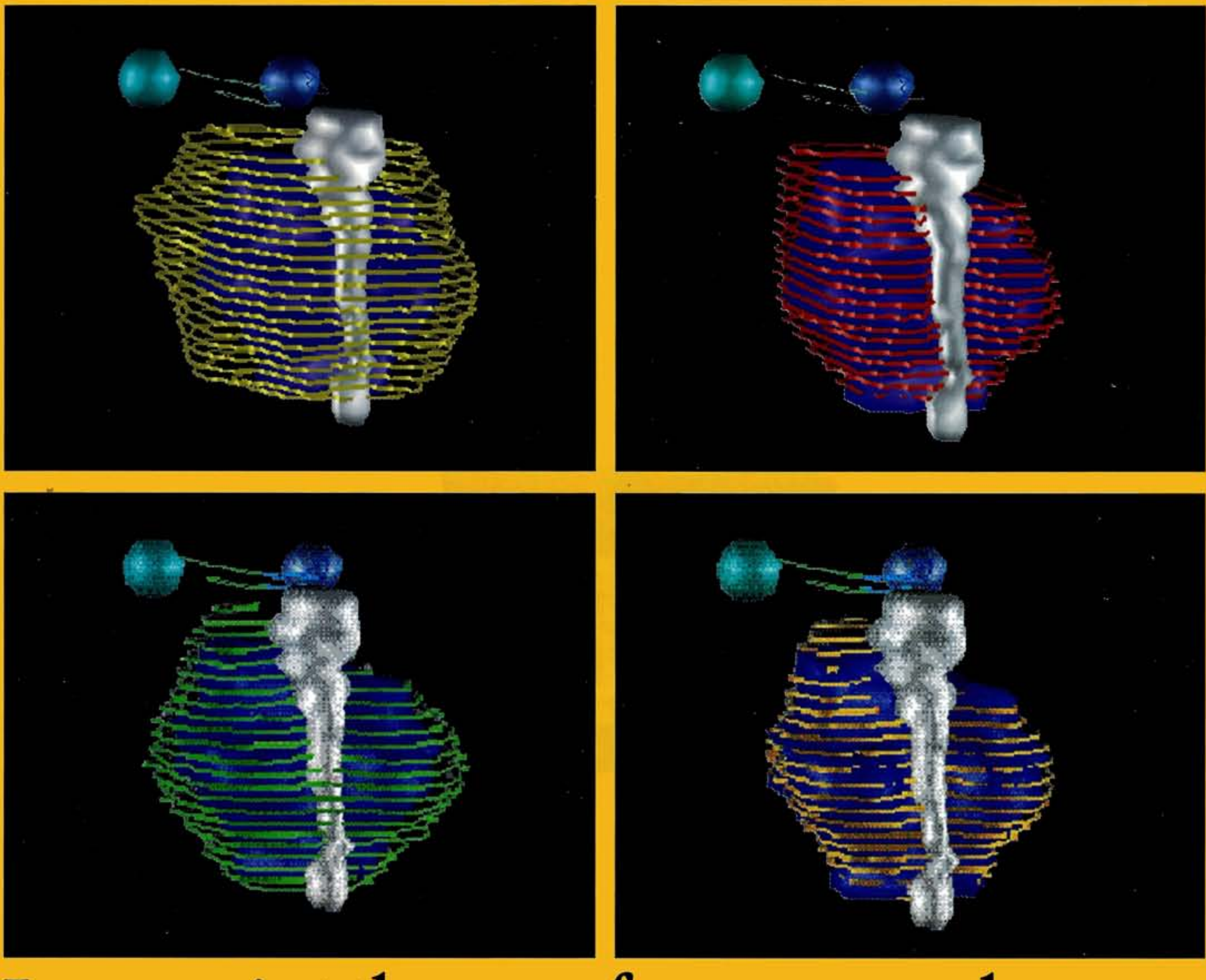
INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

CERN COURIER

VOLUME 42 NUMBER 4 MAY 2002



Ions point the way for cancer therapy

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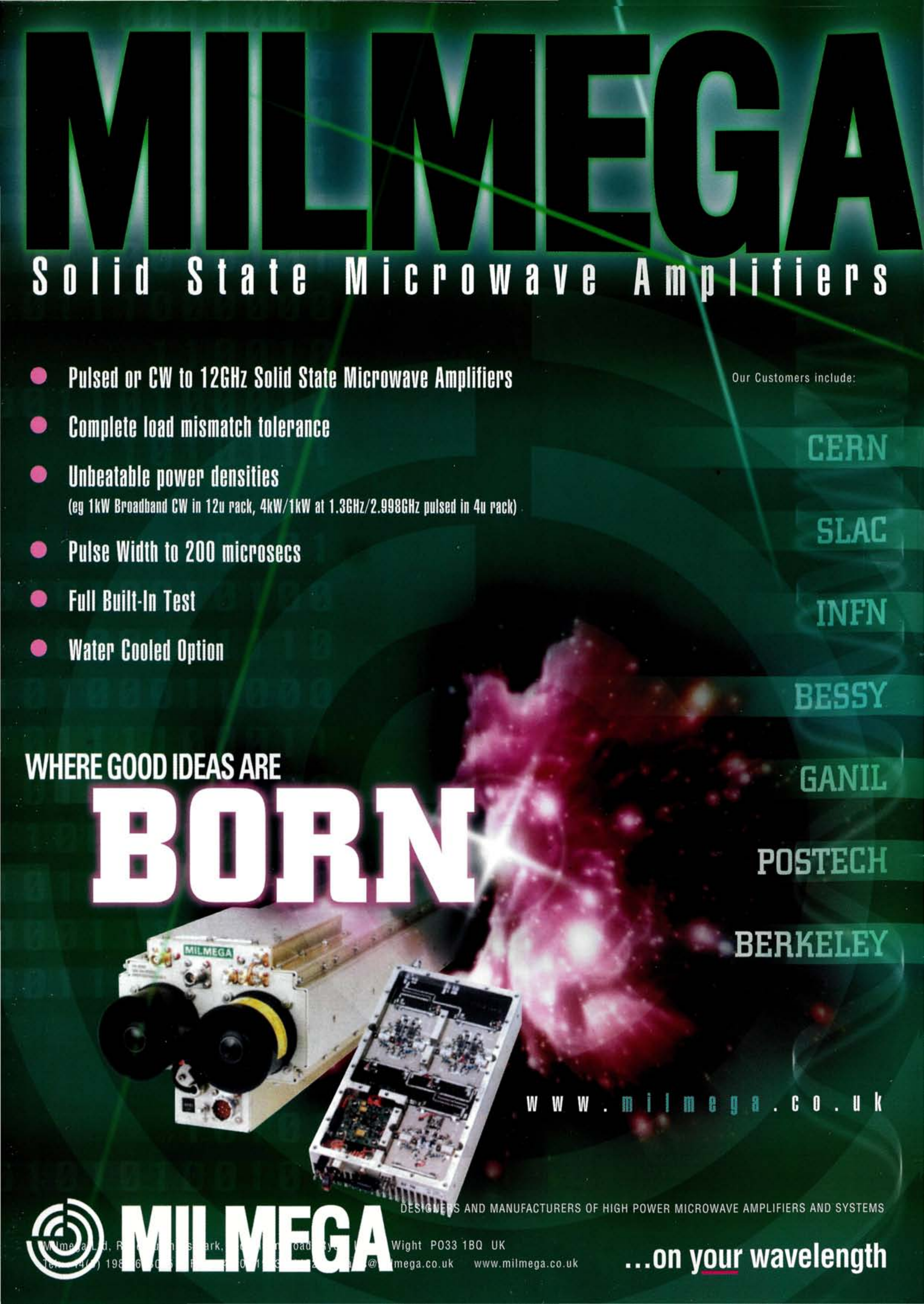
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CERN prepares for the LHC p5

Novel material mimics nature p11

Frascati appoints director p36

Cover: Light ions offer clear advantages for conformal treatment of certain forms of cancer. The top two images show a photon treatment plan for a brain tumour (purple), with the dose indicated by the cage-like structure of lines. Regions beyond the tumour are better spared in the lower two images, which illustrate the corresponding treatment plan for carbon ions (p29).

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

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Instrumentation for Measurement & Control

Magnetic Field

THM-7025

Application	Product	Specifications: Range	Resolution	Bandwidth
Linear sensing. Non-contact measurement of position, angle, vibration. Small size, low power.	CYH-22 1-axis Hall element	± 20mT	± 4μT	DC to 10kHz
	2D-VD-11 2-axis Hall element	User option	± 30μT	DC to 10kHz
	3D-H-30 3-axis Hall element	User option	± 100μT	DC to 10kHz
High sensitivity and accuracy for low fields. Site surveys and monitoring. Active field cancellation.	MAG-01 1-axis Fluxgate Teslameter	± 2mT	± 0.1nT	DC to 10Hz
	MAG-03 3-axis Fluxgate Transducer	± lmT	± 0.1nT	DC to 3kHz
Linear measurement. Feedback control. Mapping, quality control.	YR100-3-2 Hall Transducer, 1-axis	± 2T	± 12μT	DC to 10kHz
	3R100-2-2 Hall Transducer, 3-axis	± 2T	± 12μT	DC to 10kHz
Hand-held, low-cost, 3-axis for magnet and fringe fields.	THM 7025 Hall Teslameter, 3-axis	± 2T	± 10μT	DC
Precision measurement and control. Laboratory and process systems.	DTM-133 Hall Teslameter, 1-axis	± 3T	± 5μT	DC to 10Hz
	DTM-151 Hall Teslameter, 1-axis	± 3T	± 0.1μT	DC to 3Hz
Calibration of magnetic standards. Very high resolution and stability (total field).	2025 NMR Teslameter (total field)	± 13.7T	± 0.1μT	DC
	FW101 NMR Teslameter (total field)	± 2.1T	± 0.5nT	DC
Precision flux change measurement.	PDI 5025 Digital Voltage Integrator	40 V.s	±2E-8V.s	1ms to 2^{23}ms

Field units: 0.1nT = 1μG, 100nT = 1mG, 100μT = 1G, 1mT = 10G, 1T = 10,000G

Electric Current (isolated measurement)

IPCT

Application	Product	Specifications: Range	Resolution	Bandwidth
High sensitivity for low currents, currents at high voltage, differential currents.	IPCT Current Transducer	± 2A	± 10μA	DC to 4kHz
	MPCT Current Tranducer	± 5A	± 10μA	DC to 4kHz
Linear sensor for low-noise, precision current regulated amplifiers and power supplies.	864I-2000 Current Transducer	± 2000A	<4ppm	DC to 300kHz
	866-600 Current Transducer	± 600A	<4ppm	DC to 100kHz
Instruments for calibration, development, quality control.	860R-600 Current Transducer	± 600A	<5ppm	DC to 300kHz
	860R-2000 Current Transducer	± 2000A	<8ppm	DC to 150kHz
	862 Current Transducer	± 16kA	<5ppm	DC to 30kHz
Passive sensor for rf and pulse current.	FCT Fast Current Transformer	1:5 to 1:500	limited by following amplifier	150Hz to 2GHz
Passive sensor for pulse charge.	ICT Integrating Current Transformer	± 400nC	± 0.5pC	1μs to<1ps

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CNA

FTR

Application	Product	Specifications: Range	Resolution	Bandwidth
High resolution Input/Output modules that can be placed locally at the transducer or controlled unit. High Voltage and/or high noise environments. PC, PCI, VME, CAMAC host computer options.	DNA for DeviceNet	± 100mV to ± 10V	16 bit	DC to 150Hz
	CNA with fiber optic communication	± 100mV to ± 10V	16 bit	DC to 150Hz
	FTR fiber optic to RS-232-C			50 to 200kB

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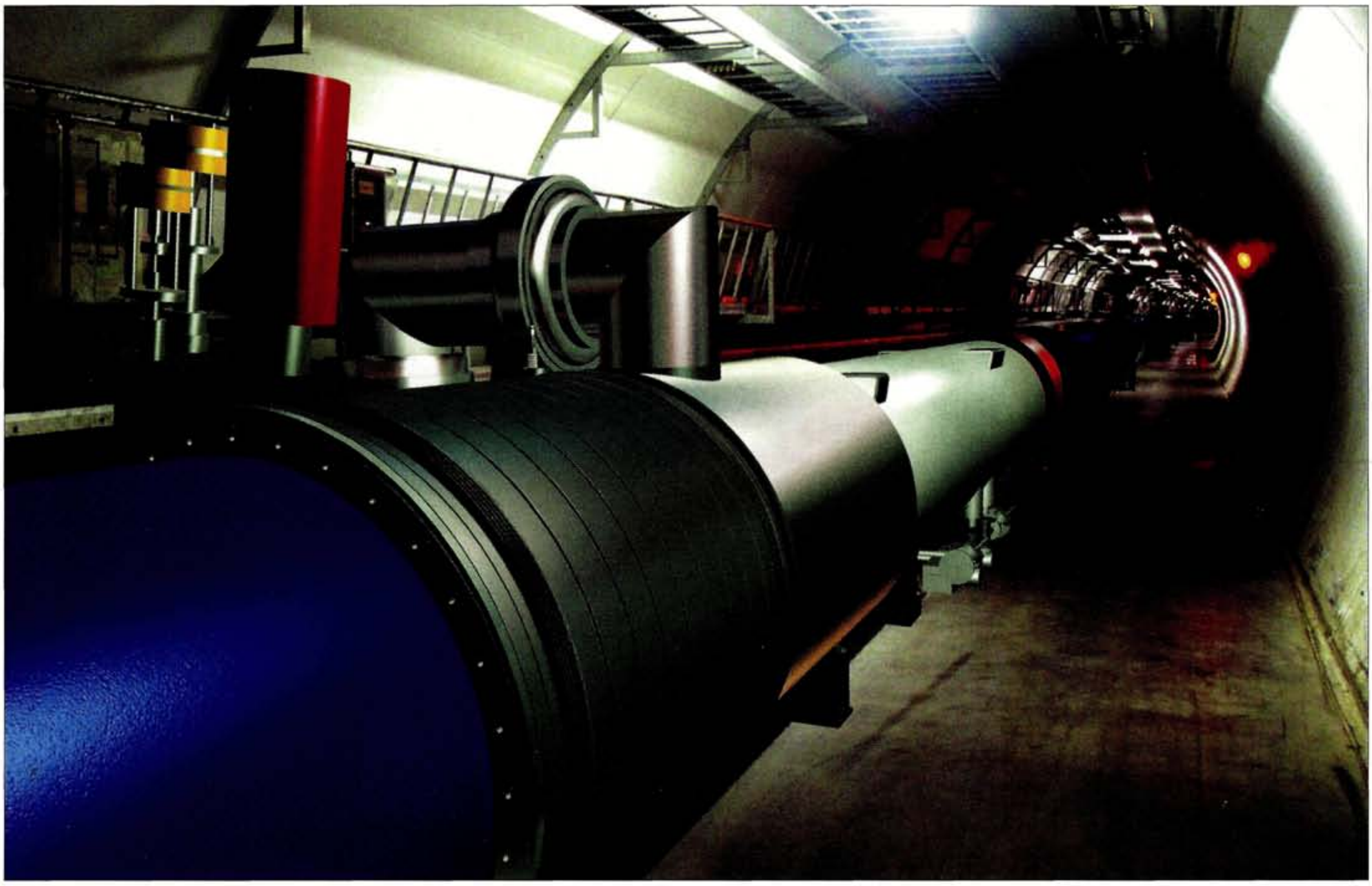
CERN

CERN prepares to focus on the LHC



CERN is preparing to focus more of its resources on the Large Hadron Collider, scheduled for completion in 2007.

At the March meetings of CERN's governing body, Council, the laboratory's management presented preliminary ideas for absorbing the cost overrun for the Large Hadron Collider (LHC) project identified last year. These focus more of the laboratory's resources on the LHC, with compensatory reductions being made in other scientific programmes.

Under the management's proposals, the running time for CERN's existing accelerators could be reduced by up to 30% each year until the LHC starts up. The largest accelerator, the Super Proton Synchrotron, which provides test beams for the LHC experiments and supports the current high-energy programme, would not run at all in 2005. Other potential areas for savings have been identified in long-range research and development, LHC computing, the fellows and associates programme (CERN fellowships are fixed-term appointments for young people; associateships allow sabbatical periods to be spent at CERN later on), and general overheads. Savings could also be made in services contracted in to the laboratory. The total amount to be redirected to the LHC is expected to amount to SwFr 500 million (€341 million).

The plan envisages LHC start-up in 2007 and full payment for the new facility by 2010 with no budget increase. CERN's director-general, Luciano Maiani, nevertheless urged Council to consider an increase in the laboratory's budget over the medium term. This would allow the LHC to be financed by 2009 and would enable limited research and development to continue, standing the laboratory in good stead for the longer term.

CERN's staff association, along with French and Swiss unions representing employees of companies working on the CERN site, also made their opinions known by presenting letters to Council. The staff association argued that in its opinion, more resources are needed to complete the LHC. The unions expressed their concerns over the impact of cutbacks at CERN on local employment.

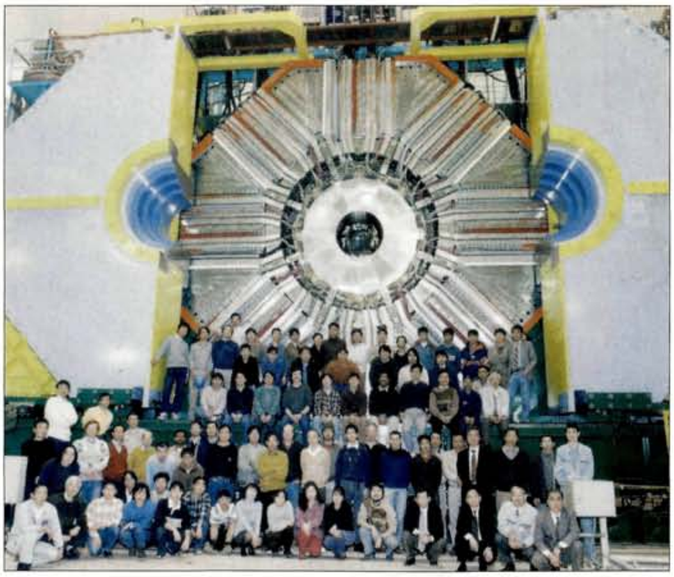
A decision on the management's proposals will be taken at the next meeting of Council in June. By then, the report of an external review committee set up in November (*CERN Courier* January/February p4) will be ready, and management proposals will also be complete. In the meantime, Council agreed to release SwFr 20 million from the 5% of the laboratory's 2002 budget initially held back pending resolution of LHC funding issues. In a separate initiative, the Swiss delegation said that Switzerland would advance SwFr 90 million to CERN over the next three years, to be deducted from later contributions.

B DECAYS

CP violation enters a new era

New results show that CP violation in the decays of particles containing heavy quarks is becoming precision physics. These studies could soon lead to new insights into quark physics, in particular the mystery of how a universe apparently composed only of matter emerged from a Big Bang which initially produced matter and antimatter in equal amounts.

What physicists call CP violation ultimately distinguishes matter from antimatter. If physics is CP-symmetric, the behaviour of left-handed particles is the same as that of right-handed antiparticles, and vice versa. Since 1964 physicists have known that this convenient symmetry does not quite work. The difference between matter and antimatter is not simply a case of human convention.



The Belle detector at the KEKB particle factory in Japan has seen new evidence for CP violation in the decays of B particles.

