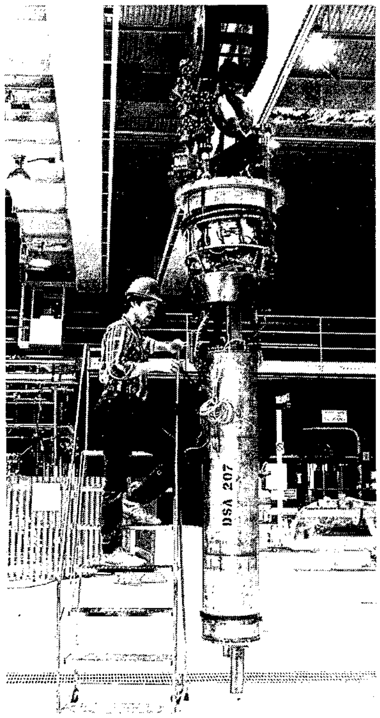
The Lawrence Berkeley Laboratory (LBL) has recently assembled and successfully tested a short (1-metre) quadrupole magnet for the planned US Superconducting Supercollider (SSC).

Earlier models had quenched at unacceptably low currents due to problems with end turn supports. These problems now seem largely corrected, and progress continues at LBL with the quadrupole R&D programme.

Following a formal collider quadrupole request for proposal to industry earlier this year, the SSC Laboratory (SSCL) in Ellis County, Texas, has announced the selection of Babcock & Wilcox for the final design and initial production of the collider quadrupole magnets.

Under the contract, still to be negotiated and approved by the US Department of Energy, SSCL and LBL will work with the company to transfer the quadrupole technology to a production environment. In this process, Babcock & Wilcox will produce several prototypes and 14 preproduction units before going on to manufacture 147 production units, with first deliveries expected in the fall of 1994. Most of the manufacturing and assembly

Short sample superconducting magnets are being continually tested for the planned US Superconducting Supercollider (SSC).



## Second experiment

*The search is on for a second experiment at the planned US Superconducting Supercollider (SSC). One detector collaboration, SDC, has support en route to a formal proposal/design report (March, page 3), while the idea of a second major detector has generated considerable interest.*

*SSC Program Advisory Committee's questioning has led the SSC Laboratory to conclude that the L* scheme, despite much excellent technical work, should not be further supported.*

*Ideas are being discussed, and guidelines should emerge this summer.*

will be done at the firm's Lynchburg, Virginia, plant.

The contract includes options for the purchase of an additional 1517 quadrupoles, which would complete the 1664 total needed for the collider. In addition to the 1664 quadrupole magnets, a variety of other types of custom quadrupoles will be designed, built, and tested at LBL and the SSC Laboratory.

Working with Babcock and Wilcox in this contract will be two subsidiary companies of Siemens in Germany – Interatom and KWU (Kraftwerk Union).

## CORNELL CESR-B B Factory proposal

Cornell has submitted a proposal to the US National Science Foundation (NSF) to upgrade the CESR electron-positron collider to a B Factory called CESR-B. Design luminosity is $3 \times 10^{33}$ per sq cm per s in the asymmetric mode with energies of 8.0 and 3.5 GeV in the two beams. This collision rate is large enough to observe CP violation in B meson decay if it appears at the level predicted by current understanding. With modest modifications, CESR-B could also operate up to 5.5 GeV per beam in the symmetric mode with a luminosity of $10^{34}$.

The design of CESR-B is solidly based on the experience gained in achieving record luminosity with CESR (March, page 15). CESR now operates routinely with luminosities above $1.8 \times 10^{32}$ and has produced as much as 11 inverse picobarns in one day of operation and a total of 525 in the first 132 days of this year. Many components of CESR would be used directly or be upgraded in the transition from CESR to CESR-B. The CESR magnets would be used for the high-energy ring (HER) and new magnets capable of operating up to 5.5 GeV installed for the low-energy ring (LER).

The total cost of the project, including the required upgrade of the CLEO detector and a substantial upgrade of the CHESS synchrotron radiation facility is $102 million. If funds become available in late 1992, the upgrade of CESR to CESR-B could be completed by 1996.

The luminosity of such a collider is directly proportional to the numbers of positrons and electrons in each bunch, and to the collision frequency, and inversely proportional to the area of the beams at the collision point. These quantities are limited by a number of factors: the short-term wakefields produced by the currents in the walls of the vacuum chambers and radiofrequency cavities; the beam-beam interaction; the synchrotron radiation produced near the interaction point; the ability to separate the two beams at the interaction point; and long-term wakefields.

The Cornell approach to increasing the luminosity of CESR is to increase the collision frequency while limiting the single bunch parameters – the number of particles per bunch and the area of the colliding beams – to values already achieved in routine operation of CESR. In addition, the design value of the beam-beam tune shift is 0.03 consistent with present CESR operation. This conservative choice of single-beam and beam-beam parameters ensures that a host of potential problems have already been solved and design effort can be concentrated on the challenges arising from the high collision frequency and the resulting large currents in the rings.

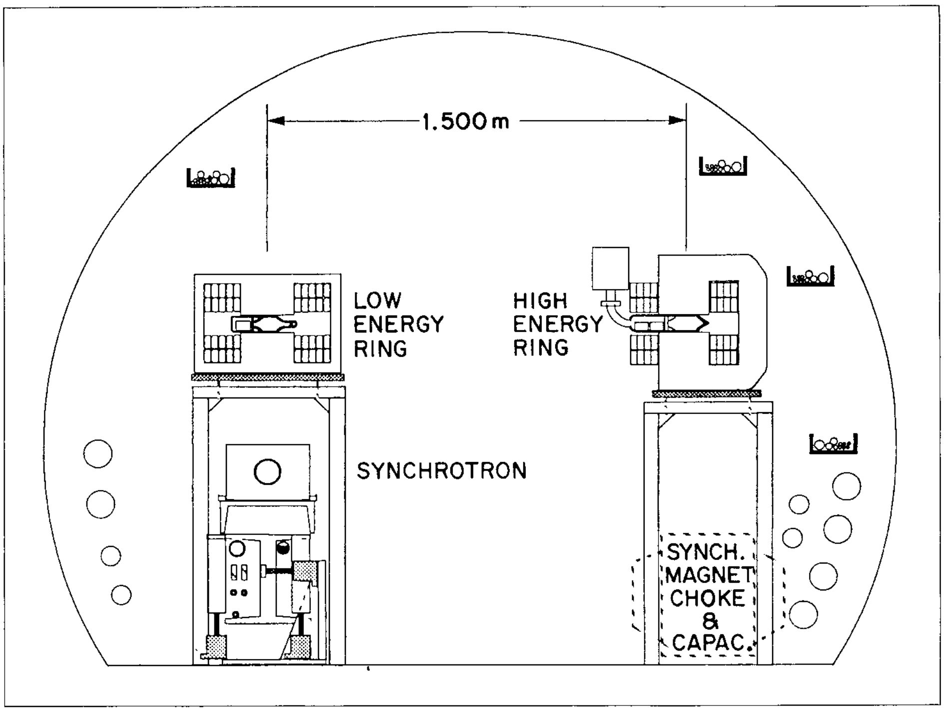
CESR-B will have 230 bunches compared to 7 in CESR. Separation of the two beams at the interaction point to avoid parasitic collisions will be achieved by intersecting the beams at a small angle (12 mrad) with 'crab crossing' – a scheme where r.f. cavities in both beams just before the interaction point are used to rotate the beams so they collide head-on, avoiding synchro-betatron oscillations that would otherwise limit luminosity.

The high collision frequency leads to currents of 0.9 and 2.0 A in HER and LER, respectively. These currents are substantially larger than the typical 100 mA currents currently stored in CESR, and require significant upgrades of vacuum and r.f. systems.

The CESR-B r.f. system would consist of 16 single-cell superconducting cavities, based on an evolution of CERN's LEP superconducting cavity design. These cavities will provide accelerating fields much larger than achievable with continuous wave copper structures. In addition, the cell design leads to strong suppression of higher order modes and their propagation out of the cavities via the round beam pipe to locations outside the cryostat where they can be easily and efficiently removed.

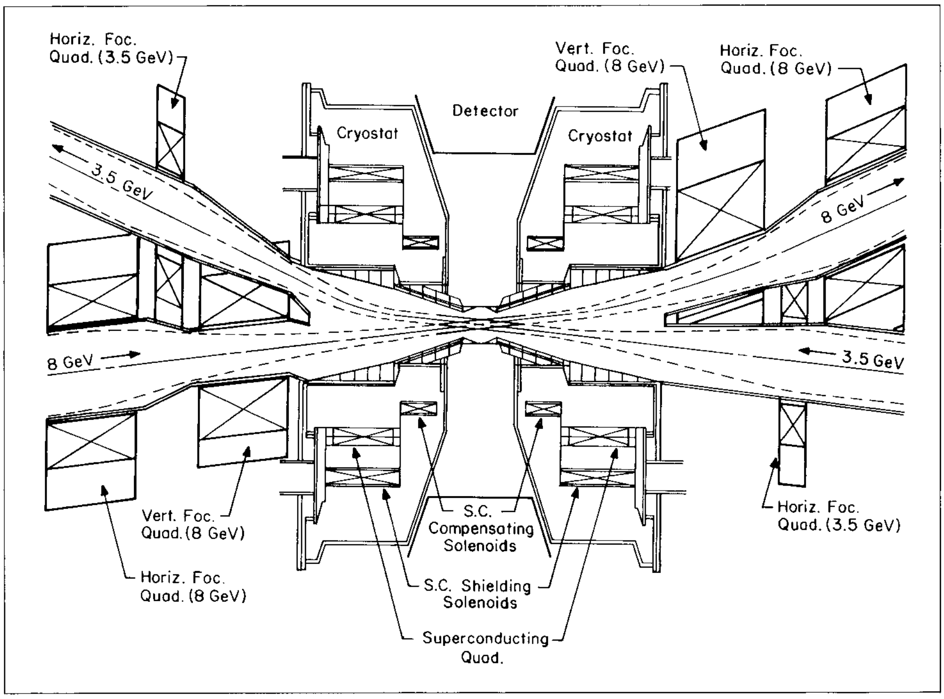
The collider design is driven by the limitations on acceptable backgrounds from synchrotron radiation and lost particles in the detector. Careful study of these potential backgrounds based on extensive experience and measurements at CESR indicates that the design is consistent with operation of the detector.

