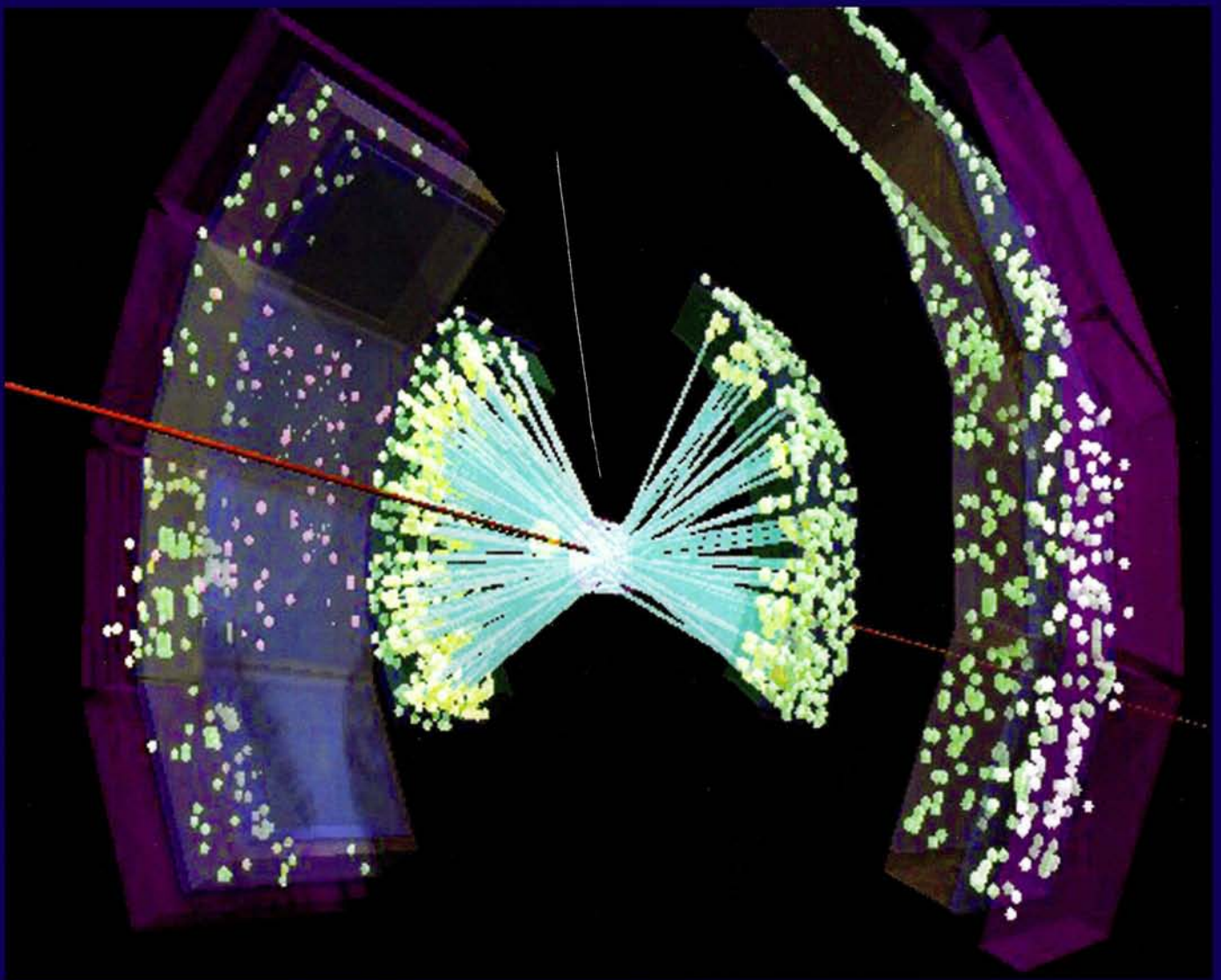


# CERN COURIER

VOLUME 41 NUMBER 8 OCTOBER 2001



## Nuclear collisions feel the heat

### **MEDICAL IMAGING**

From the physics laboratory  
to the hospital pp18 & 20

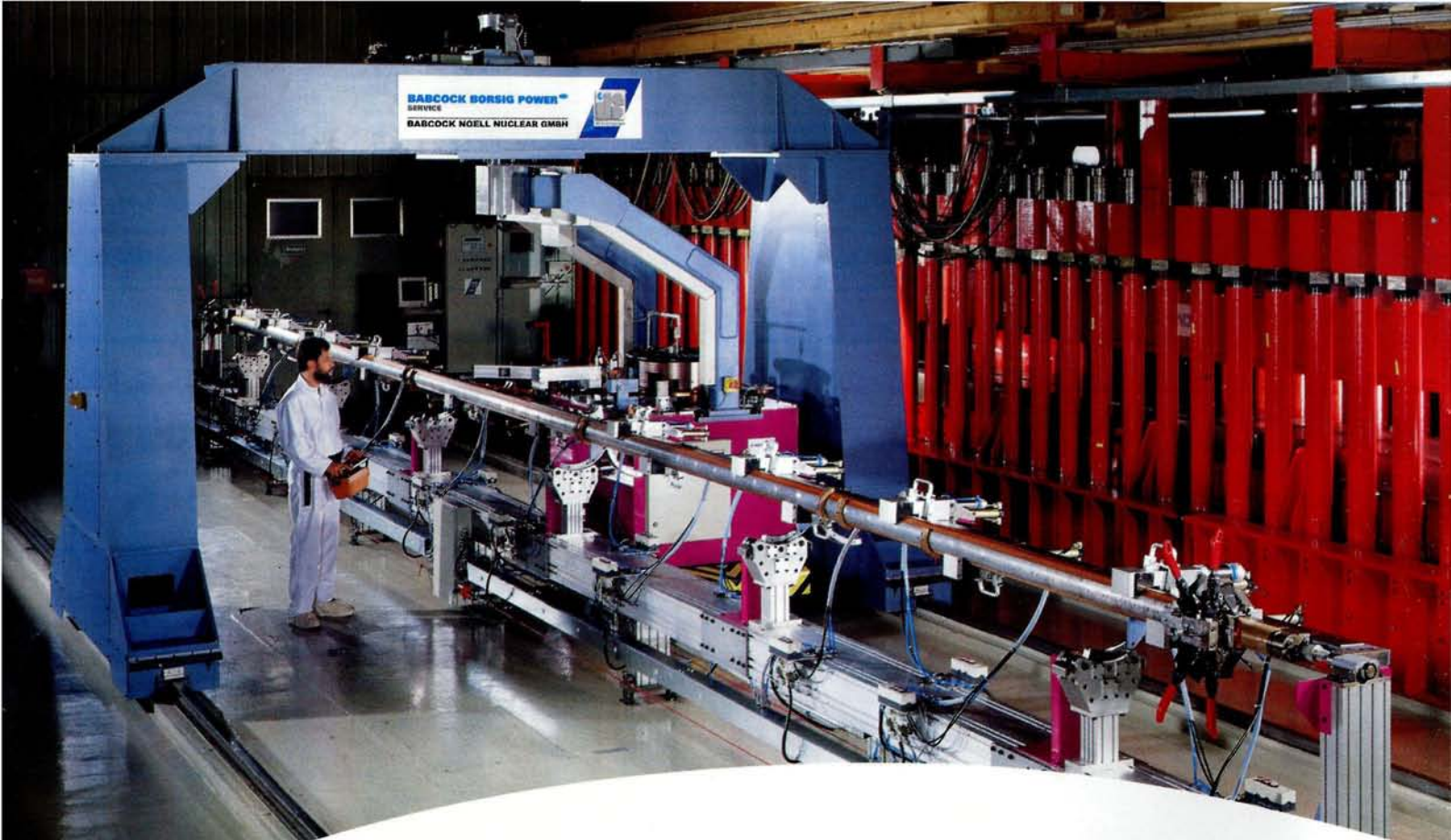
### **SUPERHEAVY NUCLEI**

Element 116 alive and well  
on the island of stability p25

### **COMPUTING**

How physicists plan to handle  
lots of data rapidly p31





Babcock Noell Nuclear GmbH (BNN) has been developing, manufacturing and supplying superconducting magnets for the LHC particle accelerator in Geneva since 1990. In 1999, BNN was also contracted to manufacture 30 pre-series magnets of the latest design. Several prototypes and the first pre-series magnets have already been supplied and have fulfilled the expectations of the design in tests performed by CERN.

# From Winding to Cryostating



Babcock Noell Nuclear GmbH has also proven its competence in the design and manufacture of the tools required for production.

In addition to completing the dipoles for the LHC, Babcock Noell Nuclear GmbH has also been developing magnets and components for nuclear fusion experiments, e.g. the non-planar coils for Wendelstein 7-X.

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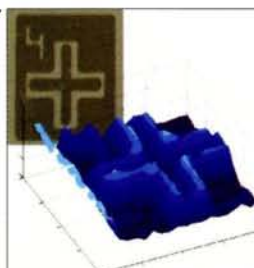
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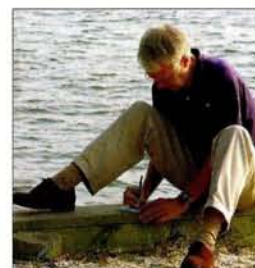
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**Cover:** A nucleus-nucleus collision as seen by PHENIX, one of the large experiments at Brookhaven's RHIC relativistic heavy ion collider, which is now operating at its full collision energy (p8).



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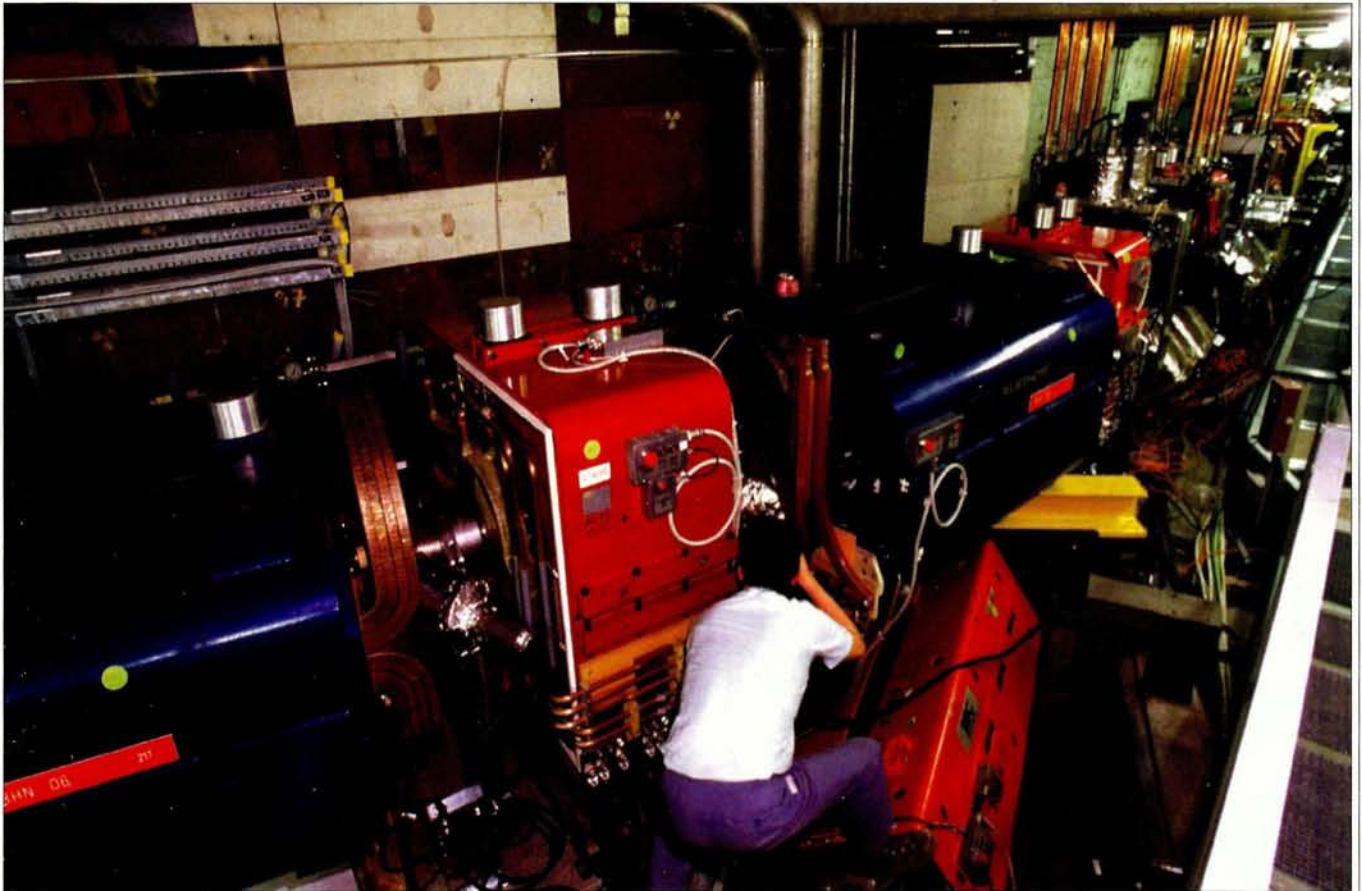
Enhanced image of Titan taken  
from *Voyager 1* in 1980.





CERN

## Getting up to speed in the year AD 2



CERN's Antiproton Decelerator has been undergoing improvements.

After coming into operation last year (*CERN Courier* September 2000 p9), CERN's Antiproton Decelerator (AD) has got up to speed for physics this year. Changes to the AD since its debut mean that the three experiments – ASACUSA, ATHENA and ATRAP – now enjoy more intense antiproton beams.

The AD is a unique machine. Its job is to decelerate, not accelerate, antiparticle beams, and it has to handle energies that decrease by an unprecedented factor of 35 from the injection ceiling at 3.57 GeV to the ejection floor at 100 MeV.

In its first incarnation in 1987 as a collector of antiprotons, precooling the particles before they passed to the accumulator ring for CERN's proton-antiproton collider, it was designed to operate at fixed energy, so this factor of 35 presented a big challenge.

The AD team's design goal was to hang onto a quarter of the injected antiprotons through their vertiginous fall in energy, and to repeat the deceleration cycle once a minute. Recent AD improvements have put the team well on the way to reaching this target.

One important new feature is in the electron

cooling system, adapted from that used for CERN's LEAR low-energy antiproton ring, which closed in 1996. Electron cooling gives the antiproton beam a final "cold shower" after the initial stochastic cooling, keeping the antiprotons tightly bunched at the lowest energies. Improvements have also been made to the radiofrequency deceleration system. This summer the AD succeeded in decelerating an injected antiproton beam without losing a single precious particle.

Meanwhile the three AD experiments are getting to the heart of the antimatter (p35).

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BEIJING

# New double-ring design for Chinese



Aerial view of the Beijing Electron-Positron Collider complex at the Chinese Institute of High Energy Physics, showing the buildings that house the circular tunnel of the 240 m circumference collider ring (centre left) and its injector (centre right). The plan is to build a second ring adjacent to the first within the same housing.

A second ring is now being planned for the Beijing Electron-Positron Collider (BEPC) at the Institute of High Energy Physics (IHEP). The precision measurements and successful completion of a run collecting 50 million J/psi particles at BEPC, as well as the planned upgrade to BEPC II (*CERN Courier* November 2000 p6), have attracted a lot of attention.

The earlier upgrade design was based on multiple bunches and bunch trains in a "pretzel" orbit at the existing BEPC storage ring, which would have increased the luminosity ten-fold. (The existing BEPC contains adjacent counter-rotating electron and positron beams in a single ring, which is the standard approach.)

In parallel, an upgrade of the Beijing Spectrometer, BES III, was designed to handle

high event rates and to reduce systematic errors. The Chinese funding agency approved these upgrades.

Many recent physics results have underlined the importance of high-precision measurements. In particular, precision measurements in the tau-charm region have a unique advantage for many interesting physics studies, such as searches for glueballs (particles without quarks) and quark-gluon hybrids, light hadron spectroscopy, the J/psi family, and excited baryons.

Special workshops were held recently at SLAC and Cornell in the US to discuss this physics, and there are proposals to build a new machine at SLAC (PEP-N) and to lower the beam energy of Cornell's CESR ring to run in this energy region. The interest of a number

of other laboratories in this physics underlines its importance.

To extend its physics potential and to be more competitive, IHEP recently modified the BEPC II design to a double ring. This significantly improves the expected performance with a calculated luminosity of  $10^{33} \text{ cm}^{-2} \text{ s}^{-1}$  at a beam energy of 1.55 GeV.

An international review on the feasibility of the new design was held on 2-6 April in Beijing. It was conducted in two partially overlapping segments, the first dealing with the accelerator collider programme and the second with the detector for the upgraded facility. Two separate reports were prepared under the chairmanship of Alex Chao of SLAC and Michel Davier of Orsay. Former SLAC director W K H Panofsky of SLAC summarized:



# machine will be more competitive

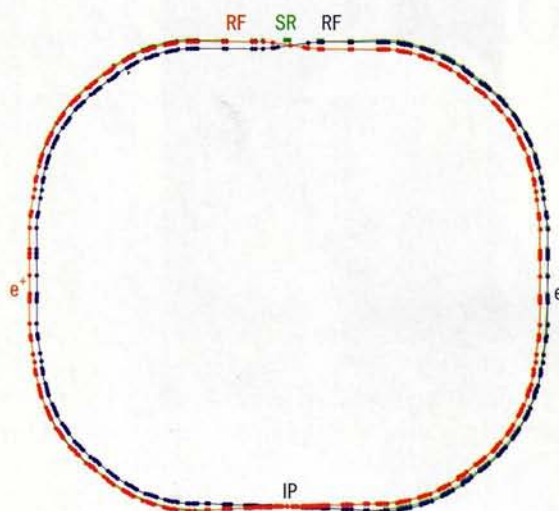
"After much excellent work leading to the feasibility study report, there is no basic reason why a luminosity greater than  $3 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$  or even  $10^{33}$  could not be reached. The review committee recommended strongly the double-ring option."

The double-ring design requires a new storage ring of slightly smaller radius to be built adjacent to the existing storage ring. The two halves of the new ring and of the old ring will be linked at two interaction points to form two identical rings, each made up of one half of the old ring and one half of the new. Each new ring can be filled with up to 93 bunches with maximum beam current of 1.1 A at a beam energy of 1.55 GeV.

The beams will collide at the south interaction point with a horizontal crossing angle of 11 mrad. To reduce the beam length, superconducting micro-beta quadrupoles will be installed near the interaction region. Superconducting cavities with a 499.8 MHz radiofrequency system will further reduce the bunch length and also provide much higher power. Low impedance vacuum chambers will be used. The upgrade of the linac injector allows full-energy injection up to 1.89 GeV and a positron injection rate of 50 mA/min. The instrumentation and control system will also be upgraded. The calculated luminosity at a beam energy of 1.55 GeV is  $10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ , which is an improvement of two orders of magnitude.

To retain dedicated synchrotron radiation running in the existing outer ring, a bridge will connect the two half outer rings at the north interaction point. At the collision point of the south interaction region, special dipole coils will be installed in the superconducting quadrupoles to keep the beam in the outer ring during dedicated synchrotron radiation running. The beam current during dedicated synchrotron radiation running could be higher than 150 mA at 2.8 GeV.

Compared with the pretzel design using a single ring, the double-ring design is much



*Two rings in Beijing.* The proposed layout of the new Beijing Electron-Positron Collider. A new ring of circumference 237 m will be built alongside the existing 240 m circumference ring. The new and old rings will be made to cross at two points (north and south) to make two identical rings – one for electrons, shown in blue, and one for positrons, shown in red. To retain dedicated synchrotron radiation running in the existing outer ring, a bridge (shown in green) will connect the two half outer rings at the north interaction point.

more competitive in performance, has fewer technical risks, and costs only about 50% more.

The proposed design of the upgraded Beijing Spectrometer (BES III) has also been improved significantly to match the high performance of the double-ring design. Starting from the interaction point, the BES III detector consists of a scintillating fibre detector; a main drift chamber; time-of-flight counters; a barrel electromagnetic calorimeter; an end-cap electromagnetic calorimeter; a superconducting magnet; and a muon detector. The superconducting magnet, providing 1.2 Tesla, has a length of 3.2 m, an inner radius of 1.05 m and an outer radius of 1.45 m.

The scintillating fibre detector provides trigger signals and reduces cosmic-ray background. It consists of two superlayers, with two layers of scintillating fibres in each,

that are read out at both ends by avalanche photodiodes via clear fibres. The position resolution per superlayer is expected to be 80  $\mu\text{m}$  radially and 1 mm along the beam axis.

The main drift chamber (length 1906 mm, inner radius 70 mm and outer radius 660 mm) consists of 36 layers with small cells and with aluminium-filled ( $1 \mu\text{m}$ ) wire and helium-based gas to reduce multiple scattering. The single-wire resolution is expected to be better than 130  $\mu\text{m}$ . The solid angle coverage for tracks going through all layers is 93%. To provide space for the superconducting micro-beta quadrupoles and to reduce the background, the end plates of the inner part will be step-shaped. The expected energy loss resolution is about 7%.

The time-of-flight counters consist of two layers of plastic scintillator with 72 pieces in azimuth per layer. The time resolution should be better than 65 ps. This will provide good kaon/pion differentiation up to 1.1 GeV. The barrel electromagnetic calorimeter is made of crystals with an energy resolution better than 2.5% at 1 GeV. The endcaps of the electromagnetic calorimeter are made of lead-scintillating fibres with an energy resolution of about 6% at 1 GeV.

An international workshop on the BES III detector on 13–15 October at IHEP, Beijing, will discuss the design and possible collaboration. New design ideas are welcome, as are international participation and contributions to the new detector.

The feasibility study report on BEPC II has been submitted to the Chinese funding agency. R&D work of key technologies is in progress. The design report should be finished by next spring, and construction should begin soon afterwards. BEPC will continue to run until spring 2005, after which there will be a long shutdown (about 9–10 months) for installation. The tuning of the new machine should start by spring 2006, and physics should be running by the end of 2006.



## CONFERENCE

# Language was no barrier at Budapest conference

This year's venue for the European Physical Society's biennial Europhysics Conference on High-Energy Physics was the new campus of Eotvos University in Budapest, Hungary. From 41 countries, nearly 600 registered participants and more than 100 registered "accompanying persons" attended the scientific and social events.

As well as the traditional parallel and plenary sessions with all of the physics developments (most of which have already been reported in *CERN Courier*), the meeting included several innovations. One was an open session of the European Committee of Future Accelerators (ECFA) in which ECFA chairman Lorenzo Foa presented the draft of an ECFA report on the future of European accelerator-based particle physics. Another innovation came when many outsiders were attracted to talks by two leading Hungarian high-energy physicists. To avoid language difficulties, the talks were presented in parallel, one in Hungarian, and the other in English.