Why CP violation happens is still a mystery, but one early outcome – when only three types of quark were known – was the realization that whatever the explanation of CP violation, it requires at least six different types of quark. In a world containing only three or even four kinds of quark, there would be no way of distinguishing matter from antimatter.

For some 35 years, CP violation experiments were confined to the study of neutral kaon particles (containing the strange quark). Only this physics arena provided the right conditions for seeing the small effect (a few parts per thousand). However, in principle CP violation could also be visible with any quark-based neutral particle which is difficult to distinguish from its antiparticle.

Accumulated results suggested that the best place to look would be the decays of the neutral B particles, containing the fifth or "b" quark. New high-energy B-factories – the electron–positron colliders PEP-II and KEKB – were constructed at the Stanford Linear Accelerator Center (SLAC) and the Japanese KEK laboratory respectively, to provide optimal conditions for this new physics. At these machines, major new experiments – Belle at KEKB and BaBar at PEP-II – provided their first tentative results in 2000, which were updated last year (*CERN Courier* April 2001 p5).

Between them, these two experiments have gone on to accumulate some 100 million examples of B pairs. For B production, the machines are tuned to the energy region at and around the upsilon 4S resonance, with the best CP violation hunting ground being the decay of a neutral B particle into a J/psi and a neutral kaon.

The underlying quark transitions responsible for CP violation are described by a triangle in a special parameter space. The larger the area of this triangle, the greater the CP violation, and measurements aim to measure the angles and sides of the triangle.

The first angle to be measured, β, is conventionally expressed as $\sin 2\beta$. Now BaBar sees $\sin 2\beta$ as $0.75 \pm 0.09 \pm 0.04$ (previously $0.34 \pm 0.20 \pm 0.05$), and Belle sees $0.82 \pm 0.12 \pm 0.05$ (previously $0.58 + 0.32 - 0.34 + 0.09 - 0.10$). B particle CP violation definitely happens, and the effect is larger than the earlier suggestions.

In addition, Belle at KEKB has seen CP violation in the decay of neutral B mesons into two charged pions – the decay rate of the neutral B particle via this route is not the same as that of the neutral B antiparticle. This is analogous to the signal seen at Brookhaven in 1964 in the decays of neutral kaons which provided the first evidence for CP violation.

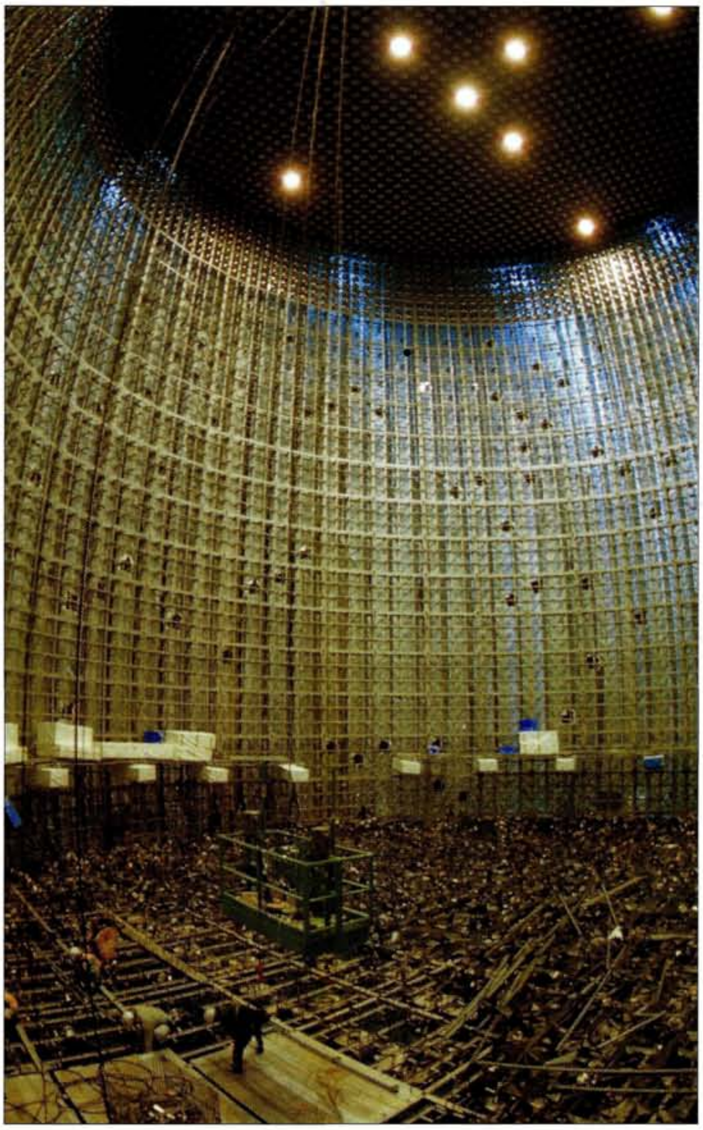
Vital to these new measurements is the performance of the electron–positron colliders at KEK and SLAC. This performance is usually expressed as luminosity, which is proportional to the rate of electron–positron collisions. KEKB's luminosity has reached a remarkable 7.25×10^{33}, not far from the ambitious 10^{34} design luminosity, but already the highest collider luminosity ever reached anywhere. PEP-II has exceeded 4.6×10^{33}. Improving on these performances requires hard work and ingenuity, particularly as they are already not far from fundamental limitations (the "beam–beam limit"), but machine physicists remain optimistic when such creditable performances have been attained so soon after commissioning such complicated new machines.

The runs are continuing, and the results will probably be updated this summer.

NEUTRINOS

Superkamiokande to be rebuilt this year

The rebuilt Superkamiokande detector's photomultiplier tubes will be encased in bubbles made of acrylic and fibre-reinforced plastic to prevent shockwave propagation should a tube implode.



By April, the Superkamiokande clean-up was well under way. All the debris on the side walls had been removed, and people were at work on the bottom layer.

Following an accident last November at the Superkamiokande detector in Japan, the experiment's spokesman, Yoji Totsuka, vowed that the detector would be rebuilt (*CERN Courier* December 2001 p5; January/February p6). Investigations carried out since then have shown a way to prevent such accidents happening again, and rebuilding is now under way.

Superkamiokande is a huge water Cherenkov detector in which some 11 200 photomultiplier tubes view 50 000 t of pure water 1000 m underground. It seems that shockwave propagation from a single tube imploding could have sparked off a chain reaction that destroyed the detector. The short-term solution is to encase the tubes in 13 mm acrylic plus fibre-reinforced plastic bubbles, which would contain the implosion. The recovery plan is to deploy some 47% of the full complement of tubes before the end of the year, allowing operation to resume with the K2K neutrino beam, sent from the KEK high-energy physics laboratory, early next year. Tubes will be deployed in such a way as to maximize the effectiveness of the detector for observing the K2K beam.

For the longer term, the Superkamiokande collaboration will be carrying out research and development into photomultiplier technology, studying aspects of glass shape and structure. The detector is scheduled to be fully rebuilt by 2007, in time for commissioning of a neutrino beam to be sent from the new Japan Hadron Facility (*CERN Courier* October 2000 p23).

US

US nuclear scientists chart a new course

More than a year after being asked to study the opportunities and priorities for US nuclear physics research in the coming decade, the Department of Energy/National Science Foundation Nuclear Science Advisory Committee (NSAC) has recently submitted its latest long-range plan for the field. This is the fifth in an influential series of reports that NSAC has prepared on a regular basis since 1979. The US nuclear physics community is a diverse one which has its roots in nuclear structure studies, but which has branched out in recent years to address questions at the forefront of a number of related areas including nucleon structure, nuclear astrophysics, the nature of hot nuclear matter and searches for physics beyond the Standard Model. As part of the planning process, town meetings sponsored by the Division of Nuclear Physics of the American Physical Society for major subfields have provided a forum for presenting new ideas. A long-range plan working group then drafted overall priorities, taking into account current developments in nuclear physics on the world scene.

Facilities like Brookhaven's Relativistic Heavy-Ion Collider are positioning US nuclear physics well for the future.

Recent investments in facilities such as the Relativistic Heavy-Ion Collider (RHIC) at Brookhaven, CEBAF at Jefferson Laboratory and the newly upgraded National Superconducting Cyclotron Laboratory at Michigan State University have positioned the field well for the future. Because of this, the plan concludes that "the highest priority of the nuclear science community is to exploit the extraordinary opportunities for scientific discoveries made possible by these investments." Unfortunately, as with many branches of the physical sciences, funding for nuclear physics in the US has not kept pace with inflation in recent years. The plan's first recommendation therefore calls for a 15% increase in base funding, which would allow more effective operation of accelerator facilities, increase support for university researchers, and revitalize the nuclear theory programme.

Looking further into the future, the plan recommends investment in areas where capabilities in the US can be dramatically improved, providing significant new capabilities on the international scene. The highest priority for major new construction is given to the Rare Isotope Accelerator – RIA (*CERN Courier* March p15). This will provide higher intensities of radioactive beams than any present or planned facility worldwide, and will be used primarily for nuclear structure and astrophysics studies, with opportunities also for experiments on fundamental symmetries and in a number of applied areas.

Next, the plan recommends the construction of the world's deepest underground science laboratory, noting that: "This laboratory will provide a compelling opportunity for nuclear scientists to explore fundamental questions in neutrino physics and astrophysics." The plan also recommends the upgrade of CEBAF to 12 GeV by the addition of additional, high-field, superconducting cavities (p19).

Finally, the plan endorses a number of smaller initiatives, including R&D towards an electron–ion collider that could be integrated into the RHIC facility. The scientific case for such a facility is currently under active consideration within the nuclear physics community.

The full report can be found at http://www.sc.doe.gov/production/henp/np/nsac/lrp.html.

MEETING

ICFA sets up international committee for linear collider project

At a meeting held in February at the Stanford Linear Accelerator Center, the International Committee for Future Accelerators (ICFA) announced that an international steering committee would be set up to promote a 500 GeV linear collider. This move reflects a growing consensus in the global high-energy physics community that such a machine should be the next major facility to follow CERN's Large Hadron Collider. Reports published by the Asian and European Committees for Future Accelerators and the US High-Energy Physics Advisory Panel all recommended a 500 GeV electron–positron linear accelerator, designed, built and operated as a fully international collaboration. The committee will be made up of members from separate Asian, European and North American steering groups, with more members from other countries. Its first meeting will be held during the 31st International Conference on High Energy Physics in Amsterdam this July.

Members of the ICFA meeting at Stanford in February announced that an international steering committee is to be set up to promote the linear collider project.

NETWORKS

Datagrid is put to the test

Three of the jobs submitted during the DataGrid testbed review ran on machines at NIKHEF in Amsterdam.

The European Union (EU) funded DataGrid project passed its first-year review at the beginning of March. In a one-day exercise, external experts appointed by the EU watched as a grid testbed was put through its paces. Jobs submitted from several institutes across Europe used grid technology to make the best use of distributed network resources.

The DataGrid project brings together five European institutions engaged in particle physics research: CERN; the French CNRS; Italy's INFN; NIKHEF in the Netherlands; and PPARC in the UK, along with the European Space Agency as principal contractors. A total of 17 institutions are involved in developing the so-called "middleware" software to analyse distributed computing, storage and data resources and to determine the best place to run a job. Middleware is also responsible for distributing the computation, as well as handling all necessary logging and book-keeping, and providing fast, secure data transfer and cataloguing.

For the first-year review, computing centres run by the five principal particle physics contractors took part, and 15 jobs were submitted. These came mostly from particle physics experiments, with a smaller number being submitted by the Earth observation and computational biology communities. The jobs were efficiently distributed across the available resources on the testbed network, providing a strong demonstration that the middleware was doing its job correctly. A few of the jobs did not finish as expected, but the reviewers accepted this, saying that they would not have believed that the demonstration was live if there had been no glitches.

The main motivation behind the DataGrid project is storing and processing the enormous amount of data that will be produced by experiments at CERN'S Large Hadron Collider. A data flow of a few petabytes per year is anticipated, and more than 50 000 workstations will be needed for analysis. Although the jobs in the first-year review consumed a total of less than one hour of computing time, they demonstrated the principle that such a task can be handled using a grid approach. In its current state, the testbed can provide 8 months of CPU time in a single day on a total of 242 machines. The next step is to expand testbed use to more users and to conduct more challenging tests. Full information about the DataGrid project is available at http://eu-datagrid.web.cern.ch/eu-datagrid/.

SPECIAL DELIVERY

The first of eight 25 m coil casings for the ATLAS experiment's barrel toroid magnet system arrived at CERN in March by road from Germany. The remaining casings, along with vacuum vessels and the coils themselves, will be making their way across Europe from Germany, Spain and Italy at the rate of about one per month for assembly and testing at CERN. ATLAS installation is scheduled to begin by the end of 2003.

CLARIFICATION

The article "Quantum gravity comes in from the cold" (*CERN Courier* March p5) may have given the impression that the quantum nature of gravity has been experimentally observed. This is not the case. The observation of Valery Nesvizhevsky and collaborators in Grenoble is of the quantization of energy levels in a classical gravitational field. The result confirms the universal nature of quantum mechanics, but does not reveal a quantum nature for gravity.

SYNCHROTRONS

Spanish synchrotron gets the green light

The Spanish government gave the green light in March to a project to build a synchrotron light source near Barcelona. Scheduled to be constructed between 2003 and 2007, the synchrotron will have a beam energy of 2.5 GeV and will serve an international user community estimated at more than 160 research groups. The project's construction budget of €120 million and the running costs of €12 million per year will be shared between the Spanish central government and the government of Catalonia.

A prototype dipole magnet, power supply and magnetic measurement bench for the Spanish synchrotron light source.

Edited by Archana Sharma

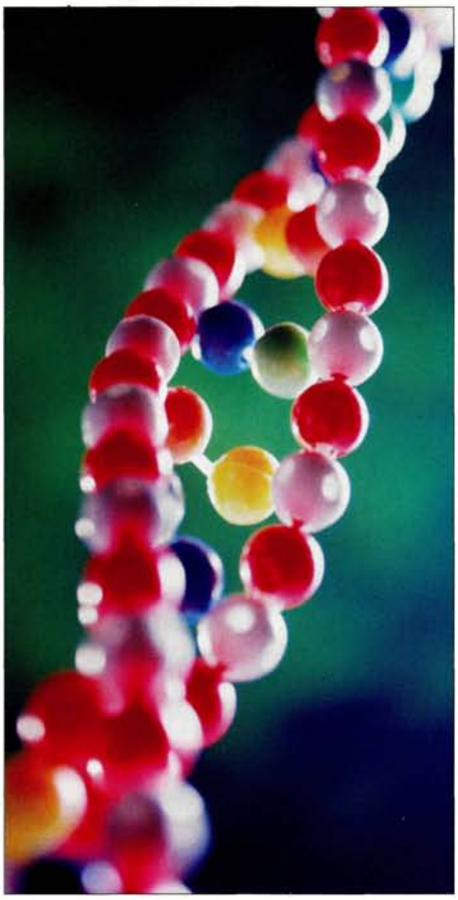
Novel heat conductor steals trick from nature

A new material proposed by European physicists could be used as a thermal conductor or an insulator – depending on the direction of heat flow. Acting as a heat valve, this material could have a significant impact on the cooling needs of microelectronic circuitry. It could also be used to route heat into microchemical reactors that are currently being developed for high-efficiency chemical synthesis. Just like natural biological molecules such as DNA, the proposed material would be a chain of linked particles – a one-dimensional solid.

The researchers, based in Como, Italy, and Lyon, France, have simulated the vibrations of atoms in a one-dimensional solid. They found that if the vibrations were anharmonic, with their vibration frequency depending on amplitude, heat would be transmitted less efficiently. By taking this observation further and arranging a three-section chain such that the central section was anharmonic and the ends harmonic, the chain would be an insulator. A further step, making one end more flexible than the other, would lead to one-way heat transfer.

Reference

M Terraneo, M Peyrard and G Casati 2002 Controlling the energy flow in nonlinear lattices: a model for a thermal rectifier *Phys. Rev. Lett.* **88** 094302.



One-dimensional solids like DNA could be configured to act as one-way heat valves, with possible applications in the fields of microelectronics and chemical synthesis.

Researchers claim table-top fusion

With little more than acetone and sound waves in a beaker, researchers from the US Oak Ridge National Laboratory, the Rensselaer Polytechnic Institute in New York and the Russian Academy of Sciences claim to have seen nuclear fusion. Mindful of the cold-fusion episode of 1989, however, the scientific community is reserving judgement until the results have proved reproducible.

This is the latest apparent manifestation of sonoluminescence, whereby light is emitted by bubbles collapsing in a liquid excited by sound. Observations of the light suggest that implosions provoked by high-frequency sound could create extremely high temperatures and pressures – high enough, perhaps, to lead to conditions that could fuse two atomic nuclei.

The researchers used neutrons to induce the formation of bubbles in liquid acetone in which the hydrogen atoms had been replaced by deuterium. Sonoluminescence resulted in the observation of light accompanied by neutrons. Tiny quantities of tritium were also detected. The researchers hypothesized that nuclear fusion had occurred, since the neutrons had different energies from those used to induce bubble formation, and tritium is an expected by-product. When the experiments were repeated with hydrogenous acetone no tritium or neutrons were observed.

Reference

R Taleyarkhan *et al.* 2002 *Science* **295 (5561)** 1868–1873.

Fusion researcher Rusi Taleyarkhan with the sonoluminescence apparatus at Oak Ridge. (Oak Ridge National Laboratory.)

New light shed on superconductivity

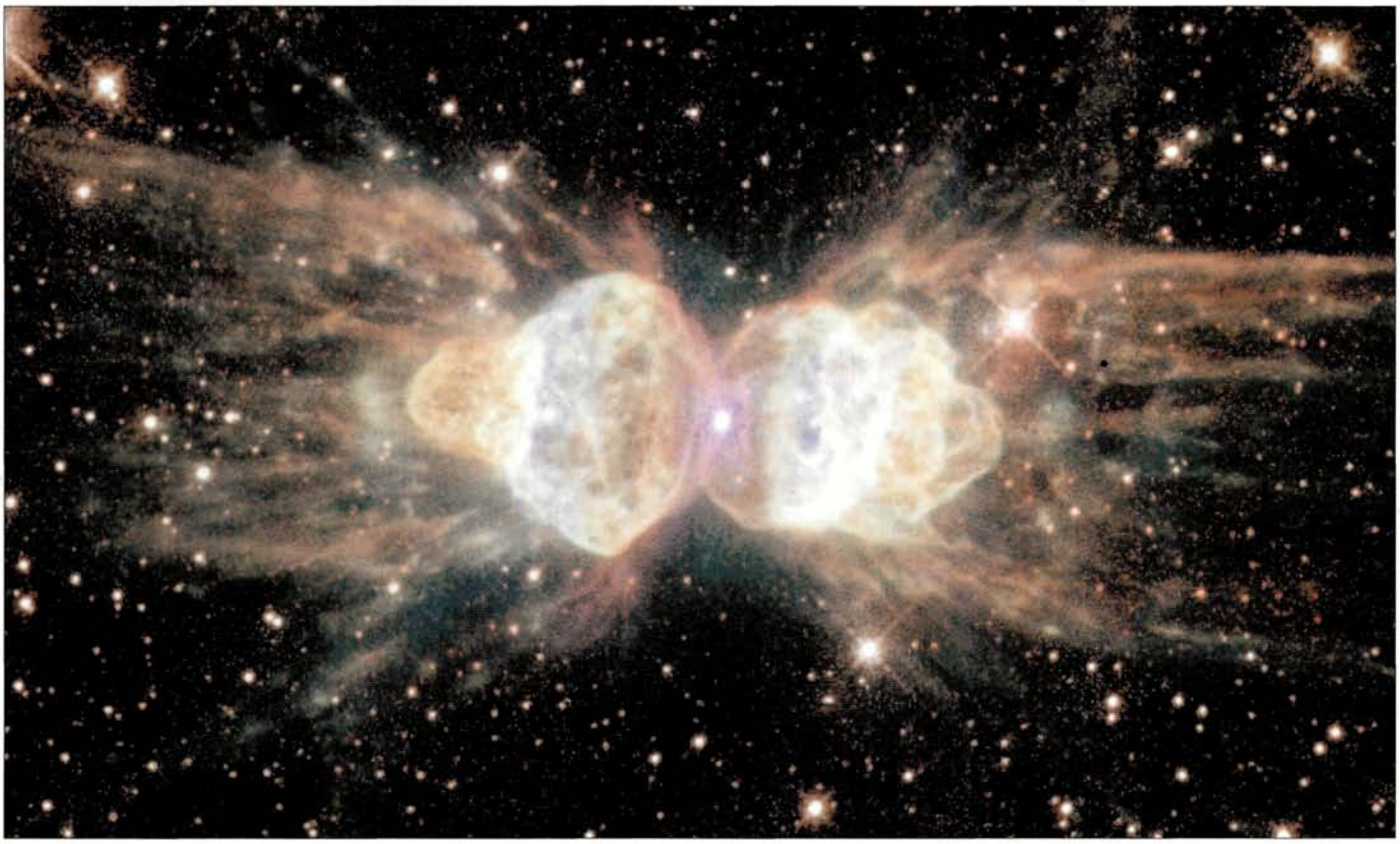
A "bluer" superconductor could explain the origin of high-temperature superconductivity, according to researchers in the Netherlands. Superconductivity occurs when electrons pair up below a certain critical temperature overcoming their mutual repulsion and losing their electrical resistance. In high-temperature, or cuprate, superconductors this process is not clearly understood.

