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CERN COURIER

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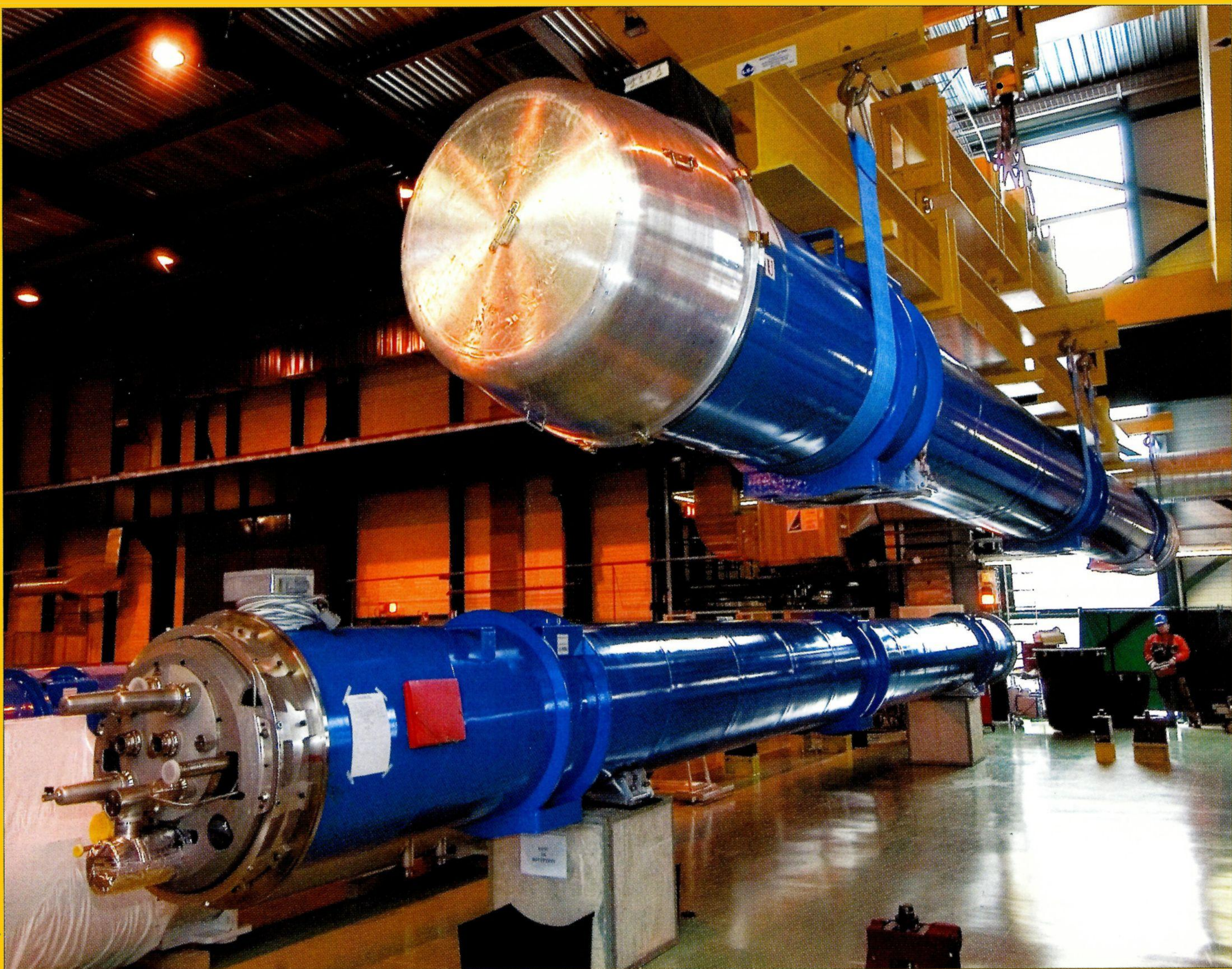
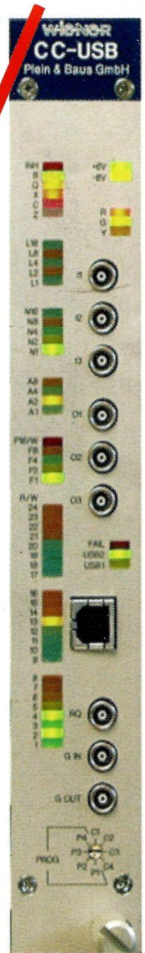