Left: ECFA chairman Lorenzo Foa presenting a draft of an ECFA (European Committee for Future Accelerators) report on the future of European accelerator-based particle physics at this year's European Physical Society's biennial Europhysics Conference on High-Energy Physics at Eotvos University in Budapest. Right: Christine Sutton of Oxford and Erik Johansson of Stockholm, who were presented with the European Physical Society's new Outreach prize at the conference. The award was for their work in bringing high-energy physics to a wider public, and in particular their interactive computer packages for educational master classes.

Julius Kuti (UC San Diego and an external member of the Hungarian Academy of Sciences) spoke on the cosmic significance of particle physics and Teraflop computing. Alex Szalay (Johns Hopkins and a member of the Hungarian Academy of Sciences) gave a talk on megamaps of the universe.

The next conference in the series will be

held in Aachen, Germany, in 2003.

The scanned transparencies of all talks at the Budapest meeting are accessible on the Web at "<http://www.hep2001.elte.hu>" (Transparencies section).

The proceedings of the Budapest conference will be published exclusively in electronic form by JHEP.

## USA

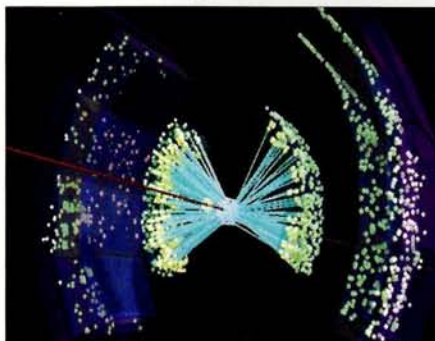
# RHIC collider running at full collision energy

The 4 km circumference Relativistic Heavy Ion Collider (RHIC) at the Brookhaven Laboratory is now running at its full design nucleon collision energy of 200 GeV and physics expectations are high.

The machine began running for physics last year at a modest energy but soon ramped up to a nucleon collision energy of 130 GeV (*CERN Courier* October 2000 p5).

In addition to running with heavy ions at full energy, the latest RHIC run will explore collisions of spin-oriented (polarized) protons.

Earlier this year the first physics results from the RHIC 2000 run were announced (*CERN Courier* June p25). These results showed that



A display of a nucleus-nucleus collision seen by PHENIX, one of the large experiments at Brookhaven's Relativistic Heavy Ion Collider.

nucleus-nucleus collisions have attained a region where the distributions of the numbers of produced particles display new behaviour.

The objective is to produce a "Little Bang", recreating the quark-gluon plasma - the primeval soup that existed from about 1  $\mu\text{m}$  after the Big Bang of creation, and then survived for about a ten-thousandth of a second until quarks had a chance to cool down sufficiently to group together and form the nuclei that we now know.

The new RHIC run will also push for high luminosity, which is a measure of the nuclear collision rate.



## SOFTWARE

# CERN sells its internal transaction management software to UK firm

CERN has sold its Internal Transaction Management system to UK internal transaction management concern Transacsys for 1 million Swiss francs (€660,000). The system, which has been cited by software giant Oracle as the blueprint for building large-scale e-business systems, is being launched commercially. Transacsys is co-operating with Oracle in the marketing of the software.

Internal transactions are the actions that people take and the processes that they use in the course of their job. Internal transactions need managing because organizations need to know and to control how people commit and expend corporate resources.

The CERN software on the one hand empowers individuals to transact and on the other hand controls such transactions in accordance with corporate rules. It has been designed to be totally flexible so that users themselves can create new processes, and implement and change them at will, with no programming required.

CERN, with an annual budget of more than



Most of the team that created CERN's Internal Transaction Management system, called Permissioning under a new deal with specialist software house Transacsys, but better known at CERN as Electronic Document Handling. Left to right: Derek Mathieson, Rotislav Titov, Per Gunnar Jonsson, Ivica Dobrovicova and James Purvis. Team member Jurgen de Jonghe is not present.

€600 million and more than 6000 regular users working in 500 institutes in 50 different countries, can support the software internally using just two people.

Permissioning is the name that Transacsys has given to this enterprise-wide process,

which enables people to have speedy authorization to execute tasks and organizations to control these processes without the need for extensive administrative resources.

In 1990 CERN developed the World Wide Web to help to empower its user community of more than 6000 physicists around the world to share information across remote locations. Soon after, CERN began to develop what became the Permissioning system, when an advanced informatics support project was launched. In this project the system, which is known as Electronic Document Handling (EDH) at CERN, was to provide an electronic replacement for a rickety system of paper administration forms that had accumulated over the years. Functionality has been progressively extended over more than eight years of constant development.

Transacsys and CERN have formed a long-term joint steering group to co-operate on further development of the system. CERN will, of course, continue to use the system and it will be free for use by other particle physics laboratories associated with CERN.

## BROOKHAVEN

## Team produces stranger than strange nuclei

An experiment at Brookhaven's Alternating Gradient Synchrotron (AGS) has "mass-produced" doubly strange hypernuclei - exotic nuclei in which two neutrons have been replaced by  $\Lambda$  hyperons (each containing three quarks - up, down and strange).

In the AGS experiment by a collaboration of physicists from Canada, Germany, Japan, Korea, Russia and the US, a beam of negative kaons (negative charge, strangeness minus 1) produced outgoing positive kaons (positive charge, strangeness plus 1).

In these reactions an incoming negative

kaon hits a nuclear proton, transforming it into a negative  $\Xi$  particle (strangeness minus 2 - consisting of a down quark and two strange quarks). This in turn transforms into a pair of  $\Lambda$  particles, each of which can lodge in the parent or a nearby nucleus, and sometimes even in the same nucleus, identified as hydrogen-4 $\Lambda\Lambda$ , containing a proton, a neutron, and two  $\Lambda$ s. The doubly strange hypernucleus thus resembles a deuteron onto which two  $\Lambda$ s have been grafted. The nuclear states are identified via their weak (beta) decay patterns into pions, each pion being

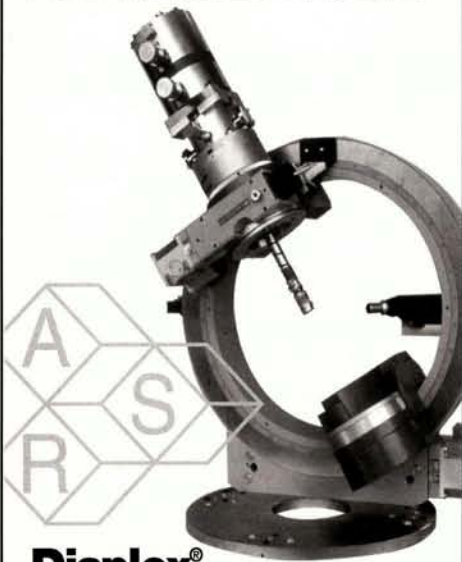
associated with a unit of strangeness change.

Such doubly strange hypernuclei have been reported before singly, but never in such quantities. Their production opens the door to the study of other such nuclei and of the mutual interaction of  $\Lambda$  particles. The substitution of a lambda for a neutron upsets the usual nuclear shell assignments due to the Pauli Exclusion Principle, so that the strange particles can penetrate to the nuclear core.

The simplest hypernuclei, containing a single strange particle, have been known and studied for almost half a century.



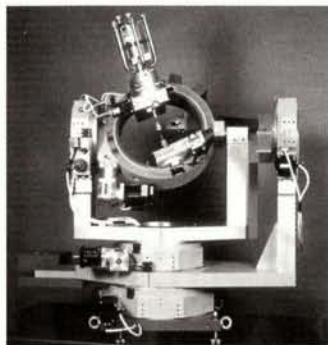
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## NEWS

### CERN

# Asia programme offers postgraduate grants

Within the framework of the CERN-Asia Fellows and Associates programme, CERN offers three grants every year to young east, south-east and south Asia\* postgraduates under the age of 33, enabling them to participate in its scientific programme in the areas of experimental and theoretical physics and accelerator technologies. The appointment is for one year, which might exceptionally be extended to two years.

Applications will be considered by the CERN Fellowship Selection Committee at its meeting on 29 January 2002. An application must consist of a completed application form, on which should be written "CERN-Asia Programme"; three separate reference letters; and a curriculum vitae including a list of scientific publications and any other information regarding the quality of the candidate. Applications, references and any other information must be provided in English only.

Applications should reach the Recruitment Office at CERN before 5 November 2001.

Application forms can be obtained from the Recruitment Service, CERN, Human Resources Division, 1211 Geneva 23, Switzerland; e-mail "Recruitment.Service@cern.ch"; fax +41 22 767 2750.

The CERN-Asia Fellows and Associates programme also offers a few short-term associateship positions to scientists aged under 40 who wish to spend a fraction of the year at CERN or a Japanese laboratory and who are "on leave of absence" from their institute. Applications are accepted from scientists who are nationals of the east, south east and south Asian\* countries and from CERN researchers who are nationals of a CERN member state.

\*Candidates are accepted from the east, south-east and south Asian countries of Afghanistan, Bangladesh, Bhutan, Brunei, Cambodia, China, India, Indonesia, Japan, Korea, the Laos Republic, Malaysia, the Maldives, Mongolia, Myanmar, Nepal, Pakistan, the Philippines, Singapore, Sri Lanka, Taiwan, Thailand and Vietnam.

## Accelerator prizes

US Particle Accelerator School prizes for Achievement in Accelerator Physics and Technology for this year went to Tor Raubenheimer of SLAC, Stanford and Dieter Moehl of CERN.

Raubenheimer received the award for the development of emittance control techniques for high-performance electron-positron linear collider and storage rings, and for his leadership role in the development of a second-generation linear collider.

Moehl was honoured for his outstanding contributions to beam cooling and to counteracting intensity limitations, and for his impact on the conception, design and operation of low-energy storage rings for ions and antiprotons.

The prizes were awarded at the 2001 Particle Accelerator Conference in Chicago.

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Edited by Archana Sharma

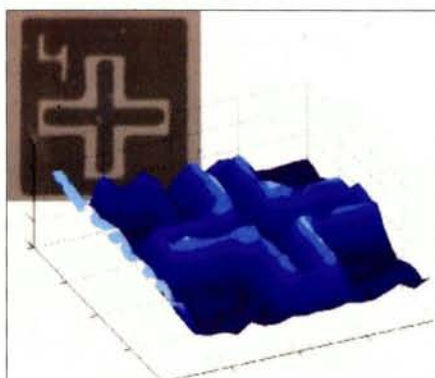
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## Antimatter microscopes detect small defects

Mixing matter with antimatter may enable materials to be examined in unprecedented detail. Physicists at the Military University, Munich, have developed an antimatter microscope, a scanning positron microscope (SPM), which is a very specialized instrument with a very useful application – detecting defects in semiconductors. It can spot a single defect site in a million silicon atoms, a sensitivity that no other method can match.

The electrical conductivity of semiconductors depends on defects, so information like this could be invaluable to the microelectronics industry. Chip manufacturers currently dedicate considerable resources to adding, removing and monitoring defects in their materials.

The SPM uses positrons – the antiparticle partners of electrons – which are positively charged and so attracted to regions of negative charge. A semiconductor such as silicon can be considered as a lattice of positively charged silicon ions embedded in a thin soup of mobile electrons. A site where the crystal lattice lacks one or more atoms is a “vacancy” – one of the most common types of defect. Lacking a positive nucleus to repel a positron, a vacancy can trap the antimatter particle temporarily. Sooner or later a positron meets an electron, and the two annihilate one another, releasing their energy as gamma-ray



*The scanning positron microscope in action. The device provides more information on a test pattern of surface defects (seen at the bottom of the picture) than a conventional electron microscope image (top).*

photons. Detecting this radiation reveals where in the sample the positron met its fate.

The positrons, which came from a radioactive sodium source, passed through a series of electric fields that homogenized their energies and bunched them into short pulses. They then passed through another series of fields that accelerated the pulse to a specified energy before focusing it into a 2 µm dot on the silicon surface. By measuring the time between the pulse and the photon flash of electron-positron annihilation, the team was able to map the defect regions.

The team found that the positrons that lodged inside defects avoided annihilation for twice as long as those positrons in other regions. By scanning the beam across the surface, it created an image of the defect pattern in the wafer.

The researchers tested their device on a cross-shaped pattern about 120 µm across, which was deposited in platinum on the surface of an oxidized silicon wafer. The positrons survived for almost twice as long in the silicon dioxide as in the platinum, enabling the researchers to reconstruct the cross.

They also imaged a scratch just 5 µm wide in the surface of a gallium arsenide semiconductor. The scratch contained vacancy clusters that increased positron lifetime.

The SPM can also give information on the type of defect – information that no other technique can provide. A positron survives for different lengths of time inside different kinds of defect, so the spectrum of positron lifetimes can reveal the types of defect present in a material. The lifetime measurement also gives unprecedented sensitivity.

The method locates defects of the order of 0.1 nm, while electrons are sensitive to only about 1 µm. This has important implications for the semiconductors' industrial production and yields. *2001 Phys. Rev. Lett. 87*

## Taiwanese porous silica successfully blocks leaky circuits

A new, highly insulating honeycomb made by Taiwanese researchers may allow micro-electronic integrated circuits to be made even smaller, increasing the power of microchip and computer technology. Most commonly used in integrated circuits is the complementary metal oxide semiconductor (CMOS) transistor, in which a layer of silicon dioxide serves as an electrical insulator, or dielectric, preventing unwanted vertical current flow between the control electrode, known as the gate, and the underlying silicon.

Conducting elements of semiconducting silicon are made by exposing them to oxygen, which oxidizes the surface layer to silica. Silica has a low dielectric constant.

When electronic devices are very small, insulating silica films must be shrunk to the same proportions. If they are too thin, they become leaky and electric currents seep out, creating problems such as crosstalk between different parts of the circuit. Hence the continual quest for a cheap alternative that is also strong, heat-resistant, easy to make into thin films and compatible with silicon wafers.

The Taiwanese team combined the air's low dielectric constant with silica's strength in a porous form of silica that consists of up to 72% of empty space.

The team's thin films of this “mesoporous silica” are honeycombs with channels meas-

uring 4–8 nm across. A technique called spin-coating was used to spread the silicon-rich solution over a surface by rapidly spinning the sample. This method is easier to combine with standard IC fabrication than previous dipping methods for making thin mesoporous silica films.

Further, by covering the pore surfaces with hydrocarbons, the researchers made them water-repellent. This keeps the dielectric constant of the films low – water absorbed from moist air makes for poorer insulators. *AIP*

### Further reading:

C M Yang *et al.* 2001 *Advanced Materials* **13** 1099–1102.

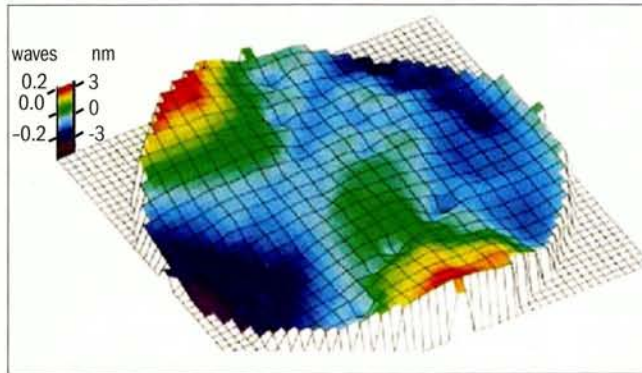


# Next-generation lithography is set to extend current pace of semiconductor innovation

In what is being hailed as the next major advance in the evolution of integrated circuits, a consortium of US industry and government laboratories has announced completion of the first full-scale prototype machine, which demonstrates all critical capabilities for making computer chips using extreme ultraviolet (EUV) light.

This breakthrough will lead to microprocessors that are 10 times as fast as today's most powerful chips and will create memory chips with similar increases in storage capacity.

Akin to photography, lithography is used to print circuits onto microchips. EUV lithography



The surface of a multilayered molybdenum-silicon reflective coating, the enabling optical technology for extreme ultraviolet lithography. Each layer is around 6–7 nm – half a wavelength.

is being developed because the current chip-printing technology is expected to reach its physical limits in the next few years.

Current lithography technology is expected to allow manufacturers to print circuits as small as 0.1  $\mu\text{m}$  across – about a thousandth of the width of a human hair.

EUV lithography technology is being developed to allow semiconductor manufacturers to print circuit lines thinner than 0.1  $\mu\text{m}$  and down to at least 0.03  $\mu\text{m}$  (30 nm), extending the current pace of semiconductor innovation at least to the end of this decade.

Processors built using EUV technology should reach speeds of up to 10 GHz in 2007. By comparison, the fastest Pentium 4 processor attains a speed of 1.5 GHz.

*Electronics Times*

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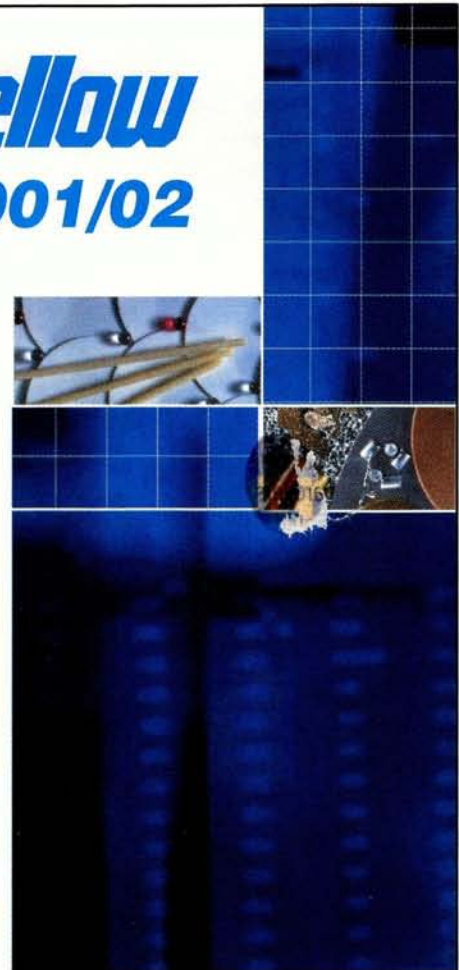
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Edited by Emma Sanders

## Observations link gamma-ray bursts to black hole formation

Over recent years, astronomers have detected numerous short, intense bursts of gamma rays coming from all over the sky. For a brief instant, these flashes of radiation are more energetic than anything else in the universe. However, their origin remains a mystery. New observations of these gamma-ray bursts (GRBs) and their X-ray afterglow support the theory of electromagnetic black hole formation.

As a giant star collapses into a black hole, an extremely strong electromagnetic field can form. This energy could accumulate matter and antimatter, which generate an enormous pulse of energy, expanding with ultrarelativistic velocities. This produces the observed burst of gamma rays when the expanding fireball ceases to be opaque.

Using the GRO/BATSE gamma-ray observa-

tory archive, the Chandra X-ray observatory, the Beppo-Sax satellite and the Rossi-XTE satellite, a team of Italian and French researchers compared detailed observations of GRB 991216 with the predictions made by their model. They say that the timing and intensity of the burst as well as the extended X-ray afterglow can be explained.

The model also explains the association of some GRBs with supernovae explosions, say the researchers. The impact of the expanding fireball on a nearby star could, under certain conditions, induce a supernova explosion in that star. Other GRB theories include the hypernova model (*CERN Courier* June p11).

### Reference

2001 *Astrophysical Journal Letters* **555** L107-120.

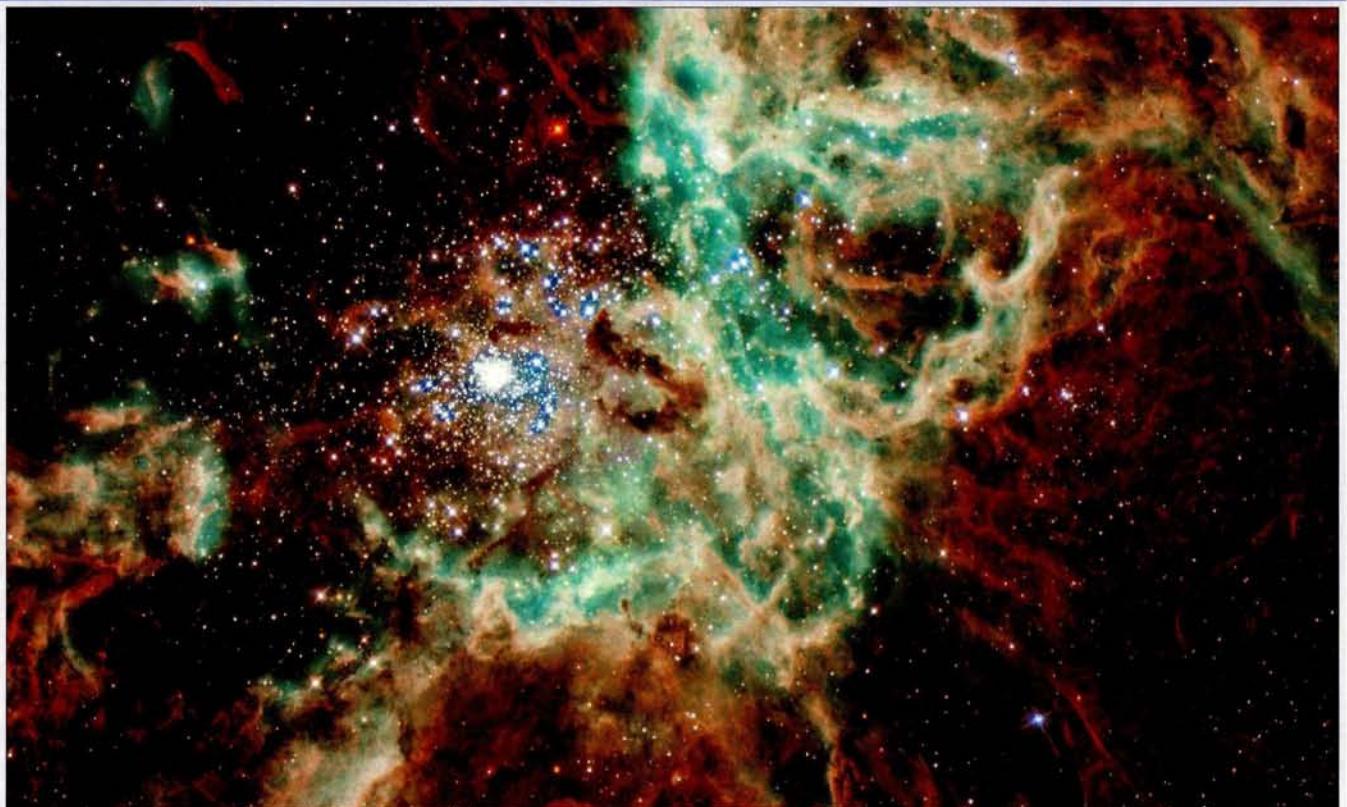
## NASA MAPs the microwave background

NASA launched its Microwave Anisotropy Probe (MAP) this summer. The experiment will measure the cosmic microwave background to one part in a million, with a sensitivity that is greater than 20  $\mu$ K.