When a cuprate superconductor is cooled below its transition temperature, a change in the amount of energy it absorbs results in different interactions between electrons and the vibrations of the crystal lattice. By analysing the light reflected from the material above and below its normal and superconducting states, the researchers could tell which frequencies of light it absorbed.

The energies of these photons are related to the binding energy of the electron pairs in the superconductor. The researchers found that the cuprate material absorbs more infrared light – photons with lower energies – when it is in its superconducting state.

Edited by Emma Sanders

Hubble telescope gets a new look



The ant nebula seen by the Hubble Space Telescope. (ESA/NASA.)

So many exciting discoveries have been made using the Hubble Space Telescope that it seems much longer than 12 years since its launch. This run is now being extended thanks to a successful servicing mission that was carried out earlier this year.

New solar panels consisting of rigid panels of gallium arsenide cells have replaced the old arrays of silicon cells. They are only two-thirds of the size of the old cells, but produce 20% more power and are less vulnerable to the vibration that can affect the sensitive instruments on board.

A new digital camera will take images with twice the area of sky and five times the sensitivity of the camera it is replacing, the Faint Object Camera. This old camera has returned to Earth and will be used to study the effects of long-term exposure in space.

A new cooling system has also been installed for Hubble's infrared camera, which has been unused since 1999 when it ran out of coolant after an accidental heat leak. The camera will now be cooled down to –193 °C by circulating neon gas. The first new astronomy images are expected this month.

Hubble looks set to continue at the forefront of optical astronomy for another 10 years until it is replaced by the Next Generation Space Telescope.

VLT identifies white dwarfs with record orbiting speeds

Two white dwarf stars have entered the record books with the fastest orbital period known for any stellar system. It takes just 5 min for these two Earth-sized stars to orbit each other – that's 100 000 times faster than the Earth orbits the Sun. The stars exist in a rarely seen transitory state; with time, their orbit will slow considerably.

White dwarfs are normal stars that are slowly running out of energy as they reach the end of their lives – our Sun will eventually become one.

The pair was identified by the Chandra X-ray telescope as a variable X-ray source, with the emission cutting off every 5 min. At the time, it was not clear what was behind this variation.

Now, VLT observations have revealed a pair of white dwarfs and the spectral lines of ionized helium show a hot spot on the surface of one of the stars at a temperature of around 250 000 °C where X-rays are emitted. With such a short orbital period, the system is a prime candidate for gravitational wave observations.

Reference

Israel *et al.* To be published in *Astronomy & Astrophysics Letters*.

Picture of the month

This image of the Eagle nebula taken using the European Southern Observatory's Very Large Telescope (VLT) in Chile gives a deeper look at one of the most famous Hubble Telescope images. The columns of gas and dust, more than a light-year in length, are illuminated by the ultraviolet light from massive stars nearby. Hubble detected many small bumps and protrusions on the three columns, which were dubbed "evaporating gaseous globules" (EGGs). Some of the EGGs were seen to have stars at their tips, but it was not known whether star-forming regions were hidden within the dusty columns as well. Now, the longer-wavelength observations using the VLT have penetrated deeper into the dust to discover young massive stars in two of the columns. Astronomers hope the study will shed light on the formation of stars and, in particular, the role of the intense UV radiation. (ESO.)

Galaxy redefines reionization epoch

Lyman alpha emission has been detected from a galaxy of redshift $z = 6.56$. If confirmed, this discovery pushes back the limits of when reionization could have occurred in the early universe.

The distant galaxy was detected as its luminosity was increased by gravitational lensing from the cluster Abell 370. It is the first galaxy to be detected with $z > 6$. Quasars have now been detected out to $z = 6.28$.

Initial observations of continuum emission using the Keck II telescope in Hawaii were followed up with spectroscopic analysis using the Subaru telescope, also in Hawaii. The authors say that whereas discriminating Lyman alpha emitters from lower redshift objects can be difficult at low redshifts, at high redshifts their signature becomes so extreme that misidentification is very unlikely.

The detection of a galaxy at this redshift suggests observations have not yet reached the redshift of reionization. Pre-reionization, neutral gas would block out emission of this kind.

Reference

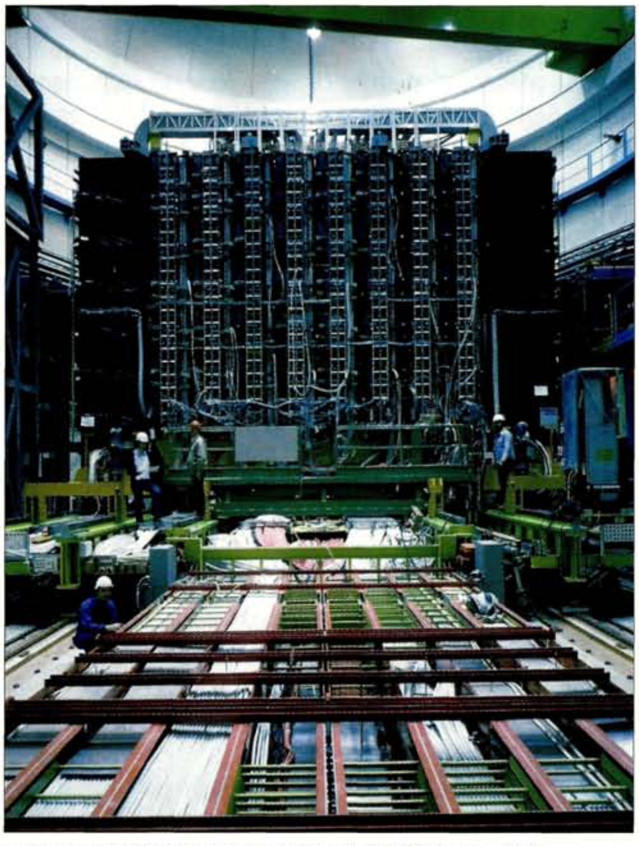
E Hu *et al.* 2002 *Astrophys. J. Lett.* **568** L75.

How CERN became popular with US physicists

In last month's issue we traced the history of CERN-US collaboration from its post-war beginnings to the advent of proton collider physics in the 1970s. Here **Gordon Fraser** continues the story to the present day, which sees US researchers as one of the largest research contingents at CERN.

In the late 1970s, CERN made the bold decision to convert its new Super Proton Synchrotron (SPS), only just getting into its stride as a fixed-target machine, into a proton–antiproton collider. The fast-tracked project began operation in 1981 and soon led to CERN's first Nobel prize. It was a new watershed for European physics.

The innovative idea to convert a major proton synchrotron in this way came from David Cline, Peter McIntyre and Carlo Rubbia, then all working in the US. It had been initially proposed to Fermilab, but the US laboratory committed itself instead to increasing the beam energy of its existing synchrotron by adding superconducting magnets. Converting the Fermilab machine into a proton–antiproton collider became a longer-term goal. With such a project scheduled in the US, there was no immediate migration to CERN's fast-tracked version.



In the early 1980s, Carlo Rubbia's 2000 tonne UA1 detector at CERN's proton–antiproton collider set a new scale for particle physics.

For the CERN collider, the lessons of the Intersecting Storage Rings (ISR) had been learned. "Keyhole" physics was not the way to go. Carlo Rubbia's 2000 tonne UA1 experiment for the new collider completely surrounded the proton–antiproton collision point, and its sheer size was impressive by the standards of the day. From the US, it had on board a Riverside contingent (a tradition having been set at the ISR) and David Cline, then at Wisconsin. As UA1 gained momentum, more physicists came from Rubbia's base at Harvard, from MIT, and from Wisconsin.

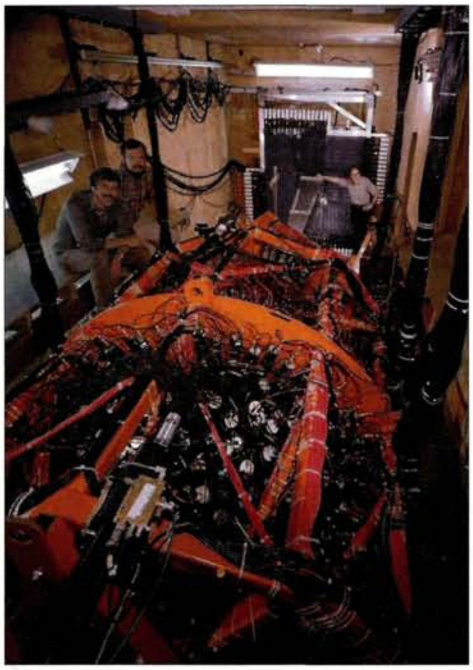
The CERN proton–antiproton collider was built to house more than one experiment, and there were several contenders. An unsuccessful bid was made by Sam Ting of MIT, who at that time was the leader of the Mark-J experiment at the PETRA electron–positron collider at the DESY laboratory, Hamburg. UA2, the second major experiment approved for the proton–antiproton collider, was essentially European. Additional high-energy antiproton experiments at CERN included a gas-jet target, attracting groups from Michigan and Rockefeller (including ISR pioneer Rod Cool), and a study of jet structure by a dedicated UCLA group.

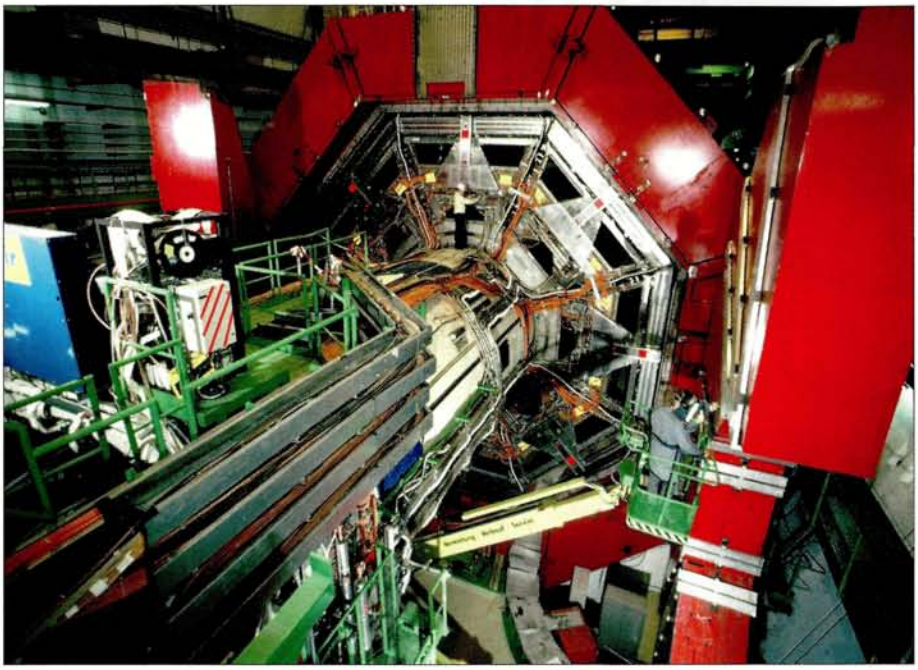
For low-energy antiprotons, CERN had the LEAR ring, and several US groups contributed to experiments here. The tradition continues with the AD antiproton decelerator, notably with Gerry Gabrielse's Harvard group making precision measurements of antiproton parameters.

The LEP era

Even while the proton–antiproton collider was getting into its stride in the early 1980s, CERN began a push for its next large machine, the 27 km LEP electron–positron collider. Such a large machine was again unique, and therefore an attraction for US physicists, who proposed the LOGIC detector. There were four slots for experiments at LEP and more than four proposals. LOGIC did not make it.

Ting, having lost out at the proton–antiproton collider, was determined to get a front seat at LEP. He, like Lederman, understood the importance of studying lepton pairs, and had got together a ▷





Left: the Plastic Ball detector, a US-German collaboration at the Berkeley Bevalac, played an important role in early high-energy heavy-ion studies before being shipped to CERN in 1986 to become part of a new generation of heavy-ion physics. Right: the L3 experiment, led by Sam Ting, was the flagship of US involvement in research at CERN's LEP electron–positron collider.

major international effort with scientists based in the US, China and Europe for a detector to analyse muons using a huge magnetic spectrometer. The proposal was initially labelled "L3" as it was the third letter of intent to be tabled for LEP, and the collaboration hoped that a more positive title would emerge. The experiment was approved, but no better name appeared. It went on to become a major US effort, with groups from Alabama, Boston, Caltech, Carnegie-Mellon, Harvard, Johns Hopkins, Los Alamos, Michigan, Northeastern, Oak Ridge, Princeton, Purdue and UC San Diego being introduced to research at CERN.

US researchers also collaborated in the other three LEP experiments. ALEPH, initially led by Jack Steinberger, included groups from Florida State, UC Santa Cruz, Washington/Seattle, and from Wisconsin, under Sau-Lan Wu, who had moved to LEP after previous research with the TASSO experiment at PETRA. OPAL included groups from Duke, Indiana, Maryland, Oregon and UC Riverside. DELPHI had participation from Ames, Iowa.

The SPS fixed-target programme had initially had little attraction for US physicists, as Fermilab's machine had higher energy and was commissioned earlier. However, a new development came in the 1980s when the SPS became the scene of experiments using high-energy beams of nuclei (although the initial US push had been for an alternative heavy-ion scenario). This was a natural extension of work which had been pioneered at the Berkeley Bevalac, and the Lawrence Berkeley Laboratory made vital contributions to the ion source and nuclear beam infrastructure for these experiments.

There is a long and distinguished list of important contributions made by US researchers during short visits or longer sabbaticals at CERN

One of the major SPS nuclear beam experiments attracted researchers from several other US centres, thus acting as a staging post for subsequent work at Brookhaven's RHIC heavy-ion collider.

Theory

Theorists work in a very different way to their experimental counterparts, with contacts and exchange of ideas playing important roles. There is a long and distinguished list of important contributions made by US researchers during short visits or longer sabbaticals at CERN. The first, not widely known because it occurred so early, was that of the American Ben Mottelson, who subsequently shared the 1975 Nobel prize with Aage Bohr and James Rainwater for work on collective and particle motion in nuclei. Mottelson did this work with Bohr in Copenhagen in the early 1950s, before CERN's Geneva site became available and when Copenhagen was the first home of the CERN Theory Group (later to become a division).

In Geneva, an early US visitor was George Zweig. There he wrote his famous 1964 paper on "aces", which was never formally published in a learned journal and which paralleled Gell-Mann's revolutionary quark ideas. Other US theorists who wrote influential papers while staying in Geneva, on varying timescales, were Mary K Gailliard, Roman Jackiw, J D Jackson, T D Lee and Lincoln Wolfenstein. Bruno Zumino became a permanent member of the division and served for a time as its head.

The LHC – the thick end of the wedge

With the unfortunate demise of the US Superconducting Supercollider (SSC) in 1993, it was natural that the enormous research and development effort that had built up in the US for its physics experiments naturally sought a home at CERN's LHC, a ring of superconducting magnets that would eventually supplant LEP in CERN's 27 km tunnel.

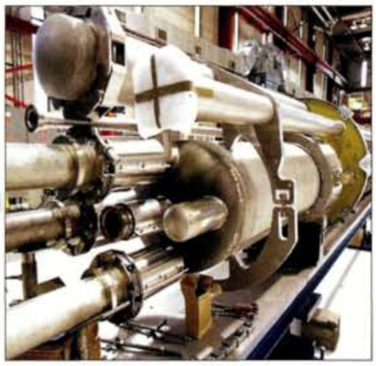
In 1994, the "Future Vision" subpanel of the High Energy Physics Advisory Panel (HEPAP) chaired by Sid Drell of SLAC recommended that in the wake of the SSC debacle "significant participation at the highest energy frontier...is through international collaboration on the LHC at CERN". The report urged that the US should collaborate in building the LHC, and that the US community should.use the opportunity to maintain the momentum that had built up for SSC detectors, transferring it to the LHC.

In 1997, the US pledged $531 million (€610 million) for the construction of the LHC and its detectors, the first time that the US had declared its readiness to contribute significantly to a particle accelerator outside the US, and the first agreement between CERN and the US government. The US formally became an observer state at CERN, with its delegation henceforth attending major meetings of CERN's governing Council.

Brookhaven, Lawrence Berkeley and Fermilab national laboratories began to produce systems for the LHC accelerator, focusing on superconducting quadrupoles and their cryostats for beam intersections, superconducting dipoles for beam separation, and cryogenic feed boxes. Fermilab became the major staging post for US participation in the CMS detector for the LHC, with Brookhaven performing an analogous role for the ATLAS experiment. ALICE and LHCb experiments at the LHC have also joined the transatlantic effort. Playing a key transatlantic coordination role in this effort is William J Willis of Columbia, whose CERN involvement dates back 40 years to the beginning of the laboratory's experimental programme, spanning the complete range of its machines.

Some 600 US scientists from about 70 research centres are now dependent on CERN for research material, making the US one of the major participants in the European laboratory's research programme in terms of the number of scientists involved.

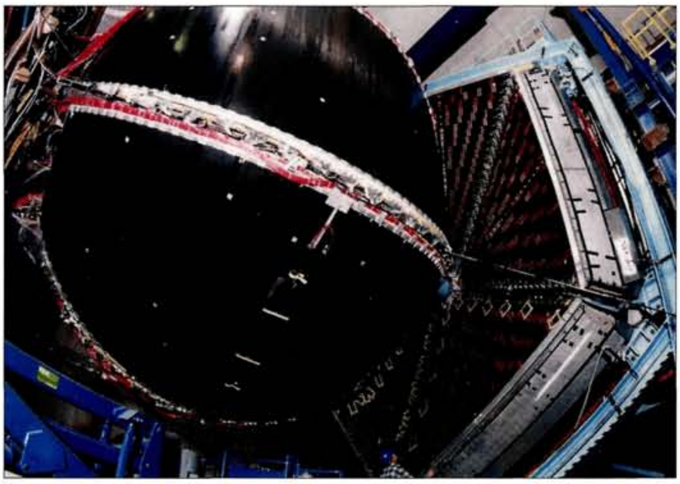
The US makes a significant contribution to CERN's LHC machine and its detectors. This picture shows a prototype LHC superconducting magnet under development at Fermilab's Industrial Center.