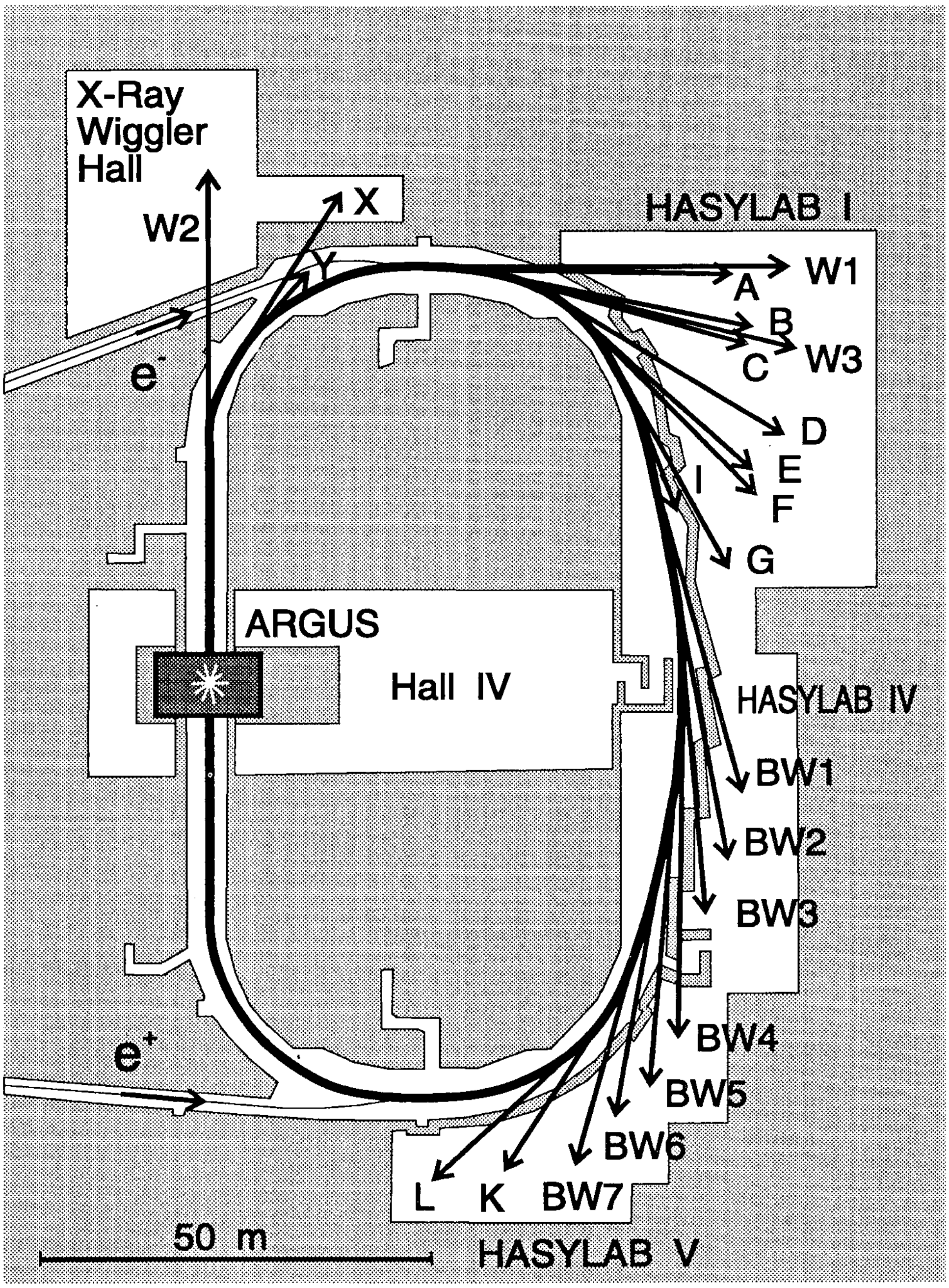
The ongoing CLEO detector is also an excellent platform for constructing a detector for CESR-B.




▲ *Schematic of Cornell's proposed CESR-B beauty factory, employing the magnets from the existing CESR electron-positron collider for the High Energy Ring (to run at 8 GeV) and a second ring for a lower energy beam (3.5 GeV). Both rings could also operate at 5.5 GeV.*

▼ *Planned CESR-B beam intersection with 'crab crossing' – r.f. cavities further from the interaction point rotate the beams so they collide head-on, avoiding problems (synchro-betatron oscillations) that would otherwise limit luminosity.*






*The DORIS electron-positron ring at the DESY Hamburg Laboratory now emerges in its third incarnation, with additional synchrotron radiation potential and just a single interaction region for high energy physics, currently used for the ARGUS experiment.*

The state-of-the-art cesium iodide electromagnetic calorimeter (October 1989, page 14) can be directly utilized at CESR-B. A precision vertex detector is required to measure B meson decay vertices in order to observe delicate CP violation effects. A new drift chamber must be constructed to accommodate collider modifications around the interaction point. Improved particle identification for separating pions and kaons would be necessary – currently a combination of time of flight counters with resolution better than 100 ps and aerogel counters is favoured. The required upgrades to the CLEO detector are about 10% of the estimated total cost of the project.

The small emittance of CESR-B would allow parasitic operation of undulators producing synchrotron radiation. In fact CESR-B would be an excellent source of synchrotron radiation for a class of experiments requiring especially high flux or brightness. Again the modest cost of the undulators and the required building modifications to provide space for the beamlines is foreseen.

## DESY DORIS-III

The DORIS electron-positron ring at the Hamburg DESY Laboratory has a long tradition – first beams were stored at the end of 1973 in the initial double-ring configuration. A six-month upgrade in 1982 resulted in the single-ring DORIS-II, attaining higher energies and improved collision rates. During its 28-year career so far, DORIS has made important contributions, particularly in heavy flavour physics, and, after a further upgrade, this looks set to continue.

In July last year, the machine was shut down for modifications mainly to increase the number of synchrotron radiation beams. It now emerges as DORIS-III, with only one interaction region for high energy physics, currently used for the ARGUS experiment.

Civil engineering has just finished, and all new components installed in the tunnel. A slightly bent bypass replacing one of the straight sections now includes six new wiggler magnets (with space for still one more) and several new synchrotron radiation beamlines.

In the bypass two of the 24 3.2m DORIS bending magnets were replaced by six shorter ones to leave space for the new wigglers, at the same time increasing the machine's circumference from 288 to 289.2 metres.

In the light of experience at the nearby HERA electron-proton collider, now being commissioned, more than one-third (110 m) of DORIS' stainless steel vacuum pipe was replaced by a new copper tube, including distributed ion getter pumps and cooling. Eventually the entire ring will be equipped in this way.

The ARGUS team continues to study particle production around the broad 4S upsilon resonance, a prolific source of information on B mesons and b quarks.

Detector improvements include accurate vertex detection to pick up heavy quark decays. A new microvertex drift chamber has replaced the original ARGUS inner detector, while an additional silicon strip vertex chamber has been designed to fit into the narrow space between the beam pipe and the microvertex chamber. After extensive studies, a 22mm-diameter beam pipe is now planned for use with ARGUS.

DORIS-III operations have to take account of HERA. During proton injection into the big machine, electrons and positrons have to be injected into DORIS at a lower rate.

## BERKELEY Advanced Light Source accelerator commissioning

The new building for the Advanced Light Source at Berkeley preserves the historic dome which once housed E.O. Lawrence's 184-inch cyclotron. Planned for completion in Spring 1993, the ALS will provide new facilities for synchrotron radiation research.

At the Lawrence Berkeley Laboratory, preparations for the Advanced Light Source (ALS), under construction since 1987, gather momentum as the projected spring 1993 completion date nears.

Based on an advanced 197-metre 1.5 GeV electron storage ring with a state-of-the-art design emittance of less than 10 nm-rad, the ALS will be an ultra-high-brightness source of ultraviolet and soft X-ray synchrotron radiation covering a wide spectral range, with photon energies from below 10 eV to above 2 keV with undulators, and to above 10 keV with wigglers. (The undulators and wigglers magnetically 'shake' the electron beam to produce the synchrotron radiation.)

Along with several comparable facilities now under construction or planned around the world, the ALS is complementary to synchrotron radiation sources based on higher energy storage rings generating hard X-rays. Both soft and hard X-ray facilities will offer comparable brightness, at least ten times more than the maximum achievable at existing sources, and will serve broad, multidisciplinary user communities ranging from materials science to the life sciences.