MAP will be the first spacecraft to follow an L2 orbit – the second Lagrange point – about the Earth and Moon, which is an exceptionally stable environment. It will take about 18 months to build up a full sky picture and carry out the analysis, so make a note in your diary for March 2003.

● For more on the microwave background and observations of fluctuations in it, see *CERN Courier* July/August p15.

### Picture of the month



This star-forming region, called the 30 Doradus nebula, contains a cluster of massive stars in its core. The ultraviolet radiation and high-speed material released from the core trigger the collapse of surrounding gas and dust clouds, forming incubators for nascent stars. The nebula is in the Large Magellanic Cloud and was imaged using the Hubble Space Telescope. (NASA/ESA.)



# Take a deep breath of nuclear spin

A technique based on using spin-oriented nuclei of helium-3, which has been developed for nuclear physics experiments, also has impressive capabilities for lung imaging.

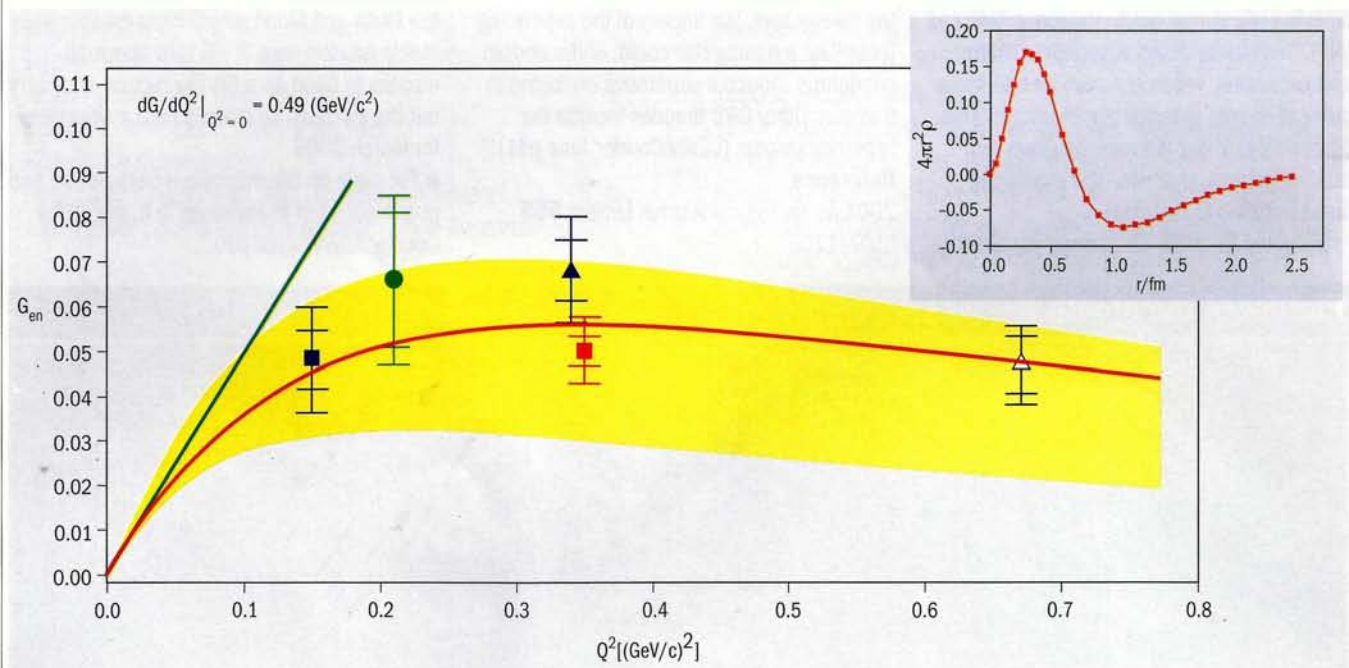


Fig. 1: physics from polarized helium-3. The electric form factor of the neutron,  $G_{en}$ , as a function of the scattering vector,  $Q^2$ . Results obtained in spin-dependent quasi-elastic scattering of electrons on the bound neutrons of helium-3 and deuterium. Inset: resulting intrinsic charge distribution of the neutron (Fourier transform) from a two-parameter fit to the data.

Lungs are full of gas, which is normally invisible, making lung ventilation examinations difficult. While X-ray and other techniques can reveal anatomical anomalies, it is difficult to follow directly the actual functioning of the lung.

Some 30 years ago, in the so-called “golden age” of optical pumping, physicists at Mainz University started to develop techniques for polarizing nuclear spins for nuclear physics studies and experiments at CERN’s Isotope Separator Online (ISOLDE). These experiments revealed interesting insights into the behaviour of exotic isotopes.

For helium-3, optical pumping has shown its potential for magnetic resonance tomography when powerful lasers in the near-infrared region were available to produce large quantities of high-grade, spin-polarized gas.

Inhaled helium-3 can be visualized on a magnetic resonance

tomogram that gives unprecedentedly detailed images of a breathing lung.

The team that developed the technique has been awarded several prestigious prizes, including the Körber prize for European science and a nomination for the German president’s “Future” prize.

### Helium-3: a fascinating tool

Although the helium-3 isotope is extremely rare in nature, it has become more widely available via the beta-decay of synthetic tritium. Since the early 1970s, helium-3 in its superfluid state has become a fascinating laboratory tool for the study of quantum mechanical phenomena that turned out to be an ideal testing ground for fundamental concepts of modern theoretical physics.

In nuclear physics, experiments involving the neutron’s spin are



hampered by the fact that a target of free, polarized neutrons is not available.

However, helium-3 is a good approximation for a target of polarized neutrons, because its nuclear spin of 1/2 is due to its unpaired neutron (the two protons have opposing spins).

To force helium-3 nuclear spins to align in one direction, the gas is exposed to a resonant, circularly polarized laser beam directed along the axis of an external magnetic field. By means of the absorption and spontaneous emission of fluorescent light, the spin of the light quanta can be transferred to the atomic electrons that in turn transmit their spin direction to the nucleus via magnetic coupling. Repeated absorption and emission accumulate the nuclei in a specific spin state. The Mainz laser pumping techniques were developed in collaboration with the specialist team of Michele Leduc at the Ecole Normale Supérieure in Paris.

Scattering a polarized, high-energy electron beam by the neutron in polarized helium-3 allows the contribution due to the electromagnetic interaction of the probe with the internal charge distribution of the neutron – the effect of interest – to be separated off and even enhanced. First precise values can now provide a test for different theoretical approaches to this fundamental property (figure 1).

**Lung tomography**

In 1994 Will Happer's group at Princeton, in collaboration with magnetic resonance imaging specialists from Duke University, Durham, North Carolina, demonstrated in a seminal paper how highly polarized xenon gas could be used to examine the lungs of a guinea pig.

On learning of this, Mainz physicists W Heil and E W Otten, together with their colleague M Thelen from the department of radiology, saw the potential usefulness of their well established helium-3 physics-laboratory techniques for human lung imaging, and they soon carried out very satisfactory trials, beginning in 1995.

Optical pumping of metastable helium-3 atoms, the method they use, can supply relatively large amounts of gas with relatively high polarization – up to 50%. These magnetic signals are a thousand times as large as those normally encountered in magnetic resonance imaging. Under these conditions, lung imaging becomes straightforward. Patients simply inhale a whiff of gas and the whole procedure is carried out at room temperature (figure 2).

One obstacle, however, was the storage and transport of the carefully prepared polarized gas, which has to be taken from the laboratory to the clinics. Collisions with the walls of a normal container would quickly destroy the spin orientation. This is overcome by storing polarized gas in glass vessels, the inner surfaces of which are coated with a few monolayers of caesium. In this way, the polarized gas can be stored at pressures of up to 10 bar and kept ready for use for more than 100 h.

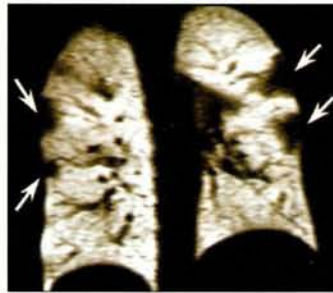
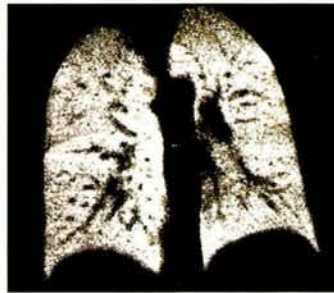


Fig. 2: helium-3 magnetic resonance imaging in medicine showing (left) the lungs of a non-smoker, and (right), the dark, unventilated patches in the lungs of a smoker.

Rather than just giving a single lung image while the patients hold their breath, helium-3 imaging can provide ultrafast sequences with a time resolution of less than a tenth of a second – a “movie” of lung ventilation during the breathing cycle.

There is another advantage: helium-3 in contact with paramagnetic oxygen soon loses its polarization. The rate of depolarization is related to the oxygen partial pressure in regions of interest of the lung and, moreover, enables the oxygen uptake in the blood to be measured. For the first time, normal lung functioning can be quantified, and disorders in respiratory distribution can be recognized before any signs or symptoms have become manifest.

The technique is still undergoing trials at Mainz University Hospital and selected European clinics, but helium-3 tomography appears to have a bright future for visualizing and assessing pulmonary ventilation. Only a few accessory tools are needed to perform helium-3 imaging with standard magnetic resonance imaging equipment, so the technique could become widely available within a relatively short time.

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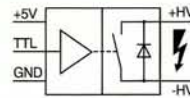
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# Biology research becomes crystal clear

A new range of PET instrumentation, based on research and development experience from high-energy physics experiments, aims to provide biology researchers with powerful tools to monitor the effects of gene therapy and to screen and test the effects of new drugs.

At the front line of medical research, molecular and cellular biologists engineer new molecular probes, including genes and proteins. Having produced them, the next task is to investigate what happens when they are inserted into living tissue.

In biology-speak, the researchers want to know how and where the new genes "express" themselves. In pharmaceutical research, the effects of potential new drugs have to be established as quickly and as cost-effectively as possible.

In the past, results have been established *in vitro* either by sacrificing the animal and analysing samples, or by taking biopsies. Until recently there has been no easy way of studying the effects of genetic manipulation or drug administration in living animals and in real time.

Now researchers have found how imaging techniques used in medical diagnosis can be adapted for genetic or drug research, providing an immediate picture of how the modified tissue behaves while it is still alive – *in vivo* and *in situ*. The techniques being used are magnetic resonance imaging (MRI), and positron emission tomography (PET).

## Creating new images

In 1952 the Nobel Prize for Physics was awarded to Felix Bloch, who in 1954 became CERN's first director-general, and Edward Purcell for their discovery of nuclear magnetic resonance (NMR). In this technique, nuclei gripped by a strong magnetic field are exposed to microwave radiation.

NMR was used initially with uniform magnetic fields to study mol-



Lead tungstate crystals for the CMS experiment at CERN's LHC. The decision to go for lead tungstate was the result of research and development work by the Crystal Clear collaboration at CERN. The crystals detect the tiny scintillations produced by electromagnetic interactions.

ecular structure. More than 25 years later, researchers began to realize how the use of non-uniform magnetic fields could produce position-dependent signals, from which a computer could reconstruct a three-dimensional structural image. The time resolution of MRI was soon improved, so that, for example, heart function could be monitored.

The other technique, PET, works by administering harmless but selective radioisotopes that emit positrons – the antiparticles of normal atomic electrons. These isotopes are taken up by

molecules involved in the metabolic functions of cells or organs and they work their way into the part of the organism being studied (such as the brain). Eventually the emitted positrons annihilate with atomic electrons, each annihilation producing a characteristic back-to-back pair of 511 keV photons (gamma rays).

Monitoring the distribution of these gammas reveals the detailed structure of where the isotope becomes localized. For instance, cancer cells are known to have a more rapid metabolism than normal cells, consuming more energy in the form of glucose. After injection, a fluorine-18 positron emitter in the form of fluorodeoxyglucose molecules (FDG) is taken up by cancer cells and accurately reveals primary cancers and metastatic activity. PET also provides a "moving image" of the metabolic function of the tissue or organ. This is particularly useful for genetic and drug research, showing how the organism is being affected as well as where.

Since its inception, PET technology has continually benefited from new developments in radiation detection, first using sodium iodide



crystals, then benefiting from the improved performance from bismuth germanate (BGO) and, more recently, exploiting superior materials such as lutetium orthosilicate or aluminate, which are faster and more effective than BGO.

Monitoring gamma rays is a vital task in any major physics detector, particularly for the component studying the absorption of energy via electromagnetic processes – the electromagnetic calorimeter. In this module of the detector, tiny scintillations of light produced by electromagnetic interactions are collected, amplified if necessary and analysed.

As part of the preparations for the experimental programme for CERN's Large Hadron Collider (LHC), the Crystal Clear research and development collaboration was established in 1990 by Paul Lecoq from CERN to look into the development of new scintillating materials.

After input from different disciplines (crystallography and solid-state physics, as well as particle physics), early accomplishments led to the decision by the collaboration for the CMS experiment at the LHC to use lead tungstate ( $\text{PbWO}_4$ ) for its electromagnetic calorimeter. The production of the 80 000 crystals for CMS is the subject of a major international collaboration (*CERN Courier* May 1999 p6).

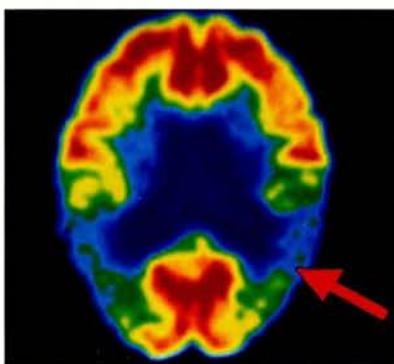
In parallel, the collaboration, now led by Stefaan Tavernier from the Vrije University in Brussels, established the use of cerium fluoride ( $\text{CeF}_3$ ) as another high-energy physics standard, and worked with specialist companies in the US, China and the Czech Republic to ensure its production on the industrial scale. Heavy scintillating fluoride glasses is another growth area, where the collaboration works with a French company. The Crystal Clear collaboration also pioneered the use of new compounds based on lutetium.

Working with the Czech Crytur company (also involved in work for cerium fluoride), the collaboration has developed scintillating crystals of yttrium aluminate perovskite (YAP) doped with increasing amounts of lutetium, which gives twice as much light as BGO and over a broader range of wavelengths. YAP is extensively used in medical instrumentation and in screens for electron microscopes but its density is marginal for high-sensitivity PET applications that have to stop 511 keV photons. Replacing up to 100% of yttrium by lutetium ions gives a very bright and fast scintillator, LuAP, with the unprecedented density of  $8.34\text{g}/\text{cm}^3$ .

### Smaller instrumentation

Physics detectors are normally large – even a small one is several metres long. However, PET cameras for medical use are more compact. Even so, the spatial resolution of commercially available cameras meant that PET analysis was, until recently, limited to relatively large subjects, such as humans and other large animals. New PET techniques extend this approach to smaller specimens, and this is where the technique becomes interesting for genetic laboratory studies.

In the Crystal Clear collaboration, YAP, lead tungstate and lutetium



*PET scan depicting the effects of Alzheimer's disease on metabolism. The arrow indicates areas of low activity in the parietotemporal cortex – a region important for processing language and memory.*

aluminate are all being investigated for their possible use in small PET scanners. On the read-out side, additional amplification can complement the traditional photomultiplier read-out of scintillation light. This can be achieved by avalanche photodetectors using applied bias voltages or by imaging silicon pixel array (ISPA) tubes using internal photocathodes and semiconductor read-out. Italian groups have achieved submillimetre resolution using YAP-based cameras.

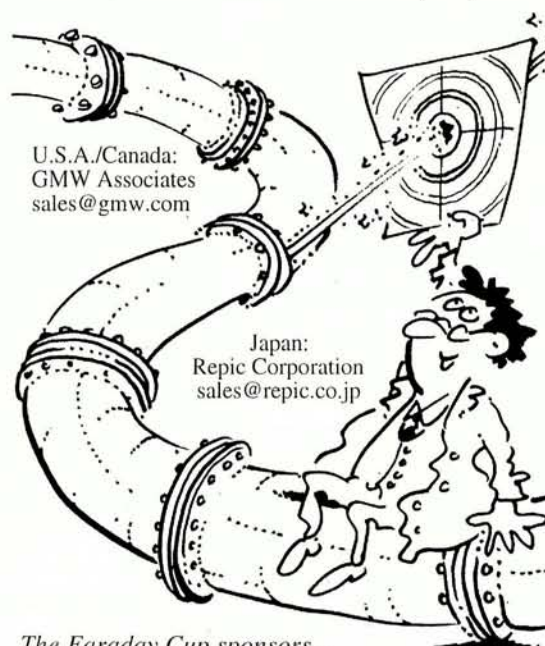
New PET scanners (ClearPET) for biological research are the subject of collaboration agreements between the Crystal Clear collaboration and specialist local centres in France, Belgium, Switzerland and Germany. A project for a mammography PET camera (ClearPEM) is under discussion with Portugal.

The work and achievements of the Crystal Clear collaboration are a good example of how particle physics expertise can seed important developments in other areas of science. Rather than being left to happen fortuitously, such symbiosis is now being encouraged and nurtured at CERN.

**Manjit Dosanjh and Gordon Fraser, CERN.**

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# Looking back on the story of the space–time odyssey

The formal inauguration of the Center for Theoretical Physics at the University of Michigan brought together distinguished speakers from a range of disciplines to look back on the achievements of physics in the 20th century, as well as to anticipate new developments in the 21st.

The inaugural conference of the Michigan Center for Theoretical Physics (MCTP), entitled 2001: a Spacetime Odyssey, was held in Ann Arbor on 21–25 May. In keeping with the MCTP's mission to provide a venue for interdisciplinary studies in theoretical physics and related mathematical sciences, the conference brought astronomers, cosmologists, particle physicists and mathematicians together to share their different perspectives on space–time at the beginning of the 21st century.

Two theories revolutionized the 20th-century view of space and time: quantum mechanics and Einstein's General Theory of Relativity. The union of these theories provides a context for elementary particle theories with extra space–time dimensions, such as the inflationary model of Big Bang cosmology; dark matter and dark energy in the universe; radiation from quantum black holes; and the fuzzy space–time geometry of superstrings and M-theory. These developments, which are derived in part from the 19th-century mathematics of Riemannian geometry and Lie groups, have in their turn inspired new directions in the pure mathematics of topology and knot theory. All of these different strands of the space–time story were represented at the conference.

## The dawn of space–time

Ann Arbor was a particularly appropriate place for such a celebration because it was here that Oskar Klein first came up with the idea of extra space–time dimensions and of using Riemannian geometry to explain not only gravity but also electromagnetism.

The conference began with "My life as a boson", a historical recollection by Peter Higgs (Edinburgh) on the discovery of the particle that bears his name. Higgs described the history leading up to his 1964 paper, the controversy over the Goldstone theorem, and some interesting reactions to his paper. Only after *Physics Letters* had rejected his original version did Higgs produce a revised text pre-

## In the beginning...

"Returning to my Ann Arbor attempts, I became immediately very eager to see how far the mentioned analogy reached, first trying to find out whether the Maxwell equations for the electromagnetic field, together with Einstein's gravitational equations, would fit into a formalism of five-dimensional Riemann geometry."

Oskar Klein, "From my life of physics" in the anthology *From a Life of Physics* (1989 World Scientific).

dicting the existence of the new particle, which was then accepted by *Physical Review Letters*. He ended his talk with the hopeful mention of "indications of H at about 115 GeV" at CERN's LEP electron–positron collider.

Joseph Silk (Oxford), Robert Kirshner (Harvard-Smithsonian Center for Astrophysics), Alan Guth (MIT), Paul Steinhardt (Princeton), Andre Linde (Stanford), Wendy Freedman (Carnegie Observatories) and Michael Turner (Chicago) each offered different perspectives on the universe. While new data pinpoint cosmological parameters with more and more accuracy, and evidence for the current acceleration of the expansion of the universe and the mysterious "dark energy" now seems convincing, controversy over their origins continued to swirl with Steinhardt's presentation of the novel "ekpyrotic" alternative to inflation. Inspired by the Horava–Witten picture of an 11-dimensional M-theory universe sandwiched between two 10-dimensional boundaries, this scenario ascribes the Hot Big Bang to a smashing together of two three-dimensional surfaces (three-branes) in a five-dimensional universe: the Big Crash.

Linde championed the old inflation with a vigorous deflation of Steinhardt's ideas. Freedman then reported a new result – the first measurement of extragalactic background light, which turned out to be about twice that of individual galaxies. The mass associated with starlight was thus measured to be about 1% of critical density. Guth emphasized the evidence for inflation and its robustness.

Shing-Tung Yau (Harvard), Isadore Singer (MIT), Arthur Jaffe (Harvard) and Bruno Zumino (Berkeley) gave us a glimpse into the realm of higher mathematics and its intriguing applications to problems in quantum field theory, superstrings and M-theory. For Singer, this was a sentimental journey, and he recalled his arrival as an undergraduate in physics at the University of Michigan in 1941. Checking into his dormitory, he was told to go upstairs and make his



bed. Sure enough, he discovered a hammer, some nails and a pile of two-by-four planks where his bed was supposed to have been.

Quantum gravity was the common theme of talks by James Hartle (UC Santa Barbara), Jacob Beckenstein (Jerusalem) and Stanley Deser (Brandeis). Hartle discussed the reconciliation of Einstein's general relativity with quantum mechanics, including the many-worlds interpretation, wormholes in space and the possibility of time travel. Beckenstein presented the case for discrete energy levels for quantum black holes as a way of understanding their thermodynamics, which was pioneered by him and Hawking in the 1970s; and Deser gave an overview of gravity's century, from Einstein to M-theory.

#### Discoveries overlooked

Particle phenomenology was covered by Lev Okun (ITEP, Moscow), John Bahcall (Princeton IAS), Helen Quinn (SLAC), Mary K Gaillard (Berkeley), Paul Frampton (North Carolina, Chapel Hill) and Martinus Veltman (Michigan). Okun recalled his early days in Moscow, the discoveries made there, such as the calculation of asymptotic freedom by Khriplovich in 1969 and the reaction (or lack thereof) in the West. He also recalled Sakharov's reaction to the possibility of vacuum bubble creation by colliders: "Such theoretical work should be forbidden."

Bahcall presented an overview of our understanding of solar neutrinos and described how upcoming data, particularly from SNO would sharpen it (as indeed happened soon after the conference; *CERN Courier* September p5).

Quinn reviewed the theoretical status of CP violation and current attempts to test it experimentally, while Frampton presented a model of spontaneous CP violation. Gaillard put the case for a derivation of the Standard Model from the compactification of the 10-dimensional het-



Space-time odysseys, left to right: Michael Duff, Bruno Zumino and Gordon Kane. (Alfred C T Wu.)