Gordon Fraser, *CERN.*

Probing the boundary of nuclear–particle physics

Founded in the 1980s as the Continuous Electron Beam Accelerator Facility (CEBAF), the US national laboratory on Chesapeake Bay adopted the name of Thomas Jefferson in 1996. America's third president would have been proud.



JLab's CLAS detector, probing the boundary of nuclear and particle physics.

When JLab's central helium liquifier came online in 1993, it doubled the world's cooling capacity at 2K to 4.8kW.

Thomas Jefferson is remembered as the man who penned the US Declaration of Independence. Less well known is his leadership of his era's scientific enterprise. Jefferson graduated from the College of William and Mary and founded the University of Virginia - institutions that two centuries later led the formation of the Southeastern Universities Research Association (SURA), which runs Jefferson Lab (JLab) for the US Department of Energy. With the recent addition of the Massachusetts Institute of Technology, SURA now incorporates 59 institutions. As well as carrying out essential basic and applied research, JLab also runs an innovative science education programme with local schools.

JLab's mission is to investigate the boundary between nuclear and particle physics, with the aims of understanding the forces between quarks and how hadrons are constructed from quarks, and of exploring the limits of our understanding of nuclear structure. Its history goes back to the mid-1970s, when scientists identified the need for a new tool to address emerging questions about the quark structure of matter. SURA's proposal for a 4 GeV linear accelerator and pulse-stretcher ring was selected after the ensuing call for proposals. In 1984 Newport News, Virginia was chosen as the home of the future laboratory.

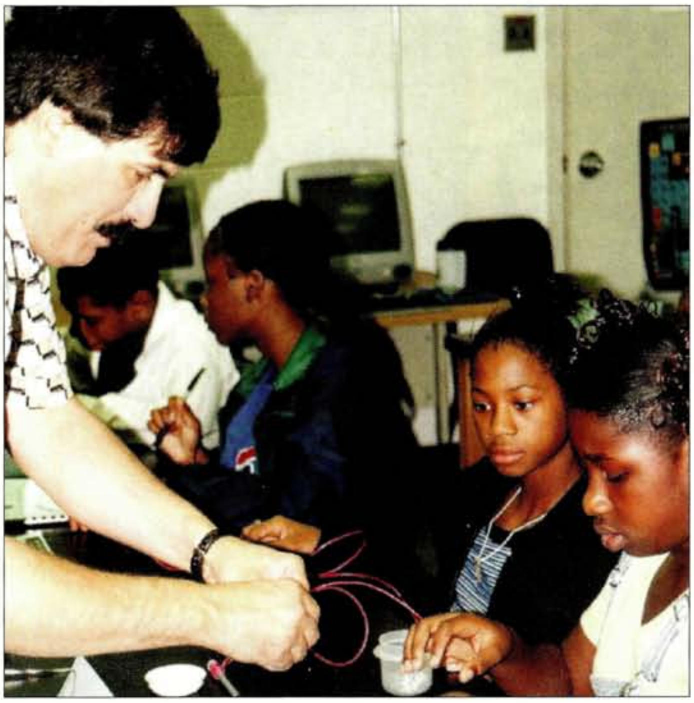
The laboratory's first director, Hermann Grunder, came from Berkeley the following year to set up the new facility. His team soon threw out the original design and replaced it with something radically new. By then, it was clear that over the lifetime of the laboratory, a beam energy of 4 GeV would not be enough. The new proposal was to build a pair of superconducting linacs with bending arcs to recirculate the beam up to five times. This would give a high-energy beam with very low energy spread and emittance, and with an intrinsically continuous wave (CW) time structure. These factors are the keys to JLab's success in taking our understanding of nucleon structure to a new level. A conceptual design report was ready in 1986, and through a fruitful collaboration with Cornell University, an accomplished centre for superconducting radiofrequency (SRF) accelerator technology (*CERN Courier* January/February p13), the Continuous Electron Beam Accelerator Facility (CEBAF) was fully operational at an initial 4 GeV by 1997.

Probing hadron structure

CEBAF uses the electromagnetic interaction to probe hadron structure. It is a 1500 MHz machine serving three experimental halls with interlaced 500 MHz beams. The beams in all three halls have the same CW time structure, but their intensities can be varied independently and the energies can be chosen from integer multiples ▷

of the single-pass accelerator energy gain, providing final energies of between 1 and 6 GeV.

The three experimental halls have complementary facilities, and each has a different mode of operation. Hall A is devoted to precision measurements, and houses twin high-resolution spectrometers that can each be placed at different angles with respect to the beam. These were instrumented by an international collaboration and are maintained by JLab, leaving experimenters to supply targets and any additional instrumentation they may need. Hall C is similar, but is used for what JLab calls major set-up experiments – those that require complex dedicated apparatus. Hall B would look more familiar to denizens of any of the world's major particle physics laboratories. It contains the CEBAF Large Acceptance Spectrometer (CLAS), a detector with a toroidal magnetic field configuration that covers 90% of 4π, and is run by a collaboration of some 200 scientists.



JLab's BEAMS programme – Becoming Enthusiastic About Math and Science – brings local schoolchildren to the lab, and aims to prepare them for life in today's science-based society.

Highlights of the CEBAF programme include studies on deuterium, the simplest nucleon bound state. These address the same problem as the classic high-energy muon and electron scattering experiments of the 1980s that measured quark distributions within nucleons, but they approach it from the other end of the energy scale and with higher precision. CEBAF experiments have shown that elastic scattering from deuterons follows a classical nuclear physics description to around one-tenth of the size of the nucleon. Complementary deuteron studies examining photodisintegration indicate that for shorter distance scales, a description of the deuteron based on quarks and gluons provides a much more economical description of the data. These experiments have identified the murky region where nuclear physics gives way to particle physics. Understanding the boundary is still some way off, but CEBAF is taking the first step to map out the terrain.

Another major strand of CEBAF research is studying the electric and magnetic form factors of nucleons. This has shown that the magnetic and electric size of nucleons is not the same, as would be naively expected from a simple quark model. CEBAF experiments are mapping the spatial distributions of up, down and strange quarks, and have already revealed important differences from the predictions of simple quark models.

At CLAS, a major line of investigation is the study of the excited state structure of the nucleon. One of the first results provides new data on the quadrupole deformations of the Delta particle, the nucleon's first excited state. These data allow discrimination between nucleon models and show that models where the pion cloud is taken into consideration as well as quarks and gluons work best – another indication that CEBAF scientists are working right on the edge between nuclear and particle physics.

For the future, JLab is planning a scientifically ambitious but economical upgrade for CEBAF. This will involve a polarized photon beam of 9 GeV (obtained by coherent bremsstrahlung using a 12 GeV electron beam and a carefully oriented crystal) being delivered to a new experimental hall at the opposite end of the linacs from the existing halls. Halls A to C will receive beams of up to 11 GeV. Most of the infrastructure is already in place, so the cost of the upgrade is modest.

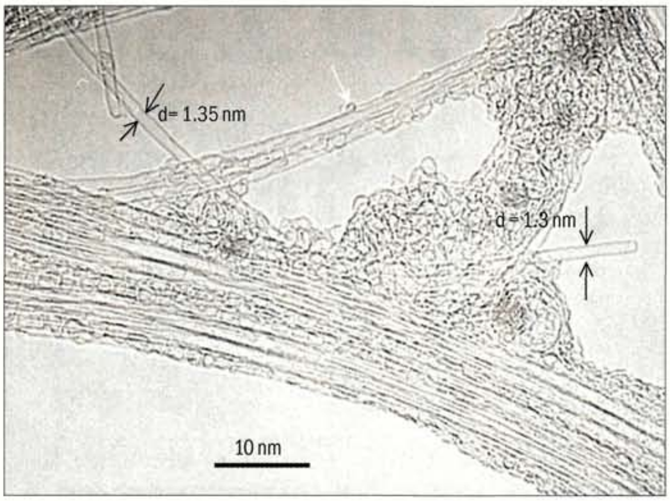
One motivation for the upgrade is to test the origin of quark confinement by probing the flux-tube model. The 9 GeV photon beam will be able to "pluck" the flux tubes many theoreticians believe form between quarks. Experiments will look for such flux tube excitations in meson spectroscopy.

The upgraded CEBAF will go further down the path already trodden by the earlier deuterium experiments, exploring the transition from classical nuclear physics to the underlying quark and gluon structure in nuclei. It will also explore the transition of the quark–quark interaction from the strong values characteristic of nuclear distance scales to the weak character observed at high energies.

Accelerating innovation

CEBAF was a pioneer of SRF in a large-scale facility. When built, its cryomodules were designed to run at 5 MV/m. They currently operate about 50% higher, and some cavities have reached 12 MV/m. CEBAF engineers literally know each module by name; there is one called Atlantic, and another called Pacific. Phoenix is a module that proved difficult to commission, and Tranquillity was quite the opposite. The energy upgrade will be achieved by adding a further 10 cryomodules, each providing 100 MV of accelerating voltage at a gradient of 21 MV/m.

In 2001, CEBAF scientists and engineers broke with electron accelerator tradition and dismantled the accelerator's thermionic gun. All CEBAF beams now originate in one of two polarized gallium arsenide photocathode guns that produce electrons at 100 keV. These devices require extremely high vacuum, and this is provided by thin-film coating of a non-evaporable getter following a technique pioneered at CERN (*CERN Courier* December 1998 p22). Fast diode lasers allow the accelerator's beam structure to be defined at the photocathode. Today, CEBAF routinely delivers precise electron beams that are spin-polarized above 80% at the full design current



Carbon nanotubes produced at the JLab free-electron laser. (Bhabendra Pradhan and Peter Eklund, Penn State University.)

of 200 μA.

In 1999, CEBAF was joined by a second experimental facility, a free-electron laser (FEL), and the laboratory added a broad new strand to its research programme. An exercise in technology transfer, the FEL was built by applying the laboratory's SRF expertise, fresh from completing CEBAF, to the task of providing a facility with both scientific and industrial relevance. The FEL programme started in the mid-1990s as an R&D project to bring the cost per kilowatt of tunable sub-picosecond laser power down to a level at which new industrial and research processes would be possible. As the world's most powerful tunable laser by over two orders of magnitude, it was immediately successful and reliable enough to be run as a user facility. To date about 30 research groups in biology, physics, chemistry and materials science have used it.

One of the highlights of the FEL user programme has been the production of copious quantities of one of the new materials of the moment, carbon nanotubes, and researchers from industry are eagerly taking all they can. Potential applications include use as electron emitters for flat-panel displays. Nanotubes can also sustain current densities hundreds of times greater than common metals, and exist in semiconducting as well as metallic form. This opens up the possibility of using them as tiny circuit elements in future electronic devices.

The FEL has also been used for critical experiments in life science, studying energy flow in proteins to elucidate protein function. This is a departure from the work done at synchrotron light sources, where only structural information can be extracted from protein crystallography. Similar dynamics experiments have also been carried out on hydrogen defects in silicon, shedding light on crucial energy-loss mechanisms in one of today's most important technological materials. Other experiments have successfully used resonant pulsed laser deposition to make high-quality films for microelectronics, and explored the use of subpicosecond light pulses in surface modification experiments.

Like CEBAF, JLab's FEL is also being upgraded. Its current is set to double to 10 mA, and its energy to triple to 160 MeV. Improvements in efficiency will lead to an overall power of over 10kW, and the FEL will also be able to be rapidly tuned. Eventually it will cover the wavelength range from 250 nm to 15 μm. JLab has also acquired the compact HELIOS synchrotron, which was first commissioned around 1990 as a turnkey instrument for X-ray lithography. HELIOS was donated to JLab in 2000 and will be used in conjunction with the FEL for studies of nonlinear phenomena and protein dynamics using a pump-probe approach. Under this scheme, an FEL pulse will disturb the system under investigation and a HELIOS pulse will be used to investigate how it responds. This offers the potential for studying any dynamical system that can be driven out of equilibrium, with applications to materials as varied as proteins and superconductors.

Such a diverse programme, taking in aspects of pure and applied science, would surely have pleased statesman of science and US president Thomas Jefferson. It also makes JLab something of a mould-breaking institution, but then as Jefferson once remarked: "A little rebellion now and then is a good thing."

Further reading

Christoph W Leemann, David R Douglas and Geoffrey A Krafft 2001 "The Continuous Electron Beam Accelerator Facility: CEBAF at the Jefferson Laboratory" *Ann. Rev. Nucl. Part. Sci.* **51** 413–450.

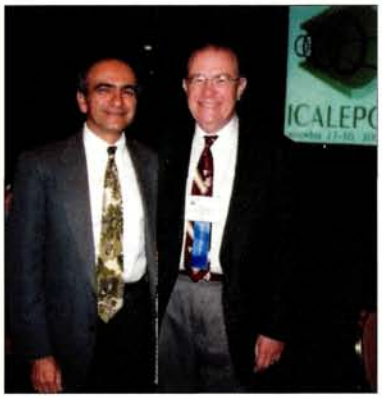
The JLab website is at http://www.jlab.org/.

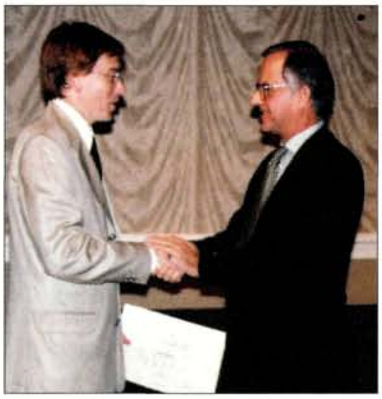
James Gillies, *CERN.*

Systems engineers find their way to San Jose

Control systems engineering in particle physics laboratories has many applications, as the ICALEPCS 2001 conference showed. **Axel Daneels** and **Rusty Humphrey** report.

The 8th biennial International Conference on Accelerator and Large Experimental Physics Control Systems, ICALEPCS 2001, was held in San Jose in November and hosted by the Stanford Linear Accelerator Center (SLAC). Some 270 control systems specialists took part, with around 120 staying on for three workshops covering databases, experimental physics and industrial control systems (EPICS) and automated beam steering.





Left: ICALEPCS 2001 conference chair Rusty Humphrey (left) relaxes with programme committee chair Hamid Shoaee at the banquet. Right: Mark Plesko (left) receives the 2001 experimental physics control systems prize from Axel Daneels. The award was made to Plesko for his achievements and creativity in the field of experimental controls systems.

The ICALEPCS conferences attract participants from a broad range of subject areas. As well as particle accelerators and detectors, other large facilities such as telescopes, fusion devices and nuclear reactors are also represented. Both hardware and software aspects are covered. The 2001 meeting saw participants coming from Africa, the Americas, Asia and Europe, representing 62 laboratories and seven companies. With such a broad base, focused workshops traditionally follow the conference. Last year, Roland Müller from Berlin's BESSY synchrotron laboratory organized one for the international accelerator database group, Greg White of SLAC convened another on automated beam steering and shaping, and Bob Dalesio of the Los Alamos National Laboratory organized a third on EPICS.

Widening applications

The broadening range of applications of control systems for large-scale facilities was demonstrated by the large number of first-time contributions from non-accelerator facilities. From the field of nuclear fusion, the laser-driven approach was represented by a talk on the Lawrence Livermore National Laboratory's National Ignition Facility (NIF) project, while the magnetic confinement approach was represented by Princeton's National Spherical Torus Experiment (NSTX). Talks on astronomy covered the European Southern Observatory's Very Large Telescope (VLT) and the VISIR mid-infra-red spectrometer being built for it, the Gemini South telescope in Chile, the Italian Osservatorio Astronomico di Capodimonte, and the Atacama Large Millimetre Array project. Participants from the LIGO gravitational wave observatory discussed the control system for its two interferometers, which are separated geographically, but operated as a single observatory. Traditional ICALEPCS ground was covered by presentations about CERN's ATLAS and CMS experiments, BaBar at SLAC, D0 and CDF at Fermilab, H1 at DESY and KLOE at Frascati.

The increased level of collaboration across different controls projects was noteworthy. Engineers from facilities such as the Spallation Neutron Source (SNS) being built at the US Oak Ridge National Laboratory, the Swiss Light Source (SLS), the Visible Multi-Object Spectrograph for the ESO's VLT and the NSTX are establishing a common development environment and sharing packages, modules, designs and experience. Papers on commercial control systems included the Argonne Tandem Linear Accelerator System, which uses the commercial VSystem, the CMS and H1 experiments, both of which have adopted the PVSS II system, and Frascati's DAFNE accelerator, which uses LabVIEW.

Established technology

Control systems for large facilities are no longer the high-risk endeavours they used to be. Trained and experienced people, tools, equipment and bandwidth are all now widely available. Several status reports at the conference on recently commissioned control systems gave ample confirmation of this. The SLS control system, ▷


With its interferometers in Hanford, Washington (left) and Livingston, Louisiana being operated as a single observatory, the LIGO gravitational wave detector presents a real challenge for control systems engineers. (Caltech/LIGO.)

for example, has proven itself to be highly reliable. It comprises 100 000 data channels with 150 electronics crates running EPICS software, and uses common object request broker architecture (CORBA) to provide a commercial (or freeware) interface and management of connections between software objects. The control system for Brookhaven's Relativistic Heavy-Ion Collider (RHIC) is another success story. It incorporates commercial hardware with software written in the C++ and TCL languages, and has many automated features such as ramp control, sequencing and tune feedback.

The H1 experiment's detector control and monitoring control system, based on PVSS II, successfully completed its final test phase with the delivery of a prototype for control of the H1 detector's high-voltage system, superconducting solenoid and luminosity monitoring system. The BaBar online team reported on the use of Objectivity/DB, an object-oriented database management system. Other reports on running facilities came from NSTX, which achieved first plasma in February 1999, and the D0 experiment, which has solved the problem of mismatch between the Oracle database format and EPICS's ASCII files.

Several very large systems in the construction phase were also discussed. The $2.5 billion (€2.9 billion) NIF project with its 192 laser beams delivering 1.8 MJ is scheduled to be fully operational by 2003. The strategy used to develop its integrated computer control system calls for incremental cycles of construction and testing to deliver a predicted total of 1 million lines of code. There is a development process with clearly defined roles and responsibilities, productivity measures, extensive documentation, regular assessment, and design and code reviews. NIF's commitment to formal testing with an independent testing team and facility is an exciting development. It requires management commitment and money, but is expected to pay off with the availability of systems that meet real functional requirements and have fewer bugs.

Six collaborating laboratories are building the SNS at Oak Ridge. They are addressing the issues of organization, communication, standardization and integration that are inherent to such a widely distributed project. LIGO requires many multiple input multiple output (MIMO) control loops. Its control system integrates project-designed data acquisition, commercial controls and EPICS. The CERN experiments ATLAS and CMS are building control systems based on the commercial Supervisory Control and Data Acquisition (SCADA) system PVSS II. CMS reported on integrating Oracle in a SCADA to store the large amount of calibration data and front-end electronic configuration data needed for the detector. ALMA will consist of 64 12 m submillimetre antennas, with baselines up to 10 km, located at an altitude of 5000 m in the Chilean Atacama desert. Its control system incorporates JAVA and CORBA.