Conventional ALS construction is virtually complete. The Light Source fills the renovated and enlarged domed hall that once housed E.O. Lawrence's 184-inch cyclotron. This dome has long since become a local landmark.

A recent milestone was successful operation of the 50 MeV electron linac, first stage of the ALS accelerator chain. This linac is a conventional two-section S-band (3 GHz) constant-impedance structure fed by a 120 kV electron gun and bunching system giving single S-band bunches each with a charge of more than 2 nC.

After going operational on 20 February, the 50 MeV linac design energy was attained on 6 March, and by mid-March beam intensity was adequate to begin commissioning the next stage of the system, the booster synchrotron, early in May. The next stage is booster acceleration.

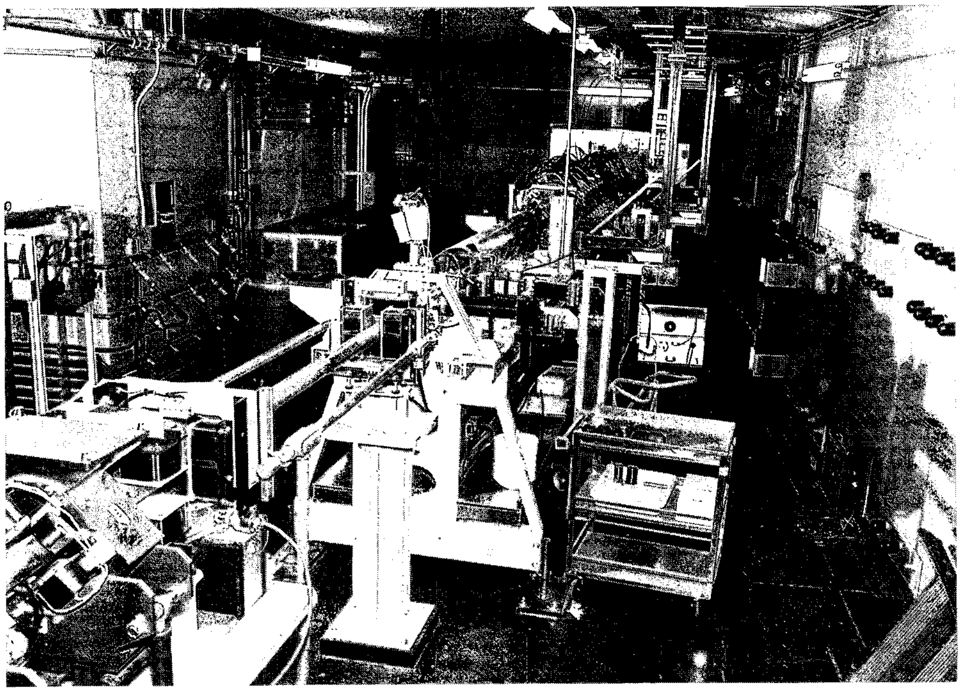
The 1.5 GeV 75-metre circumference booster synchrotron has a missing-magnet FODO lattice with four-fold symmetry. Its 1 Hz repetition rate permits filling the storage ring to its nominal 400 mA in about two minutes.

The storage ring itself is a third-generation synchrotron radiation source with a small natural emittance (3.5 nm-rad) and long dispersion-free straight sections for insertion devices.

The magnet lattice contains 12 achromatic arcs, each with three combination gradient-bend magnets, six quadrupoles, and four sextupoles in the triple-bend achromat arrangement. The ring can operate from 1 to 1.9 GeV but is optimized for 1.5 GeV. Of the 12 straight sections, one is occupied by injection hardware and one by two 500 MHz r.f. cavities. Manu-

*The 50 MeV linac injector for Berkeley's ALS, seen here looking towards the electron gun, has reached full energy with sufficient current to begin commissioning the next ALS phase, the 1.5 GeV booster synchrotron.*

*(Photos LBL)*



facture of storage ring magnets is complete and testing is under way. The 12 monolithic machined-aluminium vacuum chambers (one for each arc) to maintain the base pressure of about 0.1 ntorr are being assembled.

Ten straight sections are available for insertion devices. In collaboration with the user community, three undulators and a wiggler that span the ALS spectral region have been specified. The goals of very high brightness and useful fifth-harmonic output from the undulators impose unusually tight tolerances on the magnetic field quality and thus the mechanical structure of the undulators. Engineering designs for the insertion devices are well underway and construction of test assemblies is in progress.

The high ALS brightness has challenged optics designers, the most serious limitation being optical fabrication tolerances. It is difficult to fabricate aspheric optical surfaces (paraboloids, ellipsoids, toroids, etc.) sufficiently accurately to take full advantage of the undulator source. Very tight tolerances are required to avoid losses and maintain spectral resolution to one part in 10,000.

With X-ray beam power attaining several kilowatts per square centimetre, spherical surfaces will be used for all mirrors and gratings and the optics water-cooled.

Following experience at the US National Synchrotron Light Source (NSLS) at Brookhaven, funding of ALS experimental facilities is primarily the responsibility of user groups known as participating research teams (PRTs) – collaborations of industrial, academic, and federal laboratory scientists.

After a Call for Proposals last March, eight PRTs were selected to develop experimental facilities for six undulator and two wiggler beamlines. There will also be 24 bending-magnet ports available initially. To date seven of these have been allocated to PRTs. The ability to exploit high spectral brightness – the ability to focus a very large number of photons into a small area – was the main criterion for PRT selection. In the ultraviolet and soft X-ray regions this should result in spatial resolutions of some 100 angstroms in X-ray microscopy and holography and in spatially resolved spectroscopy.

This resolution is expected to have considerable scientific and technological impact, opening up the analysis of smaller physical, chemical, and biological systems. To take just one example, semiconductor surfaces are often inhomogeneous, making interpretation of data from illumination of a large area ambiguous. With spatial resolution, it will be possible to associate spectral features with specific surface structures.

Other beneficiaries of high brightness include very-high-resolution spectroscopy, spectroscopy of dilute species, diffraction from very small samples, and time-resolved spectroscopy and diffraction.

## BERKELEY 17 keV neutrino update

*Following the earlier 17 keV neutrino result at Berkeley (March, page 7), investigations have continued with seven months of data-taking using a germanium crystal doped with carbon-14, and four months studying background with a plain germanium crystal. The results continue to show a distortion in the beta decay spectrum compatible with a neutrino of 17 ± 1 keV.*

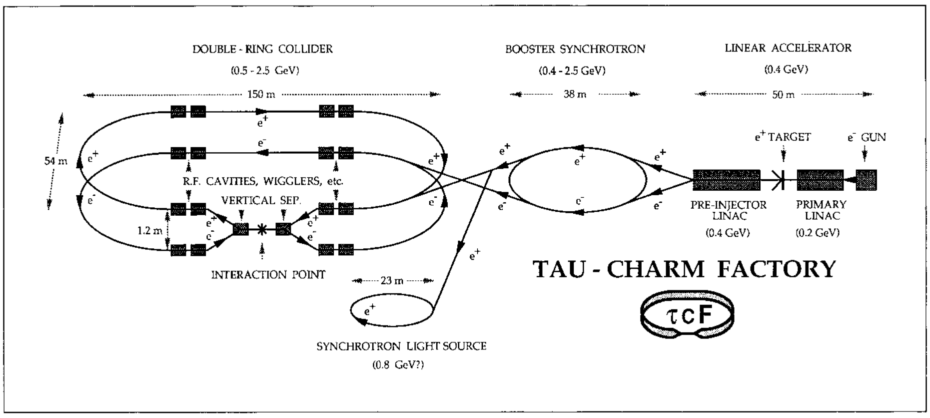
# PARTICLE FACTORIES
## Tau-charm in the spotlight

Following earlier workshops in Stanford (1989) and in Orsay (1990), some hundred physicists from Europe and the United States met from 29 April to 2 May in Seville, Spain, to consolidate plans for a Tau-Charm Factory.

The big electron-positron colliders at CERN (LEP) and Stanford (SLC) have established that there are only three families of particles within the present Standard Model. This has stressed the importance of precise experimental studies of the presently-known particles to answer the major questions facing the Standard Model: Why there are three families? Why do they have their observed mass patterns? What lies behind the quark selection rules (Kobayashi- Maskawa matrix) and what is the origin of CP violation?

It is becoming widely accepted that, in future, progress at the 'high-precision frontier' will require dedicated machines that are optimized for specific particles. These 'particle factories' must produce selected particles copiously and with low background conditions.

The Tau-Charm Factory would collide intense beams of electrons and positrons in the region of the production thresholds of the tau lepton and the charmed quark, near 4 GeV total energy. The third-generation leptons – the tau and its associated neutrino – are an especially promising sector to search for subtle discrepancies with the Standard Model. The tau is the only lepton with a wide variety of decays – both leptonic and hadronic – of which many can be calculated with high precision. Furthermore, the sensitivity to new physics is greatly increased by the relatively high tau mass (1.8 GeV). Interest in the tau and its neutrino has grown with the recent indications of a 17 keV neutrino. If confirmed, then models are predicting lepton-flavour-violating decays of the tau which should be within the experimental sensitivity of a Tau-Charm Factory.