One of the artworks that were designed and made for the conference. The image is drawn from the original cloud chamber event in which the kaon was discovered. The artist is Prof. Sherri Smith of the University of Michigan School of Art and Design, whose work has been shown at a number of venues, including the Museum of Modern Art and the Contemporary Crafts Museum in New York, and the Centre International de la Tapisserie in Switzerland. (Carol Rabuck.)

erotic string on a six-dimensional Calabi-Yau manifold. Veltman was broadly critical of current research directions, casting doubt on black holes, the acceleration of the universe and superstring theory, although he was positive about the construction of the superconducting Tesla linear electron collider.

#### Superstrings

Superstring theory and its successor, M-theory, were covered by John Schwarz (Caltech) and Alexander Polyakov (Princeton). Schwarz reviewed the phenomenon of anomaly cancellation from the Standard Model to the superstring, while Polyakov discussed the Plato's cave "holographic" universe, in which our four-dimensional space-time is a boundary of a five-dimensional anti-de Sitter space.

One of the missions of the MCTP is to convey the excitement of physics to the general public. The 2001: A Spacetime Odyssey conference achieved this very successfully with the collaboration of the Physics Department and the School of Art and Design at the University of Michigan. Ten new works by professional artists, with inspiration from physicists, were created for exhibition at the conference.

Most speakers agreed that participating in such a meeting had broadened their horizons, and perhaps even influenced their work. In his after-dinner speech at the conference banquet, Sheldon Glashow (Boston) assessed the current state of particle and astrophysics, and whether society cared enough to sustain it. After a good meal and fine wine, the future looked rosy.

The conference talks and a selection of photographs are available at "<http://www.umich.edu/~mctp/sto2001>".

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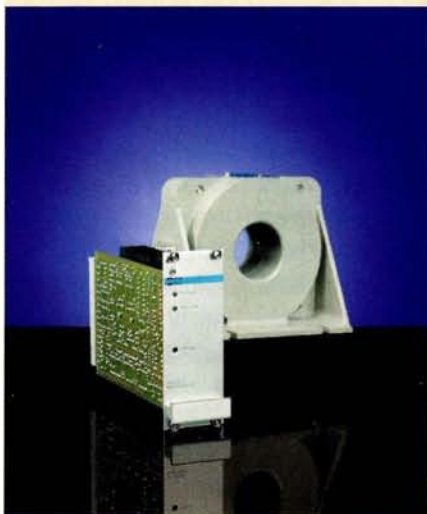
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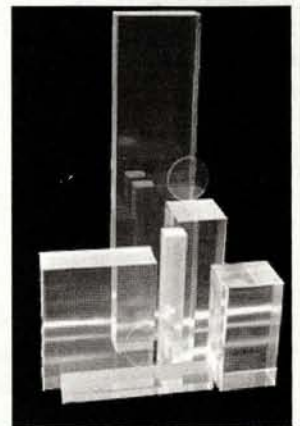
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# Second postcard from the island of stability

Experiments on synthetic nuclei continue to explore a world that is very remote from our own experience. Recent studies at the Joint Institute for Nuclear Research, Dubna, near Moscow, report another inhabitant of a long-awaited island of nuclear stability, this time with 116 protons.\*

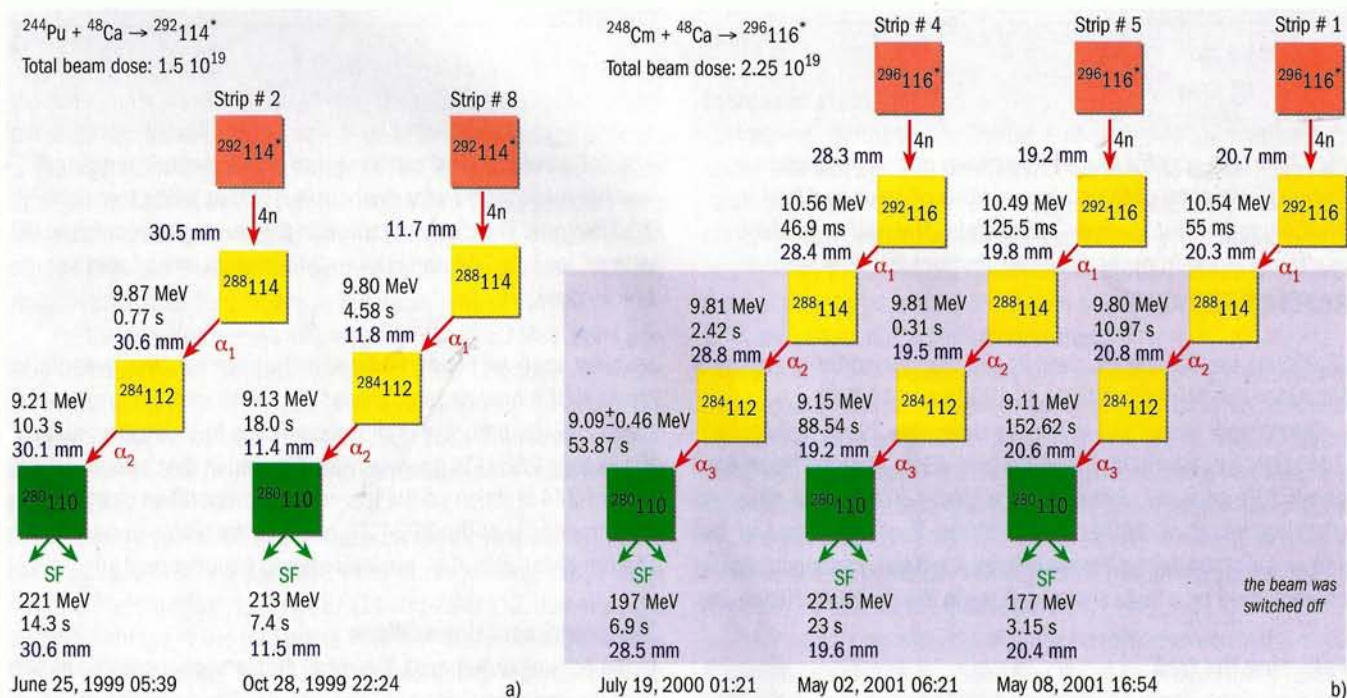


Fig.1: Prominent decay chains observed in the reactions a) calcium-48 and plutonium-244 (left) and b) calcium-48 and curium-248 (right). The darker background area corresponds to what happens when the accelerator beam is switched off.

Half a century ago, Edwin McMillan and Glenn Seaborg of Berkeley were awarded the 1951 Nobel Prize for Chemistry for their elucidation in the early 1940s of the first 'transuranic' nuclei – synthetic radioactive nuclei heavier than uranium, which conventionally marks the end of the Periodic Table of nuclei. Since then, patient work has discovered a series of highly unstable superheavy nuclei, but a fundamental nuclear prediction said that an "island of stability" would eventually be reached.

The article "First postcard from the island of nuclear stability" (*CERN Courier* September 1999 p19) reported the first results obtained at the Joint Institute for Nuclear Research (JINR), Dubna, on the synthesis of superheavy nuclei in fusion reaction induced by a calcium-48 beam. Targets of plutonium isotopes with mass num-

bers 242 and 244 furnished new nuclides, notably with 114 protons, and their subsequent alpha decays, terminated by spontaneous fission.

The conclusion was that in these reactions the even-odd isotopes of element 114 had been produced following the emission from an intermediate compound nucleus of three neutrons, together with gamma rays. The formation cross-sections were very small (~1 pb). The radioactive properties of these nuclides (energies and half-lives) demonstrated the existence of a new region of nuclear stability, which had been predicted earlier as due to nuclear shell effects.

The experiments were performed in the Flerov Laboratory of Nuclear Reactions (JINR) in collaboration with the Lawrence Livermore National Laboratory (LLNL), GSI (Darmstadt), RIKEN ▽



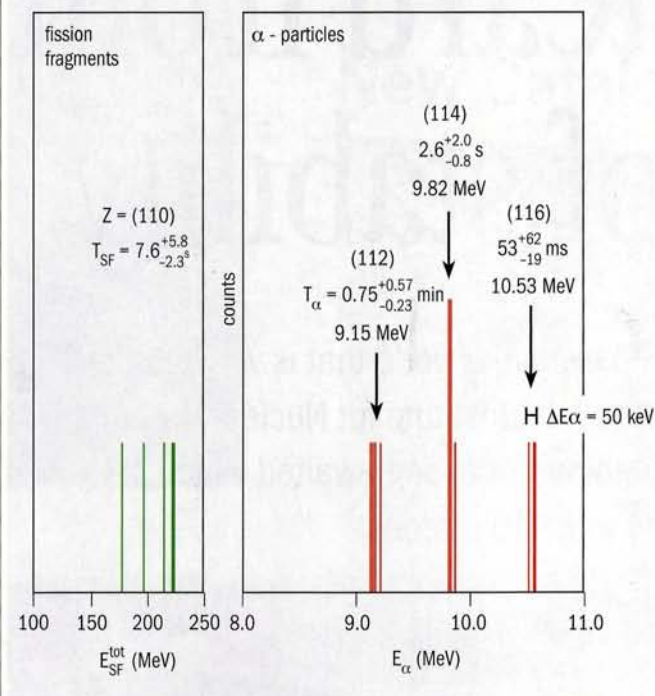


Fig. 2: Energy spectra of alpha particles and spontaneous fission fragments, obtained in reactions of calcium-48 with plutonium-244 and curium-248 targets. The half-lives of the nuclei obtained from the time distributions of the observed events are also shown.

(Saitama), the Comenius University (Bratislava) and the University of Messina (Italy) (Oganessian *et al.* 1999a and 1999b).

During work carried out in June to November 1999, a plutonium-244 target was bombarded by a calcium-48 beam (total beam dose about  $10^{19}$  ions). Two more identical decay chains were observed (Oganessian *et al.* 2000a and 2000b). Each consisted of two sequential alpha decays that were terminated by spontaneous fission characterized by a large energy release in the detectors (figure 1a).

**Following the trail**

The new alpha-decay energies are slightly higher than in the previous case and the total decay time is shorter (about 0.5 min). The probability that the observed decays are due to random coincidences is less than  $5 \times 10^{-13}$ .

Both events were observed at a beam energy that corresponded to a compound-nucleus excitation energy of 36–37 MeV. Here, the most probable de-excitation channel of the hot nucleus 292/114 corresponds to the emission of four neutrons together with gamma rays. Taking this into account, the new decay chains had to be attributed to the decay of the neighbouring even-even isotope of element 114 with mass 288.

To check this conclusion, further experiments continued with a curium-248 target (Oganessian *et al.* 2001). In Dimitrovgrad, Russia, 10 mg of the highly enriched isotope was produced. More such target material was provided by LLNL.

Changing the target from plutonium-244 to curium-248, while maintaining all other experimental conditions, makes the fusion

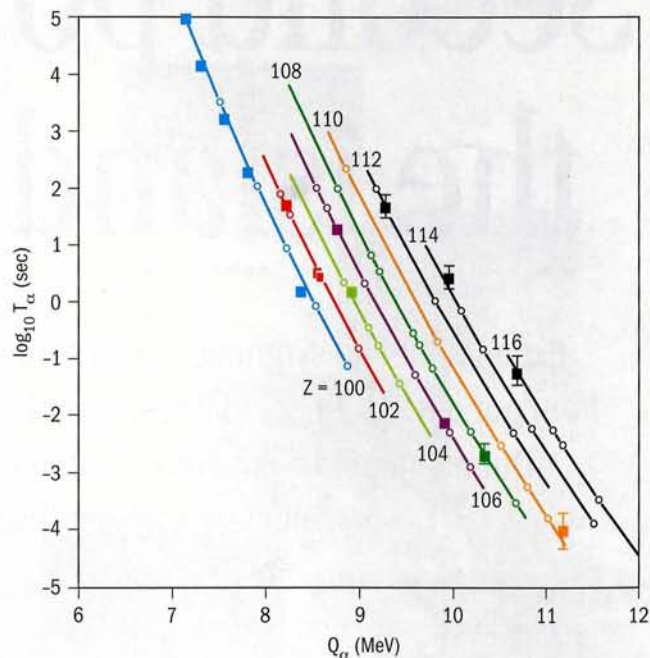


Fig. 3: Calculated and experimental alpha-decay energy and half-life relationships for even-even isotopes with more than 100 protons. The data, obtained in the reactions of calcium-48 with plutonium-244 and curium-248 targets, are shown as black squares.

reaction lead to the formation in the four-neutron evaporation channel of a new heavier nucleus, this time with 116 protons and mass 292. Its probable alpha decay leads to a daughter nucleus, the isotope 288/114 previously synthesized in the calcium-48/plutonium-244 reaction via the four-neutron evaporation channel. Thus, after the decay of the 292/116 nucleus, the whole decay chain of the daughter 288/114 nucleus should be observed (figure 1a).

**The experimental conditions**

In the original experiment, the recoil atoms were separated in flight from the beam particles and the products of incomplete fusion reactions analysed by the Dubna gas-filled recoil separator (DGFRS).

Separated heavy atoms were implanted into a  $4 \times 12$  cm<sup>2</sup> detector located in the focal plane 4 m from the target. The front detector was surrounded by side detectors in such a way that the entire array resembled a "box" with an open front. This increased the detection efficiency of alpha particles from the decay of an implanted nucleus to 87% of the total solid angle.

For each atom implanted in the sensitive layer of the detector, the velocity and energy of the recoil were measured, as well as the location on the detector area. If the nucleus of the implanted atom emitted an alpha particle or fission fragments, the latter were detected in a strict correlation with the implant on the position-sensitive surface of the detector.

Usually the experiments are performed using a continuous beam. However, for the synthesis of element 116, these conditions were changed. After implantation in the front detector of a heavy nucleus



with the expected parameters and the subsequent emission of an alpha particle with energy above 10 MeV (the two signals are strictly correlated in position), the accelerator was switched off and the subsequent decays took place without the beam.

The measurements performed immediately after turning off the accelerator beam showed that the counting rate of alpha particles (energy above 9.0 MeV) and fission fragments from spontaneous fission in a 0.8 mm position window, defined by the position resolution of the detector, amounts to 0.45 per year and 0.2 per year respectively. Random coincidences imitating a three-step 1–3 min decay chain of the nucleus 288/114 are practically impossible, even for a single event.

### Decay chains

In such conditions at a beam dose of  $2.3 \times 10^{19}$  ions, three decay chains of element 116 were registered (figure 1b). After the emission of the first alpha particle (energy  $10.53 \pm 0.06$  MeV), the sequential decay was recorded with the beam turned off (darker background in figure 1).

As can be seen from figure 1b, all decays are strictly correlated; the five signals in the front detectors – the recoil nucleus, three alpha particles and fission fragments – deviate by no more than 0.6 mm.

The alpha-particle energies and the half-lives of the nuclei in the three decay chains, the first alpha decays and those detected after the accelerator was switched off are all consistent between each other within the limits of the detector energy resolution (60 keV) and the statistical fluctuations in the decay time of the events.

All of the detected decays following the first 10.53 MeV alpha particle agree well with the decay chains of 288/114 observed in the earlier reaction (see figure 1a). Thus it is reasonable to assign the observed decay to the nuclide 292/116, produced via the evaporation of four neutrons in the complete fusion reaction using curium-248.

The energy spectrum of the three events corresponding to the nucleus 292/116, and the five events corresponding to the alpha decay of the daughter nuclei 288/114 and 284/112, as well as the summed energy of the fragments from five events of spontaneous fission of the nucleus 280/110, obtained in the experiments with the plutonium and curium targets, are shown in figure 2.

### Well defined decay energy

As expected for even-even nuclei, the experimentally observed alpha decay is characterized by a well defined decay energy, corresponding to the mass difference between the mother and daughter nuclei. The time distribution of the signals in the decay chains follows an exponential decay law. The half-lives for each nucleus are also shown in figure 2.

For allowed alpha transitions (even-even nuclei) the decay energy and probability (half-life) are connected by the well known Geiger–Nuttall relation. This is strictly fulfilled for all currently known 60 nuclei heavier than lead-208 for which data are available. Figure 3 shows the calculated and experimental data for nuclei with more than 100 protons and the data from the present experiment on the synthesis of nuclei with 112, 114 and 116 protons.

Owing to the high precision of the alpha-particle energy mea-

The conclusion can be drawn that theoretical models developed during the last 35 years and predicting the decisive influence of nuclear structure on the stability of superheavy elements are well-founded.

surements (resolution 0.5%), any other interpretation of the atomic numbers of the observed decays would have been in strong contradiction with the general characteristics of alpha decay.

Finally, in the spontaneous fission of 280/110, the fission fragment energy measured in the detectors amounted to 206 MeV. This corresponds to a mean fission fragment kinetic energy of 230 MeV (taking into account the energy loss in the dead layer of the detector), which is characteristic of the

fission of a rather heavy nucleus. In the thermal-neutron fission of uranium, the corresponding energy is 168 MeV.

### Increased stability

Comparing spontaneous fission and alpha-decay half-lives for nuclei with 110 and 112 protons with earlier data for the lighter isotopes of these elements shows a significant increase in the stability of heavy nuclei with increasing neutron number. The addition of 10 neutrons to the 270/110 nucleus makes the half-life a hundred thousand times as long. The isotopes of element 112 with masses 277 and 284 exhibit a comparable effect.

Comparing the experimental alpha-decay energy values with those calculated in different models shows that the difference between experiment and theory is in the range  $\pm 0.5$  MeV. Without going into any detailed analysis, the conclusion can be drawn that theoretical models developed during the last 35 years and predicting the decisive influence of nuclear structure on the stability of superheavy elements are well founded, not only qualitatively but also, to a certain extent, quantitatively.

This increased stability significantly extends research in the region of superheavy elements, opening up the study of such areas as their chemical properties and the measurement of their atomic masses. The development of the experimental techniques will make it possible to advance into the region of even heavier nuclei – expect more postcards in the years to come!

The experiments were carried out in collaboration with the Analytical and Nuclear Chemistry Division of the Lawrence Livermore National Laboratory.

\*Evidence for the superheavy nucleus 118, reported by Berkeley scientists in 1999 (*CERN Courier* September 1999 p18), has been retracted.

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# LHC insertions: the key to

The second of two articles about magnets for CERN's forthcoming Large Hadron Collider takes a look at the specialized magnets that perform specific tasks, such as final focus, and injection and extraction of beams. These are installed in the eight so-called insertion regions between the arcs in the 27 km LHC ring. Like the accelerator's main lattice magnets, their production is now under way.

"When the machine runs in collider mode, one should forget the lattice," said Norbert Siegel. "Where it all happens is at the interaction points." Siegel is leader of the CERN group responsible for Large Hadron Collider LHC superconducting magnets other than those of the machine's main lattice. Like other accelerators and colliders, the LHC's magnets can be divided into two categories. Lattice magnets keep protons on course and are responsible for maintaining stable circulating beams. The rest go by the name of insertion magnets, performing specific tasks such as final focus before collision, beam cleaning, injection and extraction.

## Inner triplets

For the LHC, the most complex insertion magnets are the eight so-called inner triplets that will squeeze the proton beams and bring them into collision in the centre of the four LHC experiments. The inner triplets are placed symmetrically at a distance of 23 m on either side of the interaction points, and each forms a cryogenic unit about 30 m long. They consist of four low-beta quadrupole magnets, so-named because their job is to minimize the beta-function, which is proportional to beam size, at the interaction point. Because of the special job they have to do and their proximity to the interaction points, the inner triplet magnets will be subject to unusually high heat loads. This means that a superfluid helium heat exchanger of unprecedented scale is required to keep them at their 1.9 K operating temperature.

The inner triplets are being provided as part of the US and Japanese contributions to the LHC project. They will use two types of quadrupole, along with various corrector magnets that are being supplied by CERN. One type of quadrupole is being developed at Japan's KEK laboratory, the other at the US Fermilab, which also has the task of integrating all of the components into their cryostats. After a successful development programme using short model magnets, full-size low-beta quadrupoles have been made and were tested in May.



US contribution to the LHC – superconducting separator dipole made by the US Brookhaven Laboratory.



Canada: the first series production twin-aperture quadrupole produced by the TRIUMF laboratory, Vancouver, with ALSTOM Canada.

The first piece of hardware built by the US-LHC project, which coordinates the US contribution to the accelerator, arrived at CERN from Fermilab last year (*CERN Courier* November 2000 p40). A heat exchanger test unit, it had the job of verifying the design of the inner triplet cooling system. Existing data on heat exchangers of this scale being scarce, the final inner triplet design had to wait until the test unit was put through its paces at CERN, one of the few places in the world with the capacity to provide superfluid helium at the necessary flow rate. With the tests reaching a successful conclusion,



# CERN's new accelerator



the first KEK-built, full-length prototype low-beta quadrupole on the test



ostated full-length low-beta quadrupole ready for measurements at b.

the design has now been frozen and inner triplet production started at Fermilab in July. The first inner triplet is scheduled to arrive at CERN by the end of 2002.

## Dedicated separators

As well as bringing the accelerator's counter-rotating beams together, LHC insertion magnets also have to separate them after collision. This is the job of dedicated separators, and the US Brookhaven Laboratory is developing superconducting magnets for this purpose. Brookhaven is drawing on its experience of building

the Relativistic Heavy Ion Collider (RHIC), which like the LHC is a superconducting machine. Consequently, these magnets will bear a close resemblance to RHIC's main dipoles. Following a prototyping phase, full-scale manufacture has started at Brookhaven and delivery of the first superconducting separator magnets to CERN is foreseen before the end of the year.

All LHC insertions include dispersion suppressors and matching sections. The dispersion suppressors will limit the variation of beam position at the collision points caused by a spread in particle momenta, while the matching sections tailor the beam size in the insertions to the acceptance of the machine's lattice. Dedicated insertion quadrupoles of various designs have been developed and optimized by CERN to fulfil the aperture, space and magnetic strength requirements for these tasks. All are now at the production stage in European industry, with the first due for delivery at the beginning of 2002.

## Other magnets

All of the magnets discussed above are superconducting. The LHC will, however, make use of room-temperature magnets in several of its insertions. These are being provided as part of the Russian and Canadian contributions to the LHC, and they include special quadrupoles and dipoles for the beam-cleaning insertions, and beam injection and ejection magnet systems that include fast kicker magnets and steel septum magnets. The septa are all being provided by the Russian IHEP laboratory in Protvino near Moscow, where production is well under way. In the cleaning insertions, which remove beam halo particles from the circulating beams, magnets must operate at room temperature due to the harsh radiation environment. Separation dipoles for these insertions are being made by the Russian Budker Institute of Nuclear Physics in Novosibirsk, while double-aperture quadrupoles are being provided by Canada's TRIUMF laboratory.

Finally, there is one kind of insertion magnet that plays no role in the effective working of the LHC as a collider – the huge magnet systems of the four experiments. Their magnetic fields have an influence on the beams' trajectories and have to be compensated for by orbit compensation magnets.

Production of all of the LHC insertion magnets is now well under way. Their preparation and installation in the tunnel, along with integration with other LHC systems, such as cryogenics, vacuum and power, provide challenging work for the years ahead. When that is over and the LHC is complete, it will be a phenomenally complex machine. However, as Norbert Siegel points out, once the LHC is running, attention will be diverted from the machine, as all eyes turn to the four main experimental insertions – the key to a better understanding of our universe.