Future trends

The trend towards ever more geographically distributed collaborations means that development and operation teams are also increasingly widespread. Here, the SNS development team is providing a useful case study. Although feasible, development in this way requires much travel on the part of the coordination team and efficient project management to resolve potentially competing designs. Technologically, development on a global scale can be done, but the sociological and management issues are more difficult.

Technologically, development on a global scale can be done, but the sociological and management issues are more difficult

On the software front, the explosive growth of EPICS continues, expanding well beyond its origins in the US accelerator community. Linux seems to be the favoured operating system for servers, in particular the Redhat implementation. Ethernet is ubiquitous and is an alternative to field buses.

Adequate bandwidth is currently available and more is coming. Japan's Spring-8 synchrotron team showed interesting performance measurements of gigabit Ethernet, including its latency and redundancy. CISCO announced 10 Gbps Ethernet for 2002, with the price per Mbps dropping to $4 by 2005. Ethernets of 40 and 80 Gbps are not far off. Oracle databases, whose performance keeps improving, are used almost everywhere for storing configuration data, archived data and slow real-time data. The World Wide Web is ubiquitous and has become an integral part of the software design process. Java is increasingly being investigated as an alternative to C++. There are ample CORBA projects to demonstrate the viability of the approach. However, CORBA is complicated and there are multiple implementations and many ways to use it. As NIF engineers point out, system performance with CORBA may be a problem as it is strongly dependent on the network design.

Software engineers presently lead system architecture design, but hardware engineers are starting to enlarge the design space of system architecture. There are many smart complex device designs, which incorporate significant computing and communications capabilities. How network and system architectures will evolve when there are many such devices, each one of them a network object, remains to be seen.

Many presentations highlighted the creative use of sophisticated hardware and software tools to solve very specific and complex problems. At Argonne's Advanced Photon Source, for example, the control system incorporates accelerator orbit feedback. At Japan's KEK laboratory, beam feedback is also built into accelerator control systems. At the NIF, the control system will control wave front development; and LIGO's control system will sense and control wavelengths and frequencies.

Control systems are increasingly being taken up by industry. The SLS reported that vendors successfully delivered turnkey accelerator subsystems, including a complete linac, with EPICS-based controls as part of the contract.

The success of ICALEPCS 2001 is a tribute to the vitality of the field. The community now looks forward to the next ICALEPCS conference, which will be hosted by the Pohang University of Science and Technology in Gyeongju, South Korea, in October 2003.

Axel Daneels, *CERN and* **Rusty Humphrey**, *SLAC.*

Radioactive beam resea

Research using accelerated beams of short-lived nuclei has grown into a major activity. **Karsten Riisager** reports from a recent symposium in Copenhagen that looked at the status and future prospects of the field.

If you have access to a high-energy accelerator or a nuclear reactor it is relatively easy to produce a lot of radioactive nuclei. It is a much harder job to include selectivity so that just one specific isotope among those produced reaches detectors. This is particularly true for short-lived nuclei with half-lives of a second or less, or for nuclei with very low abundances. Spatial separation of production and detection sites is necessary, and the practical solution is to bring nuclei of interest from one site to the other in the form of a radioactive beam. Following a pioneering experiment carried out in 1951 at the Niels Bohr Institute (NBI) in Copenhagen, several ways have been developed to do this. A symposium celebrating the NBI experiment, and taking the opportunity to assess current state-of-the-art techniques, was held at the Royal Danish Academy in Copenhagen in November 2001.

Otto Kofoed-Hansen and Karl Ove Nielsen were the authors of NBI's first experiment. Their basic intent was to measure the recoil momentum resulting from the emission of a neutrino in beta decay. The best way to do this is with noble gas atoms, so Kofoed-Hansen and Nielsen set out to collect neutron-rich krypton isotopes produced in the fission of uranium. Their technique was similar in principle to the converter technique currently being suggested for use in the next generation of radioactive ion-beam facilities. Deuterons from the NBI cyclotron generated neutrons in an internal target. These bombarded an external uranium oxide target in which baking powder was mixed to create a gas flow out of the target. The krypton atoms produced flowed towards a nearby isotope separator. They were ionized, mass separated and then collected, allowing the decay measurements to be done.

Soon after, the NBI cyclotron was moved to a new area and the experiment closed. The idea was taken up again a decade later and finally led to the creation of the ISOLDE facility at CERN where experiments began in 1967. Nielsen was again actively involved in the start-up phase. Both he and Kofoed-Hansen, who continued in weak interaction physics, were active at CERN for many years.

Radioactive beam techniques

One of the two major techniques used for producing radioactive beams today, isotope separation online (ISOL), is a direct descendant of the NBI experiment. At the symposium, Juha Äystö of CERN and the University of Jyväskylä discussed the widespread use of ISOL around the world today. In an ISOL system, the nuclei produced are thermalized and extracted through an ion guide if they are still in an ionized state, or through an ion source if they are not. Target and ion source technology is a key element of ISOL systems, as Helge Ravn of CERN pointed out. Current developments are leading towards ever more selective systems and targets capable of coping with very high power. The hope is to go from present generation targets, which can take up to 30 kW, to targets that are able to withstand up to or above 1 MW. The converter method with neutrons offers one possible approach. An alternative was discussed by Alex Mueller of Orsay, who suggested using an electron beam converted into bremsstrahlung photons to induce photofission. Conventional fission in a high-flux reactor is also being explored in the Munich Accelerator for Fission Fragments (MAFF) project presented by Dietrich Habs of Garching.

The other major technique for production of a radioactive beam is

The annual group photo for the Copenhagen theoretical physics institut pioneers Otto Kofoed-Hansen and Karl Ove Nielsen are fourth from the row, and Christian Møller (subsequently head of CERN's Theory Divisior Mottelson and Aage Bohr (eighth and ninth from the left, second row; p1

arch notches up 50 years

ıte is always an illustrious gathering. In this 1951 photo, radioactive beam
e left and fourth from the right, second row. Niels Bohr is fifth from the left, front
ɔn) is second from the right. Also seen are 1975 Nobel prize winners Ben
ɔ15). J K Bøggild (fourth from the right, front row) was a pioneer Council member.

separation in flight. At low energies, fusion (and transfer) reactions dominate – this is the way superheavy elements are made – but at energies above 100 MeV per nucleon, projectile fragmentation and fission are the important reaction mechanisms. The rather thick production targets currently in use lead to very efficient use of the primary beam, explained Brad Sherrill of Michigan State University, but the radioactive beam produced is quite extended in phase space.

Many experiments can still be done, but stopping in a gas cell and reacceleration to achieve better beam quality is being investigated at several laboratories, as outlined by Piet van Duppen of Leuven. This is one of the key ingredients in the US Rare Isotope Accelerator (RIA) project discussed by Jerry Nolen of Argonne (*CERN Courier* March p15). Two major projects to upgrade existing fragmentation facilities were discussed. Isao Tanihata of the Japanese institute of physical and chemical research, RIKEN, presented his laboratory's radioactive beam factory upgrade, and Walter Henning of GSI in Darmstadt presented his laboratory's upgrade project.

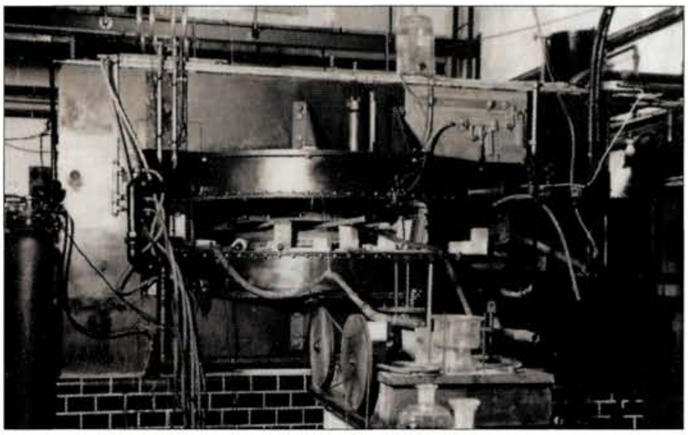
Participants at the recent radioactive beam symposium at the Royal Danish Academy are overlooked by a 1896 academy meeting painted by Peter Severin Krøyer.

In the future, acceleration of an ISOL beam will be the way to fill the energy gap between high-energy fragmentation beams and classical ISOL beams. The good news at the symposium was that early efforts at Louvain-la-Neuve, Belgium, and Oak Ridge, Tennessee, US, have now been joined not only by the impressive ISAC programme in Canada, presented by Alan Shotter of TRIUMF, but also by two recent European accelerators, SPIRAL at GANIL in Caen, France, and REX-ISOLDE at CERN. Further developments in this direction are being pursued in Europe, partly at existing laboratories through the EURISOL network, and partly through new projects such as MAFF and the CASIM project in the UK. In the US, this approach is being pursued with RIA.

Physics issues

Although the symposium focused on the many recent impressive technical developments in radioactive beam production, there was room for a number of overviews on the physics questions tackled with radioactive nuclei. Many laboratories have a broad user community ranging from solid state applications through atomic and nuclear physics to particle and astrophysics. Marek Lewitowicz of GANIL showcased light nuclei, where experiments go as far as possible towards neutron matter and have already found halo nuclei (in which the core of the nucleus is surrounded by one or more loosely bound orbiting neutrons) and evidence for changes in standard shell structure. Intermediate mass nuclei produced in fission, in which rapid shape changes occur as a function of neutron and proton number, were discussed by John Durell of Manchester, UK.

Witek Nazarewicz of Oak Ridge gave an overview of theoretical issues, emphasizing new concepts needed for a description of the nuclear structure in new regions of the nuclear chart. For example, there is a strong coupling to the continuum in nuclei far from beta-stability, the treatment of pairing in such nuclei also presents ▷


The cyclotron at the Copenhagen theoretical physics institute was the scene of the first radioactive beam experiment in 1951. (Niels Bohr Archive, Copenhagen.)

problems and the question of clustering in nuclei might also re-emerge here. As often happens in nuclear physics, interdisciplinary aspects abound for radioactive beams. Nuclear astrophysics is one of the important neighbouring disciplines where, as Karlheinz Langanke of Aarhus pointed out, more nuclear physics input is needed. A proper understanding of objects such as supernovae and X-ray bursters depends on weak and nuclear interaction rates, and rates involving several nuclei that have not yet been produced in the laboratory. Theoretical models currently employed would benefit from new experiment input.

As Peder-Gregers Hansen of Michigan State University remarked, certain fields are so difficult that the timescale for progress is generations. This applies to neutrino physics and to highly unstable nuclei, both of which were explored in the pioneering experiment of Kofoed-Hansen and Nielsen, as well as to the emerging field of nuclear astrophysics. Radioactive beams and nuclear astrophysics have converged significantly over the last decade. The same might happen in the future for neutrino physics if the recent idea of CERN's Piero Zucchelli – to use in-flight decay of radioactive beams such as ^{6}He as a source for neutrino beams – is implemented.

The Danish symposium has shown that radioactive beam research is thriving. The field promises several more decades at least of research to exhaust the possibilities first opened up by one pioneering experiment at the NBI half a century ago.

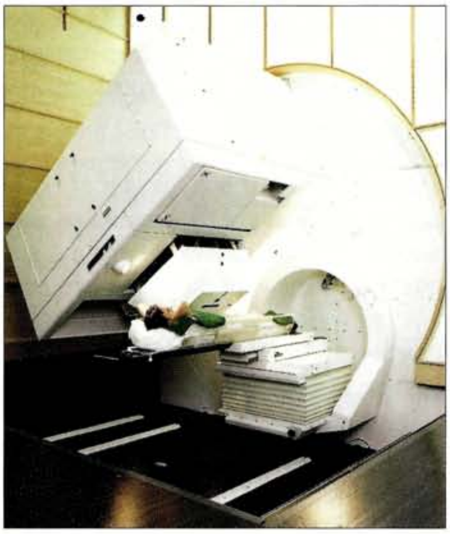
Further reading

Otto Kofoed-Hansen 1976 *CERN Yellow Report* 76-13.
R Bennett *et al.* 2000 *Radioactive Nuclear Beam Facilities, NuPECC report.*

Karsten Riisager, *Aarhus.*

Cancer therapy initiative is launched at CERN

The inaugural meeting of the new European ENLIGHT network for cancer therapy research was held at CERN in February. ENLIGHT brings together all of Europe's leading players in this emerging field.



Left: Clinicians, oncologists, physicists and engineers from around the world came to the first ENLIGHT meeting held at CERN to discuss particle accelerators and beam systems for light-ion cancer therapy. Above: Switzerland's Paul Scherrer Institute has incorporated a sophisticated dose-delivery system into a gantry that rotates around the patient.

The European Network for Research in Light-Ion Hadron Therapy (ENLIGHT) has been established to coordinate European efforts in radiation therapy using light-ion beams. Light to physicists, carbon ions are heavy to biologists and were first used to treat patients at the Japanese Heavy-Ion Medical Accelerator Centre (HIMAC) in Chiba, which has been operational for six years. The facility at Germany's GSI laboratory, which switched on in 1997 (*CERN Courier* December 1998 p14), has also shown that light-ion therapy can be remarkably successful in curing cancer.

Clinicians, oncologists, physicists and engineers from around the world came to the first ENLIGHT meeting to discuss the physics and engineering of particle accelerators and beam systems needed to provide light ions. Following a welcome from CERN's director-general Luciano Maiani, proceedings began with an address from Jean-Pierre Gérard, past chairman of the European Society for Therapeutic Radiology and Oncology (ESTRO), who said that the meeting could come to be seen as a landmark in the fight against cancer. He drew attention to the "three Cs" that define the advantages of using radiation therapy: cancer care, conservative treatment, and cost. Radiation therapy is used to cure up to 50% of all cancers; it is non-invasive and its side-effects are often short-lived; and it costs just 5% of the total budget for cancer treatment.

Professor Gérard also pointed out that improving technologies are leading to better results. Data from HIMAC and GSI have convinced him that ions are the ultimate weapon for cancer control when no other treatment is possible. If four or five centres ▷

were set up, he said, each treating approximately 1000 otherwise incurable patients per year, about 2500 lives could be saved annually. In Professor Gérard's opinion, working together is the key to success. A concerted effort by physicists and engineers to tackle design issues and by clinicians to deal with patient selection, along with a multidisciplinary approach to imaging, dosimetry and data-handling, has been vital for the success of the two pioneering facilities.

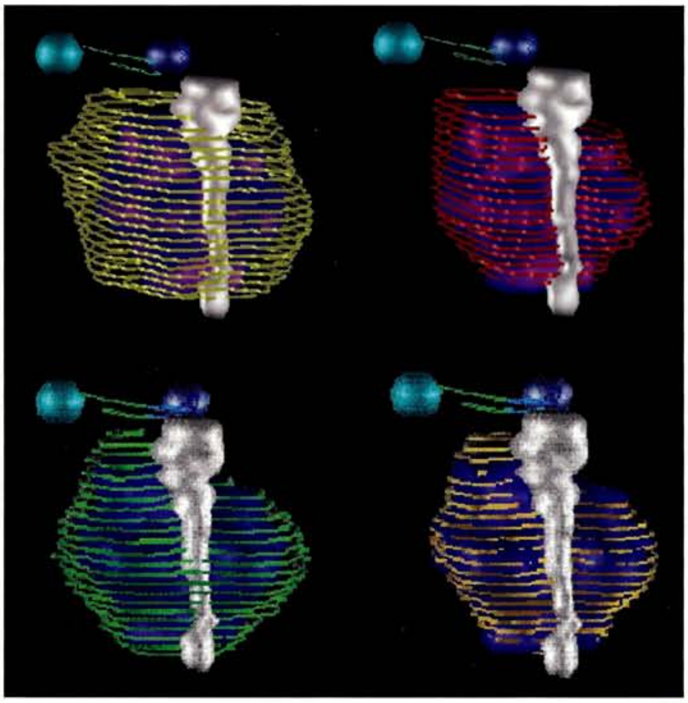
The main aim of radiation therapy is to deliver a maximally effective dose of radiation to a designated tumour site while sparing as much of the surrounding healthy tissue from damage as possible. Conventional radiation therapy using photon beams is characterized by exponential absorption following a maximum, which is reached at a depth of 2–3 cm for beams with a maximum energy of 8 MeV. For selective irradiation of deep-seated tumours, radiotherapists use multiple beams, usually pointing to the geometrical centre of the target area. However, there are still many cases of tumours located near critical organs for which this type of therapy is inappropriate. The dose must be limited to avoid damage to the organ in question, which lowers the chances of successful tumour control.

Hadron therapy

Visionary physicist and founder of Fermilab Robert Wilson first proposed the use of hadrons for cancer treatment in 1946. He observed that unlike photons, protons and light ions deposit their energy at the end of their path and could therefore be used to irradiate tissues close to critical organs. This idea was first put into practice at the Lawrence Berkeley Laboratory (LBL), where 30 patients were treated with protons between 1954 and 1957.

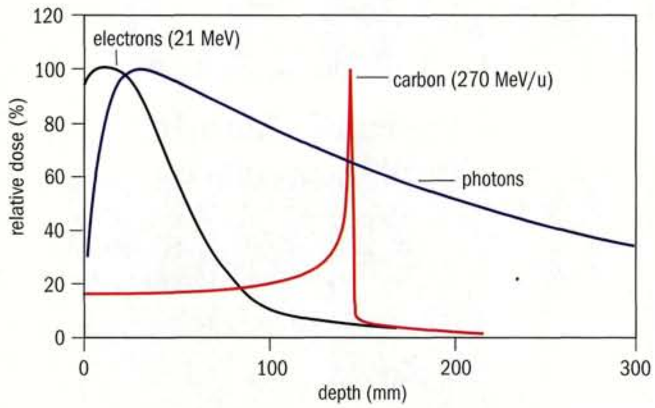
Using beams of hadrons – protons or light ions – radiotherapists can overcome the limitations of photon beams. As well as depositing most of their energy at the end of their range, hadrons penetrate the patient with practically no diffusion and they can easily be formed as narrow-focused and scanned pencil beams of variable penetration depth. This means that they can bring about severe damage to the DNA in cancer cells while sparing both traversed and deeper healthy tissue. This characteristic also enables them to be used to accurately irradiate any part of the tumour. Hadron beams allow highly conformal treatment (in which the beam conforms to the shape of the tumour) of deep-seated tumours to the nearest millimetre, while delivering minimal doses to surrounding tissues.

Since Wilson's initial proposal, about 30 000 patients have been treated with protons and very good results have been obtained for head and neck tumours. Most of these patients were treated in nuclear research centres not originally designed for cancer therapy. Nevertheless, results have been extremely positive with local control and survival rates higher than those for conventional radiotherapy. At Switzerland's Paul Scherrer Institute (PSI), an excellent dose delivery system has been developed and integrated in a gantry system that rotates around the patient. The success of therapy projects at nuclear research centres, along with improved accelerator technology and dose delivery systems, has led to a number of dedicated proton therapy facilities being established. These include the Loma Linda University Medical Center in California, US; the Kashiwa and Tsukuba centres in Japan; and the Northeast Proton Therapy Center in Boston, US. At PSI, a second cyclotron is being built exclusively for proton therapy. Known as the PROSCAN project, this facility is due for completion in 2003.