Magnets begin descent to the LHC

Modules



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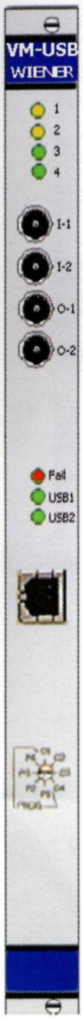

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⇒ 2 user-programmable NIM inputs and 2 outputs (with LEMO connectors)

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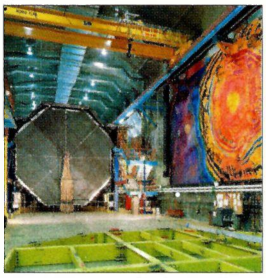
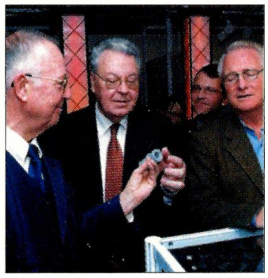


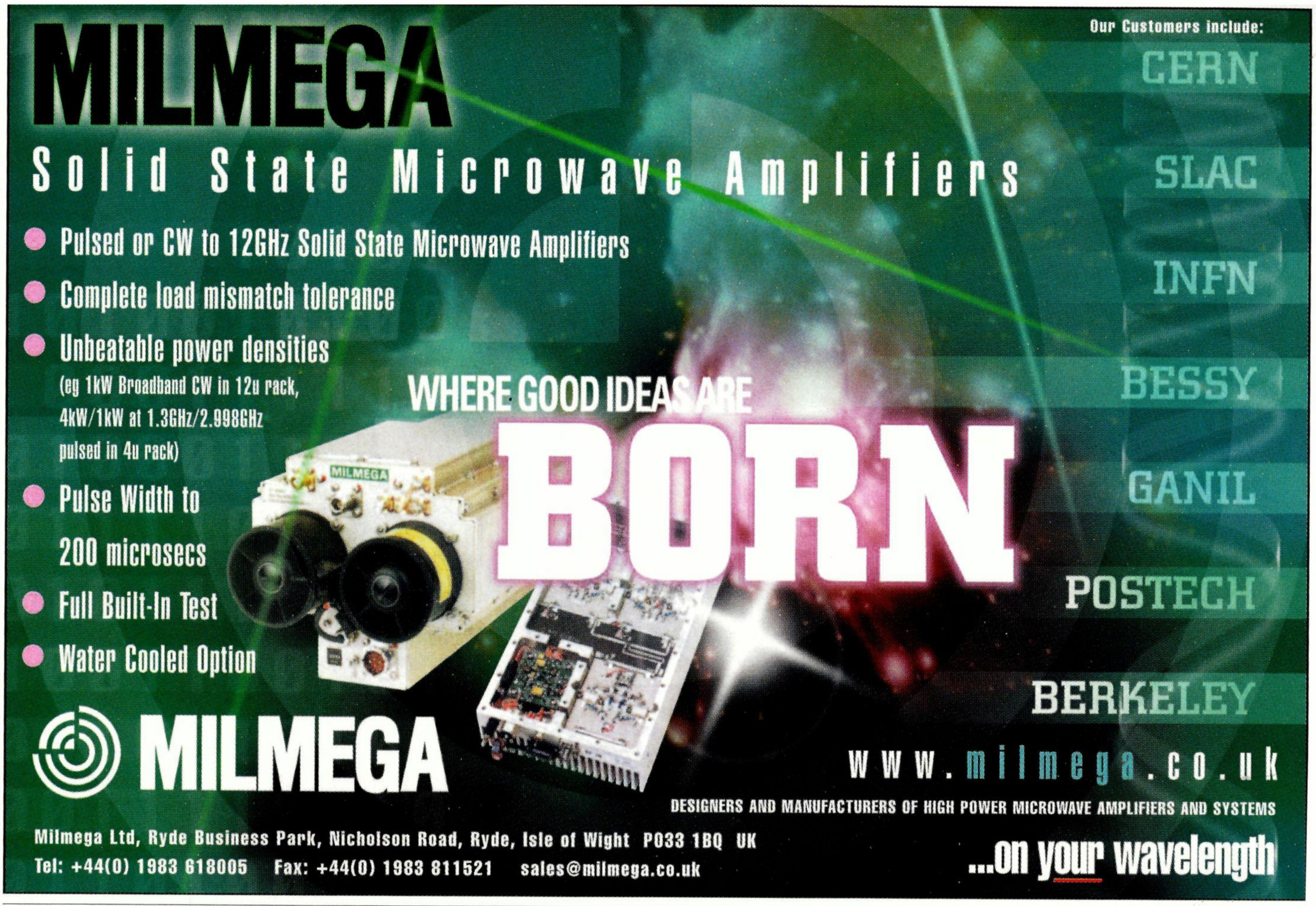
MINOS opens for business p7

STAR's silicon strip detector p31



German firms come to CERN p33

Cover: The first of 1232 dipole magnets to be installed in the Large Hadron Collider at CERN sets off on its journey from the surface to the collider tunnel (p5).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NEWS

CERN

First dipole descends to LHC

The first LHC dipole being lowered down the oval shaft.