*Schematic of a projected Tau-Charm Factory laboratory in Spain.*

The advantages of a Tau-Charm Factory include not only the large data samples foreseen (10-50 million events per year of each particle) but also very low backgrounds – which can be measured experimentally – and the ability to produce taus nearly at rest. In addition, experiments can single-tag taus (as well as charmed mesons). Single-tagged data samples significantly reduce backgrounds and systematic errors (flux uncertainties, for example, are eliminated).

By generating huge samples of J/psis, (about $10^{10}$ per year), a Tau-Charm Factory will also answer important questions that remain at lower energies. A 'J/psi Factory' is seen as a natural future extension of present programmes exploring quark dynamics up to 3 GeV and testing symmetry principles in the decays of light mesons and baryons. In particular J/psi decays are an ideal way to study gluonium and other gluonic matter, for which the lack of experimental evidence remains as a major open problem for QCD.

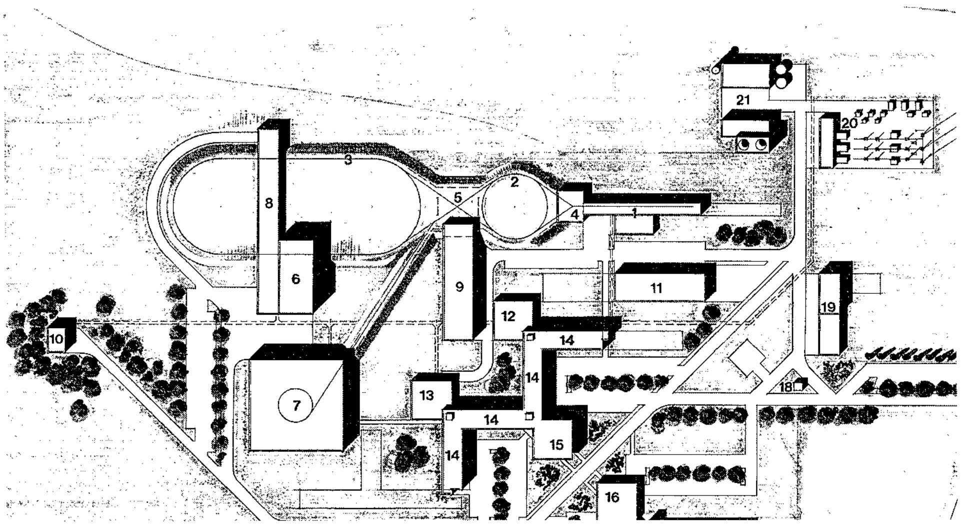
Interest in the Tau-Charm Factory has grown since the original idea by Jasper Kirkby and the first machine design by John Jowett, both at CERN. Detailed machine designs have subsequently been carried out at Stanford, Orsay, Novosibirsk and CERN – all agreeing that a luminosity of $10^{33}$ per sq cm per s can be achieved.

The Soviet Laboratories at Dubna (JINR) and ITEP (Moscow) are considering the possibility of a Tau-Charm Factory in collaboration with INP Novosibirsk.

In Europe, interest focuses on Spain where, following the initiative of Juan Antonio Rubio of CIEMAT (Madrid) and CERN, considerable support has grown within the scientific community as well as within industry and the central and regional governments. Among several regions that have expressed interest in the Tau-Charm Factory, Andalucia is strongly backing a site for the installation near Seville.

Following a request from the Spanish Government early last year, CERN carried out a concep-

Possible Tau-Charm Factory site layout, from a CERN design in collaboration with LAL-Orsay and Spain. 1 = Linac; 2 = Booster; 3 = Main ring; 4, 5 = Switchyards; 6, 7= Experimental halls; 8 = r.f. + exp. service hall; 9 = Machine access and service hall; 10 = Cryogenics; 11 = Workshops; 12 = Control room; 13 = Computer centre; 14, 15 = Offices and labs.



tual study, along with collaborators from LAL-Orsay and Spain, of a Tau-Charm Factory Laboratory in Spain. This study has been completed and the Spanish authorities have recently proposed considerable funds for the project. Discussions are now underway for CERN to provide the necessary technical expertise and the training of Spanish fellows and technicians.

The machine design envisages a collider and a dedicated synchrotron radiation source, both fed by an intense electron-positron injector operating at up to 2.5 GeV. The collider comprises a pair of 360-m racetrack-shaped rings, spaced vertically by 1.2 m. These are filled with up to 0.6 A positron and electron currents, at energies between 1.5 and 2.5 GeV. The beams are brought together at a single interaction point, with a second interaction region left open as a future option. With high currents and tight focusing at the interaction point, the luminosity is expected to reach $10^{33}$, a hundred times that of the best current machine at these energies (BEPC, Beijing).

The Seville meeting also looked at the design of the detector for the Spanish machine. The detector is being developed by an enthusiastic team of physicists and engineers from CERN, France, Germany, Italy, Portugal, Spain, the UK and other European countries, as well as a US team led by Martin Perl of Stanford, who discovered the tau lepton in 1975.

The current ideas for the detector follow the style of CLEO II at Cornell (October 1989, page 14), with a large cesium iodide electromagnetic calorimeter, but optimized for tau-charm physics. In particular it includes a fine-grained outer hadron calorimeter/muon detector to complete the detector coverage and enable the invisible neutrinos produced in tau and charm decays to be 'seen'.

The Tau-Charm Factory is creating a lot of interest in Spain, which has never had a national centre for experimental high energy physics. As well as attracting the international physics community to Spain, the Tau-Charm Factory provides unique opportunities to breed a new generation of Spanish machine physicists and to provide a springboard for industrial spinoffs and future research projects in particle and accelerator physics. With the final decision on the project expected later this year, the first beams should collide early in 1997.

# SOUTH AMERICA
## Looking for partners

A Regional Meeting on Fundamental Physics organized at the CIF International Physics Centre in Bogota, Colombia, in April, looked at future international collaboration possibilities for physicists from the South American Andean region in general, and from Colombia in particular.

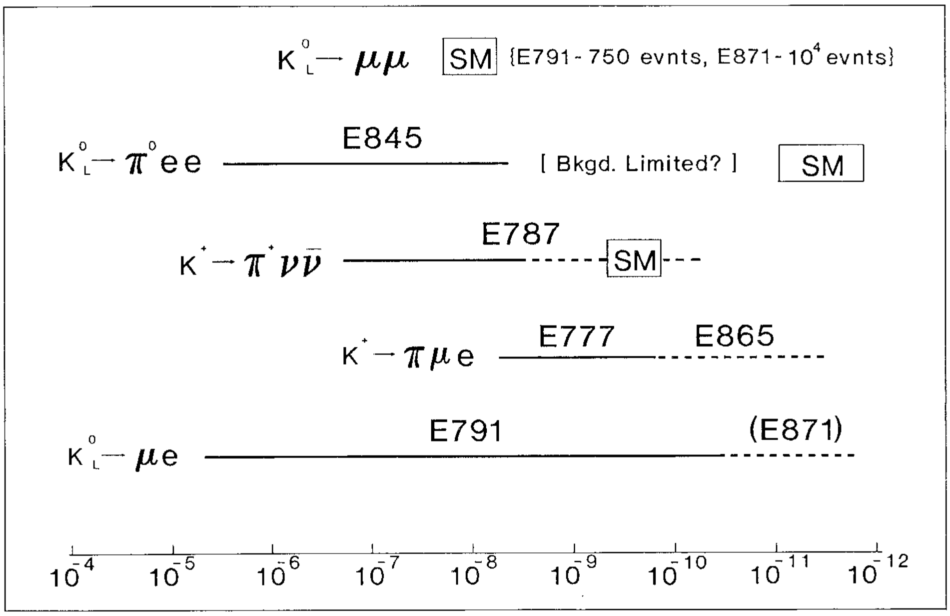
There is a strong tradition of Latin American collaboration at Fermilab, and all the signs are that this will continue to flourish. In addition, a new collaboration agreement drawn up between CIF and the Canadian TRIUMF Laboratory in Vancouver opens up new horizons.

Cayetano Lopez of Madrid, a former Vice President of CERN Council, looked at possibilities in Europe. Spain, now playing an influential role in CERN and with plans to create a home-based accelerator centre, could provide a natural cultural bridge.

A collaboration agreement has been signed between CERN and Brazil (April 1990, page 26), and accords will soon be signed with Argentina and Chile. At the Bogota meeting Georges Charpak of CERN pointed out the usefulness of such agreements, in particular for Colombia, where CIF, founded in 1985, provides a natural base.

Apart from accelerator-based physics, countries with high mountains near the Equator provide natural advantages for observational physics.

*Status of Brookhaven search for 'rare' (suppressed or classically forbidden) kaon decays. The black line shows the limits listed in the 1986 'Review of particle Properties' (left extremity of black line), current (right extremity) and anticipated progress (dotted line). Standard Model (SM) predictions are indicated.*




Concluding the meeting, Galileo Violini of CIF looked forward to increased opportunities across a broad front. A special steering committee has been set up with representation from Italy, the US (Leon Lederman of Chicago) and Canada (Erich Vogt of TRIUMF) as well as South American Countries.

# BROOKHAVEN Rare kaon decays, phase II

Hints on forthcoming particle physics attractions often come from experiments at energies well below the threshold for production of the new particles themselves. For example hadron substructure was presaged by the observation of the very anomalous magnetic moment of the proton, and the fourth quark, charm, by the unexplained suppression of certain kaon decays.