## Further reading

"LHC lattice magnets enter production" *CERN Courier* June p15.



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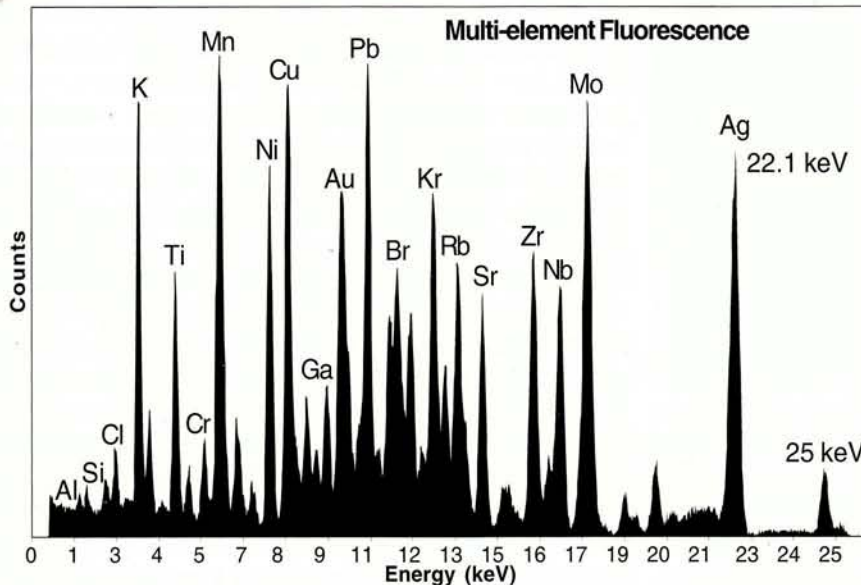
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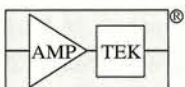
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# Close encounters with clusters of computers

To satisfy their ever-increasing demand for more and affordable computing power, particle physics experiments are using clusters of off-the-shelf PCs. A recent workshop at Fermilab looked at the implications of this move.

Recent revolutions in computer hardware and software technologies have paved the way for the large-scale deployment of clusters of off-the-shelf commodity computers to address problems that were previously the domain of tightly coupled multiprocessor computers. Near-term projects within high-energy physics and other computing communities will deploy clusters of some thousands of processors serving hundreds or even thousands of independent users. This will expand the reach in both dimensions by an order of magnitude from the current, successful production facilities.

A Large-Scale Cluster Computing Workshop held at Fermilab earlier this year examined these issues. The goals of the workshop were:

- to determine what tools exist that can scale up to the cluster sizes foreseen for the next generation of high-energy physics experiments (several thousand nodes) and by implication to identify areas where some investment of money or effort is likely to be needed;
- to compare and record experiences gained with such tools;
- to produce a practical guide to all stages of planning, installing, building and operating a large computing cluster in HEP;
- to identify and connect groups with similar interest within HEP and the larger clustering community.

## Thousands of nodes

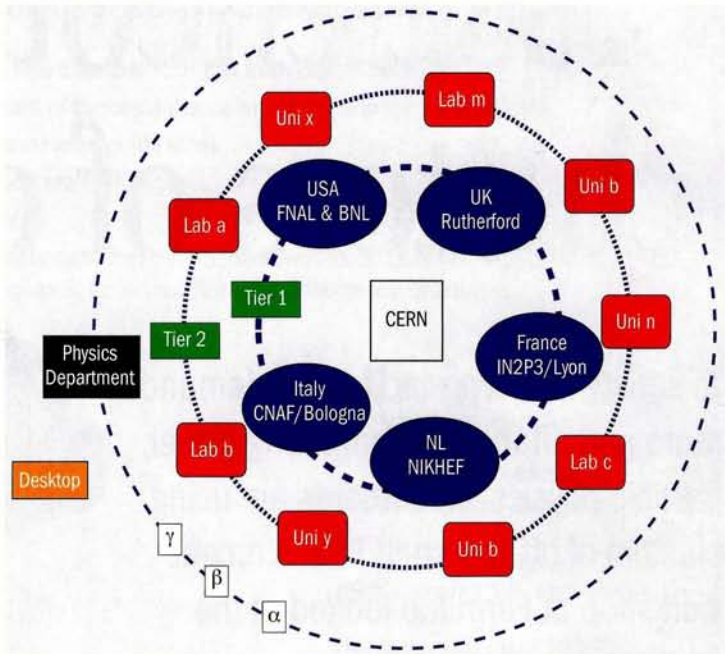
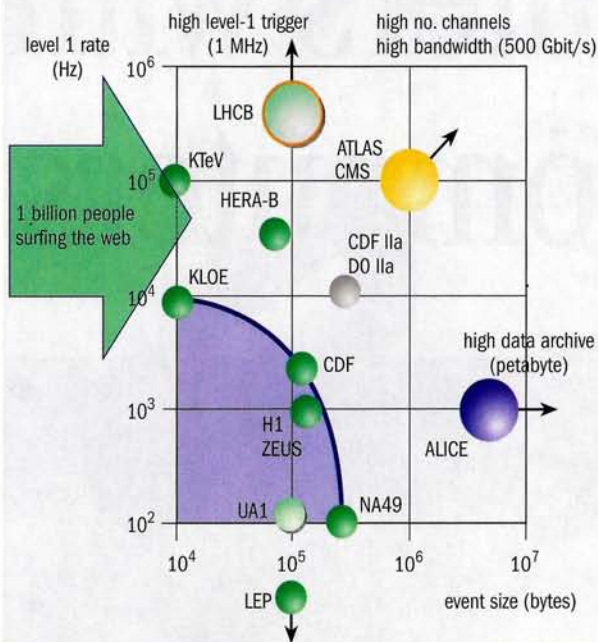
Computing experts with responsibility and/or experience of such large clusters were invited. The clusters of interest were those equipping centres of the sizes of Tier 0 (thousands of nodes) for CERN's LHC project, or Tier 1 (at least 200–1000 nodes) as described in the MONARC (Models of Networked Analysis at Regional Centres for LHC Experiments) project at "<http://monarc.web.cern.ch/MONARC>". The attendees came not only from various particle physics sites worldwide but also from other branches of science, including biomedicine and various Grid computing projects, as well as from industry.



*Presenting LHC computing needs – Wolfgang von Rueden, head of the Physics Data Processing Group in CERN's Information Technology Division.*

The attendees shared freely their experiences and ideas, and proceedings are currently being edited from material collected by the convenors and offered by attendees. In addition the convenors, again with the help of material offered by the attendees, are in the process of producing a guide to building and operating a large cluster. This is intended to describe all phases in the life of a cluster and the tools used or planned to be used. This guide should then be publicized (made available on the Web and presented at appropriate meetings and conferences) and regularly kept up to date as more experience is gained. It is planned to hold a similar workshop in 18–24 months to update the guide. All of the workshop material ▷





Left: Particle physics experiments spearhead the demand for more computing power. Right: clustered computers. The MONARC project is a multilayered approach based on a large central site to collect and store raw data (Tier 0 at CERN), with multitiers (for example National Computing Centres, Tier 1), down to individual user's desks (Tier 4), each with data extracts and/or data copies and performing different stages of physics analysis.

is available via "<http://conferences.fnal.gov/lccw>".

The meeting began with an overview of the challenge facing high-energy physics. Matthias Kasemann, head of Fermilab's Computing Division, described the laboratory's current and near-term scientific programme, including participation in CERN's future LHC programme, notably in the CMS experiment. He described Fermilab's current and future computing needs for its Tevatron collider Run II experiments, pointing out where clusters, or computing "farms" as they are sometimes known, are used already. He noted that the overwhelming importance of data in current and future generations of high-energy physics experiments had prompted the interest in Data Grids. He posed some questions for the workshop to consider:

- Should or could a cluster emulate a mainframe?
- How much could particle physics computer models be adjusted to make most efficient use of clusters?
- Where do clusters not make sense?
- What is the real total cost of ownership of clusters?
- Could we harness the unused power of desktops?
- How can we use clusters for high I/O applications?
- How can we design clusters for high availability?

**LHC computing needs**

Wolfgang von Rueden, head of the Physics Data Processing group in CERN's Information Technology Division, presented the LHC computing needs. He described CERN's role in the project, displayed the relative event sizes and data rates expected from Fermilab Run II and from LHC experiments, and presented a table of their main characteristics, pointing out in particular the huge increases in data expected and consequently the huge increase in computing power that must be installed and operated.

The other problem posed by modern experiments is their geographical spread, with collaborators throughout the world requiring access to data and computer power. Von Rueden noted that typical particle physics computing is more appropriately characterized as high throughput computing as opposed to high performance computing.

The need to exploit national resources and to reduce the dependence on links to CERN has produced the MONARC multilayered model. This is based on a large central site to collect and store raw data (Tier 0 at CERN) and multitiers (for example National Computing Centres, Tier 1 – examples of these are Fermilab for the US part of the CMS experiment at the LHC and Brookhaven for the US part of the ATLAS experiment), down to individual user's desks (Tier 4), each with data extracts and/or data copies and each one performing different stages of physics analysis.

Von Rueden showed where Grid Computing will be applied. He

**The other problem posed by modern experiments is their geographical spread, with collaborators throughout the world requiring access to data and computer power**

ended by expressing the hope that the workshop could provide answers to a number of topical problem questions, such as cluster scaling and making efficient use of resources, and some good ideas to make progress in the domain of the management of large clusters.

The remainder of the meeting was given over to some formal presentations of clustering as seen by some large sites (CERN, Fermilab and SLAC) and also





Two "farms" of PCs at Fermilab. Such clusters have largely replaced multiprocessor mainframes.



Fermilab Computing Division head Matthias Kasemann discusses computing requirements for the CMS experiment at CERN's LHC with Vivian O'Dell.

## The Grid: crossing borders and boundaries

The World Wide Web was invented at CERN to exchange information among particle physicists, but particle physics experiments now generate more data than the Web can handle. So physicists often put data on tapes and ship the tapes from one place to another – an anachronism in the Internet era. However, that is changing, and the US Department of Energy's new Scientific discovery through advanced computing program (SciDAC) will accelerate the change.

Fermilab is receiving additional funds through SciDAC, some of which will be channelled into Fermilab contributions to the Compact Muon Solenoid Detector (CMS) being built for CERN. A major element in this is the formulation of a distributed computing system for widespread access to data when CERN's LHC Large Hadron Collider begins operation in 2006. Fermilab's D0 experiment has established its own computing grid called SAM, which is used to offer access for

experiment collaborators at six sites in Europe.

With SciDAC support, the nine-institution Particle Physics DataGrid collaboration (Fermilab, SLAC, Lawrence Berkeley, Argonne, Brookhaven, Jefferson, CalTech, Wisconsin and UC San Diego) will develop the distributed computing concept for particle physics experiments at the major US high-energy physics research facilities. Both DO and US participation in the CMS experiment for the LHC are member experiments. The goal is to offer access to the worldwide research community, developing "middleware" to make maximum use of the bandwidths available on the network.

The DataGrid collaboration will serve high-energy physics experiments with large-scale computing needs, such as D0 at Fermilab, BaBar at SLAC and the CMS experiment, now under construction to operate at CERN, by making the experiments' data available to scientists at widespread locations.

from small sites without on-site accelerators of their own (NIKHEF in Amsterdam and CCIN2P3 in Lyon). However, the largest part of the workshop was a series of interactive panel sessions, each seeded with questions and topics to discuss, and each introduced by a few short talks. Full details of these and most of the overheads presented during the workshop can be seen on the workshop Web site.

Many tools were highlighted: some commercial, some developed locally and some adopted from the open source community. In choosing whether to use commercial tools or develop one's own, it should be noted that so-called "enterprise packages" are typically priced for commercial sites where downtime is expensive and has quantifiable cost. They usually have considerable initial installation and integration costs. However, one must not forget the often high ongoing costs for home-built tools as well as vulnerability to personnel loss/reallocation.

### Discussing the G word

There were discussions on how various institutes and groups performed monitoring, resource allocation, system upgrades, problem debugging and all of the other tasks associated with running clusters. Some highlighted lessons learned and how to improve a given procedure next time. According to Chuck Boeheim of SLAC, "A cluster is a very good error amplifier."

Different sites described their methods for installing, operating and administering their clusters. The G word (for Grid) cropped up often, but everyone agreed that it was not a magic word and that it would need lots of work to implement something of general use.

One of the panels described the three Grid projects of most relevance to high-energy physics, namely the European DataGrid project (*CERN Courier* March 2001 p5) and two US projects – PPDG (Particle Physics Data Grid) and GriPhyN (Grid Physics Network).

A number of sites described how they access data. Within an individual experiment, a number of collaborations have worldwide "pseudo-grids" operational today. In this context, Kors Bos of NIKHEF, Amsterdam, referred to the existing SAM database for the D0 experiment at Fermilab as an "early-generation Grid". These already point toward issues of reliability, allocation, scalability and optimization for the more general Grid.

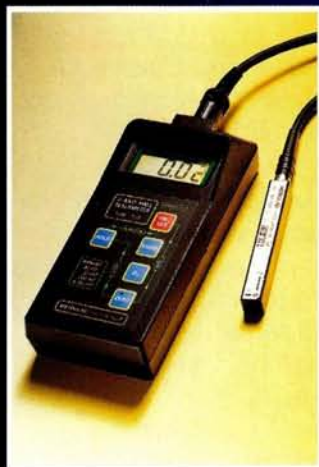
Delegates agreed that the meeting had been useful and that it should be repeated in approximately 18 months. There was no summary made of the Large-Scale Cluster Computing Workshop, the primary goal being to share experiences, but returning to the questions posed at the start by Matthias Kasemann, it is clear that clusters have replaced mainframes in virtually all of the high-energy physics world, but that the administration of them is particularly far from simple and poses increasing problems as cluster sizes scale. In-house support costs must be balanced against bought-in solutions, not only for hardware and software but also for operations and management. Finally, delegates attending the workshop agreed that there are several solutions for, and a number of practical examples of, the use of desktop machines to increase the overall computing power available.

**Alan Silverman, CERN and Dane Skow, Fermilab.**



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	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	± 1mT	± 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 <sup>23</sup> 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 Transducer	± 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

## ► Distributed I/O



**CNA**



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		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

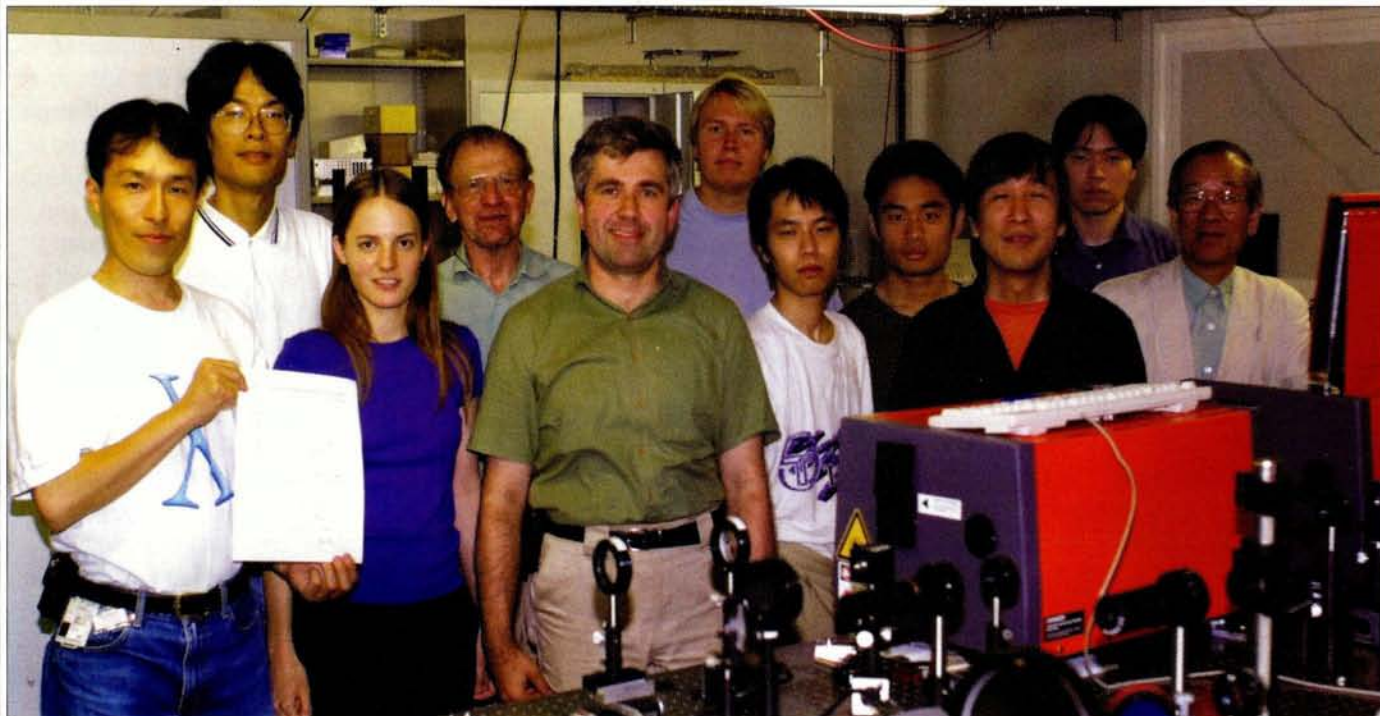
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# Weighing the antiproton

The ASACUSA collaboration has just published a determination of the antiproton charge and mass to an incredible six parts in a hundred million.\* How was this impressive precision achieved and why is it significant?



Members of the ASACUSA antiproton experiment at CERN. ASACUSA involves physicists from Bulgaria, CERN, Denmark, France, Germany, Hungary, Japan, the Netherlands, Russia and the UK.

Knowing the exact charges and masses of the protons, electrons and neutrons that constitute matter is evidently of fundamental importance for the entire edifice of particle physics. Furthermore, once we know these, we know, according to CPT-symmetry, the values for the corresponding components of the antiworld. Given the fact that we already know the particle values very precisely, should we even bother making the measurements for antiparticles?

Such an omission could hardly be more risky. The CPT theorem – which says that all observed phenomena will remain unchanged if we replace particles by antiparticles, invert their motions, and reflect everything in a mirror – is based on falsifiable assumptions. In a universe as old and as big as the one we see, there is time and space enough for even minute deviations from perfect CPT symmetry to become observable, perhaps even to predominate.

## Warning messages

Nature even seems to be sending us warning messages in this respect: having provided a full kit of parts for making a large-scale universe that is matter-antimatter symmetric, the one that it in fact assembles from these parts is completely asymmetric. Of course

we have explanations for this imbalance, but they are not beyond question. Even worse, the CPT theorem itself rests, as T D Lee notes, “on a foundation which has to be unsound, at least at the Planck length ( $10^{-33}$  cm – the measurement precision when quantum fluctuations begin to have gravitational implications), and maybe at a much larger distance” (T D Lee 1995 *The Discovery of Nuclear Antimatter* Italian Physical Society Conf. Proceedings vol. 53 eds L Maiani and R A Ricci). The symmetry between matter and antimatter, he concludes, “must rest on experimental evidence”.

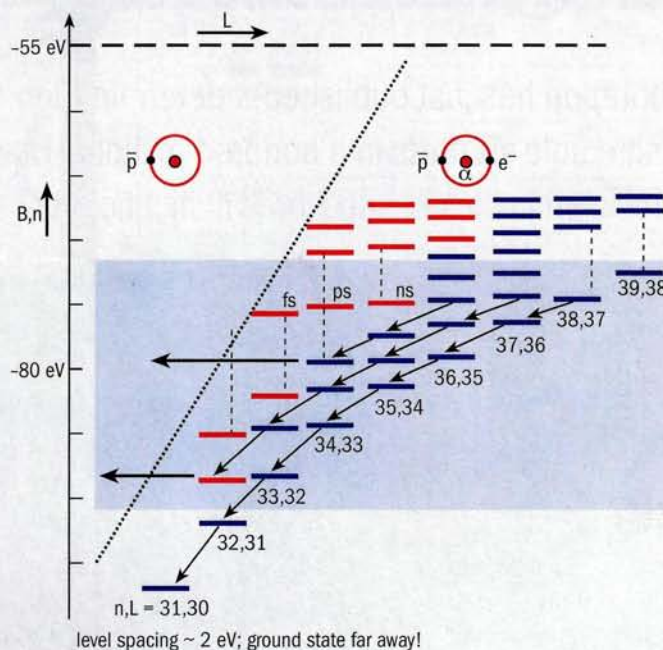
How then can we measure the antiproton charge,  $Q$ , and mass,  $M$ , with very high precision? For the proton, as few particle physicists realize, the charge is measured by taking an acoustic cavity containing sulphur hexafluoride and trying to make it “sing” in tune with an oscillating electric field. The extent to which it does not can then be interpreted as a limit on the net charge of bulk matter: if the proton’s and the electron’s charges were not very close, sulphur hexafluoride would sing louder than it does.

In the case of electrons the charge,  $e$ , is no longer obtained, as one might think, from a Millikan-type oil drop experiment, but by combining measurements of the Josephson constant,  $e/h$ , and  $\Delta$



### Thinking about antiprotonic helium

A useful starting point for thinking about antiprotonic helium is the semiclassical picture of the Bohr hydrogen atom usually presented in undergraduate textbooks. It has now been established that if the antiproton approaches an ordinary helium atom slowly enough, it readily replaces one of its electrons, entering an orbit with the same semiclassical radius (some  $10^5$  nuclear radii – well beyond the range of annihilation – producing strong interactions) and therefore the same binding energy of about 39.5 eV.



The energy levels of the antiprotonic helium atom.

As a first approximation

we assume (as is also done in textbooks for ordinary helium) that it does not interact with the remaining electron, but that this nevertheless partially screens the nuclear charge to the value  $1.7e$  instead of  $2e$ . This approximation is adequate to reveal the general properties of the spectrum.

The total (kinetic plus potential) energy in such hydrogen-like atoms is quantized with energy levels  $E_n = -E_R/n^2$ , where  $E_R$  is the energy equivalent of the antiproton-helium Rydberg constant. Doing the calculations we then easily find that  $n$  is about 38 for  $E_n = 39.5$  eV, and that the de Broglie wavelength of the antiproton is  $n$  times smaller than that of the electron (0.05 nm), justifying our semiclassical assumption. The electron itself is fully quantum mechanical as it was before the antiproton approached.

The figure shows a schematic energy level diagram for the atom. Evidently the antiproton is in a very highly excited state. Hold the figure vertically in front of you and the  $n = 1, L = 0$

ground state energy of about  $-60$  keV will be found way off the page to the left and a few hundred metres underground!

Now one might have thought that if, during its nanosecond-long approach to the atom, the antiproton had been able to displace the first electron so easily, it would within a few more nanoseconds just as easily have ejected the second one and that the atom (right thumbnail sketch) would quickly become a positive ion (left thumbnail sketch).