At last the superconducting dipole magnet rests in position in the LHC tunnel.

On 7 March the first of the superconducting dipole magnets for the Large Hadron Collider (LHC), under construction at CERN, was lowered into the accelerator tunnel.

The 15 m-long dipoles, each weighing 35 t, are the most complex components of the machine. In total, 1232 dipoles will be lowered 50 m below the surface via a special oval shaft. They will then be taken through a transfer tunnel to their final destination in the LHC tunnel, carried by a specially designed vehicle travelling at 3 km per hour.

In addition to the dipole magnets, the LHC will be equipped with hundreds of smaller magnets. More than 1800 magnet assemblies will have to be installed. Once in position, the magnets will be connected to the cryogenic system to form a large string operating with superfluid helium, which will maintain the accelerator at a temperature of 1.9 K.

The lowering of this first magnet into the tunnel coincided with another milestone: the delivery of half of the superconducting dipole magnets. The remaining 616 dipoles are due to arrive by autumn 2006. The construction of these superconducting magnets represents a huge challenge both for CERN and for European industry; for example, some 7000 km of niobium-titanium superconducting cable has had to be produced to form the magnetic cores.

Altogether some 100 companies in Europe are involved in manufacturing the magnet components. The greatest task was the move from the prototyping and pre-series phase to large-scale production. This has been met successfully and three industrial sites, in France, Germany and Italy, are manufacturing about 10 magnets each week.

KEK

B-factory achieves record luminosity

On 19 February the Belle experiment running at Japan's KEKB accelerator, the KEK B-factory, accumulated a record integrated luminosity of 1 fb^{-1} in a single day, corresponding to roughly 1 million $B\bar{B}$ meson pairs.

KEKB's design luminosity of 1×10^{34} $cm^2 s^{-1}$ was first reached in May 2003. Since then the record has regularly been broken and on 15 February a new peak of 1.516×10^{34} $cm^2 s^{-1}$ was achieved. On average the KEKB luminosity is about 20% higher than it was a year ago. During operation of the TRISTAN accelerator at KEK from 1987 to 1995, the total integrated luminosity seen by the VENUS detector was 400 pb^{-1}. Belle is now collecting the same amount of data in less than half a day.

Most of the performance increase is due to the novel scheme of continuous beam injection used at KEKB in which the detector keeps taking data while the electron and positron beams are being injected into the accelerator. This was previously thought to be almost impossible owing to the large noise introduced by the injected beams. However, the KEK accelerator group has developed a sophisticated scheme of continuous beam injection, while the detector group has also developed an electronics system that is more tolerant to noise.

DETECTORS

Russian team builds biggest MDT chambers for muon spectrometer

The Institute for Theoretical and Experimental Physics (ITEP) in Protvino, Russia, is producing some of the largest and most challenging chambers for the muon spectrometer of the ATLAS detector at CERN. Monitored drift-tube (MDT) chambers come in a variety of sizes, but the 192 chambers now being produced at ITEP include 16 with a length of 6.3 m and between them incorporate 60 000 precision MDT tubes.

MDTs have been constructed in many institutes in Europe, the US, Russia and China, but this is the first time that chambers of this size have been successfully produced. Despite the huge size of the chambers, the 50 μm thick anode wires are positioned to better than 20 μm. Production in Protvino is expected to finish by mid-April.

The Protvino group with the rig for assembling large monitored drift-tube chambers. Behind is one of the biggest of all, a 6.3 m chamber for the ATLAS muon end cap.

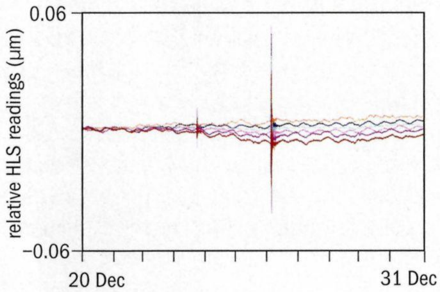
SENSORS

Tsunami earthquake detected in ATLAS cavern

During the Christmas break, the hydrostatic level sensors (HLSs) in the ATLAS cavern revealed a new facet of their capabilities. Installed by the CERN survey group to monitor any deformation or movement of the structure on which the detector feet rest, these sensors with submicrometre resolution coupled to the heavy ATLAS mechanical infrastructure took on the function of a seismograph.