Brookhaven's rare kaon decay programme, which began in the mid-1980s, continues to probe the high energy frontier in this tradition. All four Alternating Gradient Synchrotron (AGS) experiments (E777, E787, E791, and E845) have now established new sensitivity records for suppressed reactions like the decay of the long-lived neutral kaon into two charged muons. These high statistics samples of suppressed decay modes allow the parameters of the Standard Model to be fine tuned.

However the main goal is to search for decay modes which are at least extremely suppressed, if not forbidden, in the Standard Model.

E777 and E791 search for violations of the hitherto sacrosanct conservation of lepton number – reactions such as a charged kaon decaying into a pion, a muon and an electron, or a neutral kaon giving a muon and an electron. The branching ratio limit obtained by E777 was $2.1 \times 10^{-10}$, while a limit of $6.1 \times 10^{-11}$ was reported by E791 on the muon-electron mode which is expected to improve slightly when the 1990 data sample is analysed.

GHz rates of beam particles with MHz kaon rates are now possible because of the high proton current from the AGS and the sophisticated data acquisition systems of these experiments. Typically the level 1 trigger rate exceeds 10KHz with about a hundred events per second finally written to tape.

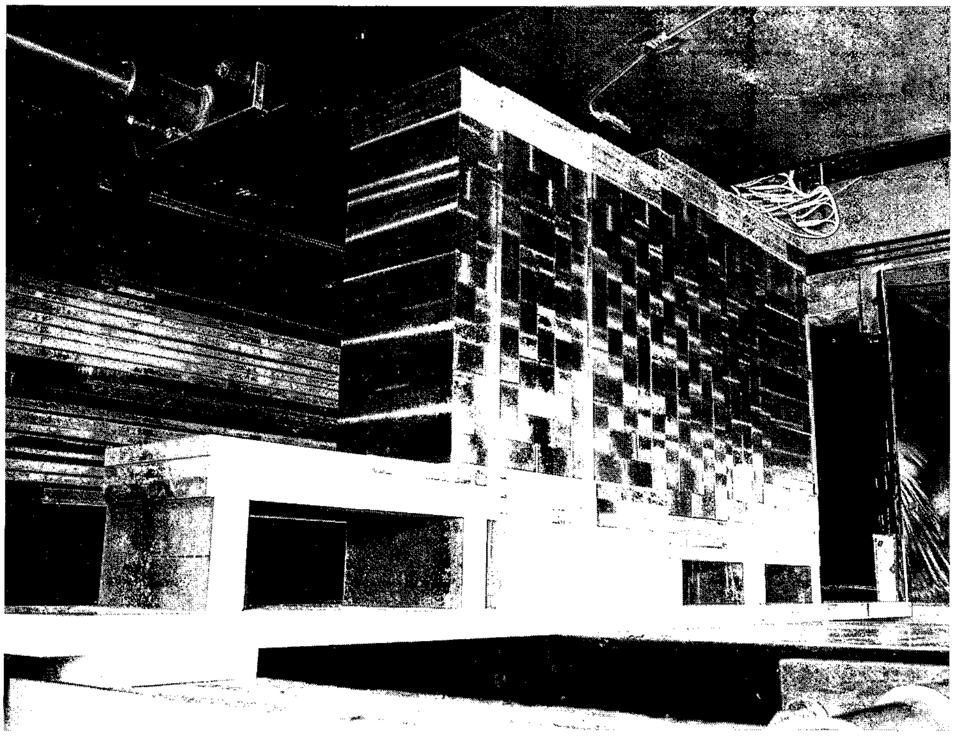
E787 searches for the decay of a charged kaon into a charged pion and accompanying neutrinos, a second order weak process predicted by the Standard Model to occur at a level of a few times $10^{-10}$. A result significantly above or below this level would indicate new physics, while a measurement consistent with the Standard Model would determine the poorly-known mixing between top and down quarks.

The decay of a neutral kaon into a neutral pion and an electron-positron pair is suppressed in the Standard Model. E845 found no evidence for this decay mode (less than $5.5 \times 10^{-9}$) but found an unanticipated background due to decays into an electron-positron pair and a photon. Unfortunately this background kinematically overlaps the decay mode of interest and will be a major irritation to other experiments pushing the sensitivity for this decay mode toward the Standard Model value.

Brookhaven's rare kaon decay programme might now be said to have completed Phase I and to be preparing for Phase II, incorporating detector and secondary beamline upgrades to exploit higher beam intensities from the AGS Complex after commissioning the new Booster and improving the radiofrequency system.

The successor to E777 is E865. This experiment will utilize a more intense kaon beam, larger apparatus, and improved hardware made

Tungsten/copper beam plug currently being tested by Brookhaven experiment E871 – a 'Phase II' kaon decay search.



possible by advancing technology to achieve a factor of 70 greater sensitivity for the pion/muon/electron decay. An improved search future muon/electron decay is planned by E871. The design of this experiment includes a neutral 'beam plug' to allow both increased acceptance and enhanced tracking detector performance relative to E791. A test during the current AGS run, should, if successful, allow E871 to improve the sensitivity limit of E791 by a factor of twenty. Among the upgrades planned in progress for E787 are a new separated stopping beamline, a new drift chamber for better momentum resolution, and a cesium iodide photon veto to replace the present lead-scintillator sandwich.

Phase II of the rare kaon decay programme should be completed around 1995-7. Also expected in this time frame is a new precision measurement of the anomalous magnetic moment of the muon (April 1989, page 7). These studies will provide sensitive tests of new physics prior to the new generation of superconducting proton supercolliders planned at CERN and in the US.

## g-2 experiment

*The Brookhaven experiment to measure the anomalous magnetic moment (g-2) of the muon (April 1989, page 7) has completed winding the first of its four 14-metre diameter superconducting coils. The new experiment seeks to improve by a factor of 20 an already remarkable CERN measurement of muon magnetism made 15 years ago. The new precision will allow new insights into the behaviour of the W and Z particles, carriers of the weak force.*

## KEK
## Approaching 100% polarization

The major effort underway to develop new techniques fort the planned Japan Linear Collider(JLC) project (May, page 4) at the Japanese KEK Laboratory continues to produce good news.

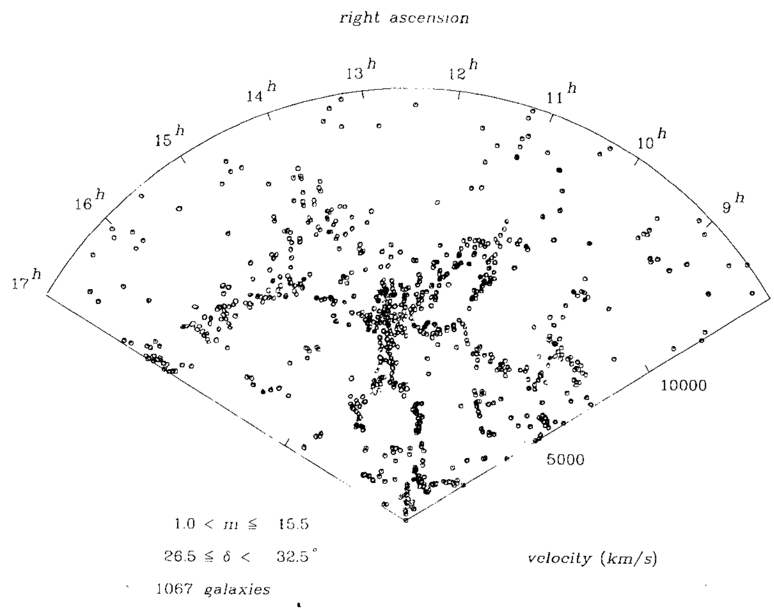
In February the KEK/Nagoya/NEC group made a breakthrough in polarized electron source, achieving 71 per cent polarization with a superlattice photocathode, however more surprises were in store.

The Nagoya University group has been looking at improving a strained crystal technique to remove valence band degeneracy and enhance selective electron pumping. Their latest product is a thin gallium arsenide epilayer grown on a gallium phosphor arsenide substrate. With this new sample, only two months after the February achievement, they have attained even higher polarizations, reaching 86 per cent. Such rapid progress suggests a 100 per cent polarized beam for JLC!