Top: three-dimensional treatment plans for conformal treatment of a brain tumour clearly show the advantages of using carbon ions. The patient's eyes and brain stem are visible in these images. The tumour is shown in purple and the irradiated area is enclosed within the cage-like structure of lines. In the top two images for irradiation with photons, parts of the brain stem are within the cage. In the lower images, which illustrate carbon ion irradiation, the brain stem is spared. Bottom: these scans show the effect of combined radiotherapy using photons and carbon ions to treat a tumour (left). After six weeks (right) the tumour has disappeared. (J Debus, DKFZ/GSI.)

The existing PSI facility is one of Europe's leading centres for the treatment of melanomas of the eyes and skin, where 60–70 MeV protons are used. Therapy of this nature, in which the tumour is not deep-seated, is well established in Europe, with major facilities in France, Germany and the UK as well as at PSI.



Energy deposition at the end of the particle range makes hadrons ideal for treating deep-seated tumours.

ESTRO and ENLIGHT

ESTRO is the European Society for Therapeutic Radiology and Oncology (www.estro.be). It is composed of individual members working in the field of radiotherapy and oncology. ESTRO's principal objectives are to foster radiation oncology and to develop standards for the quality assurance of radiation oncology, radiophysics, radiation technology and radiobiology in Europe.

ENLIGHT is the European Network for Research in Light-Ion Hadron Therapy. It is funded by the European Union and coordinated by ESTRO. ENLIGHT members are currently: ESTRO; the European Organization for Research in the Treatment of Cancer (EORTC); the Espace de Traitement Oncologique par Ions Légers Européen (ETOILE) in France; the Karolinska Institute in Sweden; the German Heavy-Ion Project (GHIP); Hospital Virgen Macarena in Spain; Med-Austron in Austria; the Italian TERA foundation; and CERN. The network aims to foster collaboration between members and other potentially interested parties to maximize the clinical effectiveness of each project while reducing cost and increasing reliability.

Treatment of deep-seated tumours is less well established, and it is this area that the ENLIGHT network will address.

Reaching new patients

Seminal work on the use of light ions was carried out using beams from LBL's Bevalac from 1957 until the accelerator was closed in 1993. More than 2000 patients were treated with helium ions between 1957 and 1987, and heavier ions – mainly neon – were used to treat more than 400 patients from 1975 until 1993. Neon is not the optimal ion for therapy. Its linear energy transfer (LET) rate of more than 20 eV/nm in the first layer of tissue is too high and can cause irreparable damage to healthy tissue. The high LET also implies a risk of microscopic cold spots that can lead to tumour recurrence. Moreover, neon can fragment into lighter ions that penetrate beyond the tumour.

About 10 years ago, radiobiologists and radiotherapists reached the conclusion that the optimal ions are found in the range between lithium and carbon. Since then, clinical results with such ions have come mainly from HIMAC and GSI. About 1000 patients have been successfully treated with carbon ion beams at HIMAC since 1994. At GSI, scientists working with colleagues from the German Cancer Research Centre, DKFZ, in Heidelberg have treated more than 100 patients since 1997 with equally impressive results. The GSI facility uses sophisticated raster scanning techniques in conjunction with online medical imaging in real time for treatment with a carbon ion beam. Only around 50–70 patients can be treated each year at this facility, however. Although it is still too soon to draw definitive conclusions, the results obtained at HIMAC and GSI meet theoretical expectations, making hadron therapy an important avenue to follow.

Results to date indicate that proton treatment is most beneficial for melanomas of the eye, tumours originating in the base of the skull, and those capable of infiltrating the skull. Certain cancers – such as those of the pancreas, liver, and the saliva-producing parotid gland – can be resistant to conventional radiotherapy with photons. For these, ion-beam therapy offers a promising approach. One study has shown that around 3000 people out of a population of 10 million develop radio-resistant tumours per year, and it is estimated that around half of these would benefit from carbon-ion treatment. In Europe, around 30 000 patients per year would benefit from treatment with carbon ions.

The last decade has seen many initiatives in Europe to design hadron therapy centres using proton and ion beams. Notable among these is GSI's pilot project with DKFZ. This has led to a dedicated centre in Heidelberg, construction of which begins this year. In parallel, the Italian TERA foundation, ETOILE in France, the Karolinska Institute in Sweden and Med-Austron in Austria have prepared plans for centres that are at various stages of design, approval and financing. These four projects are using results from the Proton-Ion Medical Machine Study (PIMMS; *CERN Courier* October 1998 p20). Led by CERN, PIMMS involved researchers from the TERA foundation, Med-Austron, and Onkologie 2000 in the Czech Republic in the design of a dedicated ion therapy synchrotron. The study group also benefited from close contacts with GSI.

Participants at the meeting agreed unanimously that a unified approach to hadron therapy in Europe is needed. The key role that CERN could play in terms of technical coordination in helping to establish a European platform for ion-beam accelerators, medical imaging, simulation and the handling of distributed data was pointed out several times. Going beyond formal agreement, many participants set up active collaborations for specific aspects of hadron-therapy projects.

The workshop highlighted the achievements of HIMAC and GSI, and clearly demonstrated the advantages to be gained from a broad-based multi-disciplinary collaboration. A concerted effort will now be made to establish an integrated hadron-therapy project within the forthcoming Sixth European Union Framework Programme. CERN's Hans Hoffman, who chaired the ENLIGHT meeting, brought it to a close by suggesting that a fourth C should be added to Professor Gérard's three: carbon ions.

Manjit Dosanjh, *CERN.*

CERN workshop marks a transition

In 1963, Nicola Cabibbo proposed a mechanism to describe transformations between up, down and strange quarks. Almost a decade later, Makoto Kobayashi and Toshihide Maskawa generalized quark mixing to six quarks. At a recent workshop hosted by CERN, more than 200 researchers took stock of how far experiment has come in unravelling the mixing matrix.

More than 200 physicists from around the world came to CERN in February for a workshop on the status of the unitarity triangle.

Quark mixing is a topic that has attracted intense scrutiny ever since it was first proposed in the 1960s. Recently, CERN's Large Electron-Positron collider (LEP) has made important measurements concerning mixing, particularly hadrons containing b quarks (*CERN Courier* October 1998 p23). Properties such as B hadron lifetimes, the oscillations between particles and antiparticles for neutral B mesons, and the couplings of the b quark to the other quark flavours were all studied at LEP, and the results have had a significant impact on our understanding of quark mixing.

The LEP experiments were the first to observe the time dependence of oscillations of the neutral B^0 meson and measure its oscillation frequency precisely. However, the data used for most of these B physics analyses were taken a number of years ago. The LEP detectors have now been dismantled and the collaborations are reaching the end of their studies. The more complex analyses (for example, the search for high-frequency oscillations of neutral strange quark-containing B_s^0 mesons) have just been completed. Meanwhile, the B-factories at SLAC in California, US, and KEK in Japan (p6) are dedicated to studying this physics and are producing enormous samples of B mesons. In particular, they have recently demonstrated CP violation in the B^0 meson system. Experiments at the upgraded Tevatron at Fermilab in Chicago, US, also have a rich B physics programme and are starting to take data.

To mark this transition, a workshop on the subject of quark mixing was held at CERN in February. Its aim was to review the current status of theory and experiment and to provide an opportunity for the fruitful exchange of ideas between the theoretical and experimental communities. The meeting's title – workshop on the CKM unitarity triangle – refers to the Cabibbo-Kobayashi-Maskawa (CKM) matrix that describes quark mixing in the Standard Model.

The concept of quark mixing was first developed by Cabibbo, who introduced a single mixing angle to describe transitions between up, down and strange quarks. With the discovery of the charm quark, this was extended to a matrix describing mixing between quarks of the first two generations. Kobayashi and Maskawa then generalized mixing for six quark flavours, described by the three-by-three ▷

CKM matrix. This gives the couplings V_{ij} between the up-type quarks i = u,c,t and the down-type quarks j = d,s,b. The matrix should be unitary (a weakly decaying quark should transform into one of the other known quark flavours) and this unitarity condition leads to relationships between the elements of the matrix. The nine complex matrix elements can be described by four parameters – three mixing angles and a phase (one mixing angle and no phase would be required if there were only four quark flavours). The introduction of a phase is crucial, as Kobayashi and Maskawa recognized. That it allows for CP violation – matter-antimatter asymmetry – in the Standard Model led them to propose that mixing occurs between three generations of quarks – long before the members of the last generation (b and t) were discovered.

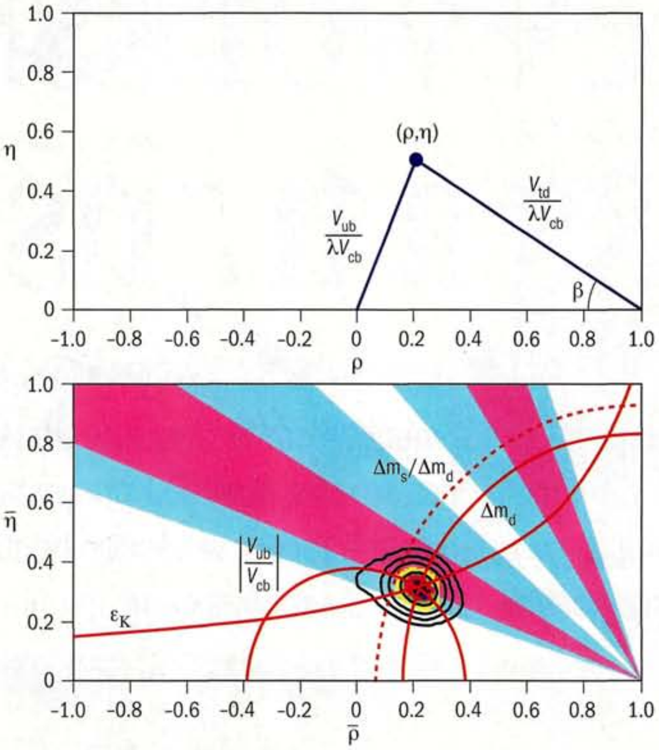


Fig. 1. Measuring the parameters of the unitarity triangle (top) is important for understanding matter–antimatter asymmetry. In a recent fit for the apex (bottom), the contours show the 68, 95, 99 and 99.9% confidence level regions. The red lines are constraints coming from measured parameters, and the pink and blue bands correspond to the direct measurement of the angle β from the B-factories (at 68 and 95% confidence).

The unitarity triangle

A widely used parameterization of the quark mixing matrix which was developed by Lincoln Wolfenstein of Carnegie Mellon University, US, expresses the elements as an expansion in the powers of λ – the sine of the Cabibbo angle – which has a known value of 0.22 from kaon and hyperon decays. The remaining three parameters required to describe the mixing are denoted as A, ρ and η. In this parameterization, the element V_{cb} is given by $A\lambda^2$ and has been well measured from the semi-leptonic decays of hadrons containing the b quark, leading to a value for A of 0.84. The values of the two parameters ρ and η remain to be determined.

One of the unitarity conditions of the CKM matrix is $V_{ud}V^*_{ub} + V_{cd}V^*_{cb} + V_{td}V^*_{tb} = 0$. Dividing by $V_{cd}V^*_{cb}$ leads to a triangular relationship in the ρ, η plane, where the length of the base is unity. The left-hand side of the matrix is proportional to V_{ub}/V_{cb}, which can be measured by studying semileptonic B meson decays into charmless final states, and the right-hand side is proportional to V_{td}/V_{cb}, which can be extracted from the B^0 oscillation frequency.

This triangle is known as the unitarity triangle, and it neatly summarizes the state of knowledge of this physics. The angles of its sides correspond to the phases of the matrix elements involved, and are directly related to the CP asymmetries that are predicted to occur in B decays. In particular, the time-dependent asymmetry between the decays of B^0 and anti-B^0 mesons to a J/ψ and a K_s is expected to have the form sin2β sinΔm_dt, where Δm_d is the B^0 oscillation frequency and β is the angle between the right-hand side of the triangle and its base (twice the phase of B^0 mixing). This is the channel that the B-factories have used to observe CP violation in the B^0 system. Many other decay modes (including those for B^0_s mesons) can be used to measure different CP asymmetries, and thus determine the other angles of the triangle. However, that programme of measurements lies in the future, in particular at the dedicated B physics experiments at hadron colliders – LHCb at CERN's LHC, and BTeV at Fermilab's Tevatron.

First workshop

The workshop at CERN was intended to be the first of two meetings and concentrated on measurements of the sides of the triangle using existing data. The second workshop will cast an eye towards future B physics to be carried out at the LHC. The meeting was organized by Achille Stocchi and Marco Battaglia from the DELPHI experiment at LEP, who have played an important role in the working groups that were set up by the LEP collaborations to supervise the combination of their results.

The work of these groups has been widely appreciated and their data have been used by rapporteurs at conferences and featured in the Particle Data Group (PDG) review of particle properties. They have expanded to provide world averages including representatives from the SLD experiment at SLAC, CLEO at Cornell, and Fermilab's CDF. One of the aims of the workshop was to discuss how the work of these LEP-based groups should be taken over by representatives of the experiments that are now leading the field, in particular the B-factories. Weiming Yao from the PDG chaired a dedicated session on this issue, with discussion involving representatives from all of the experiments in a very constructive atmosphere. The B-factory experiments, BaBar at SLAC and Belle at KEK, expressed their commitment to taking the lead in future B physics averaging.

Relating measured quantities to the CKM matrix elements involves understanding how the quarks are bound into hadrons, since the couplings refer to quarks but the observed particles are hadrons. This is the realm of QCD, but in the non-perturbative regime in which an exact solution is not possible. A key theoretical framework in the field of unitarity triangle studies is lattice QCD, in which the equations can be solved by discretizing space–time onto a network of points. The accuracy of the predictions is then limited

Workshop organizers Marco Battaglia (left) and Achille Stocchi in conversation at the CERN CKM meeting.

by the computing power available, which limits the size of the lattice and the spacing of its points; in the limit of zero lattice spacing the exact solution of QCD would be recovered. In addition, to save on computing resources, the pair production of light quarks from the vacuum (the so-called quenched approximation has usually been neglected). Lattice QCD has the attraction that most of the theoretical parameters required for unitarity triangle studies have been calculated in a consistent framework. Some first results are becoming available without quenching using two light quark flavours. These can be used to estimate the effect of the quenched approximation, which appears to be encouragingly small for most variables studied. Discussion started at the workshop on creating a "lattice data group" with representatives from the numerous groups pursuing lattice QCD. This would aim to provide a consensus on the best use of lattice results, combining them where relevant along the lines of the PDG for experimental results.

The workshop was based around three working groups, the first of which concentrated on the left-hand side of the triangle and the second on the right-hand side. The third working group studied the thorny issue of how all the various measurements that are relevant to the unitarity triangle should best be combined. Converting the measured quantities into constraints on ρ and η is only possible with the guidance of theory, with corresponding uncertainties. How best to deal with theoretical errors has proved controversial in the past, because they do not generally follow the Gaussian distribution that straightforward error combination relies on.

There are two main schools of thought concerning the fit for the apex of the triangle – those following Bayesian statistics and those following Frequentist statistics. It was a major success of the workshop to bring proponents of these two approaches together and compare in detail the results when their fitting programs are applied to the same inputs. The main difference is that when an input parameter has a quoted statistical (Gaussian) component to its uncertainty and a systematic component that is taken to be flat between certain limits, the Bayesian approach convolutes the two errors, whereas the Frequentist approach corresponds to adding them linearly, giving a more conservative result. If the two fitting programs are fed with the same input likelihoods, the allowed regions that result are very similar. The issue therefore becomes not one of which statistical school to believe, but rather of how to ensure that the theoretical uncertainties are correctly handled. The latest result of the unitarity triangle fit from the group using the Bayesian approach – performed during the workshop itself using all the agreed inputs from the other working groups – is shown in figure 1 (p34). This fit gives an indirect measurement of the angle β, corresponding to $\sin 2\beta$ lying within the range 0.57–0.81 at 95% confidence level. It is in excellent agreement with the direct measurement from the B-factories, which is indicated by the coloured bands.

The workshop was very well attended, with more than 200 participants and a strong international mix of delegates. The four days of meetings involved lively discussion, with sessions running late into the evening, and the summary session took place on a Saturday morning. The success of this first meeting has led to the proposal for the next meeting to be held by the Institute of Particle Physics Phenomenology in Durham, UK, in conjunction with the next in their series of workshops on heavy-flavour physics and CP violation. The second meeting will therefore take place in either Durham or the nearby Lake District next spring.

Further information

See http://ckm-workshop.web.cern.ch.

Roger Forty, *CERN.*

PEOPLE

APPOINTMENTS

New director for Frascati Labs

Sergio Bertolucci has been appointed director of the Italian INFN's National Laboratories in Frascati. A former Pisa scholar, he has worked at DESY, Fermilab and Frascati. He was a member of the group that founded Fermilab's CDF experiment and has been involved in the design, construction and running of the CDF detector. Recently he has been technical coordinator of the team responsible for the design and construction of the KLOE detector at Frascati's DAFNE storage ring. In 2000 he was appointed head of Frascati's accelerator division and of the DAFNE project. Bertolucci is a member of the LHC committee at CERN and DESY's physics research committee.

The European Physical Society Interdivisional Group on Accelerators (EPS-IGA) prize selection committee, chaired by DESY's Ferdinand Willeke, has awarded the 2002 EPS-IGA prizes to two CERN scientists. The prize for a person early on in their career who has made a recent, significant and original contribution to the field goes to Frank Zimmermann (top) for his many important contributions to accelerator physics. Zimmermann worked at DESY in Hamburg and SLAC in California before coming to CERN in 1999. His prize citation draws particular attention to the significant contribution that he has made towards understanding fast-ion and electron-cloud instabilities – work that has greatly benefited the entire accelerator community. The prize for outstanding work in the accelerator field is awarded to Kurt Hübner for his excellent leadership in the field of accelerator physics and technology. He has been at CERN since 1964 and he served as the laboratory's director of accelerators from 1994 until 2001. He has provided guidance for generations of accelerator physicists and engineers, and contributed greatly to the prosperity of accelerators at CERN and many other labs. The prizes will be awarded at the European Particle Accelerator Conference (EPAC'02) in Paris in June, where the winners will make oral presentations of their work.

Parvez Butt (left), chairman of the Pakistan Atomic Energy Commission, with CERN's director-general, Luciano Maiani, in March following the signature of a letter of intent to establish formal agreement between CERN and Pakistan. Through such an agreement, Pakistan would make a substantial contribution to the Large Hadron Collider and its detectors, coordinated by the Pakistani National Center for Physics.

AWARDS

Templeton prize is awarded to physicist

Particle physicist turned Anglican priest, John Polkinghorne, has been awarded this year's £700 000 (€1.14 million) Templeton prize for progress in religion. He becomes the fourth physicist to win the prize in recent years, joining Paul Davies (1995), Ian Barbour (1999) and Freeman Dyson (2000). Polkinghorne resigned a professorship at the University of Cambridge in 1979 to study theology. Later, while serving as vicar of the parish of Blean near Canterbury in England, he wrote *One World*, the first of a trilogy exploring science and faith. He ended his career back at Cambridge, retiring in 1996 as president of Queen's College. Polkinghorne sees science and religion as complementary. "Both," he said, "believe that there is a truth to be sought and found, a truth whose attainment comes through the pursuit of well motivated belief."

John Polkinghorne. (Karen Marshall.)

New chief executive takes over at IOP

Julia King will succeed Alun Jones as chief executive of the UK Institute of Physics on 1 September. Currently director of engineering and technology for Rolls-Royce's marine business, King has held senior positions in industry and academia. "At a time when the links between academia and industry and between science and engineering have been recognized as vital," said Institute president Sir Peter Williams, "I can think of no-one better suited to succeed Alun." Under Jones, the Institute has doubled its membership and developed a thriving publishing business, with titles that include *CERN Courier*.