The signals recorded by the sensors are shown in the figure, which reveals two perturbations, one on 23 December starting at 15.45 GMT and the other on 26 December at 01.23 GMT. Seeing these unusual readings raised the question of whether they were connected with the earthquake off the Indonesian coast that gave rise to the devastating tsunami.

The Geneva Centre for the Study of Geological Risks was duly contacted and it confirmed that the earthquake off the coast of Sumatra, which measured 9.0 on the Richter scale, was indeed responsible for the large peak recorded at CERN. When a seismic event occurs, the resulting vibrations spread out in all directions and two types of wave can be distinguished: primary waves, which propagate through the earth at speeds of 6–8 km s^{-1}, and the slower waves that are confined to the surface of the Earth (such as the horizontal Love wave, which can cause structural damage to buildings).



Traces from the six level sensors installed on the ATLAS bedplates (four in the corners and two in the middle in a figure of "H"), relative to their position on 20 December. Apart from the natural drift of the readings, two spikes picked up by all sensors can clearly be seen on 23 and 26 December.

The epicentre of the Sumatra earthquake was some 9000 km from CERN and happened at 00:59 GMT (07:59 local time). The primary waves need about 20 minutes to reach the ATLAS cavern, which is consistent with the first perturbations recorded by the sensors at 01.23 GMT on 26 December.

The earlier, smaller perturbation is linked to another earthquake measuring 8.1 on the Richter scale, which is thought to have been correlated with the earthquake of 26 December. It happened at 14.59 GMT on 23 December north of Macquarie Island (between Australia and Antarctica), much further away from CERN.

NEUTRINOS

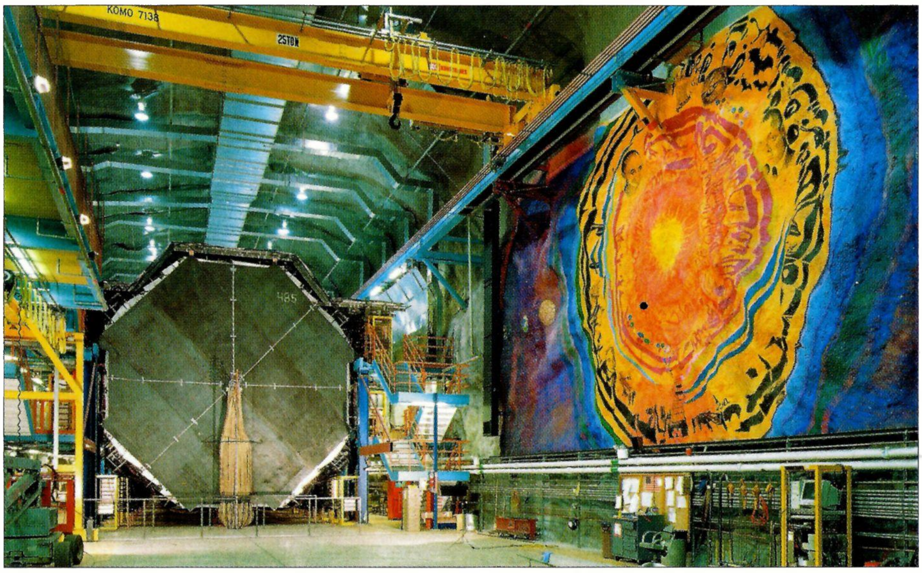
First neutrinos head for MINOS

The Main Injector Neutrino Oscillation Search (MINOS) experiment was officially inaugurated in a ceremony at Fermilab on 4 March. MINOS is the latest weapon in the arsenal of neutrino-oscillation searches. Its main goal is to measure the largest difference in mass-squared between different neutrino species (Δm^2_{23}) with an accuracy of 10% – more than a factor of two better than it is known today.

MINOS takes over from the KEK to Kamioka (K2K) experiment in Japan, which has finished taking data with a similar set-up. The unique feature of MINOS, however, is its 1.5 T magnetic field. This enables the experiment to distinguish positively and negatively charged tracks and hence discriminate between neutrinos and antineutrinos.

MINOS uses a neutrino beam produced by Fermilab's Neutrinos at the Main Injector (NuMI) facility, where 120 GeV protons from the Main Injector hit a graphite target, producing hadrons including pions. A "horn" focusing system selects positive pions, which then decay in a 700 m-long decay pipe. After passing through a beam absorber, the beam comprises mostly muon neutrinos. An important advantage of the system is that the energy of the neutrinos can be tuned by moving the horn focusing system.