The most important characteristic of this atom is that energy and angular

momentum conservation prevents this from happening, at least immediately. Instead, the antiproton de-excites spontaneously (black arrows) through a chain of metastable states, emitting optical-frequency (2 eV or 600 nm) photons as it goes with microsecond-scale lifetimes.

Only when it arrives at one of the red states do the energy and angular momentum transfers become favourable for removing the second electron and so for changing the neutral atom into a positive ion. Once this happens the antiproton's fate is sealed – such ions are very unstable in collisions with ordinary helium atoms, and these soon send the antiproton into the nucleus, where it annihilates.

ASACUSA's trick is to stimulate transitions to green states with a tunable laser beam, and to detect the resonance condition between the laser beam and the atom by the ensuing annihilation.

the fine structure constant,  $\alpha$ , which appears as a scale factor for all energy levels in the hydrogen atom and is proportional to  $e^2/h$ . That way, not only  $e$  but also  $h$ , the Planck constant, can be determined.

As antisuiphur hexafluoride is not exactly common on Earth (and also for want of a suitable container for it), we must look elsewhere for a value of the antiproton's charge. The electron  $e/h$  and  $e^2/h$  experiments give us a clue as to how this can be done.

Some years ago the antiproton's  $Q/M$  value was measured relative to that of the proton's by the Harvard group at CERN's LEAR low-energy antiproton ring (R A Ricci 1999 *Phys. Rev. Lett.* **82** 3198) to the staggering precision of 9 parts in  $10^{11}$ . This value was not

deduced from measurements of the curvature of its trajectory in a magnetic field (such a measurement could never be made with a better error margin than a few parts per thousand) but by tickling it with microwaves to determine its cyclotron frequency,  $Q/M \times B$ , in the field  $B$ .

In physics we build on what we know, not on what we don't know, so we are not allowed to assume that unknown CPT-violations do not scale  $Q$  and  $M$  proportionately, leaving  $Q/M$  unchanged. The question of values for the charge and mass individually was therefore still open. An independent measure of some other combination of  $Q$  and  $M$  was needed, just as the fine structure constant gives a different combination of  $e$  and  $h$  above to the one



given by the Josephson constant. What better than the Rydberg constant of the antiproton, which is proportional to  $Q^2M$ ?

For this we need an atom in which the antiproton orbits a nucleus, as the electron does in hydrogen. A good candidate (indeed the only one available at present) is the antiprotonic helium atom (an antiproton and an electron orbiting an alpha-particle nucleus), easily created by stopping antiprotons from CERN's antiproton decelerator in helium gas.

By probing this atom with laser beams, ASACUSA can measure a number of optical transition frequencies between pairs of antiproton orbital states with principal and angular momentum quantum numbers ( $n, L$ ) differing by one (see box). In sharp contrast with the case of electrons in ordinary helium and of hydrogen, these take values around 35–40 when the almost stationary antiproton is captured into an atomic orbit by a helium nucleus (see box). Every such transition of the antiproton in this atom has the antiproton Rydberg constant as a common scale factor.

Now, of course, much of the art of high-precision experimentation lies in accounting for small systematic errors. Stopping the antiprotons in very cold (6 K) helium reduced those due to the Doppler effect severely. The major remaining systematic effect was the so-called density shift arising from the buffeting that the antiprotonic atom suffers from neighbouring ordinary helium atoms. On the theoretical side, the difficulty is that antiprotonic helium is a three-body system, not a two-body system like hydrogen, requiring sophisticated computer calculations.

Among the many transition frequencies measured, the experimenters therefore selected those with the most favourable experimental and theoretical conditions. Instead of trying to work out a value for the Rydberg constant, and combining it with the  $Q/M$  value, the equivalent procedure was adopted, asking the theorists to estimate how much the proton values for  $Q$  and  $M$  used in their calculations had to be changed to give the experimental frequencies, under the 9 parts in  $10^{11}$  constraint given by the Harvard  $Q/M$  ratio. This could be interpreted as a confidence limit on the charge and mass relative to those of the proton.

The result was that if there is any difference between the antiproton  $Q$  or  $M$  and the proton's value, it is, with a 90% confidence level, less than 6 parts in  $10^8$ . This constraint is about 10 times as tight as that obtained by the same procedure at LEAR and a thousand times as tight as that obtained without using antiprotonic helium.

Can we stop here? No. As has been often pointed out, in science we can never verify concepts (like CPT symmetry) with absolute finality – there is always the possibility that still more precise measurements, or measurements of new quantities, will falsify them. This is why the ASACUSA group is now planning further improvements to its laser system that will push the limit to a few parts in one billion, and why it is now also measuring the magnetism of the antiproton to a few parts in  $10^5$  or better by flipping the electron's spin in its orbital magnetic field. The first results are being displayed prominently in the photograph by Hiroyuke Torii of Tokyo.

**John Eades, CERN.**

\*2001 *Phys. Rev. Lett.* **87** p093401-1.

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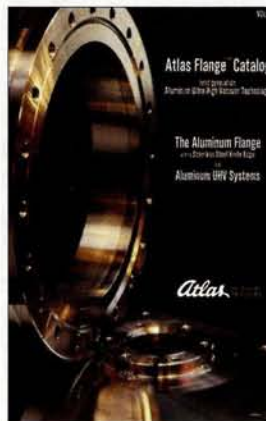
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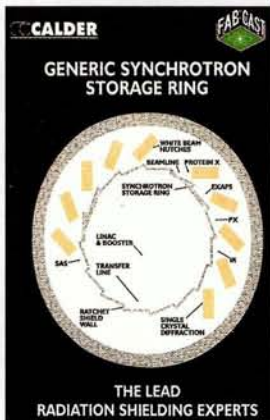
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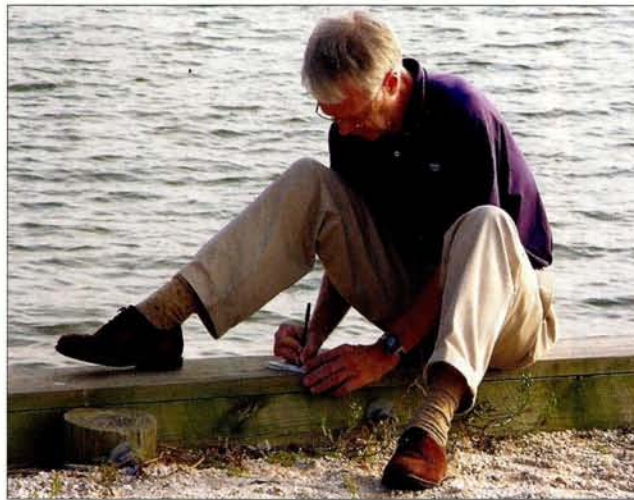


## AWARDS

# Dirac prize goes to interdisciplinary scientist

The Dirac medal and prize this year goes to Prof. John J Hopfield of Princeton, who has made important contributions in an impressively broad spectrum of scientific subjects. His special and rare gift is his ability to cross the interdisciplinary boundary to discover new questions and propose answers that uncover the conceptual structure behind the experimental facts.

His early research on light emitting diodes has been recognized by the award of the American Physical Society's Buckley prize for condensed matter physics. In biology he understood the need for and proposed the "proof-reading" principle by which the replication mechanism manages to achieve accuracy far beyond that possible



John J Hopfield of Princeton – ICTP Dirac medal winner.

in equilibrium processes. His famous model of neural processing demonstrated how qualitatively different computation in a computer and

computation in the brain could be. More recently, Hopfield has found an entirely different organizing principle in olfaction and demonstrated a new principle in which neural function can take advantage of the temporal structure of the "spiking" interneural communication.

The award, from the Abdus Salam International Centre for Theoretical Physics in Trieste, Italy, is intended "to honour and encourage high-level research in the fields of physics and mathematics" and usually reflects the purely theoretical orientation of the centre's mainstream research. Commenting on the award, Hopfield said: "I am pleased that the rather

different kind of theory which needs to be done in connection with biology could be recognized by such a community of theorists."

## Prizes awarded at French conference

At the biennial conference of the French Physical Society (SFP), which was held in Strasbourg at the beginning of July, awards were given to physicists for their work.

The Ricard prize for "very original work in physics" was given to **Yves Déclais**, director of the Institut de Physique Nucleaire of Lyon. He was head of the neutrino oscillation search experiment located close to the CHOOZ nuclear plant, in the French Ardennes. This experiment eliminated the possibility that the oscillation between electronic and muon neutrinos is the source of the atmospheric neutrino disappearance observed by Kamioka.

The Robin prize rewards a physicist for his/her whole career. It was given this time to **Jacques Haissinski** from Orsay, a pioneer of electron-positron collisions and a former chairman of CERN's LEP Experiments Committee.

Haissinski was also spokesman of the CELLO Experiment at DESY and head of the DAPNIA service at Saclay. He is currently co-spokesman of the EROS Experiment, investigating galactic structures through the

microlensing effect and searching for dark compact halo objects.

The Joliot-Curie prize, which is given biennially to a particle physicist, was awarded to **Yannis Karyotakis** from Annecy. He was a member of the L3 experiment at CERN and is now the technical coordinator of the BaBar experiment at SLAC, recently observing for the first time CP violation in the system of the beauty mesons.

The Gentner-Kastler prize is jointly given by the SFP and the German DPG (Deutsche Physikalische Gesellschaft) to a physicist who has made outstanding contributions in their field. The prize is given to a French physicist one year and a German physicist the next.

This year it was awarded to **Konrad Kleinknecht** from Mainz. He was a member of the famous CDHS neutrino experiment at CERN and of the Aleph experiment at LEP. He is also one of the pioneers of kaon physics, being in particular a very active member of the NA31 and NA48 experiments at CERN which resulted in the discovery and measurement of direct CP violation in kaon decays.

**Toshi-Aki Shibata** of Tokyo's Institute of Technology received this year's Philipp Franz von Siebold award from the Federal German government. This is given



annually to a young Japanese (aged under 50 years) who has contributed significantly to Japanese-German cultural and social exchange. Shibata has participated in various experiments at CERN from 1982 as a member of the Mainz and Heidelberg groups, first on low-energy antiproton-proton scattering at CERN's LEAR low-energy antiproton ring, and then in deep-inelastic scattering studies using high-energy muon beams at CERN's SPS synchrotron. Returning to Japan, he maintained his German connections by joining the HERMES collaboration at DESY's HERA electron-proton collider in Hamburg. He is pictured receiving the award from Federal German president **Johannes Rau**.



## Diamond ring project has a new leader

Gerhard Materlik has been appointed chief executive officer for the multinational DIAMOND synchrotron radiation ring project at the UK Rutherford Appleton Laboratory (CERN Courier May 2000 p7).

He transfers from DESY in Hamburg, where he has been an associate director of the HASYLAB synchrotron radiation laboratory. Since 1995 he has been coordinating the X-Ray Free-Electron Laser Project at DESY (CERN Courier July 2000).

The building of the new DIAMOND synchrotron, in partnership with the Wellcome Trust, was announced in 1998, and the French government joined the project during the following year.

## Uggerhoj retires

Erik Uggerhoj of Aarhus, Denmark, who celebrated his 70th birthday in September, is formally retiring. As the dynamic founding director of the Institute for Storage Ring Facilities at Aarhus, he set the institute on a clear path towards innovation and ensured the worldwide reputation that it now enjoys.

He is also a well known figure at CERN, having been the colourful spokesman for a possibly unprecedented number of experiments, dating back to 1974. His enthusiasm for and insight into particle channelling in crystals has led to numerous fruitful developments in beam handling.

## European board

The new chairman of the European Physical Society's High-Energy Particle Physics Board is Michel Spiro of Saclay. He will take over from Giora Mikenberg of the Weizmann Institute in Israel, who has presided for the past two years over the European board.

## MEETINGS



Jack Steinberger, 1988 Nobel prizewinner, addressing a group of eager listeners at the 51st annual meeting of Nobel laureates, which was held in Lindau, Germany.

**The 51st Annual Meeting of Nobel Laureates**, the seventeenth dedicated to physics, was held in Lindau, Germany, at the end of June. More than 600 students and young researchers, not only from Europe but also from the US and India, came for the opportunity to meet 18 Nobel laureates. Following lectures and debating on applications arising from basic research, or on the role of physics in the life sciences, the students could discuss the sciences or science careers with the prizewinners of their choice.

**The ESO-CERN-ESA Symposium on Astronomy, Cosmology and Fundamental Physics** will be held in Garching, Germany, on 4-7 March, 2002.

This symposium is the first to be co-organized and co-sponsored by all three organizations. It is intended to give a broad overview of scientific areas of interest to the communities of the three organizations: current observational cosmology, including the microwave background fluctuations and new constraints on the cosmological parameters; searches for dark matter; high-energy astrophysics (sources and backgrounds); recent develop-

ments and prospects in particle physics; fundamental physics from ground and space; extrasolar planets, and future perspectives at ESO, CERN and ESA.

Review speakers include R Battiston, P de Bernardis, C Cesarsky, K Danzmann, J Ellis, F Gianotti, F Halzen, G Hasinger, P Hernandez, B Leibundgut, P Madau, L Maiani, M. Mayor, Y Mellier, M Perryman, R Plaga, G Raffelt, M Rees, B Schutz, D Southwood, C Tao, N Turok, E van den Heuvel, E van Dishoeck, M Vietri, S Vitale, A Watson and L Woltjer.

A large number of posters are also anticipated, with exciting recent results from the communities of the three organizations, and there will be special poster sessions in the programme. There will also be a limited number of contributed talks.

More details, registration and accommodation forms are available at "<http://www.eso.org/gen-fac/meetings/symp2002>" or contact symposium secretaries Christina Stoffer and Britt Sjoeborg, European Southern Observatory, Karl-Schwarzschild-Str. 2, 85748, Garching bei Muenchen, Germany; e-mail "symp2002@eso.org"; fax +49 89 32006 480.



The 9th international Conference on Supersymmetry and Unification of Fundamental Interactions took place recently at the Joint Institute for Nuclear Research, Dubna, near Moscow. This year is the 30th anniversary of the discovery of supersymmetry (CERN Courier March p19).



## Change of director at NIKHEF, Amsterdam

On 22 June a symposium, Past and Future Policies on Facilities for Nuclear and High-Energy Physics Research, held at NIKHEF, Amsterdam, marked the retirement of Ger van Middelkoop as director of the laboratory and as professor of physics at Amsterdam's Vrije Universiteit. Originally a nuclear physicist, he "converted", as he put it, to particle physics. He has played an important role in restructuring particle and nuclear physics in the Netherlands and their incorporation under the NIKHEF umbrella. He has also been very influential in CERN-Netherlands relations.

Before his mandate as director of NIKHEF (1996-2001), he served as director of NIKHEF's former nuclear physics division from



Ger van Middelkoop (right), with Jos Engelen, his successor as director of the NIKHEF laboratory.

1983 to 1988. In the intervening period he was the spokesman for the New Muon Collaboration at CERN. This period and the results obtained in muon-scattering experiments at CERN were recalled at the symposium by Dietrich von Harrach (Mainz).

The other main speakers at the symposium were CERN research director Roger Cashmore, on "LHC experiments: the science, the technology and the organization" and DESY director Albrecht Wagner, on future linear colliders, in particular TESLA. Many friends and colleagues from the Netherlands and abroad attended. On 1 July Ger van Middelkoop was succeeded as director of NIKHEF by Jos Engelen.

## Maurice Goldhaber celebrates 90th



He's 90 years young – Maurice Goldhaber (centre) with birthday symposium speakers (left to right) Martin Deutsch, William Marciano, Norman Ramsey and Stuart Freedman.

As mentioned briefly in the September issue of *CERN Courier* (p37), distinguished physicist Maurice Goldhaber recently celebrated his 90th birthday. Befitting one who was the director of the laboratory during the key period of 1961 of 73, Brookhaven held a major event on 26 July.

Goldhaber's milestone physics contributions go back to studies of the photodisintegration of the deuteron with Chadwick in Cambridge in 1935, and they include work on dipole nuclear vibrations with Teller in 1948, on the classification of nuclear isomers and their interpretation in the shell model, and the classic 1958 experiment with Sunyar that determined the helicity of the neutrino. Later he was influential in promoting experiments to search for proton decay.

Speakers at the Brookhaven Birthday Symposium included Norman Ramsey on "My many memories of Maurice"; Stuart Freedman on "Reminiscences of time and reversals"; Martin Deutsch on "Maurice in my past"; William Marciano on "Proton decay"; and Maurice's brother, Gerson Goldhaber.

Brookhaven director John Marburger announced the award of the first Brookhaven Gertude and Maurice Goldhaber Distinguished Postdoctoral Fellowships.

Asked about the secret of his longevity, Goldhaber replied: "I have no time to age."



The cryogenics barrel for the electromagnetic calorimeter of the ATLAS experiment at CERN's LHC collider eases its way through the 1323 m high Faucille pass in the Jura mountains before its final descent to CERN, at the end of a journey that began 46 days previously in the Kawasaki Heavy Industries factory in Harima, near Kobe, Japan, where the module had been constructed under contract with the US Brookhaven laboratory. The barrel is 7 m high, 5.8 m wide, 7.2 m long and weighs 100 tonnes.



## Fred Hoyle 1915–2001

Flamboyant, brilliant, controversial, non-conformist, defiant, multitalented – all of these adjectives and more befitted distinguished astrophysicist and cosmologist Fred Hoyle, who died on 20 August aged 85.

After undergraduate education at Cambridge, Hoyle's formal research career was interrupted by the Second World War. His Cambridge research supervisor departed for another position, but, with his work progressing well, Hoyle did not immediately feel the need to find a replacement. Finding that he had to have one for administrative purposes, he turned to Dirac, who rarely took research students but could not resist the "impressive counterlogic" of a supervisor who didn't want a research student who didn't want a supervisor.

During the Second World War, Hoyle worked, like many of his contemporary researchers, on



*Fred Hoyle 1915–2001*

radar development. Among his colleagues were Thomas Gold and Hermann Bondi, and the trio subsequently proposed a "Steady State" theory of creation in which the universe is continually expanding, with fresh matter filling the "gaps". Promoting this theory on BBC Radio in 1950, Hoyle facetiously coined the term "Big Bang" to describe the opposite

point of view proposed by Gamow. The name has stuck ever since.

In the 1950s Hoyle worked with William Fowler and the Burbidges on the formation of heavy elements in stars – work that became classic and helped to earn the Nobel Prize for Fowler in 1983. As well as opening up the mysteries of stellar processes, this work also had important implications for nuclear physics.

In 1958 Hoyle became Plumian Professor of Astronomy at Cambridge (the chair once held by Eddington) and went on to head the new Cambridge Institute of Theoretical Astronomy, being very influential in maintaining and reinforcing Cambridge's worldwide reputation in astronomy.

After bitter wrangling, he resigned from Cambridge in 1972 but continued to propose controversial ideas, including a now unfash- ▶

## Nathan Isgur 1947–2001

As reported briefly in *CERN Courier* (September p41), Nathan Isgur, a distinguished theoretical physicist who made landmark contributions to the physics of quarks in hadrons, died on 24 July. For several years he had been fighting multiple myeloma – a rare cancer of the bone marrow. Isgur was chief scientist of the Thomas Jefferson Accelerator Facility at Newport News.

Born on 25 May 1947 in South Houston, Texas, Isgur went to Caltech for his undergraduate education, intending to major in molecular biology. However, exposure to the Feynman Lectures and Feynman himself, and a poor memory for chemical names led Nathan to switch to physics, obtaining a BSc in 1968.

He went to Toronto for a PhD, obtaining his degree in 1974, and avoiding the war in Vietnam. He was appointed a member of the Toronto faculty in 1976. Isgur was a superb teacher and lecturer, and many of his undergraduate and graduate students now have faculty positions at US and Canadian universities.

At Toronto he collaborated with Gabriel Karl of Guelph on the physics of baryons in the quark model. The QCD-improved quark model for baryons was very successful and is still the



*Nathan Isgur 1947–2001*

benchmark for baryons.

During various leaves at Oxford, Isgur collaborated with Jack Paton on flux-tube models for gluons in hadrons. Their model

made predictions for new excited hadrons involving gluonic excitation, which still remain to be confirmed. In another notable collaboration, with Chris Llewellyn Smith, the applicability of perturbative QCD to exclusive processes was examined in detail.

Isgur's most celebrated work was with Mark Wise at Caltech, one of his former undergraduate students. Their study of semileptonic decays of heavy mesons containing charm or beauty quarks led to the discovery of heavy quark symmetry in QCD. This symmetry, which becomes exact in the limit of infinite quark mass, allows an economical description of many heavy meson decays. Two of their seminal papers each have more than a thousand citations on the SPIRES database at SLAC. The discovery also led to the award of the 2001 American Physical Society J J Sakurai prize to Isgur, Wise and Mikhail Voloshin.

In 1990 Isgur moved from Toronto to Jefferson Lab to assume leadership of the theory group. He was attracted both by the opportunity to build a new theory group, and to guide the experimental programme of the new facility. Simultaneous with his appointment at the lab, he joined the faculty at the College of William and Mary. ▶



## Michael Murtagh 1943–2001

ionable Steady State theory of the universe, and the notion that life and disease on Earth originate from cosmic bombardment. He was also a prolific writer of science reviews and books, and of science fiction, the latter frequently with his son Geoffrey as co-author.

In his 1994 autobiography *Home is Where the Wind Blows*, Hoyle recounts how he was invited to lunch by Pauli at the 1958 Solvay meeting. Pauli remarked: "I have just read your novel *The Black Cloud*. I think it is much better than your astronomical work."

Fred Hoyle was the president of the Royal Astronomical Society from 1971 to 1973 and a Foreign Associate of the US National Academy of Sciences. He received prestigious awards in many countries, including the 1997 Crafoord prize, awarded by the Royal Swedish Academy of Sciences, shared with Edwin Salpeter of Cornell. He was knighted in 1972.

Chair of Brookhaven's physics department, Michael Murtagh, a senior physicist whose tenure at the laboratory extended over 34 years, died on 12 July at the age of 57.

Born in Lurgan, Armagh, Northern Ireland, he obtained a BSc at the National University of Ireland, Maynooth, and an MSc at University College Dublin. He was a fellow at Dublin's Institute for Advanced Studies before moving to the US, where he earned his PhD at Harvard in 1974.

Murtagh went to Brookhaven in 1970 as a guest junior research associate. In 1973 he joined the physics department as a research associate. He was named assistant physicist



Michael Murtagh  
1943–2001

in 1975, associate physicist in 1977 and physicist in 1979, receiving tenure in 1985.

He worked on neutrino physics using bubble chambers, from 1978 to 1986 being involved in Experiment 734 at the Alternate Gradient Synchrotron, which made precision measurements of neutrino elastic scattering from electrons and protons, and searching for neutrino oscillations.

From 1991 to 1993, Michael Murtagh served as Physics Department Associate Chair, becoming Deputy Chair in 1993. In 1998 he was named Physics Chair. He was elected a fellow of the American Physical Society in 1996.