Anda Philip (left), who is Romania's permanent representative to the United Nations office in Geneva, and CERN research director Roger Cashmore shake hands on the signature of a co-operation agreement between Romania and CERN, which was reached in March.

CERN

CERN forms Italian research partnership

CERN gained a new Italian partner in February when former director-general, now extraordinary commissioner of the Italian Institute for New Technologies, Energy and the Environment (ENEA), Carlo Rubbia, signed a collaboration agreement with Luciano Maiani, the laboratory's current director-general.

ENEA, an organization employing 3400 people in 10 labs around Italy, carries out research into renewable energies, new materials and medical science. The agreement will lead to common research projects in areas where CERN technologies have potential applications in these fields.

Lillestøl recognized for outreach efforts

On 8 March CERN/Norwegian physicist and science communicator Egil Lillestøl received the 2001 Award for Outreach Activities from the Meltzer Foundation and the University of Bergen, Norway. The award was given for his enthusiastic outreach effort over many years, which has included articles in the press, programmes for radio and television, and numerous radio interviews in Norway and other countries. Egil also regularly gives special lectures on modern physics for CERN staff.

Another outcome of his effort has been an illustrated book, *Search for Infinity: Solving the Mysteries of the Universe* (1994), co-written with Norwegian journalist Inge Sellevåg and then *CERN Courier* editor Gordon Fraser.

Physicist and science communicator Egil Lillestøl (right) receives the 2001 Award for Outreach Activities from the Meltzer Foundation and the University of Bergen, Norway. He is pictured with the director of the university, Kaare Rommetveit (left), and Kirsti Koch Christensen, rector.

AWARDS

CMS rewards eight suppliers for their contribution and service

At the third ceremony to honour its top suppliers, the CMS collaboration presented awards to eight firms – seven involved in the manufacture of the experiment's magnet.

CMS suppliers who have made a particularly difficult, important or innovative contribution are eligible for a Crystal award, while Gold awards recognize exceptional service.

This year, three companies received the Crystal award. Finnish firm Outokumpu Pori Oy is supplying superconducting strand to make the CMS magnet cable. By the beginning of 2002 the company had delivered 1400 km of strand, corresponding to 70% of the total order. Nexans Suisse is sheathing the magnet's superconducting cable in extremely pure aluminium. Working with the Swiss Federal Institute of Technology (ETH) in Zurich, the company has developed a co-extrusion process that avoids exposing the cable to potentially damaging high temperatures. By the end of January, Nexans had completed two-thirds of the order. The third company to receive a Crystal award, Plascore Inc, is not involved in magnet construction. The US firm has produced some 2000 honeycomb-structured polyester panels – key components for the CMS endcap muon chambers – on schedule and in compliance with CMS's exacting specifications.

Three other firms – Brugg Cables, Sumitomo Chemicals and Alcan – all involved in the manufacture of the coil, received the Gold award. Swiss firm Brugg Cables is manufacturing the cable from strands provided by Outokumpu Pori Oy. Japanese firm Sumitomo Chemicals has produced the highly pure aluminium for sheathing the cables and Alcan has supplied a high-quality aluminium alloy. Two other recipients of the Gold award have worked on the magnet yoke. French firm André Laurent manufactured prestressed tie bars to ensure the rigid assembly of the yoke rings, and German firm Noell Konecranes produced the air-pad systems that allow the heavy yoke parts to be moved round the detector work site. All of the projects rewarded this year by CMS result from close collaboration and partnership between industry and many CMS institutes, notably CERN, Fermilab and ETH Zurich.

Winners of the third round of CMS suppliers' awards visit the detector's assembly site.

At an informal lunch in March, Alexei Sissakian, vice-director of the Joint Institute for Nuclear Research (JINR), Dubna, near Moscow, Russia, presented diplomas of honour to Jim Allaby (left) and Gordon Fraser, who are retiring from CERN. Allaby was among the first CERN scientists to work in Russia in the late 1960s and co-chaired the CERN–JINR joint scientific committee with Sissakian for many years. Fraser, editor of *CERN Courier* until January this year, has consistently highlighted scientific and technological co-operation between CERN and JINR through the pages of this magazine.

Interim director of the US Brookhaven laboratory, **Peter Paul** (seated, centre), and **Vladimir Kadyshevsky** (seated, right), director of the Joint Institute for Nuclear Research (JINR) in Dubna, Russia, signed a collaboration agreement between the two laboratories in February. At the ceremony, held at Brookhaven, were (standing, left to right) STAR collaboration spokesman **Timothy Hallman**, JINR vice-director **Alexei Sissakian**, Brookhaven associate director for high-energy and nuclear physics **Timothy Kirk**, JINR high-energy laboratory director **Yuri Panebratsev** and (seated, left) **Satoshi Ozaki** of the Brookhaven director's office. At the ceremony, honorary doctorates were also presented to Paul, Ozaki and Hallman. (Roger Stoutenburgh.)

CERN received a royal visit in March. Crown Prince of Bhutan, **Dasho Jigme Khesar Namgyal Wangchuk** (right), visited the assembly site of the CMS experiment accompanied by the Himalayan kingdom's permanent representative to the United Nations in Geneva, **Bap Kesang**

Dutch ambassador to Switzerland, **Roelof Smit** (seated), seen with CERN director of administration **Jan van der Boon**, visited the laboratory in February.

MEETINGS

The Second Symposium on Applications of Particle Detectors in Medicine, Biology and Astrophysics (SAMBA) will take place in Trieste, Italy, on 27–29 May. Information is available at http://www.elettra.trieste.it/sites/samba/; email samba2@elettra.trieste.it.

The Seventh International Workshop on Meson Production, Properties and Interaction will take place at the Jagellonian University in Cracow, Poland, on 24–28 May. Topics include hadronic meson production in various reactions; electromagnetic meson production; meson interaction with mesons, nucleons and nuclei; structure of hadrons; mesons and fundamental symmetries; and exotic systems. Details are available at http://users.uj.edu.pl/~meson2k/.

The 22nd Physics in Collision Conference will be held at Stanford, California, US, on 20–22 June. Topics for discussion include flavour physics, astroparticle physics, QCD, neutrino physics and electroweak physics. Details are available at http://www.conf.slac.stanford.edu/pic/ or from the conference coordinator Maura Chatwell, email maura@slac.stanford.edu.

The Ninth International Conference on Quantum Chromodynamics (QCD'02) will be held on 2–9 July in Montpellier, France. The deadline for registration and abstracts is 15 May. Information is available at http://www.lpm.univ-montp2.fr:7082/~qcd/; email qcd@lpm.univ-montp2.fr.

OBITUARIES

Willibald Jentschke (1911–2002)

Willibald Jentschke 1911–2002.

Willibald Jentschke, founder of DESY and former director-general of CERN, passed away on 11 March 2002, a few months after celebrating his 90th birthday.

Born in Vienna in 1911, Jentschke obtained his PhD in nuclear physics at the age of 24. He continued working in this field in Vienna for many years. In 1951 he became the director of the cyclotron laboratory at the University of Urbana, Illinois, US.

When the University of Hamburg offered him the chair of experimental physics in 1955, he requested funds to create a modern research facility in Germany, to carry out competitive research on an international level and to offer students an excellent education. At that time he was considering a 2 GeV proton synchrotron. After intense discussions, during which he became famous for his negotiating skills and insistence, the Hamburg government decided to offer him the outstanding sum of DM 7.5 million (€3.83 million) for the construction of an accelerator. Accepting this offer, he became a member of the faculty in 1956.

Now was the time to decide what accelerator to build. With strong support from his university colleagues, Jentschke tackled this question and decided to build a 7.5 GeV electron synchrotron. After lengthy negotiations with the German Federal Government and the German States, the Deutsches Elektronen-Synchrotron (DESY) was founded on 18 December 1959. Jentschke became the first director of DESY and remained in this position until 1970.

The decision to build an electron synchrotron was driven by the wish to create complementary research options in Europe, especially in view of CERN, which was building a proton synchrotron. However, this decision also had another important, far-reaching consequence: soon after the start of high-energy physics experiments at DESY, research with synchrotron radiation became the second strong research area of the laboratory. Building accelerators for particle physics and synchrotron radiation, and doing experiments with them, has remained the mission of DESY for more than 40 years.

As a very important part of the research policy at the laboratory, Jentschke fostered strong links with universities and laboratories in Germany. He started the first international collaborations – something that would later

Bo Andersson 1937–2002

Bo Andersson 1937 - 2002.

Pioneering strong-interaction theorist Bo Andersson died on 4 March from a heart attack. He was on his way home from lecturing at the St Petersburg winter school.

Andersson had deep respect for experiment as the final arbiter in any physics issue and actively engaged in dialogue to ensure that incisive studies were carried out. His quest for a deeper understanding of theoretical issues, and many fruitful new ideas and thought-provoking presentations have made him a visible and constructive participant in international meetings over the years. His unconventional style and original thinking left nobody indifferent. His interests ranged well beyond those of physics and his openness earned him many friends around the world.

Andersson began his career as a student of Gunnar Källén in Lund, presenting his PhD thesis on photoproduction and analyticity properties of vertex functions in 1967. He continued the latter line of work for several years, partly in Lund and partly at Stony Brook, Princeton and CERN.

In the mid-1970s, more permanently back in Lund, he joined the university's nuclear emulsion group trying to understand heavy-ion reactions, and later got involved in preparations for a neutrino-emulsion experiment at Fermilab. It was also at this time that he began the ambitious programme of exploring strong interactions that was to occupy him for the rest of his life.

Andersson's best-known contribution is the Lund string fragmentation model, developed with long-time colleague Gösta Gustafson and a succession of students. Here the confinement of quarks and gluons is modelled by string-like force fields or colour flux tubes connecting them. When quarks and gluons are kicked apart in high-energy collisions, these fields stretch. The energy thereby pumped into them goes partly into creating new quark-antiquark pairs that screen the colour of the original end-points. The force fields successively break into smaller pieces, each ultimately associated with one of the hadrons observed in the final state. The string model formalizes these concepts and gives a detailed picture of final state properties.

One novel aspect of this model was the emphasis on colour structure, reflected in the way that quarks and gluons are ordered along the string. This gave unique predictions for energy and particle flow in three-jet events from electron-positron annihilation, first observed by the JADE collaboration in 1980. While originally formulated for the later stages become very important, leading, for example, to the "HERA model" of international collaboration. He also attracted excellent scientists to join him in Hamburg, and together with them he shaped the laboratory into its present form.

After the start of the DESY research programme, Jentschke had to take a crucial decision about the future direction of research at DESY. From today's point of view, the choice of an electron-positron collider, DORIS, as the next machine seems simple. With the knowledge of the 1960s, however, no exciting physics was to be expected from such a machine. A bigger synchrotron appeared a safer bet. After many intense discussions, the advocates for each type of machine were about balanced. At this point Jentschke decided in favour of DORIS, of exploring new territory. Today we know that this was the right choice, not only for particle physics but also for the future of synchrotron radiation. When Jentschke left DESY in 1970 to become director-general of CERN, the scientific future of DESY was well mapped out – its financial future was also secure, since today's model of funding of the laboratory was settled in 1969.

Jentschke served as director-general of CERN Laboratory I (the original Meyrin site) from 1971 until 1975. During the same period John Adams was director-general of the neighbouring CERN Laboratory II, where the new SPS proton synchrotron was being constructed. The original plan had been to build the SPS on a greenfield site somewhere else in Europe, but Adams convinced CERN Council of the wisdom of building the new machine alongside CERN's existing PS synchrotron and other machines, which could then act as an injector complex. Having two director-generals in adjacent laboratories was an unusual and delicate situation, but to their credit, Jentschke and Adams handled it well.

For CERN's Lab I, Jentschke oversaw the exploitation of important new research investments, notably the Intersecting Storage Rings, high-intensity proton beams and an ambitious research programme for neutrino physics. In 1973 this effort enabled physicists using the Gargamelle bubble chamber to discover the neutral currents of the weak interaction. Faced with a major discovery, CERN was nervous. However, Jentschke ensured that the CERN result was accorded its due recognition and went on record as one of CERN's great achievements.

Following his time in Geneva, Jentschke returned to Hamburg, having spent a sabbatical year at SLAC. At the end of 1979 he became a professor emeritus. He continued to be interested in developments at DESY and was very happy to celebrate his 90th birthday there with his old friends and colleagues (*CERN Courier* March p33).

The secret of Jentschke's success was his personality – a unique blend of knowledge, competence, vision, ideas, charm, courage and the talent to recognize and attract excellent colleagues. He listened and talked to the people working with him, asked questions and generated ideas. He wanted a team and people to fit into it. This spirit is still present at DESY today. As director-general of CERN, he wrote in 1975: "I believe that we must base our future plans on international collaboration, certainly within Europe, or perhaps, if conditions eventually permit, within a wider context."

This vision is becoming reality today – it is his testament.

Albrecht Wagner, DESY.

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of a collision, where outgoing quarks and gluons turn into hadrons, this concept of colour coherence has been extended to gluon emission from the collision itself. These features have become standard in describing multiparticle production.

The physical and mathematical properties of the string model were a continuous source of inspiration for Andersson. Studies of string quantization and other fundamental aspects went hand in hand with applications such as Bose-Einstein correlations, polarization phenomena and baryon production. Understanding heavy-ion collisions was another important topic.

The Lund group has also dealt with gluon radiation in high-energy collisions. The starting point was a colour dipole emission picture, closely matching string colour topology. This allows a description of radiation in the final and initial stages of a collision through the colour dipole model, CDM, and the linked dipole chain, LDC. This picture has also allowed a consistent reformulation of evolution equations for the quark and gluon content of protons, improving our understanding of data from HERA, for example.

By matching colour dipole emission with colour string fragmentation, an essentially complete framework for multiparticle production emerged. This also included predictions for the transition region between these two complementary descriptions.

The wish to improve contact between theory and experiment led the Lund group to develop event generators to describe high-energy collisions. These Lund Monte Carlos, with names such as Jetset, Lepto, Pythia, Fritiof and Ariadne, have made a significant impact on the experimental community. Today there is hardly a high-energy physics experiment that does not use them.

While remaining in Lund, as a full professor since 1984, Andersson spent sabbatical periods at Western Ontario, Orsay, CERN, UCLA, Berkeley, Stony Brook and Brookhaven. He encouraged international collaboration and was among the first to invite long-term visitors from Russia after the fall of the Berlin Wall. These included young mathematics students who were welcomed to Lund on a programme that he set up. In recent years he has often visited China and there encouraged the development of phenomenological research.

Bo Andersson was due to retire in June, but was planning to remain as active as ever. He still supervised two PhD students, the last of some 20. A one-day symposium planned for him in June – coinciding with the 25th anniversary of the Lund model – will now be dedicated to his memory.

Gösta Gustafson, Torbjörn Sjöstrand and Bengt E Y Svensson, Lund.

RECRUITMENT

For advertising enquiries, contact CERN Courier recruitment/classified, IOP Publishing Ltd, Dirac House, Temple Back, Bristol BS1 6BE, UK.
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Steve Holmes, Associate Director for Accelerators
Fermilab, MS105
Job Code: HBD-CC
P.O. Box 500
Batavia, IL 60510, USA
E-mail: holmes@fnal.gov
Ph: 630-840-3211

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NORTHERN ILLINOIS UNIVERSITY nicadd

RESEARCH POSITION IN ACCELERATOR PHYSICS

The Northern Illinois Center for Accelerator and Detector Development (NICADD), part of the Department of Physics at Northern Illinois University, has an opening for a research associate in accelerator physics. The newly funded NICADD has received significant federal support for collaborative research with Fermilab and has nearly completed assembly of an accelerator research group. Opportunities include research at the Fermilab/NICADD photoinjector beam line and design and development of the recently proposed third-generation photoinjector (Pi3). The successful candidate may also pursue other lines of research involving advanced accelerator techniques. The appointment shall be for three years, depending on the availability of funding. Candidates are required to have a Ph.D. in physics or a related field. Send letter of application, curriculum vitae and the names/addresses/phone numbers of three current professional references to:

Professor Courtlandt Bohn, Physics Department/NICADD,
Northern Illinois University DeKalb, IL 60115
(815) 753-3546

Email: kgordon@nicadd.niu.edu

Preference will be given to complete applications received by July 1, 2002, however applications will be accepted until the position is filled.

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RESEARCH ASSOCIATE POSITIONS INDIANA UNIVERSITY

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Successful candidates will be based at Fermilab and will participate in Run 2 of the Tevatron. The Indiana group is involved in various aspects of the muon and fiber tracker detectors and is active in the areas of muon identification, b-jet tagging, B-physics analyses and new particle searches including Higgs boson searches.

Applicants should send a curriculum vitae, a list of publications, a statement of research interests and at least three letters of recommendation to:

Ms. Donna Martin, Physics Department, Indiana University
Bloomington, IN 47405, USA Fax: (812) 855-0440

For more information, contact Prof. Rick Van Kooten (rvankoot@indiana.edu, 812-855-2650), Prof. Andrzej Zieminski (zieminsk@indiana.edu, 812-855-4089) and/or visit http://physics.indiana.edu.

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HEAD OF COMPUTING DIVISION

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The Division assists in developing systems requirements for future computing and storage needs, and also develops the software for operating these systems as required. The Division staff has a substantial involvement in the development of scientific software, including physics simulation and computational codes. Many of these activities are carried out in collaboration with the worldwide high-energy physics community. The Division receives substantial support for these activities from competitively awarded funding sources. The Division staff supports the data acquisition systems of experiments. The Division manages Fermilab's high bandwidth connections to public and private wide area networks that support its worldwide scientific collaborations. The Division supports the general computing infrastructure at the Laboratory, including many aspects of computer security.

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Qualified candidates must possess the capability to provide leadership in the operational, computing, R&D, and physics roles of the Division. A broad and deep understanding of the present state of computing technologies and the trends that project these technologies into the future, both in the commercial, open source, and academic computer science sectors, is required. Management and organizational skills in a highly technical environment are essential, as is exposure to science, based on large facilities and dispersed collaborations of scientists. The individual selected must be familiar with Department of Energy regulations and take responsibility for elements of the Laboratory's computing in these matters. Experience in high-energy physics is an advantage, but not required.

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Fermilab

Postdoctoral Research Associate

The PHOBOS group in the Chemistry Department at Brookhaven National Laboratory is seeking outside candidates for the position of research associate. PHOBOS has successfully completed Year 2 of running at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL) with colliding gold beams at energies from 20 to 200 GeV in the nucleon-nucleon CMS frame, and proton beams at 200 GeV. Since RHIC will not be running until early 2003, the main activity of the group until then will be on extensive analysis of this high-statistics data set. The group has major involvement in analyses pertaining to charged multiplicity and correlation (HBT, reaction plane) measurements. Our focus is on understanding the large-scale features of heavy ion collisions and how to relate them to the underlying dynamics. Will lead a new analysis or join an existing effort on this data set. The group also plays a major role in the PHOBOS experiment, with areas of responsibility ranging from experimental operations to data production with overall software development. Will have the opportunity to assume a leadership role within any of these areas within PHOBOS during the next RHIC run. In addition, will be able to participate in developing possible future upgrade paths for the detector and research program of the group. The group consists of 6 scientific staff plus visiting students from collaborating institutions. Requires a Ph.D. in physics or nuclear chemistry. Preference will be given to candidates with strong data analysis and programming skills in C++. Interested applicants should send a curriculum vitae and arrange for three letters of recommendation to be sent to: Dr. Nigel George, Bldg. 555, Brookhaven National Laboratory, Upton, NY 11973. E-mail inquiries should be sent to nigel@bnl.gov. BNL is an equal opportunity employer committed to workforce diversity.