The neutrino beam is aimed at the MINOS "far" detector, located in the Soudan Underground Laboratory in northeastern Minnesota, some 730 km away from Fermilab. The laboratory is 700 m underground in an old iron mine. To reduce errors by measuring directly the beam composition and neutrino energy spectrum, a "near" detector is also incorporated in the experiment 1 km from the target. It is essentially a miniature of the 6000 t far detector.



The MINOS far detector in its cavern in the Soudan Underground Laboratory. Each year up to 40 000 members of the public descend to view the laboratory. An added attraction is the 18.3 × 7.6 m mural painted on the cavern wall by Minneapolis artist Joseph Giannetti.

An important milestone was reached on 4 December 2004, when the first beam reached the target hall. The horns were powered in January and the near detector has already recorded its first events.

● MINOS is a collaboration of 200 scientists, engineers, technical specialists and students from 32 institutions in Brazil, France, Greece, Russia, the UK and the US.

US FUNDING

US budget changes priorities for HEP

On 8 February the White House released its budget proposal for the financial year 2006. The science and technology budget of the US Department of Energy has been reduced overall by about 3.8% compared with 2005, whereas the budget for high-energy physics (HEP) is reduced by about 3%. The proposal is pending approval by Congress.

The HEP programme for 2006 has been structured in such a way "not only to maximize the scientific returns on our investment in these facilities, but also to invest in R&D now for the most promising new facilities that will come online in the next decade". This has necessitated some prioritization.

The planned operations, upgrade and infrastructure for the Tevatron at Fermilab are cited as the highest priority, with a high priority also given to operations, upgrades and infrastructure of the B-factory at SLAC. However, B-factory operations will be terminated by 2008 at the latest. Support for a leadership role for US research groups in the physics programme for the Large Hadron Collider at CERN will also continue to be a high priority, and the preconceptual R&D needed to explore the nature of dark energy will continue in 2006.

A major casualty is the engineering design of the B Physics at the Tevatron (BTeV) experiment, which was scheduled to begin in 2005 as a new "major item of equipment" and will instead be terminated by the end of 2005. The reasons given are the timescale and the "lesser scientific potential" compared with other projects, although it is "still important scientifically". Support was strong only if the project could be completed by 2010, which is "not feasible given schedule and funding constraints".

Support for a future electron–positron linear collider, however, has increased relative to 2005 for "the continued international participation and leadership in linear collider R&D and planning by US scientists". R&D for other new accelerator and detector technologies, particularly in the emerging area of neutrino physics, will also increase.