# Cosmic strings

## A particle physics solution to the large-scale structure of the Universe

*The large-scale structure of the Universe. Galaxies and clusters of galaxies appear to be located on the surface of huge 'bubbles' nested together. Inside the bubbles are enormous voids, up to 150 million light years across.*




*The past decade has seen a developing interplay between elementary particle physics and cosmology. The former has had great success in demonstrating the unification of the weak and electromagnetic forces at energies just above 250 GeV ($10^{16}$ degrees Kelvin). The 'Standard Model' of particle physics seems to describe accurately the interactions of quarks and leptons at and below these energies, as demonstrated daily in CERN's LEP electron-positron collider.*

*However the frontiers of particle physics also involve energies much greater than the energies available in terrestrial accelerators. Theories which attempt to unify the strong and electroweak forces (Grand Unified Theories – GUT) require energies of around $10^{15}$ GeV. For this reason many particle physicists have turned to the early Universe, where these sorts of energies were believed to exist just $10^{-35}$ seconds after the Big Bang. The Universe is a unique, exciting Laboratory for investigating physics at extremely high energies and very short distances.*

*In this article (first published in the Bulletin of the UK Science and Engineering Research Council) Ed Copeland of Sussex University looks at links between cosmology and elementary particle physics.*

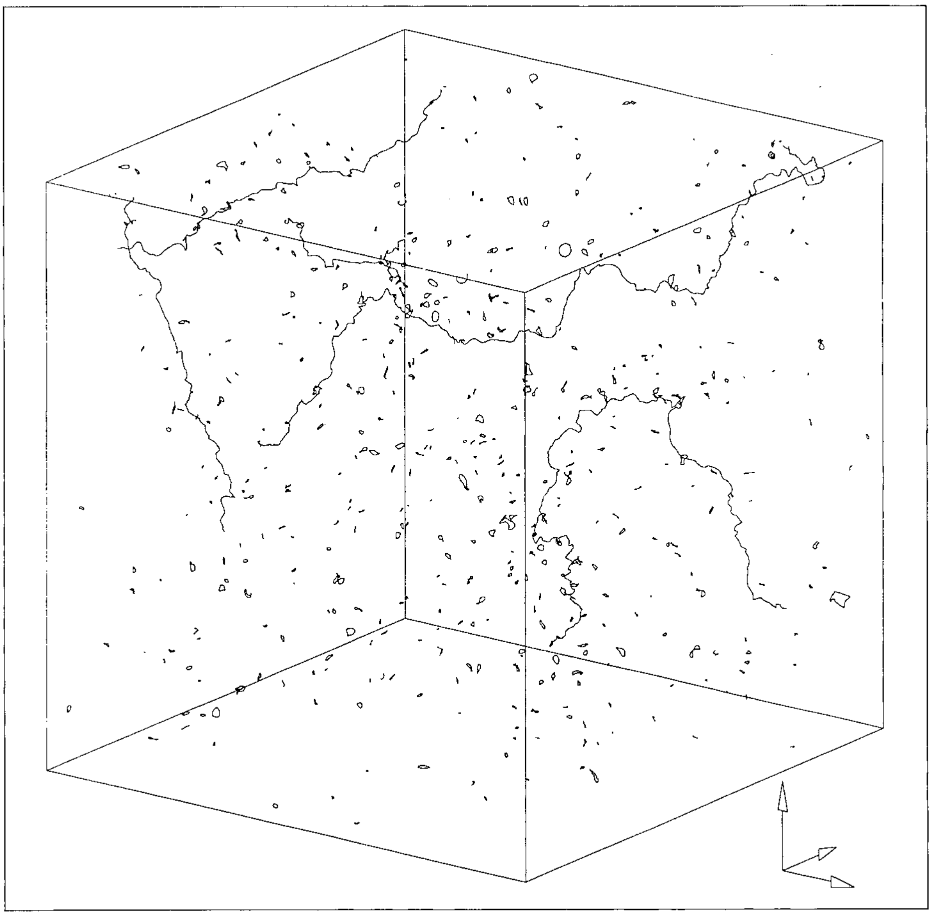
For cosmology, the standard hot Big Bang model seems to provide an accurate account of the history of the Universe from about $10^{-2}$ seconds after the bang when the temperature was 10 MeV until today, 10 to 20 billion years later, and a temperature of 2.7 K ($10^{-10}$ MeV). Extending our knowledge of the Universe to earlier times and higher temperatures requires knowledge about the fundamental particles (quarks, leptons) and their interactions at very high energies – thus cosmology and elementary particle physics are linked together.

The hot Big Bang model accounts for the expansion of the Universe today, the 2.7K cosmic microwave background radiation, and through primordial nucleosynthesis, the abundances of the light elements helium, deuterium, and lithium. The microwave background is a fossil record of the Universe from the time when matter and radiation decoupled (100,000 years after the bang). Its incredible isotropy (we observe the same temperature in all directions to better than one part in 10,000) and pure blackbody spectrum in all wavelengths are consistent with the standard cosmological picture. Our Universe is very smooth, homogeneous and isotropic on the scales of our observable horizon.

Therein lies the problem. Each evening, weather permitting, we can look at the night sky and see no evidence for isotropy and uniformity. Rather we see lots of structure. If the Universe started off as smooth as is indicated from the microwave background, what were the seeds that led to all this structure?

Actually the Universe is full of interesting structure on scales much larger than we can see with the naked eye. Recently astronomers have been devoting a great deal of

*Evolution of a cosmic string system. Note the large number of small loops and the few infinite strings stretching right across the box. The event horizon is about 3.5 times the side of the box. (Picture Shellard, Cambridge; and Allen, Wisconsin).*



time and effort to mapping the large-scale structure, and their initial results are fascinating. They indicate that galaxies and clusters of galaxies appear to be located on the apparent surface of huge bubbles nested together. Inside the bubbles are enormous voids, up to 150 million light years across, empty of all but a few galaxies. Galaxies form at the intersections of these bubbles, along filaments 200-300 million light years in length. On these scales the Universe is anything but smooth. Many cosmologists believe that there has not been enough time for gravity alone to push galaxies into these special positions. The bubbly structures are an imprint of processes that occurred at the earliest moments of creation, some $10^{-35}$ seconds after the Big Bang. It is in this era that the candidate seeds for the observed structure could be born; cosmic strings provide one such candidate.

The unification of the forces of nature is mediated through phase transitions, during which a particular symmetry, which previously unified the forces at a high temperature, is broken as the temperature falls below a critical value, leaving behind distinct separate forces. Experimentally this is seen in the weak and electromagnetic forces, around 250 GeV. Above this energy they are described together as one electroweak force, whereas at home (well below this energy) we do not associate turning on an electric light bulb (electromagnetic effect) with the radioactive decay of an atomic nucleus (weak force). The same principle applies at the GUT scale, $10^{15}$ GeV. Above this energy, the strong and electroweak forces are described as one. Cooling below the energy, a phase transition occurs as the symmetry unifying the forces is broken, and we are left with two distinct forces.

These GUT transitions could have important cosmological consequences. One comes from the fact that the transition would probably be 'flawed', as noted by a number of authors, including T. Kibble, A. Vilenkin and Y. Zeldovich. As the Universe expands and cools, the phase transition could leave regions of space trapped in the 'old' high energy phase (where the forces are still unified), surrounded by the 'new' low energy or broken phase. Such 'defects' are regularly seen at much lower energies in condensed matter physics.

They can take many forms; for example they could be pointlike (monopoles), sheetlike (domain walls) or one-dimensional stringlike objects, hence cosmic strings. Monopoles and domain walls are potential problems for cosmology, but cosmic strings appear to be ideal candidates to act as structure forming seeds. They are extremely thin, about $10^{-29}$ cm (the radius of an atomic nucleus is around $10^{-13}$ cm) but possess an immense tension (the 'old' phase of high energy still exists there) of $10^{36}$ Newtons.

Numerical and analytical calculations indicate that at birth the strings emerge as a tangled mesh; around 80% of the network is in long 'infinite' strings winding their way across the visible Universe and the rest is in closed loops (for topological reasons they must be either infinite or closed).

As the Universe expands, the string network begins to evolve. The long strings moving at close to the speed of light intersect each other as they stretch out, chopping off loops as they do so. Some of the loops chop themselves up further, others reconnect on to the long strings, but a picture emerges where the initial high density of infinite string diminishes as more and more loops are formed. Eventually a 'scaling solution' is reached where the density of long strings is a constant fraction (around $10^{-5}$) of the total energy density of the Universe.

The evolution equations are nonlinear and difficult to solve analytically, so most of the work is numerical with different groups independently running codes. The simulations differ on the exact evolution of the loops of string. One group reaches a scaling solution as with the long strings, but others appear not to reach this point. Because of the large amount of small-scale structure on the long strings, created each time they intercommute, they tend to find that most of their loops are close to the smallest possible allowed size. Although this difference needs to be accounted for, most of the string 'action' for galaxies comes from the long strings, an area where there is general agreement.

The strings lose energy primarily through gravitational radiation. As they oscillate rapidly, close to the speed of light, the loops radiate, shrink and eventually disappear. The detection (or lack of detection) of such radiation could well confirm or rule out the whole scenario.

The extreme tension of the long strings distorts the spacetime in which they live, causing a flat spacetime to become conical, the string passing through the vertex of the cone. This distortion causes particles moving by the string to be drawn in, effectively attracted behind it into wakes. All the long strings passing through a sea of particles will then leave wakes in their trail.

In these regions, where there is now an excess of matter, conditions are established for the formation of large-scale structure, as the massive particles become gravitationally bound to one another. As matter, both luminous and dark, is attracted into these regions, they leave behind empty spaces. The important question is whether this scenario can produce enough density perturbations to account for the observed distribution of galaxies, clusters and voids, as well as the bubbly nature of the distribution. This is a complicated issue, and groups are currently running large many-body codes to investigate these questions. It appears that the answer could depend critically on the scaling density of long strings. If it is too high then the strings are close together and the voids produced are not large enough.

Models which rely on physics from $10^{-35}$ seconds after the Big Bang are of little use if they do not leave some observationally verifiable signature. Fortunately cosmic strings leave some unique calling cards. A string situated between Earth and a faraway galaxy would bend the flow of light passing either side of it from the galaxy, due to the conical nature of the spacetime around the string. The result is that we would see two images of the galaxy instead of just one, an effect known as gravitational lensing.

There are a number of potential lensed quasars, but also many candidate lensing objects, not just strings. However a chain of galaxy pairs across the sky would be a strong signature of a string, indicating the lens was long and thin, not pointlike.