At Jefferson Lab, Isgur initiated a programme to strengthen ties with the local and regional nuclear physics groups. Through joint appointments with local universities, he was able to double the number of positions in the theory group. Following this success, the lab extended the approach to joint experimental appointments. Isgur also instituted a programme of bridged positions, which allowed universities to recruit bright, young nuclear physicists for positions a few years before the incumbents retired.

These two programmes resulted in more than 60 new nuclear physics faculty positions in the south-east of the US. He devoted a great deal of effort to these programmes and was very pleased when they were imitated elsewhere. Isgur was strongly concerned to keep the Jefferson experimental programme focused on key issues and often asked experimentalists: "What new physics will we learn from this experiment?"

He was very effective in these interactions because of his ability to express new physics ideas in simple terms. This, as well as his skill in creating enthusiasm for physics in a non-technical audience, was a great asset in meetings with policymakers and funders.

In recognition of his contributions, Isgur was

appointed chief scientist of the lab in 1996.

When Isgur's illness was diagnosed, he started to publish at an accelerated rate. He published some 10 papers in refereed journals in the last four years and left about seven preprints in process of publication.

During his last two years at the lab he established a collaborative lattice QCD effort with MIT. This involved the addition of two new staff members to the theory group as well as substantial prototype computing hardware.

Isgur was extremely committed to assuring a bright future for the laboratory's experimental programme through his constant efforts on behalf of the 12 GeV upgrade project and the proposal for a new experimental facility to search for exotic states involving gluonic excitation.

He was a fellow of both the American Physical Society and the Royal Society of Canada, and he received many honours both in Canada and the US.

Those of us who knew Nathan Isgur have lost a very special friend and physics has lost a great leader and teacher.

*Gabriel Karl, Guelph, and John Domingo, Jefferson Lab.*

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The NSCL at Michigan State University is seeking a highly qualified accelerator physicist to join the Accelerator R&D group. The applicant should have a strong background in accelerator beam dynamics and a proven trajectory in developing large computer codes for linear accelerators and cyclotrons.

The NSCL is presently operating two superconducting cyclotrons and is embarked on the design of a linear accelerator. The successful applicant will develop new codes and maintain the extensive library of codes now in use.

Depending on the successful applicant's qualifications, appointments will be made at any of three ranks in the NSCL Continuing Appointment System that approximately parallels the university tenure stream faculty system (see CA Handbook at <http://www.msu.edu/unit/facrecds/policy/nscl01.htm>). Interested individuals should send a CV and arrange for three letters of reference to be sent directly to

Ms. M. Chris Townsend, Laboratory Administrator,  
National Superconducting Cyclotron Laboratory, Michigan State University,  
164 S. Shaw Lane, East Lansing, MI 48824-1321,  
[townsend@nscl.msu.edu](mailto:townsend@nscl.msu.edu).

For more information, see our website at <http://www.nsl.msu.edu>.

MSU is an equal opportunity / affirmative action institution.

### THE INSTITUT DE PHYSIQUE OF THE UNIVERSITY OF NEUCHÂTEL (SWITZERLAND) has an OPEN POSTDOCTORAL POSITION IN PARTICLE PHYSICS.

The appointment is for one year, with possible extensions for up to four years.

A PhD in physics or an equivalent title is required.

The main task is to participate in the long baseline OPERA experiment, more precisely to make preparations for the analysis of emulsions in Neuchâtel, and to help build and test the target tracker. In parallel the successful applicant will have the opportunity to contribute to an effort to develop new techniques for time projection chambers, to achieve larger sizes and lower background levels. This is in view of a future experiment in low energy neutrino physics, to search for double beta decay, or to investigate low energy solar neutrinos.

Jean-Luc Vuilleumier,  
Institut de physique, A.-L. Breguet 1,  
CH-2000 Neuchâtel, Switzerland  
Email: [jean-luc.vuilleumier@unine.ch](mailto:jean-luc.vuilleumier@unine.ch)  
Phone: +41 32 718 2906 Fax: +41 32 718 2901



Université de Neuchâtel



### DEUTSCHES ELEKTRONEN SYNCHROTRON DESY

DESY is one of the leading laboratories in particle physics and synchrotron radiation research. For its location in Zeuthen near Berlin DESY is offering a

### POSTDOCTORAL RESEARCH POSITION

to young scientists to participate in data taking and data analysis of the AMANDA neutrino telescope at the geographic South Pole. The accepted candidate is also expected to contribute to the preparation and construction of the next generation cubic kilometer detector, Icecube. The candidate should participate in operations at the South Pole, which are performed between November and February.

Applicants should have a PhD in physics. They should have worked in high energy physics or astroparticle experiments and should be able to cooperate within an engaged research team.

The position is limited to a duration of 2 years with a possible extension for a third year. The salary will be according to the German civil services BAT-O IIa.

DESY encourages especially women to apply.

Interested young scientists send their letter of application and three names of referees and their addresses by November, 15th, 2001 to:

DESY Zeuthen, Personalabteilung  
Platanenallee 6, 15738 Zeuthen, Germany



### THE UNIVERSITY of LIVERPOOL

### SENIOR/PRINCIPAL EXPERIMENTAL OFFICER IN PARTICLE PHYSICS

Department of Physics

Initial salary within the range £20,267 - £32,215 pa

Working within the Liverpool Particle Physics Group, you will contribute to a research area in the current research program which includes ATLAS and LHCb at CERN, H1 at DESY, BaBar at SLAC and CDF at Fermilab.

You will possess a PhD in Experimental Particle Physics and have several years' postdoctoral experience. The post is funded by PPARC and will be for a period of three years initially.

You will be expected to spend time at the overseas laboratories as appropriate. Informal enquiries to Professor P Booth on +44 151 794 3363, email: [booth@hep.ph.liv.ac.uk](mailto:booth@hep.ph.liv.ac.uk) or Professor J Dainton on +44 151 794 3374, email: [jbd@hep.ph.liv.ac.uk](mailto:jbd@hep.ph.liv.ac.uk)

Quote Ref: B/672/CC Closing Date: 15 November 2001



Further particulars and details of the application procedure should be requested from the Director of Personnel, The University of Liverpool, Liverpool L69 3BX on +44 151 794 2210 (24 hr answerphone) or via email: [jobs@liv.ac.uk](mailto:jobs@liv.ac.uk) Web site at <http://www.liv.ac.uk>

COMMITTED TO EQUAL OPPORTUNITIES



# Dean of Computer and Communication Sciences

at the Swiss Federal Institute of Technology Lausanne (EPFL)



ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE

The EPFL is a growing, dynamic, well-funded university developing research programs in engineering, basic and life sciences. In the context of a campus-wide reorganization its current departments of Computer Science and Communication Systems will be merged into "Computer and Communication Sciences". This field has a high priority within EPFL and it is expanding substantially its student body, faculty and research funding. A National Competence Center of Research, funded by the Swiss National Science Foundation, is being created in the field of mobile communications and information systems with EPFL as a leading house.



To lead the new combined faculty, EPFL invites applications for the position of the "Dean of Computer and Communication Sciences". The ideal candidate has an outstanding academic record and a strong vision for research, teaching and industrial developments in the field.

Applications including CV, publication list, addresses for references, and a vision statement should be sent as soon as possible, but not later than Jan. 10, 2002 to the address below:

Prof. Martin Hasler  
Chairman of the Search Committee  
Department of Communication Systems  
Swiss Federal Institute of Technology  
CH-1015 Lausanne, Switzerland  
Phone +41.21.693.26.22  
e-mail: martin.hasler@epfl.ch

More information on EPFL, the two departments and the National Competence Center of Research can be found at <http://www.epfl.ch>, <http://diwww.epfl.ch>, <http://dscwww.epfl.ch> and <http://www.terminodes.org>, respectively.



## FACULTY POSITIONS IN DEPARTMENT OF PHYSICS UNIVERSITY OF CALIFORNIA, SAN DIEGO

The Department of Physics at the University of California, San Diego, is beginning a substantial increase of its faculty as part of the growth of the entire campus. The department is presently large and broad-based and will add eight faculty appointments at the tenure-track assistant professor level during the next three years.

Outstanding applicants at the associate or full professor level will also be considered in exceptional cases. Recruitment is occurring in a variety of fields of physics, including experimental particle physics where an appointment effective as early as July 1, 2002 is possible. The present effort in particle physics experiment includes a major involvement in the BABAR experiment at SLAC and the CMS experiment at CERN. Applicants should have a Ph.D. in physics and a clear record of research accomplishments. In addition, they should have a strong interest in undergraduate and graduate instruction and evidence of teaching skills. Salary will be commensurate with experience and qualifications, based on University of California pay scales. Applications, consisting of a curriculum vitae, list of publications, summary of research that would be pursued at UCSD, and the names, addresses, and other contact information of at least three referees should be sent by mail only to: **Faculty Search Committee for (state your field of research), Department of Physics CC-0354, University of California, San Diego, 9500 Gilman Drive, La Jolla, CA 92093-0354.** Review of applications begins December 1, 2001 and will continue until the positions are filled.

*UCSD is an equal opportunity/affirmative action employer.*

# MIT

**The Physics Department of the Massachusetts Institute of Technology** is seeking to make junior faculty appointments in the area of subatomic physics covering the energy scales from the QCD scale to the Planck scale. Candidates will be evaluated on the basis of potential contribution to both the undergraduate and graduate teaching programs of the Department of Physics, and to the research programs carried out in the Center for Theoretical Physics. Current faculty in the Center for Theoretical Physics span a broad range of interests, including QCD, electroweak physics, unification, cosmology, and string theory.

Faculty members at MIT teach undergraduate and graduate physics courses, serve as mentors and advisors, and oversee students' research projects. Candidates must show promise in teaching as well as in research. Preference will be given to applicants at the Assistant Professor level. Applicants should submit by regular mail a curriculum vitae (include email address), a publications list, a brief description of research interests and goals, and should have at least three letters of reference sent directly to:

**Professor Robert Jaffe, Chair, Search Committee, Center for Theoretical Physics, 6-311, 77 Massachusetts Avenue, Cambridge, MA 02139-4307.**

The deadline for applications is December 1, 2001.

**MIT is an Affirmative Action/Equal Opportunity employer.**

**Women and minority candidates are strongly encouraged to apply.**



## MASSACHUSETTS INSTITUTE OF TECHNOLOGY

An Equal Opportunity/Affirmative Action Employer  
Non-Smoking Environment  
[web.mit.edu/personnel/www](http://web.mit.edu/personnel/www)





UPPSALA  
UNIVERSITET

The Svedberg Laboratory is a Swedish national research facility with purpose to make available resources for accelerator-based research. The laboratory has a cyclotron, the Gustaf Werner Cyclotron, and a cooler ring, CELSIUS.

## The Svedberg Laboratory recruits a Senior Research Engineer

to work on tasks related to accelerator technology at CELSIUS, with emphasis on the electron cooler.

The successful applicant will be PhD or MSc in electrical engineering or physics. Work experience in high voltage, ultra-high vacuum, and accelerator technology are considered merits. Cooperative skills are required.

Information about the position can be requested from Dag Reistad, telephone no. +46-18-471 3177.

Please send your application so that it arrives no later than 19 November 2001 to

**Registrar, Uppsala Universitet, Box 256, SE-751 05 Uppsala, Sweden.**

Please refer to position no. 2001/3749.



## Research Positions LIGO Laboratory

### California Institute of Technology (Caltech) Massachusetts Institute of Technology (MIT)

The Laser Interferometer Gravitational-Wave Observatory (LIGO) project led by Caltech and MIT scientists is a gravitational-wave observatory, consisting of two facilities with laser interferometric detectors located at Hanford, Washington and Livingston, Louisiana. The project is sponsored by the National Science Foundation. Commissioning of the LIGO detectors is underway and early data collection for astrophysical searches will take place this coming year.

The LIGO Laboratory expects to have positions at Caltech, MIT, and at the two observatory sites. Scientists will be involved in the commissioning and operation of LIGO itself, analysis of data, both for diagnostic purposes and astrophysics searches, as well as a vigorous R&D program for future detector improvements. Expertise related to astrophysics, modeling, data analysis, electronics, optics, vibration isolation, and control systems is useful. Most importantly, candidates should be broadly trained physicists, willing to learn new experimental and analytical techniques, and ready to share in the excitement of building and operating a gravitational-wave observatory for studies in physics and astrophysics. In general, appointments will be at the post-doctoral level with one-year initial appointments with the possibility of renewal for up to two subsequent years. In some cases, appointments with an initial term of three years or of an indefinite term may be considered. Appointment is contingent upon completion of all requirements for a Ph.D.

Applications for positions at any LIGO Laboratory site (MIT, Caltech, Hanford, or Livingston) should be sent either to Dr. Barry C. Barish, California Institute of Technology, LIGO 18-34, Pasadena, CA 91125, or to Dr. David Shoemaker, Massachusetts Institute of Technology, LIGO Project, NW17-161, 175 Albany Street, Cambridge, MA 02139 and should include a curriculum vitae, list of publications, and the names, addresses, email addresses, and telephone numbers of three or more references. Applicants should request that three or more letters of recommendation be sent directly to the attention of Dr. Barish or Dr. Shoemaker. Consideration of applications will begin on December 1, 2001 and will continue until all positions have been filled.

*Caltech and MIT are Affirmative Action/Equal Opportunity Employers  
Women, Minorities, Veterans, and Disabled Persons are encouraged to apply*

**Further information about the LIGO Project is available from:**  
<http://www.ligo.caltech.edu>



UNIVERSITY OF  
CAMBRIDGE

Cavendish Laboratory, Department of Physics

## Research Associate Appointment in Development of a combined PET/MRI scanning system

The Department hopes soon to be in a position to appoint this post, depending on final confirmation of funds supporting it.

Applications are invited for an EPSRC-funded postdoctoral Research Associate vacancy in the Low Temperature Physics research group at the Cavendish Laboratory. The project is a collaboration between the University Physics Department and Medical Imaging groups at the University Clinical School based on the Addenbrooke's Hospital site. Our aim is to design and build a novel combined PET and MRI scanner. A scanner capable of simultaneous PET and MRI imaging would be a significant advance in the field of medical imaging.

The post will involve a major role in this ongoing EPSRC project to design and build novel MRI systems. Applicants will have a PhD in Physics, Electrical Engineering or an allied subject. The work will include the development of a read-out system for the PET camera capable of operating close to the MRI system. A background in radiation detection, for example experimental High Energy Physics, would be an advantage. There is also scope within the project to contribute to algorithm development for improved image reconstruction and 3D image visualisation using modern parallel computing methods.

The appointment will be for up to 2 years in the first instance, with the possibility of renewal for a further period or periods subject to the availability of funding. The salary will be in the range £17,451 - £26,229 per annum and is pensionable.

Applications including a CV and the names of two referees should be sent to Secretary LTP Group, Cavendish Laboratory, Madingley Road, Cambridge CB3 0HE. Alternatively, applications and informal enquiries can be sent to Dr Richard Ansorge by e-mail to [Richard.Ansorge@phy.cam.ac.uk](mailto:Richard.Ansorge@phy.cam.ac.uk). The closing date for applications is 31 October 2001.

The University is committed to equality of opportunity



## Postdoctoral or Associate Research Scientist Position in Atomic and Muon Physics

Our group at Yale is doing research in atomic and muon physics with the Swiss meson facility at the Paul Scherrer Institute in Villigen, Switzerland (near Zurich). Our principal experiment at present is the measurement of the Lamb shift in the 2S state of muonic hydrogen ( $\mu^-p$ ) using laser techniques. The Lamb shift experiment is approved at PSI. Research and development of the equipment for the experiment is well underway and runs with the muon beam are expected to start within one year. Future laser spectroscopy measurements will include the hfs of the 2S state in  $\mu^-p$  and related measurements of  $\mu^-d$ . Residence at PSI and trips to our colleagues at the University of Paris will be involved. Our research position is open now and is a two year appointment initially which could be extended. Laser experience is desirable. The salary will be in the range from \$35K to \$50K/yr.

Candidates should send a CV, the names of two references, and a brief summary of past research to:

**Professor Vernon W. Hughes, Yale University  
Physics Department, 260 Whitney Ave, PO Box 208121,  
New Haven, CT. 06520-8121.**

[Vernon.Hughes@yale.edu](mailto:Vernon.Hughes@yale.edu) Send a copy by email to  
[Satish.Dhawan@yale.edu](mailto:Satish.Dhawan@yale.edu)

Yale University



## ACCELERATOR PHYSICIST Competition #844-0831

**TRIUMF**, Canada's National Laboratory for Particle and Nuclear Physics, is seeking an Accelerator Physicist to work on operational and developmental aspects of the 500 MeV cyclotron, and other accelerators for the production of exotic ions or medical isotopes.

Qualified applicants will have a relevant PhD in Physics or Engineering Physics, or equivalent education, with demonstrated practical hands-on experience acquired in an accelerator laboratory. The post-graduate degree, or previous work experience, will be in the fields of beam physics or accelerator physics, preferably with cyclotrons. Previous experience will include beam dynamics, optics, accelerator structures, instrumentation and diagnostics. The successful candidate will have demonstrated initiative, sound judgement, and excellent interpersonal skills. A strong academic background with thorough knowledge of electromagnetism, and a basic knowledge of accelerator engineering and physics, are essential.

TRIUMF is an equal opportunity employer offering a salary commensurate with experience, and a competitive benefits package. Applications for this position will be accepted until the position is filled. All qualified applicants are invited to submit their resumes as soon as possible to: **TRIUMF, Human Resources (Comp# 844-0831), 4004 Wesbrook Mall, Vancouver, B.C. V6T 2A3**

## CORNELL UNIVERSITY

### SENIOR RESEARCH ASSOCIATE Superconducting RF Research and Development

Cornell University Laboratory of Nuclear Studies has an opening for a Deputy Leader of the Superconducting Radio Frequency Program at the Senior Research Associate level. Cornell is a leading institution in the development of RF superconductivity (SRF). Our program covers SRF systems for the Cornell Electron Storage Ring (CESR), as well as development activities with the International TESLA (superconducting linear collider) and the international Muon Collider collaborations, and we anticipate the launching of new SRF projects in the immediate future. Our program has a strong basic R&D component to address limitation mechanisms in SRF cavities. The Laboratory of Nuclear Studies provides an academic environment with opportunities for supervising graduate students and teaching SRF related courses.

This is a continuing appointment subject to availability of funds under our NSF contract. A PhD in physics is required with at least seven years related experience in RF superconductivity. Further information about SRF activities at the Laboratory of Nuclear Studies can be found on <http://www.lns.cornell.edu/public/CESR/SRF>. Please send an application with curriculum vitae and three reference names to:

**Prof. Hasan Padamsee, Cornell University,  
Newman Lab, Ithaca, NY 14853-5001  
e-mail to [search@lns.cornell.edu](mailto:search@lns.cornell.edu)**

*Cornell University is an equal opportunity, affirmative-action employer.*

## ASSISTANT DIRECTOR, CENTER FOR COSMOLOGICAL PHYSICS

The National Science Foundation has established a Center for Cosmological Physics at the University of Chicago. Ed Blucher, John Carlstrom, Sean Carroll, James Cronin, Joshua Frieman, Wayne Hu, Stephan Meyer, Angela Olinto, Randall Landsberg, Simon Swordy, Michael Turner and Bruce Winstein are charter members.

The Center focuses on phenomena outside the Standard Model of Particle Physics which can be explored on a cosmological scale. Initial thrusts include: characterization of the Dark Energy, testing if the Universe underwent a period of inflation, and understanding the highest energy cosmic rays.

The Assistant Director will manage our Center while simultaneously participating in research.

Responsibilities will include budget analysis and preparation of scientific reports. He or she will supervise an Administrative Assistant, a secretary, and a part-time budget officer; organize symposia; and work with the Director and advisory groups to develop scientific goals and plan for future initiatives. The initial term is for 5 years.

Qualifications: Ph.D. in physics or astronomy. Significant post-doctoral experience (not necessarily in Cosmology) which includes management and supervisory responsibilities is desirable. Salary commensurate with experience.

Applications will be accepted until the job is filled. Applications should include a CV, publication list and 3 letters of recommendation from those familiar with the management capabilities of the applicant. Women and minorities are encouraged to apply.

Direct Applications to:

**Professor Bruce Winstein**  
Director, Center for Cosmological Physics  
Enrico Fermi Institute  
5640 S. Ellis Avenue, Chicago, IL 60637  
[bruce@cfcp.uchicago.edu](mailto:bruce@cfcp.uchicago.edu)  
<http://cfcp.uchicago.edu/>

## THE UNIVERSITY OF CHICAGO

### NEED TO RECRUIT?

**Call Debra Wills on**

**+44 (0)117 930 1196**

**E-mail [debra.wills@iop.org](mailto:debra.wills@iop.org)**





**DESY is one of the five large accelerator centres worldwide. The research spectrum reaches from elementary particle physics up to molecular biology and medicine and is unique in Europe.**

In preparation for the construction of the planned linear accelerator TESLA, DESY is establishing an integrated information management, to collect and distributes all data and documents which are generated worldwide during the project in order to provide all participants with correct and up to date information. Different information systems like EDM/PDM, Facility Management, Asset Management and SAP are used and the organisational framework will be adapted to the application of these systems.

For the integration of information systems we are looking for a

## Computer Scientist

as soon as possible for a postdoctoral position which is limited to a duration of 3 years.

You should have a degree in computer science or a comparable field and good knowledge of the structure and design of relational data bases as well as of Web-based Client server applications. If you bring along creativity, initiative and the motivation to work in a team, have an interest in an international research environment, please send your full CV to the adress below.

The salary and the social benefits correspond to those in public services. While this is a full time position, part time employment may be a possibility.

Due to German law handicapped applicants will be given preference in case of equal qualifications.

DESY is an equal opportunity employer and welcomes applications of qualified women.

### Deutsches Elektronen-Synchrotron DESY

Notkestrasse 85 • code: 81/2001 • D-22603 Hamburg • Germany  
Phone ++49(0)40/8998-2473 • www.desy.de

**Deadline for applications: 15.10.2001**

## CERN COURIER RECRUITMENT BOOKING DEADLINE

**November issue: 12 October**

**Contact Debra Wills:**

**Tel. +44 (0)117 930 1196 Fax +44 (0)117 930 1178**

**E-mail [debra.wills@iop.org](mailto:debra.wills@iop.org)**

**[cerncourier.com](http://cerncourier.com)**

## STANFORD UNIVERSITY

### PEHONG AND ADELE CHEN PARTICLE ASTROPHYSICS AND COSMOLOGY INSTITUTE DIRECTOR

The Stanford Linear Accelerator Center (SLAC) and the Department of Physics are pleased to announce a search for the first Director of the newly established Pehong and Adele Chen Particle Astrophysics and Cosmology Institute of Stanford University.