HADRON PHYSICS

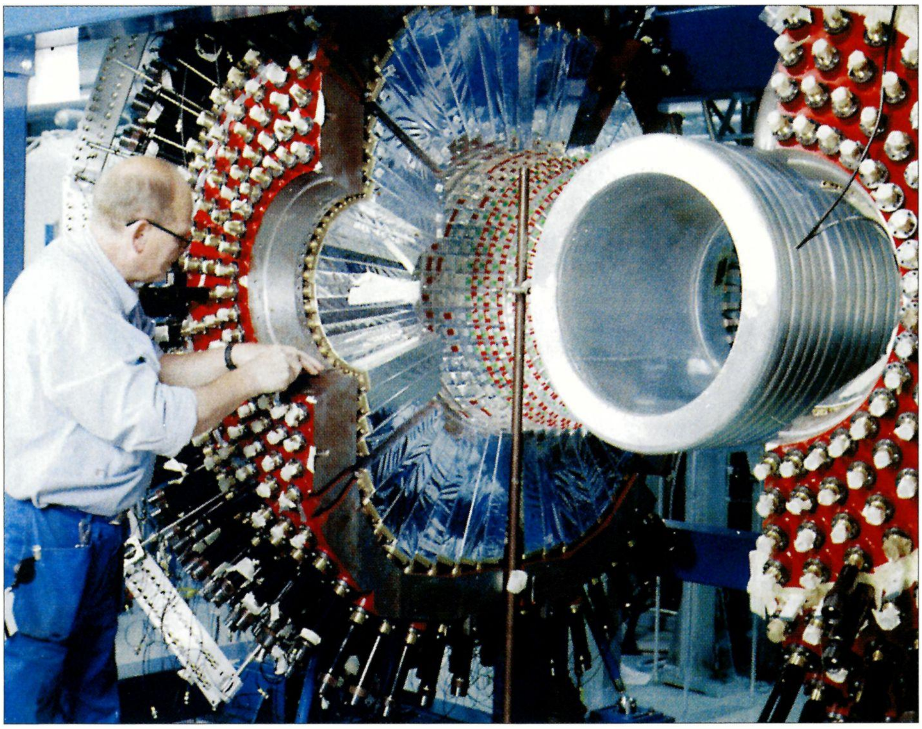
WASA finds a new home at COSY

The Wide Angle Shower Apparatus (WASA) detector, currently at the CELSIUS facility of The Svedberg Laboratory (TSL) in Uppsala, Sweden, is to find a new home. CELSIUS was commissioned in 1983, using the hardware of CERN's ICE ring, and its experimental programme will end in summer 2005. The WASA detector, built in the 1990s by a collaboration between Sweden, Poland, Germany, Russia and Japan, will then be relocated to the Cooler Synchrotron (COSY) ring at the Forschungszentrum Jülich (FZJ) in Germany.

WASA is a fixed-target 4π detector comprising a central part and a forward part. The central detector, built around the interaction point, is designed mainly for the detection of the decay products of π^0 and η mesons: photons, electrons and charged pions. It consists of an inner drift chamber, a superconducting solenoid and a caesium-iodide calorimeter. The forward detector, designed to detect target recoil and scattered beam particles, consists of 11 planes of plastic scintillator counters and proportional counter drift tubes. The target consists of a beam of frozen hydrogen or deuterium pellets about 25 μm in diameter, which will allow luminosities of up to 10^{32} cm^{-1} s^{-1} in interactions with the circulating beam at COSY.

The transfer of WASA to COSY will be mutually beneficial. Photon detection is important for understanding the physics of hadronic reactions, since many of the produced mesons and excited baryonic states have a significant number of decay branches into multi-photon final states. This calls for a detector with a wide-acceptance electromagnetic calorimeter. Until now, such a detector has been missing from COSY, and WASA fits the bill nicely.

WASA will also benefit from the higher energy of the COSY beam compared with CELSIUS, which is well above the threshold for η' production in proton–proton interactions. (COSY offers beam momenta of up to 3.7 GeV c^{-1} with polarized and cooled proton and deuteron beams, whereas CELSIUS can only go up to 2.1 GeV c^{-1}.)



The open WASA detector during its installation at CELSIUS. The superconducting solenoid is surrounded by one of the two half-spheres of caesium-iodide crystals inside the magnetic field return yoke (in red).

WASA will be shipped to the Forschungszentrum Jülich this autumn and the experimental programme is expected to start in the beginning of 2007. Once at COSY, the WASA detector offers an opportunity to deepen our understanding of non-perturbative quantum chromodynamics (QCD) through a precise study of symmetry breaking and very specific investigations of hadron structure.

For example, the η and η' decays that vanish in the limit of equal-light quark masses (for example $\eta' \rightarrow \eta\pi\pi$) allow the exploration of explicit isospin symmetry-breaking in QCD. Furthermore, precision measurements of rare η and η' decays can be used to obtain new limits on the breaking of the charge, parity and time symmetries or their combinations. Last but not least, WASA at COSY can contribute significantly to testing the various models offered to explain exotic and crypto-exotic hadrons – such as the light scalar mesons $a_0/f_0(980)$, pentaquarks like the Θ^+ or hyperon resonances like the $\Lambda(1405)$ – through precise measurements of decay chains and couplings to other hadrons.

Another promising process where precise measurement can confront theoretical predictions is the isospin-violating process $dd \rightarrow \alpha\pi^0$. Pioneering measurements have already been performed at the Indiana Cooler (*CERN Courier* June 2003 p8). At COSY such studies can be extended to higher energies and, in particular, to the reaction $dd \rightarrow \alpha\pi^0\eta$, which should be driven by the isospin-violating a_0–f_0 mixing.

COSY can produce more than 10^6 η' mesons per day, and their subsequent hadronic, radiative, leptonic and forbidden decays can be detected by WASA. The expected event rates will substantially increase world statistics.

● The WASA-at-COSY project is a collaborative effort between many institutions, in particular TSL and FZJ. The project currently comprises 137 members from 24 institutes in seven countries.

X-RAY SOURCES

Cornell gets funding for brighter X-rays

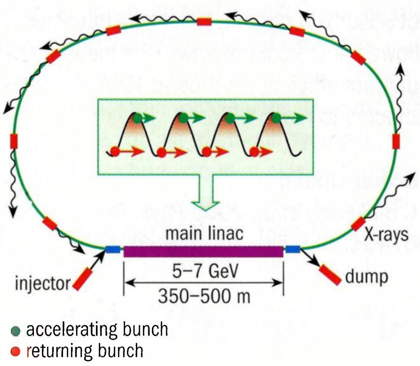
The US National Science Foundation (NSF) has awarded Cornell University $18 million to begin developing a high-brilliance, high-current Energy Recovery Linac (ERL) synchrotron radiation X-ray source.