Perhaps the most convincing evidence for their existence would be from the unique signature they would leave in the Universe's microwave background. This background, the residual glow of the Big Bang itself, is extremely uniform, but a string moving rapidly through it would heat up the microwave slightly in the wake of the string, and cool it in front of the string. The microwave background would appear roughly $10^{-4}$ of a degree hotter on one side of the string than on the other. Maps of the microwave background would show this temperature jump as a line tracing the position and shape of the otherwise invisible string: a truly unique signature. It says a great deal for the expertise in this area of detection that such a small jump may soon be detectable, so cosmic strings should soon be confirmed or ruled out.

Particle physics is having a dramatic and exciting effect on cosmology. Many astronomers are trying to get valued telescope time to search for the exotic cosmic strings. There are other topologically-inspired candidates that have not been mentioned here, but are causing great interest as possible seeds for large-scale structure. They include superconducting cosmic strings and global textures. If discovered in astronomical observations, cosmic strings will provide substantial evidence for Grand Unified Theories.

*E.J. Copeland (Sussex, UK)*

# Brookhaven National Laboratory

## Electrical Engineer Research

A challenging opportunity exists within our Relativistic Heavy Ion Collider Project (RHIC). RHIC will be a world-class particle accelerator where researchers will study fundamental properties of matter under conditions that have not existed since the beginning of the universe. You'll be responsible for the design and testing of analog/digital ICs, as well as the operation, programming and maintenance of the Cadence CAD System. An MSEE and minimum of five years' experience in the design of analog integrated circuits are required. Proven experience in the simulation, layout and extraction of IC designs using an integrated CAD system is necessary.

Brookhaven offers a stimulating work environment and superior benefits which include 24 days' annual vacation. If you would like to be considered for this position, please forward your resume, including salary requirements, to: Nancy L. Sobrito, Position #NS0946, Brookhaven National Laboratory, Associated Universities, Inc., Personnel Division, Bldg. 185, Upton, LI, NY 11973.

## Mechanical Engineer NSLS

The National Synchrotron Light Source (NSLS) Department at Brookhaven National Laboratory has a senior position open for an engineer with an advanced degree and a minimum of ten years' experience in the area of particle accelerators. Knowledge of magnet design and fabrication, and ultra-high vacuum engineering is desirable. The successful candidate will be responsible for overseeing general mechanical engineering, including the design room and staff shops within the NSLS Department.

Applicants should submit a curriculum vitae and the names of three references to: Dr. E.B. Forsyth, Search Committee Chair, Accelerator Development Department, Building 1005S, Brookhaven National Laboratory, Associated Universities., Inc., Upton, L.I., NY 11973. Equal opportunity employer M/F/H/V.

BROOKHAVEN
NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC

**University of Alberta**
**Edmonton**

# Faculty Positions in Particle Physics

The Department of Physics invites applications for two faculty positions in Experimental Elementary Particle Physics. Over the next few years we plan to build up a strong group in this area and are looking for outstanding individuals with proven ability and a demonstrated potential for excellence in teaching and research.

We specifically seek candidates now for tenure-track positions at the Assistant Professor level. Appointment of exceptional candidates at a more senior level will be considered.

The Assistant Professor salary range is from $36,910 to $53,374 per annum (under review), depending upon experience.

In accordance with Canadian Immigration requirements, this advertisement is directed to Canadian citizens and permanent residents.

Send curriculum vitae and the names of three (3) referees, by September 1, 1991 to:

**Chairman, Search Committee**
**Department of Physics**
**University of Alberta**
**Edmonton, Alberta T6G 2J1**

*The University of Alberta is committed to the principle of equity in employment. The University encourages applications from aboriginal persons, disabled persons, members of visible minorities, and women.*

ALBERT-LUDWIGS-UNIVERSITÄT
FAKULTÄT FÜR PHYSIK

**Albert-Ludwigs-Universität Freiburg**

In der Fakultät für Physik Freiburg (Deutschland) ist eine

**Professur (C 4)**
**für Experimentalphysik**

mit dem Schwerpunkt Hochenergiephysik wieder zu besetzen. Zusammenarbeit in Experimenten im Bereich der Verbundforschung der Physik der Elementarteilchen ist erwünscht.

Volle Beteiligung an der Lehre in der Fakultät und an der akademischen Selbstverwaltung wird erwartet.

Habilitation oder eine gleichwertige wissenschaftliche Qualifikation wird vorausgesetzt.

Die Universtät Freiburg strebt eine Erhöhung des Anteils von Frauen in Forschung und Lehre an und fordert daher entsprechend qualifizierte Wissenschaftlerinnen ausdrücklich auf, sich zu bewerben.

Bewerbungen mit Lebenslauf, Darstellung des beruflichen und wissenschaftlichen Werdegangs, Schriftenverzeichnis und Angaben über die bisherige Lehrtätigkeit sind zu richten bis 31.08.1991 an den

**Dekan der Fakultät für Physik,**
**Hermann-Herder-Str. 3, 7800 Freiburg/Brsg.**

# People and things



*HEPAP*

*The US High Energy Physics Advisory Panel (HEPAP) this year is: Stanley Wojcicki (Stanford, Chairman), Edmond Berger (Argonne), Karl Berkelman (Cornell), Alex Chao (SSC), Jonathan Dorfan (SLAC), Jerome Friedman (MIT), Mary K. Gaillard (Berkeley), Robert Gluckstern (Maryland), Laurence Littenberg (Brookhaven), Pierre Ramond (Florida), Don Reeder (Madison, Wisconsin), Melvyn Shochet (Chicago), Arthur Smith (Princeton), Kenneth Stanfield (Fermilab), Mark Strovink (Berkeley), Michael Witherell (Santa Barbara).*

*On people*

*Rich Orr has retired from Fermilab after a 21-year career at the Laboratory covering many different aspects of management – science, R&D, accelerator construction and operation, support, and administration – in a series of key posts under successive Fermilab Directors.*

*New members of the US National Academy of Science include Mary K. Gaillard of Berkeley and Toichiro Kinoshita of Cornell, while Richard Dalitz of Oxford becomes a Foreign Associate.*

*Georg Bollen of Mainz receives the 1991 Mattauch-Herzog Prize of the German Working Group for Mass Spectrometry for his thesis work at CERN's ISOLDE on-line mass separator involving very accurate isotope mass measurements.*

*DESY Research Director*

*Albrecht Wagner becomes DESY Research Director, taking over from Paul Söding, who returns to active research. Wagner has been a member of the OPAL collaboration at CERN, where he had worked earlier on hyperon and kaon decays. He has also carried out heavy ion studies at Berkeley, turning later to DESY's DORIS ring and subsequently the JADE group at the PETRA ring.*

*Prix Scientifique UAP*

*Sergio Ferrara of CERN's Theory Division has been awarded the Prix Scientifique UAP for his pioneer contributions to the theory of supergravity.*

*D.Z. Freeman (MIT) and P. van Nieuwenhuizen (Stony Brook) write: 'It is a great pleasure to con-*

*The traditional Bernard Gregory Lectures at CERN and in Paris were given this year by distinguished mathematician Benoit Mandelbrot of Yale and IBM's T.J. Watson Research Center on 'Fractals in physics – from fraction dimensions to negative dimensions'. Mandelbrot's pioneer fractal ideas have stimulated a whole new area of applied mathematics whose characteristic vivid computer graphics are always admired.*

*(Photo Maurice Jacob)*

gratulate our coauthor and friend Sergio Ferrara. In 1976, after the three of us invented supergravity, the gauge theory of supersymmetry, enormous activity followed. Within a month, S. Deser and B. Zumino found a simpler reformulation of the results. The extended and conformal supergravities were constructed, and a tensor calculus for general supergravity models established.

It was soon realized that only in supergravity models (but not rigidly supersymmetric models) can one spontaneously break supersymmetry without creating an unacceptably large cosmological constant. The general form of supersymmetric extensions of the Standard Model was found, exhibiting both gauge and supersymmetric spontaneous symmetry breaking, with gravitinos acquiring a mass through the super-Higgs effect, and mass relations between particles and their superpartners were derived. In many of these developments, Ferrara played a major role. He also coinvented the rigidly supersymmetric gauge theories and started many active international collaborations.'


▲ Participants at the 'Electronics for Future Colliders' conference held 22-23 May at the HQ of electronics suppliers LeCroy, Chestnut Ridge, New York, to look at electronics prospects for the coming generation of proton and ion colliders. The optimistic mood of the meeting was reflected by one participant, who, after surveying the already remarkable electronics achievements of recent years, said 'you ain't seen nothing yet!'.

## Third European Particle Accelerator Conference

The Third European Particle Accelerator Conference (EPAC92) will take place in the reunified city of Berlin, at the Technical University of Berlin, from 24-28 March 1992. As is now usual for EPAC, the programme will provide a comprehensive overview of research, technol-

A special symposium, held at CERN on 2-3 May in memory of distinguished CERN theorist John Bell who died on 1 October last year, attracted prominent physicists from all over the world and provided a rarely encountered level of scientific erudition, in keeping with the lofty standards set by John Bell himself. The proceedings were introduced by Sir Rudolf Peierls, to whose Birmingham school the young Bell came in 1953 to learn about modern theoretical physics, seen here (left) at the symposium with spontaneous symmetry-breaking pioneer Tom Kibble of London's Imperial College.

(Photo CERN HI2.5.91)

# USA advertisements in CERN COURIER

**Format A4** **Monthly publication**

All advertisements are published in both English and French editions. Second language versions accepted without extra charge.