The Director will occupy an endowed, tenured, full professorship chair and will have joint appointments in the Stanford Linear Accelerator Center and in the Department of Physics. The Director will report to the Vice-Provost for Research of Stanford University. The Institute will serve as a focal point for eminent researchers and visitors in experimental, observational, and theoretical particle astrophysics and cosmology. The Institute building will be at the Stanford Linear Accelerator Center and will contain the main offices, meeting rooms and small laboratories. Facilities required for major experimental projects will be available at SLAC and near the Department of Physics. The Institute will have ten Stanford faculty along with staff, students and visitors. The Institute faculty will have appointments at SLAC, the Department of Physics and/or the Department of Applied Physics. Candidates should have demonstrated outstanding research accomplishments and leadership in fields such as particle astrophysics, astrophysics, cosmology, astronomy or related areas of physics. The Director will have major responsibility for the development of the Institute's faculty and staff, for setting the goals and style of the Institute, and for bringing additional funding to the Institute. Directorship terms of service are five years and renewable.

Applications containing a CV and a list of references should be sent before November 1, 2001 to the address given below. Stanford University is an equal employment opportunity employer. We especially invite applications from women and minority scientists.

**Prof. Martin L. Perl and Steven Chu, Co-chairs  
Chen Institute Director Search Committee**

**Stanford University, Stanford Linear Accelerator Center  
2575 Sand Hill Road, Mail Stop 61, Menlo Park, CA 94025**

# SLAC

## Postdoctoral Positions

The C. N. Yang Institute for Theoretical Physics at Stony Brook University seeks candidates for postdoctoral positions with anticipated appointment date of 1 September 2002. Research fields at the institute include, but are not limited to, elementary particle theory, gauge field theory, statistical mechanics, supersymmetry and superstring theory. Candidates are required to have Ph.D. in Physics.

We recommend electronic application at: (<http://www.physics.sunysb.edu/itp/jobs>). In the absence of web access, please email for instructions by auto-reply: ([job-forms@insti.physics.sunysb.edu](mailto:job-forms@insti.physics.sunysb.edu)). If you cannot connect electronically, please write to: CNYITP Search, Stony Brook University, Stony Brook, NY 11794-3840.

Review of applications will begin 1 December 2001, and continue until the positions are filled.

Applications from women, people of color, disabled persons, and veterans are especially welcome. AA/EOE





## Grid Computing Opportunities at CERN funded by PPARC

Opportunities now exist for computing specialists to work on grid computing at CERN, funded by PPARC. The staff appointed will be employed either through a UK university or CERN. Grid Computing uses distributed computing, processing and data storage to address some of the most complex new scientific and engineering challenges. The CERN experiments on the LHC will have enormous computing requirements and will require a large and complex computing system.

LHC computing will be implemented as a *computational grid*, integrating large distributed *computing fabrics* into a virtual computing environment. The development and prototyping work will be organised as a project that will include many scientific institutes and industrial partners. CERN will co-ordinate the project, which will be integrated with several European, national and US projects.

PPARC and CERN are offering a number of grid computing posts available at CERN, aimed at addressing the LHC computing challenge. Candidates should have at least two years solid practical computing experience in one or more of the following areas: systems management using Unix/Linux or Windows 2000; large-scale systems and storage management; relational and/or object database management systems; internet services and technologies; object-oriented programming, preferably in C++ or Java; software engineering; local and wide area networking technologies; network management; computer and network security; development of high energy physics applications, and, preferably, a university degree in computer science, physics or a related discipline. Posts are available at a range of levels (including managerial/project leader) and computing fields. For more details see the CERN IT jobs web site here:  
<http://it-div-jobs.web.cern.ch/it-div-jobs/lhc>.

Applications for these posts should comprise: a curriculum vitae of a maximum of two sides of A4 paper; the names of 3 referees and a **brief** description of the work at CERN you propose to do and why you are suited to such work. Applications should be sent to **Guy Rickett** at PPARC, **Polaris House, North Star Avenue, SWINDON, SN2 1SZ, UK** or by email to [guy.rickett@pparc.ac.uk](mailto:guy.rickett@pparc.ac.uk). Applications received by 19 October 2001 will be considered for the first round of appointments. Later appointments may be available. For further enquiries contact Guy Rickett at PPARC phone +44(0)1793 442014 or by email to [guy.rickett@pparc.ac.uk](mailto:guy.rickett@pparc.ac.uk) or Les Robertson at CERN by email: [les.robertson@cern.ch](mailto:les.robertson@cern.ch) or phone: +41 22 76 74916.

# PPARC

### Assistant Professor of Physics

The Department of Physics expects to appoint a specialist in particle theory as Assistant Professor of Physics. This is a tenure-track position to begin in September 2002. Candidates should have broad experience in particle theory, including strong interests in new phenomena. All highly qualified candidates will be considered.

Applicants should send a curriculum vitae, a brief research statement, and the names of at least three referees to:

**Ctirad Uher, Chair, Department of Physics, 2477 Randall Laboratory, University of Michigan, Ann Arbor, MI 48109-1120.**

To be guaranteed full consideration, an application must arrive by January 1, 2002.

The University of Michigan is a non-discriminatory/affirmative action employer.

## POSTDOCTORAL FELLOW CENTER FOR COSMOLOGICAL PHYSICS

THE NSF has just established the Center for Cosmological Physics (CfCP) at the University of Chicago. Research at the Center focuses on interdisciplinary topics in Cosmological physics: characterizing the Dark Energy, studying the inflationary era, and understanding the highest energy cosmic rays. Studies of the CMB (polarization anisotropies and the Sunyaev-Zeldovich effect) and Cosmic Infrared Background; analysis of Sloan Digital Sky Survey and other large-scale structure data; high-energy astrophysics with photons and cosmic rays, and numerous topics in theoretical cosmology constitute the initial slate of activities. The CfCP will have active visitor, symposia, and education/outreach program.

Several Center Fellow positions are now open. Center Fellows have the freedom to work on any of the efforts in our Center.

We seek candidates with a recent Ph.D. in physics, astrophysics, or related fields, with an interest in pursuing experimental or theoretical interdisciplinary research in cosmology. **PRIOR EXPERIENCE IN COSMOLOGICAL PHYSICS IS NOT A REQUIREMENT.** Positions are for two years, with possible renewal for a third.

A CV, statement of research interests, and at least three letters of recommendation should be sent to [centerfellow@cfcp.uchicago.edu](mailto:centerfellow@cfcp.uchicago.edu)

or to **Bruce Winstein, Director, Center for Cosmological Physics, Enrico Fermi Institute, 5640 S. Ellis Avenue, Chicago, IL 60637.**

Information about the CfCP can be found at <http://cfcp.uchicago.edu/>

Women and minorities are encouraged to apply. Applications are now being accepted for positions which are available immediately. The deadline is December 10th for positions which will begin July 1, 2002.

# THE UNIVERSITY OF CHICAGO

Department of Physics



### Lectureship in Experimental Particle Physics

The Department of Physics, Queen Mary, University of London invites applications for a new **Lectureship in Experimental Particle Physics**.

Candidates are expected to have outstanding research achievements. The successful candidate, based at Queen Mary, will be welcome to join one of the Group's current experiments, BaBar at SLAC, H1 at HERA, or ATLAS for the LHC, and have the opportunity to participate in GRID e-Science activities. He/she will also be encouraged to initiate new projects within areas such as the Next Linear Collider or Neutrino Factories.

The appointment is expected to begin early in 2002. The present salary will be within the Lecturer scale £22,401 to £34,349, including London Allowance.

For further information please contact the Head of Department, **Prof D.J. Dunstan** ([d.dunstan@qmul.ac.uk](mailto:d.dunstan@qmul.ac.uk)) or the Head of Experimental Particle Physics, **Prof A.A. Carter** ([a.a.carter@qmul.ac.uk](mailto:a.a.carter@qmul.ac.uk)).

An application form is available from [phys-recruit@qmul.ac.uk](mailto:phys-recruit@qmul.ac.uk) or by telephone, +44 (0)20-7882-5030, quoting reference **Phys2307**.

Completed forms should be returned to the: **Recruitment Secretary, Mrs D. Paige, Department of Physics, Queen Mary, University of London, London E1 4NS by November 5th 2001.**



## Faculty Position Department of Physics

The Department of Physics at the University of California at Davis invites applications for a faculty position in observational or theoretical cosmology. This position has a targeted start date of July 1, 2002. The appointment will be a tenure-track Assistant or tenured Associate Professor level as determined by qualifications and experience.

This position is one of four positions created for our cosmology program. The current cosmology group consists of Professors Andreas Albrecht, Robert Becker, and Lloyd Knox. The cosmology program benefits from full access to Lick and Keck observatories and from overlapping interests with our strong departmental programs in condensed matter, nuclear physics, quantum gravity, and especially with our particle physics program. Outstanding persons in all areas of cosmology will be considered. The successful candidate will have a Ph.D. in physics or astrophysics and will be expected to teach at the undergraduate and graduate levels and to conduct any active research program in cosmology.

This position is open until filled; but to assure full consideration, applications should be received by November 30, 2001. To initiate the application process, please mail your curriculum vitae, publication list, research statement, and the names (including address, e-mail, fax, and phone number) of three or more references to:

Professor Winston Ko, Chair  
Department of Physics  
University of California, Davis  
One Shields Avenue  
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Further information about the department may be found on our website at <http://www.physics.ucdavis.edu>

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# BOOKSHELF

## Superconducting Materials for High Energy Colliders

edited by L Cifarelli and L Maritato, World Scientific Science and Culture Series – Physics, ISBN 080243197.

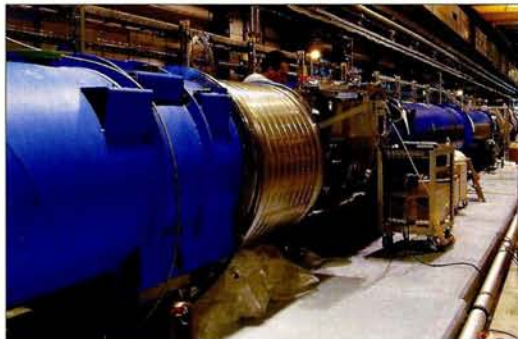
Imagine the ultimate high-energy physics project – 10 times as powerful as CERN's mighty LHC collider. This ambitious goal, which is aiming for a hadron collider with a collision energy of 200–1000 TeV and with a luminosity as high as  $10^{36}$ , is the theme of Antonino Zichichi's foreword to this book. The vision of the multihundred TeV "ultimate collider", the Eloisatron, is supported by the conviction that no energy threshold well beyond the Standard Model seems near.

The book is dedicated to the memory of Tom Ypsilantis (*CERN Courier* October 2000 p48) and gives a full description of a workshop held in Erice, Sicily, at the end of 1999 on superconducting materials for future high-energy colliders. This marked the return of a full European perspective of the Eloisatron workshops, after a period during which the European community had been busy designing the LHC, while our US colleagues emerged from the trauma of the cancelled SSC and set up a new programme that is now focused on the VLHC.

With the LHC on track to produce physics by 2006, European scientists began to look beyond the present horizon. The workshop provided an excellent forum where materials scientists met with accelerator specialists to exchange information and to focus R&D towards common goals.

Superconductivity is the key accelerator technology, and the communities striving for high field (magnets) and for high gradient (radiofrequency cavities) exploit the absence of electrical resistance at low temperatures. In the reverse direction, high-energy physics has provided the right environment (and resources) to achieve real progress in applied superconductivity, by developing high-critical current density cables with fine filaments and achieving mass-production. A good example is magnetic resonance imaging (MRI), which could not have progressed from a laboratory-scale experiment to a general medical technique without the impetus of high-energy physics cryogenics.

At the Erice workshop, Philippe Lebrun, head of CERN's LHC division, addressed the problem of technical management of mega-



Test string for superconducting magnets for CERN's LHC collider. Particle physics is a major focus for research and development work in applied superconductivity.

science projects and described what we are learning with the LHC, the first global accelerator project, and reviewed the main machine subsystems, including the powerful cryogenics needed to keep some 50 000 tons of superconducting magnets at 1.9 K – the coldest point of the universe and twice as cold as the relic cosmic microwave radiation. Also for the LHC, Tom Taylor covered the vigorous technical effort that is under way to design and build the LHC's superconducting components to conform to stringent energy and luminosity requirements, and the room for improvements.

Kjell Johnsen, the designer of CERN's ISR, the first hadron collider, reviewed the tentative feasibility study of the Eloisatron, just 10 years after it was issued, showing that the machine, although very ambitious, is technically feasible with a 300 km ring where some 16 000 dipoles reaching 10 tesla can provide 100 TeV proton beams (200 TeV collisions).

On basic superconductivity, C Grimaldi (Lausanne) introduced the present understanding of high-temperature superconductors (HTS), stressing that much work still needs to be done, but the reward would be the cheap and easy cryogenics of liquid nitrogen.

J Halbrittner (Karlsruhe) described the detailed analysis of radiofrequency losses in superconducting cavities, showing the present superiority of bulk niobium cavities over sputtered ones for very high power.

Superconducting cavities for frontier colliders were the topic of an extensive review by H Padamsee (Cornell) on the impressive progress with bulk niobium and niobium-sputtered copper cavities. With proper selection and treatment of the material, the

road is open to 40 MV/m and a TeV electron-positron superconducting linear collider. A Cassinese (INFN-Naples) described microwave measurements of superconducting films of niobium and niobium-tin, stressing the need to understand surface resistance.

L Rossi (Milan) turned to the design and characteristics of accelerator magnets, highlighting the demands on superconductor performance to build 5–15 T dipole and quadrupole magnets. He included an overview of worldwide R&D for magnets beyond the LHC-phase1, emphasizing the necessity of a vigorous effort to improve niobium-tin

characteristics to reach a critical current of 1000 A/mm<sup>2</sup> at 18 T (LHC-phase1 material reaches this level at 8 T and 4.2 K) and showed the novel magnet designs being explored in the US for VLHC studies.

The Japanese effort on doped niobium-tin reinforced with a copper-niobium matrix was covered by K Watanabe (IMR, Tohoku) who showed the potential of this technique to overcome the problems posed by the brittleness of niobium-tin. Japan is also leading the effort on the less brittle niobium-aluminium superconductor, and K Inoue (NRIM, Tsukuba) described the potential of the recently developed, rapid-quenching and transforming process. Although very difficult, this process could achieve interesting current densities.

For HTS, K Salama (Houston) reviewed the fabrication technique for bismuth- and yttrium-based, silver-stabilized superconducting tapes, reporting an improvement in critical current of almost an order of magnitude using suitable heat treatment. His former assistant, L Martini (ENEL-Ricerca, Milan), reported on his unique "accordion-folding method" to produce short (0.1–1 m) Bi-2223 samples with a very low silver content, useful for low-consumption multi-kA current leads (needed in large quantities for the LHC).

J Scudiere (American Superconductor Corporation) reviewed the results obtained by the leading company in HTS development and production. The impressive results on short samples have yet to be reproduced in long samples. However, for fields above 18 T, HTS could become a viable alternative to niobium within a few years. He highlighted the necessity of reasonable homogeneity and reliability of such a delicate (ceramic)



material under "industrial" conditions and indicated that a production rate of at least 2000 km/year of tapes is needed to reduce prices to a reasonable level. Considering that such a quantity is approximately equivalent to about 50 LHC dipoles, major projects are needed to drive this promising material to market (as for MRI). Finally, C M Friends (BICC General Superconductors) reported on 13 kA HTS current leads for the LHC and the development of Bi-2223 tapes and of round wires (radial filaments) for low losses in AC conditions.

The book gives the impression that accelerator technology is far from saturation and there is plenty of room yet for exciting developments and significant breakthroughs. On an optimistic note, in the two years since the workshop was held, the increase in conductor performance from LHC values to final goals is already half-achieved. A field of 14.5 T at 4.2 K was attained earlier this year at Berkeley in a short model with a new niobium-tin coil configuration.

Lucio Rossi, Milan.

**The Golden Age of Theoretical Physics** by Jagdish Mehra, World Scientific, ISBN 9810243421, two-volume set £56.

Jagdish Mehra has spent much of his long career carefully documenting the development of quantum mechanics and the people involved. One of the results is his monumental work (with Helmut Rechenberg) *The Historical Development of Quantum Theory*. The six-volume/nine-book series, completed last year, is imposing. His other contributions include the collected works of Eugene Wigner; books on Einstein, Hilbert and general relativity; and the more popular *The Beat of a Different Drum*, a biography of Richard Feynman.

His new collection brings together 37 essays, based on his invited lectures, mostly covering modern physics – relativity, quantum theory and quantum mechanics, spin and statistics, quantum electrodynamics, elementary particles – and physicists – Einstein, Planck, Gibbs, Bohr, Sommerfeld, Bose, de Broglie, Pauli, Heisenberg, Dirac, Schrödinger, Wigner and Landau.

Mehra is a scientists' historian who understands concepts and traces their evolution, as well as the personalities involved.

In the introduction to the book, he explains his own fascination with literature, philosophy

and history and his quest to reconcile these with his solid grounding in physical science.

Gordon Fraser, CERN

**Heavy Quark Physics** by Aneesh V Manohar and Mark B Wise, Cambridge University Press, ISBN 0521642418 (hbk) £40/\$64.95.

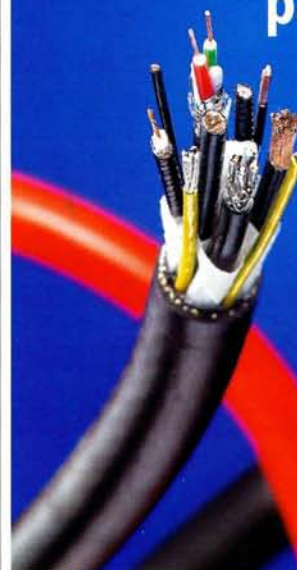
Most of the achievements in the understanding of the physics of particles containing heavy quarks date from the past decade, both on the experimental and on the theoretical side. More and more precise measurements of b hadron properties carried out at CESR, LEP and the Tevatron colliders have gone in parallel with the development of the Heavy Quark Effective Theory (HQET), which has become the key tool for a quantitative description of the interactions of heavy particles. Such important theoretical developments were up to now documented in a fairly large number of papers, published over the years by the pioneers of the field. Manohar and Wise now provide us with a valuable textbook on heavy quark physics. The presentation of the material is clear and concise, covering the majority of the fundamental theoretical results currently available in the field.

The book starts with a review of the Standard Model. A discussion of spin-flavour symmetry follows, including the implications for the heavy hadron spectroscopy and for the hadron production rates in the heavy quark hadronization. Then HQET is developed, first at one loop in the infinite mass limit, then including radiative corrections and  $1/m_Q$  corrections. Many important results are derived, such as the heavy meson decay constants, the form factors in the semileptonic decay of B mesons to D and D\* mesons, and the semileptonic decays of  $\Lambda_b$  to  $\Lambda_c$  baryons (heavy-to-heavy currents) and  $\Lambda_c$  to  $\Lambda$  (heavy-to-light).

Chiral perturbation theory is also discussed, deriving the matrix elements for the semileptonic decay of heavy-to-light mesons, as well as corrections to heavy-to-heavy transitions ( $B \rightarrow D^{(*)} \ell \nu$ ). The powerful operator product expansion formalism is finally developed and used to calculate inclusive weak decays of b hadrons.

Some of the calculations are reported step by step, especially when they involve techniques and subtleties developed for the purpose that have become key tools in HQET. Each chapter is complemented with problems that are non-trivial applications of the

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## BOOKSHELF

theory discussed, and a collection of bibliographical references.

The book is aimed at readers with a solid background in quantum field theory who are aiming to get acquainted with the techniques of HQET. The illuminating discussions of the approximations and assumptions made at each step, and of their implications on the validity of the results derived, make it valuable reading for all physicists who want to get a better insight into heavy quark physics, even without going through all of the calculations.

Heavy quark physics is now entering an exciting new era in which high-luminosity machines will significantly improve our experimental knowledge, demanding corresponding progress in the precision of theoretical predictions. This text provides a concise and systematic summary of today's knowledge, and will stay as a bibliographical milestone while new developments take place.

*Duccio Abbaneo, CERN*

**At the Frontier of Particle Physics: Handbook of QCD – Boris Ioffe Festschrift** edited by M Shifman, three volumes, World Scientific, ISBN 9810244452, set £112.

As would be expected from such a meticulous editor (see *The Supersymmetric World – The Beginnings of the Theory* edited by G Kane and M Shifman, World Scientific, ISBN 981024522X reviewed in *CERN Courier* September p50), these three volumes contain a wealth of well-prepared and highly valuable information. They bring together 33 reviews covering all aspects of the analytical aspects of the theory of quantum chromodynamics (QCD), assembled to mark the 75th birthday of Boris Ioffe. The majority of the work provides an encyclopedia of QCD that is useful for students and for research workers.

The first part of the work is more historical, and it includes contributions from Ludwig Faddeev on quantizing Yang-Mills fields, and from David Gross on the discovery of asymptotic freedom and the emergence of QCD. These are followed by an amusing aside by Shifman: "How the asymptotic freedom of the Yang-Mills Field could have been discovered three times before Gross, Wilczek and Politzer, but was not".

Introducing all of this is the material specifically on Ioffe and on events in Russia at the end of the 20th century, with very useful editorial explanations. After the introductory festschrifts, Boris Ioffe's *Top Secret*

*Assignment* (which won the 1999 Novy Mir prize after being published in that magazine) and Yuri Orlov's *Snapshots from the 1950s* (based on excerpts from Orlov's book *Dangerous Thoughts – William Morrow 1991*, New York) are full of fascinating insights. *Gordon Fraser, CERN*

**Oeuvre et engagement de Frédéric Joliot-Curie** eds Monique Bordry and Pierre Radvanyi, EDP Science, ISBN 2868835252.

Frédéric Joliot-Curie, a major French scientific figure, was born in 1900 and the 100th anniversary of his birth called for a special celebration. This took place on 9–10 October 2000 at the Collège de France, where he was a professor until his death in 1958 and where he long communicated his insight and enthusiasm to the many members of his laboratory.

The symposium consisted of three series of formal talks, each followed either by numerous testimonies from many of those who had the privilege to work with Joliot-Curie, or know him well, or by round-table discussions with invited participants. These three main themes covered artificial radioactivity (the discovery for which he, together with his wife Irène, received the 1935 Nobel Prize for Chemistry), nuclear energy, and social and political commitments.

Joliot-Curie was not only a great scientist but he also played a key role in the early development of nuclear energy in France, and was for more than two decades a very important figure in French political and social circles.

The symposium was opened by Hubert Curien, former president of the CERN council, and closed by an address from Minister of Research Roger-Gérard Schwartzenberg. A plaque commemorating the discovery of artificial radioactivity was unveiled at the Institut du Radium (*CERN Courier* December 2000 p40).

This beautifully edited book brings together the texts of all of the invited talks, testimonies and round-table presentations during the symposium. It is in French except for two historical texts in English. The book pays ample tribute to Joliot-Curie but also provides much topical matter. It not only brings the past alive, but also shows in a brilliant and well documented way how many questions on which Joliot-Curie strongly made his mark are still very important today. There are many historical photographs and a good biographical summary. The cover is graced by a Picasso portrait. *Maurice Jacob, CERN* □



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