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INDIANA UNIVERSITY

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Prof. Robert Gardner (rwg@indiana.edu)
Department of Physics, Indiana University
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Review of applications will begin immediately and will continue until the position is filled.

More information about the iVDGL project may be found at http://www.ivdgl.org/
Information about the iGOC can be found at http://igoc.iu.edu
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Ruprecht-Karls-Universität Heidelberg

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The PhD positions are allocated to the ATLAS project and the H1 project at HERA. The ATLAS position is dedicated to the construction, simulation and test operation of the level-1 calorimeter trigger. In the H1 project the successful candidate will participate in the analysis of HERA data with special emphasis on the study of exclusive meson final states. Both positions require a diploma or a master in physics. The expected duration of the thesis is 3 years,

More information on the projects can be obtained directly from Prof Karlheinz Meier, email meierk@kip.uni-heidelberg.de

The Ruprecht-Karls-Universität is seeking to increase the number of women in academic positions. Therefore qualified women are especially encouraged to apply. Applicants with a physical handicap will be given preference, if equally well qualified.

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Kirchhoff-Institut für Physik
Prof. K. Meier
Schröderstrasse 90
D-69120 Heidelberg

Im Fachbereich 7-Physik- der Universität Siegen ist eine

Juniorprofessur

(Bes.-Gr. C1)
für
„Strukturphysik der Kondensierten Materie" (Experimentalphysik)
zu besetzen.

Universität Siegen

Der/die Bewerber/in soll durch Strukturuntersuchungen der kondensierten Materie mit Röntgen- und Synchrotronstrahlung oder Neutronen wissenschaftlich ausgewiesen sein und zur Lehre im Bereich der Experimentalphysik und der Angewandten Physik befähigt sein.

Vorausgesetzt werden eine Promotion mit wissenschaftlich weit herausragenden Ergebnissen und darüberhinaus gründliche Kenntnisse und Erfahrungen auf dem Gebiet der experimentellen Verfahren und Geräte sowie der theoretischen Grundlagen und Methoden des Gebietes „Strukturphysik der Kondensierten Materie".

Die Mitwirkung in der universitären Selbstverwaltung gehört ebenfalls zu den Aufgaben der Stelleninhaberin/des Stelleninhabers.

Die Universität Siegen strebt eine Erhöhung des Anteils von Frauen in Forschung und Lehre an. Ensprechend qualifizierte Wissenschaftlerinnen werden um ihre Bewerbung gebeten.

Bewerbungen geeigneter Schwerbehinderter sind erwünscht.

Bewerbungen mit den üblichen Unterlagen (Lebenslauf, Zeugniskopien, Lichtbild, Schriftenverzeichnis) richten Sie bitte **innerhalb von sechs Wochen** nach Erscheinen dieser Anzeige an den **Dekan des Fachbereichs 7 – Physik** der Universität Siegen, 57068 Siegen.

Michigan Technological University

The Particle Astrophysics group anticipates making a postdoctoral appointment to start in summer 2002. The successful candidate will join the group's research efforts in the Pierre Auger Cosmic Ray Observatory. Prior experience with cosmic ray data analysis, electronics, atmospheric monitoring, or stellar photometry is desirable. A PhD in Physics or Astronomy is required. Applicants should send their curriculum vitae, publication list and statement of research interests, and should have 3 letters of reference sent to **Prof. David Nitz, Department of Physics, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931-1295.** Applications will be accepted until the position is filled.

Michigan Technological University is an equal opportunity educational institution/equal opportunity employer.

Associate Scientist

The Fermi National Accelerator Laboratory has an opening for a Scientist position on the CMS experiment. This position offers the opportunity to participate in the research program at the LHC. The successful candidate will actively participate in the CMS experiment with particular responsibilities in the management of the regional computing facilities for CMS physics analysis at Fermilab and at Universities in the United States.

As a member of the laboratory, the candidate is expected to take a major role in the research program and physics analysis associated with CMS. He/she should take leadership in establishing the U.S. CMS physics facility at Fermilab.

Technical duties include management responsibilities for planning, implementing, and commissioning the U.S. CMS Regional Computing Centers at Fermilab (Tier-1 center) and at U.S. Universities (Tier-2 centers), as the Level-2 Project Manager for U.S. CMS User Facilities.

A Ph.D. in particle physics and postdoctoral experience in experimental particle physics, physics analysis and computing is required. Management and organizational skills in a highly technical environment are requisite, as is exposure to science based on large facilities and dispersed collaborations of scientists.

Candidates should have a strong interest in experimental high-energy physics, and a broad and deep understanding of the present state of computing technologies and the trends that project these technologies into the future.

The position is posted as a tenure track Associate Scientist but could be modified to a tenured Scientist-I position for an appropriately qualified candidate.

Candidates should submit a curriculum vitae, a list of publications, a letter expressing interest and describing related experience, and three letters of references to:

L.A.T. Bauerdick, MS 234
Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, IL 60510, USA

The deadline for applications is June 15, 2002

Fermilab

A U.S. Department of Energy Laboratory. EEO/AA Employer

UNIVERSITY OF WISCONSIN MADISON

Postdoctoral Position in Experimental Particle Physics

A University of Wisconsin-Madison research group on the BaBar experiment at SLAC seeks outstanding applicants for one or more positions of postdoctoral Research Associate. Applicants should have a Ph.D. in high energy physics or expect a Ph.D. degree in the near future. In addition, applications are expected to have significant research experience in the area of analysis.

The successful candidate will be based at SLAC and participate in the measurement of the CP asymmetry in B decays or rare decays in the B system.

Please send a full CV and three letters of recommendation to the following address (preferably by e-mail or by fax):

Prof. Sau Lan Wu
CERN, PPE Division
Bldg. 32, R-A05
CH-1217 Geneva 23
Switzerland

wu@wisconsin.cern.ch

Tel: (4122) 767-7171, Fax: (4122) 782-8395

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THE INSTITUTE OF MATHEMATICAL SCIENCES CHENNAI (MADRAS) 600 113, INDIA

The Institute of Mathematical Sciences, founded in 1962, is a national institute for higher learning whose primary purpose is to foster high quality fundamental research in frontier disciplines of Mathematical Sciences. It is an autonomous body funded by the Department of Atomic Energy, Government of India.

Applications are invited for **faculty positions** from exceptional candidates in various areas of Theoretical Physics. Currently, our research is centered around the fields of Condensed Matter Physics, Statistical Mechanics, High Energy Physics Phenomenology, QCD and Lattice Gauge Theory, Quantum Field Theory, String Theory, Gravitation, Mathematical Physics, Nonlinear Dynamics, Quantum Optics and Foundations of Quantum Mechanics. At present, we have 28 faculty members in these areas of Theoretical Physics. The Institute also has strong Mathematics and Theoretical Computer Science groups.

We are also developing new areas of expertise, specifically in the fields of Theoretical and Computational Biology, Computational Physics, Quantum Information Theory and Astroparticle Physics. We would like to invite applications from researchers with a proven record of independence, originality and leadership who can significantly enhance activities of the Institute faculty.

Initial faculty appointments are made at the level of Fellow 'D' in the scale of Rs.10,000 - 15,200 on a contractual basis. However, candidates with a proven track record can be considered for higher positions. The Institute follows the Central Government pattern of pay and allowances for its staff. Emoluments at the level of Fellow 'D' are approximately INR 20,000, and include medical and other benefits, as applicable to Central Government employees stationed at Chennai.

A complete *curriculum vitae* together with a list of publications may be sent to:

The Director
The Institute of Mathematical Sciences
C.I.T. Campus, Taramani Chennai 600 113, India
Email: director@imsc.ernet.in

Applicants should arrange for at least 3 letters of recommendation to be sent to the above address directly.

More details may be obtained from our web page
http://www.imsc.ernet.in

Deutsches Elektronen-Synchrotron
Accelerator Physics

DESY

DESY is one of the large accelerator centers worldwide. The research spectrum reaches from elementary particle physics and solid state physics up to molecular biology and medicine.

The group – MPY – is responsible for the theoretical and experimental investigation of accelerator physics' problems together with the development and operation of complex accelerator facilities.

We are looking for a

Physicist (m/f)
BAT Ib

to participate in the preparation of detailed technical design report. It is intended to provide a significant extension of the synchrotron light capabilities at DESY. For this reason PETRA, the second largest accelerator at DESY with a circumference of ca. 2,3 km, should be converted into a light source of international significance. The performance of this future machine should be comparable with presently existing synchrotron light sources in the hard x-ray regime.

You will be expected to contribute in solving both technical and accelerator physics' problems. The main focus of your work will be on the orbital stabilization of the electron beam.

You should have a Ph. D. in physics. The successful candidate must be capable of working on his/her own initiative. To meet the above demands you should have substantial knowledge of accelerator physics as well as experience in specifying accelerator hardware. If you fulfil the prerequisites, please send your application incl. 3 referees to our personnel division.

The salary and the social benefits correspond to those in public services. DESY is open for flexi-time and other modern models for working hours.

Handicapped persons will be given preference to other equally qualified applicants.

DESY is committed to equal opportunities and therefore welcomes applications of qualified women.

Deutsches Elektronen-Synchrotron DESY
code: 54/2002 • Notkestr. 85 • D-22603 Hamburg • Germany
Phone +49 40 8998-3862 • www.desy.de
email: personal.abteilung@desy.de

Deadline for applications: open

PENNSTATE

POSTDOCTORAL POSITION

The Department of Physics at Penn State is looking to fill a postdoctoral research associate position focusing on the development of large area neutron detectors and neutron scattering studies in condensed matter physics.

Further information on the instrument can be obtained at

http://sokol.phys.psu.edu/CNCS.

Candidates must have a Ph.D. in Physics with experience in the development and construction of large area detectors.

Please send applications, including a vita, statement of research, and at least two letters of recommendation, to

Prof. Paul Sokol,
Box D, Department of Physics,
104 Davey Laboratory,
The Pennsylvania State University,
University Park, PA 16802
USA.

(phone: 814-863-5811,
e-mail: pes4@psu.edu) AA/EOE

Research Associate Position
Experimental Elementary Particle Physics
Princeton University

The Elementary Particles group at Princeton University has an opening for a postdoctoral research associate to work on the Fermilab Booster Neutrino Experiment, MiniBooNE. Interested persons should send an application to:

Prof. Peter Meyers, Physics Dept.
Princeton University, POB 708
Princeton, NJ 08544-0708

The application should include a curriculum vitae, a statement of research interests and the names of three referees. Applicants should arrange to have referees' letters sent directly to the address above.

Review of the applications will begin **May 15, 2002** and will continue until the position is filled.

Princeton University is an Affirmative Action/Equal Opportunity Employer

BOOKSHELF

Chaos in the Kitchen = Symmetry at the Table edited by Beate Block and Maggie DeWolf, Mountainair press, ISBN 092952618X, $25 (€29).

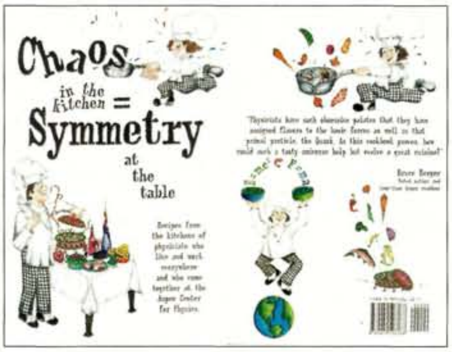
It is somewhat unusual to review a cookbook in *CERN Courier*, but then this is a somewhat unusual cookbook. A collection of recipes assembled by the wife of a physicist at the Aspen Center for Physics, the book is as much a glimpse into the mindset of physics as it is a book about cooking.

The introductory pages deal with Aspen, but you'd have had to have been there to get the most out of it. The recipes begin with sections devoted to extraordinary chefs. There you'll learn how to make risk-free mayonnaise, and why it's best to whip egg whites in copper bowls. You'll also learn some of the culinary secrets of Fermilab's famed Chez Leon. One of the extraordinary chefs is Tita Alvarez Johnson, who founded the restaurant and gives it a memorable atmosphere to this day.

The rest of the book is divided into chapters sorted by region. Contributors are often mentioned by name, occasionally along with tasters. This makes for interesting, if slightly voyeuristic, reading. Here physicists will find the recipes of colleagues, their wives and even mothers-in-law. The presence of fondue Chinois betrays a CERN influence, and at least one Aspen visitor must have been to a La Thuille meeting, since the Aosta valley speciality "la Grolla" makes an appearance. In these chapters, you can even learn that at least one delegate to CERN Council has a soft spot for chocolate (a Belgian, of course).

The final section, "Drinks and amusements", is definitely by physicists for physicists. There you'll find a learned treatise on "Interparticle forces in multiphase colloid systems" – or how to resurrect coagulated sauce béarnaise. The thermodynamics of the perfect Martini are also covered here.

A chef once told me that to review a cookbook properly, you have to make all of the recipes. After spotting mysterious ingredients, such as powder steam and others still more exotic, this reviewer shied away from that approach and chose instead to dip into the book simply for the pleasure of it. Making the recipes will follow, starting with those from Chez Leon. Although the book may tell you how to make Tita's recipes, unfortunately it doesn't give her recipe for creating a memorable atmosphere – that you will have to discover for yourself.



All proceeds from *Chaos in the Kitchen = Symmetry at the Table* go to the Aspen Center for Physics. Ordering information is available from The Aspen Center for Physics, 700 West Gillespie St, Aspen, Colorado 81611, USA, or email jane@aspenphys.org.
James Gillies, CERN.

Electron Scattering for Nuclear and Nucleon Structure by John Dirk Walecka, *Cambridge Monographs on Particle Physics, Nuclear Physics and Cosmology*, Cambridge University Press, ISBN 0521780438, £60 (€98).

The author is well placed to write a monograph on this classic subject which, like no other, bridges the gap between nuclear and particle physics through common concepts and techniques. He can look back on a long and distinguished career in this field as professor of physics at Stanford University, as scientific director of CEBAF (now Jefferson Lab), and now as professor of physics at the College of William and Mary.

The book is based largely on a series of lectures on the subject given at CEBAF. Given the author's track record, it is only natural that the book should focus on electron scattering in the few-gigaelectronvolts energy domain. At the same time, it exploits the power of the theoretical concepts developed originally for low-energy scattering, to address an audience much wider than students and researchers at laboratories such as MIT Bates, JLab and the Mainz microtron. This is achieved through a clear structure and pedagogical distinction between the theoretical framework and practical applications.

The book is organized into five parts, two of which contain the core material. Part 2 – "General analysis" – is one of the most comprehensive reviews of the theory and phenomenology of electron-nucleus and electron-nucleon scattering that can be found in the literature today. This chapter is recommended reading not only for nuclear physicists, but also for every graduate student working on electron, muon and neutrino scattering, to acquire a detailed understanding of the roots and the development of the formalism applied to present-day high-energy experiments. It includes discussions of polarized deep inelastic scattering and of parity violation in electron scattering.

Part 4 – "Selected examples" – is targeted specifically at nuclear physicists. The applications of scattering theory focus on detailed discussions of classic nuclear-structure problems and experiments; three sections on the quark model, QCD, and the Standard Model embed the subject in the wider theoretical context. Recent deep inelastic electron and muon scattering experiments are not covered in a systematic way (however, they have been discussed in many other excellent reviews).

The three remaining parts of the book are more succinct. Part 1 is an easy-to-read introduction, and part 3 discusses quantum electrodynamics and provides an introduction to radiative corrections, which unfortunately is too concise to be of much practical use. Finally, part 5 gives an overview of future directions, which again focuses on the CEBAF/JLab experimental programme. A useful feature is an extensive set of appendices, providing handy reference material.

The author has accomplished a successful blend of textbook and monograph. Written by a nuclear physicist for nuclear physicists, it is a must for students and seasoned researchers alike engaged in electron–nucleus scattering. This book will also be eminently useful and rewarding for the deep-inelastic-scattering community to read, to learn about the origin of their field and its intimate relationship with one of the most important subject matters in nuclear physics.
Rüdiger Voss, CERN.

Books received

Antimatter – the Ultimate Mirror by Gordon Fraser, Cambridge University Press, ISBN 0521893097, £12.95 ($18).

Former *CERN Courier* editor Gordon Fraser has added brand-new material for the paperback edition of his fast-paced account of the story of antimatter.

VIEWPOINT

Accelerator science needs more brain power

Although the application of accelerators to science grew in the early 20th century, **Maury Tigner** says that further technical advances depend on greater intellectual input.

Galileo's remark, "measure what is measurable, and make measurable what is not so", says it all with respect to contemporary quantitative science. He gives pride of place not only to measurement, but also to extending the means of measurement beyond its current circle of light.

While these principles are broadly respected, the latter tends to be somewhat narrowly construed to our detriment. The particular example I have in mind is that of accelerators – although there are others. The range of applications of accelerators to science – and technological applications as well – has grown steadily, particularly with the rapidly expanding use of synchrotron radiation for the life, materials and engineering sciences, to say nothing of the growing use of accelerators for neutron production in these same fields. There are two excellent reasons for the stakeholders in these fields to take a more active role in this part of instrumentation development:

- the control of increasing facility costs needs intellectual input;
- the need for new capabilities in pushing forward the frontiers in the various sciences demands involvement by those who best understand these capabilities.

Accelerator history

Before proceeding, it would be best to review the history of accelerator science and technology. The first half of the 20th century saw rapid development of the various accelerator types we use today. With a few exceptions, these developments were driven by the scientists who needed them for their research, both scientists working in university environments and those in the larger facilities that began to grow after the Second World War. With the scientific need for higher and higher energies enabled by the discovery of the alternating gradient principle and the development of systematic design methods for accelerators, a specialization of labour developed in which accelerator science became an identifiable speciality diverging from nuclear and particle science. This, coupled with the closing of most university accelerators, forced by the need for ever larger facilities, has effectively removed intellectual involvement in accelerator development from most university campuses (with a few notable exceptions). To continue with the example of particle physics, today only 13% of experimental particle physicists in North America claim involvement in accelerator work, and two-thirds of them reside at national laboratories. By contrast, three-quarters of experimental particle scientists reside at universities. The health of accelerator-based science depends on redressing this imbalance in intellectual centres of gravity.

Maury Tigner. (Frank DiMeo/Cornell University Photography.)

While the laboratory structure that has developed, driven by these trends, has been hugely successful, the need for reconsideration is apparent. Progress at the energy frontier of particle science is now strongly compromised by the cost of the required facilities. Cost is also a factor in facilities for radiation production for the life, materials and engineering sciences – though not yet as urgent as for particle science. However, technical advances in improving brightness, coherence and time structure of radiation-producing accelerators are needed to continue advancing on the important frontiers. These advances need the intellectual input of those who know exactly what characteristics are needed, and who are capable of matching technical possibilities to these needs.

One often hears that the culture changes implied by these observations cannot take place because the subjects are not themselves accelerator specialists – how can one contribute to such a mature and well developed field dominated by experts? The point is that the problems to be solved and the concepts to be developed have significant components outside of the traditional accelerator science and technology purview – just the sort of instrument-developing activity that good experimental scientists have always engaged in. Of course the specialists are needed, but new ideas "outside the box" are required. It should be obvious that at this stage of world science, more intellectual input into this part of instrument development is needed. It's a matter of perspective. University and lab scientists, and their cultural underpinnings, need to see themselves in this picture if we are to continue the progress that can be afforded by the use of accelerators.

Maury Tigner, Cornell University.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