**Advertising Rates** (US Dollars)

| *Insertions* | *Full* (7½ x 10½) | *Half* (7¼ x 5⅛) | *Half* (3½ x 10½) | *Quarter* (3½ x 5⅛) |
|---|---|---|---|---|
| 1 | 1625 | 960 | 960 | 561 |
| 3 | 1558 | 905 | 905 | 520 |
| 5 | 1500 | 855 | 855 | 485 |
| 10 | 1420 | 790 | 790 | 450 |

**Color Rates**

| | |
|---|---|
| Each additional color | $ 1000 |
| Half page color | $ 1500 |
| Covers 2 and 3 | $ 1200 (per color) |
| Cover 4 (back) | $ 1300 (per color) |

***These prices include no entitlement to special placing.***

| | |
|---|---|
| Publication date | 1st of month of cover date |
| Closing date for positive films and copy | 1st of month preceding cover date |
| | The cost of making films and of translation for advertisements are charged in addition ($ 150 US). |
| | Advertisements cancelled after 1st of month preceding cover date will be invoiced. |
| Screen (offset) | 160 |

These rates are effective for the year 1991.

**Inquiries for USA and Japan:**
**Yvette M. Perez, Gordon and Breach Science Publishers, Frankford Arsenal, Bldg 110, 5301 Tacony Street, Box 330, Philadelphia, PA 19137**
**Tel.: + 1 (215) 537 7262 Fax: + 1 (215) 537 0711**
***Inquiries for Europe*** **please see page III.**

## GENERAL ENGINEER/PROJECT MANAGER

**The U.S. DEPARTMENT OF ENERGY** currently has a vacancy in the Batavia Area office located at Fermi National Accelerator Laboratory site for a degreed individual who will serve as Project Manager for the Fermilab Main Injector construction project which has been designated a DOE major systems acquisition project.

The Project Manager is responsible for day to day management of the estimated $197 million project, scheduled to begin in FY 1992 and which will take approximately 4-5 years to complete. This project includes the construction of a two mile underground enclosure for relocating the Fermi Main Ring Accelerator and associated technical components.

Candidates must have an engineering degree with extensive knowledge of construction and facility management fields, particularly the construction of unique state-of-the art research facilities. The position is graded as GM-15 in the Federal government's pay system. Salaries range from the low 60's to the low 80's. Competitive benefits package includes relocation allowance.

If you are interested in being considered, send your resume or Federal application form (SF 171) no later than July 31, 1991 to:

**U.S. DEPARTMENT OF ENERGY**
*Chicago Operations Office*
*Federal Personnel Branch/Ms. Lyon*
*9800 Cass Avenue*
*Argonne, Illinois 60439*

EQUAL OPPORTUNITY EMPLOYER/U.S. CITIZENSHIP REQUIRED

ogy and special applications in the field of accelerators, this time with particular emphasis on synchrotron radiation sources and technology. (A special feature will be a session entirely devoted to developments in the field of compact synchrotron radiation sources and their applications.) Parallel sessions will be kept to the minimum. An industrial exhibition is also planned.

The participation of members of the whole community, European and non-European, is welcomed, and that of young scientists and students joining the field in particular. A limited amount of financial support is set aside for the latter and applications should be made to the Chairman of the Local Organizing Committee. The deadline for the receipt of abstracts is 30 September.

Further information from Prof. H. Henke, Chairman of the Local Organizing Committee, Technical University of Berlin, Institut für Theoretische Elektrotechnik, Einsteinufer 17, D – 1000 Berlin 10,
Tel. (004930) 314 22490,
Fax. (004930) 314 22284.

## CEBAF meeting

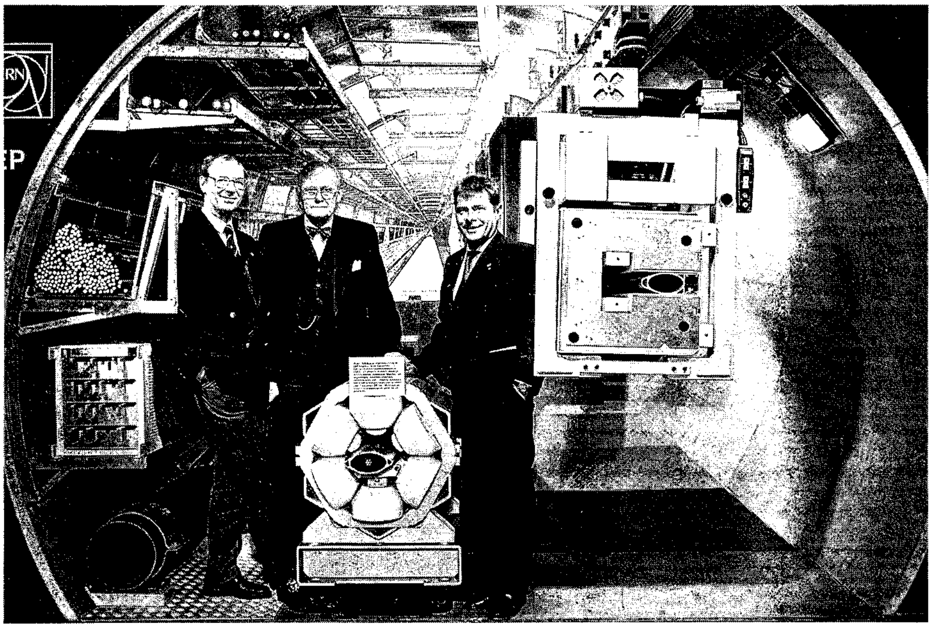
An Accelerator Instrumentation Workshop will be held from 28-31 October 28-31 at CEBAF, Newport News, Virginia, to study engineering aspects of hardware devices and systems employed in particle accelerators for beam diagnostics and control. Information from Cela Callaghan, CEBAF Center, MS 12A, 12000 Jefferson Avenue, Newport News, Virginia 23606, USA;
tel: (804) 249-7397,
fax: (804) 249-7398,
bitnet APD at CEBAF

## Arne Lundby 1923-1991

Arne Lundby, who died in March, came to CERN in 1956 after starting his career in Enrico Fermi's Chicago group. An ingenious experimenter, he collaborated in an important series of pioneer CERN hadron dynamics studies, including the pion-proton 'backward peak' and the famous proton-antiproton 'dip'. Later he turned to heavy quark spectroscopy, where he continued to play an active role after his 'retirement' in 1988. He was also a gifted teacher who liked to keep in contact with his students. He was a Professor at Oslo University and a Member of the Norwegian Academy of Sciences.

CERN's travelling exhibition visited Denmark for the first time, installed at the Tycho Brahe Planetarium in Copenhagen. Seen here in front of a mock-up of CERN's LEP tunnel are, left to right, Egil Lillestol of CERN, Thor A. Bak of the University of Copenhagen, and Director of the Planetarium Nils Armand Pedersen.

(Photo Peter Thernvig)



## LHC News

CERN is launching LHC News, a new publication introducing the Large Hadron Collider being planned for the LEP tunnel. LHC News will be published, in English only, several times a year. To get on the mailing list contact Monika Wilson at CERN, 1211 Geneva 23, Switzerland, fax (+41 22) 782 1906, bitnet monika at cernvm.cern.ch

# How to visit CERN

# Comment visiter le CERN

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 à 14 h. 30. Elles durent environ trois heures et sont gratuites. La limite d'âge minimum imposée est de seize ans.

Please write or call: / Ecrire ou téléphoner:

**CERN**
**Visits Organization / Organisation des visites**
**1211 GENEVA 23 Switzerland**
**Tel. 022/767 40 52 or/ou 767 41 02**
**Telex 419 000 CER**

## Advertisements in CERN COURIER

**Format A4** **Monthly publication**

All advertisements are published in both English and French editions. Second language versions accepted without extra charge.

| Space (page) | Actual size (mm) width by height | Cost per insertion (Swiss Francs) | | | |
|---|---|---|---|---|---|
| | | 1 insertion | 3 insertions | 5 insertions | 10 insertions |
| 1/1 | 185 × 265 | 1980 | 1900 | 1830 | 1730 |
| 1/2 | 185 × 130<br>90 × 265 | 1170 | 1100 | 1040 | 960 |
| 1/4 | 90 × 130 | 690 | 630 | 590 | 550 |

***These prices include no entitlement to special placing.***

Supplement for:
— one additional colour 1500 SwF
— Covers:
Covers 2 and 3 (one colour) 2000 SwF
Cover 4 (one colour) 2500 SwF
Publication date 1st of month of cover date
Closing date for positive films and copy 1st of month preceding cover date
The cost of making films and of translation for advertisements are charged in addition.
Screen (offset) 60 or 54 Swiss (150 English)
Advertisements cancelled after 1st of month preceding cover date will be invoiced.

These rates are effective for the year 1991.

*Inquiries for Europe:*

**Micheline FALCIOLA / CERN COURIER – CERN**
**CH-1211 Geneva 23 Switzerland**
**Telephone: 022/767 41 03** **Telex 419 000 CER CH**
**Telefax 022/782 19 06**

***Inquiries for the rest of the world:* please see page III.**

**ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE**

**EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH**

# MOVING?

Please remember to let us know in good time. All notices of change of address must be accompanied by old and new addresses. (Include label from magazine wrapper.)

Any enquiries regarding subscriptions should be addressed to:

**Monika WILSON**
**CERN COURIER/CERN**
**1211 Geneva 23 Switzerland**