All existing hard X-ray synchrotron radiation facilities are based on storage rings. Equilibrium emittance considerations limit the X-ray brilliance that is practically attainable and the ability to make short intense X-ray pulses. In an ERL the electron bunches are not stored; rather, electron bunches with very low emittance are created then accelerated by a superconducting linac.

After one circuit around a transport loop, where the X-rays are produced, the electron energy is extracted back into the radio-frequency (RF) field of the linac and used to accelerate new bunches. The energy-depleted bunches are dumped.

The beams from ERLs are predicted to be around 1000 times better in terms of brightness, coherence and pulse duration than current X-rays. They will enable investigations that are impossible to perform with existing X-ray sources.

The ERL is based on accelerator physics and superconducting microwave technology in which Cornell's Laboratory of Elementary Particle Physics is a world leader. The NSF award to Cornell will fund the prototyping of critical components of the machine. The design team, led by Cornell's professors Sol Gruner and Maury Tigner, has already almost completed the prototype design; scientists from Jefferson Laboratory worked with Cornell on the initial design. Prototype construction and testing should finish in 2008. Cornell then will seek funding for a full-scale ERL facility as an upgrade of the present synchrotron radiation facility, the Cornell High Energy Synchrotron Source (CHESS), which is based on the Cornell Electron Storage Ring (CESR) (*CERN Courier* January 2002 p13).



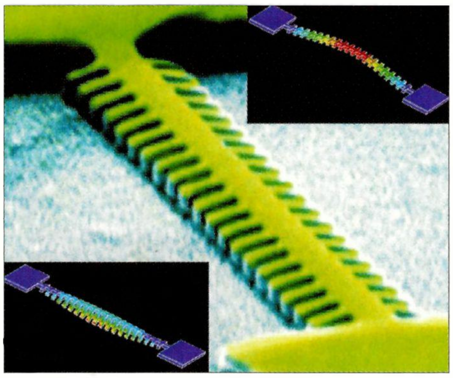
In the proposed Energy Recovery Linac, electrons are accelerated to high energy, and produce X-rays in one trip around a ring of magnets. Returning electrons give up their remaining energy to the microwaves in the linac before they are dumped.

Compiled by Steve Reucroft and John Swain, Northeastern University

Displacement joins the quantum club

Under the right circumstances almost anything can be quantized, and many such quantities have been observed directly in experiments. Now it seems that a new quantity may have joined the list: displacement. Researchers at Boston University used silicon to construct a comb-like structure with "teeth" some 500 nm long and 200 nm wide. They then equipped it with a current-carrying gold strip so that it could be made to oscillate in a magnetic field.

What they have observed is quite remarkable. At millikelvin temperatures, where quantum effects dominate over thermal ones, they have seen preferences for distinct amplitudes of the displacement, just as one would expect for a quantum simple harmonic oscillator. The actual displacements due to the driving force are only femtometres, but the mechanical structure amplifies them up to the level where they become observable. The displacements reach frequencies up to 1 GHz, which makes this the highest frequency bulk mechanical oscillator to date.



Scanning electron micrograph of a suspended antenna oscillator. The device consists of a silicon beam measuring 10.7 μm × 400 nm with "paddles" on both sides. Inset are simulations of the fundamental resonance mode (top) and the high-order collective mode (bottom).

Further reading

Alexei Gaidarzhy *et al.* 2005 *Phys. Rev. Lett.* **94** 030402.

Silicon dot pushes boundary of single-photon detectors

While solid-state detectors, such as avalanche photodiodes, are starting to put the squeeze on photomultiplier tubes and other older single-photon detectors, still newer technology is making progress. Physicists at Toshiba Research Europe and the University of Cambridge have developed a novel single-photon detector based on a quantum dot - a tiny silicon disc measuring only 30 × 8 nm^2.

The dot's size makes it like an artificial atom (albeit with a very non-Coulomb potential) with the usual quantized electron energy states. The quantum dot is encased within a resonant tunnelling diode designed so that under normal circumstances no current can flow through it. If, however, the dot absorbs a photon, tunnelling becomes allowed and a current flows. The measured quantum efficiency is around 12% but is expected to reach 65%.

Further reading

J C Blakesley *et al.* 2005 *Phys. Rev. Lett.* **94** 067401.

Study challenges claims about grammar versus mathematics

An open question about the nature of human intelligence is the degree to which language is linked to other cognitive functions. Numerous claims have been made, for example, that the ability to do mathematics should be linked to the ability to handle grammar, and indeed such an idea does seem quite natural. Now, however, it looks as though this idea must be discarded.

Rosemary Varley and colleagues at the University of Sheffield studied three men with brain damage, which affected their ability to handle grammar. To the surprise of the researchers, the men retained full ability to do computations, including recursion, and also to deal with structure-dependent concepts such as expressions with brackets. This is the first time it has been shown that if mathematics is a language, it is certainly not like language as we know it from linguistics.

Further reading

Rosemary A Varley *et al.* 2005 *Proc. Nat. Acad. Sci.* **102** 3519.

Transitions viewed on the atomic scale

Phase transitions are often thought of macroscopically, as arising from big changes in the structure of a material, such as when ice melts, or water turns to steam, but of course these changes must be linked to events that happen atom by atom. Now a team at the Universidad Autonoma de Madrid in Spain has managed not only to see the structure of two phases, atom by atom, but to film the transition between them.

The team used a special scanning-tunnelling electron microscope stabilized so that it can track the same set of atoms in a sample, even as the temperature of the sample changes. Looking at a film of lead deposited on germanium, the researchers could watch a small array of atoms as the film switched between a smooth phase at temperatures above 86 K and a corrugated one below. They also observed similar behaviour for lead on silicon, and obtained results that agree with theories that assume that point-like defects do not play critical roles in such phase transitions.

Further reading

I Brihuega *et al.* 2005 *Phys. Rev. Lett.* **94** 046101.

Radio astronomers observe a possible dark-matter galaxy

An international team of astronomers has discovered what appears to be an invisible galaxy made almost entirely of dark matter – the first ever detected. The mystery galaxy, VIRGOHI21, lies in the Virgo cluster of galaxies, some 50 million light-years from Earth.

Astronomers know that the visible galaxies contain more than the luminous matter observed; the rotation velocities indicate the presence of haloes of large amounts of dark matter. However, simulations of cold dark matter in the universe predict more dark haloes than galaxies, leading to the idea that there are dark haloes without stars: dark galaxies.

The team, from the UK, France, Italy and Australia, has been searching for dark galaxies by studying the distribution of hydrogen atoms throughout the universe through their emissions at radio wavelengths, in particular using the 21 cm line of atomic hydrogen. VIRGOHI21, a huge cloud of neutral hydrogen with a mass 100 million times heavier than the Sun, was first seen with the University of Manchester's Lovell Telescope at Jodrell Bank, UK. The sighting was later confirmed with the Arecibo telescope in Puerto Rico.

The speed at which it spins indicates that there is more to VIRGOHI21 than hydrogen. The rotation velocity implies a mass 1000 times greater than the amount of hydrogen, and at the distance of the Virgo cluster this should be in the form of a galaxy shining at 12th magnitude. However, when the team studied the area in question using the Isaac Newton Telescope in La Palma, Canary Islands, they found no visible trace of an optical counterpart for VIRGOHI21.

Left: the ellipse on this image, taken by Cardiff astronomers using the Isaac Newton Telescope, La Palma, shows the region of the sky where the dark galaxy was found. Right: on the basis of the radio measurements, astronomers observing at optical wavelengths would expect to see the ellipse filled with a spiral galaxy, like NGC 7479 shown here. (Courtesy Nik Szymanek using the Faulkes Telescope North, Maui, copyright FTLLC.)

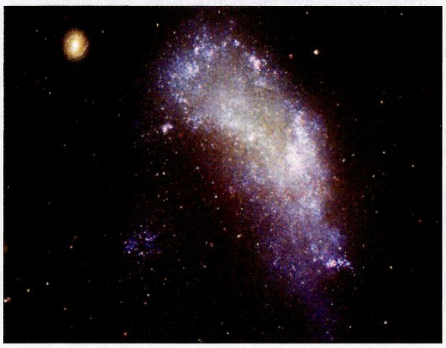
Dark galaxies are thought to form when the density of matter in a galaxy is too low to create the conditions for star formation. The observations of VIRGOHI21 may have other explanations, but they are consistent with the hydrogen being in a flat disc of rotating material – which is what is seen in ordinary spiral galaxies. Similar objects that have previously been discovered have since turned out to contain stars when studied with high-powered optical telescopes. Others have been found to be the remnants of two galaxies colliding, but in this case there is no evidence for such an encounter.

The team first observed the dark object in 2000, but it has taken almost five years to rule out the other possible explanations.

Further reading

R Minchin *et al.* www.arxiv.org/abs/astro-ph/0502312.

Picture of the month



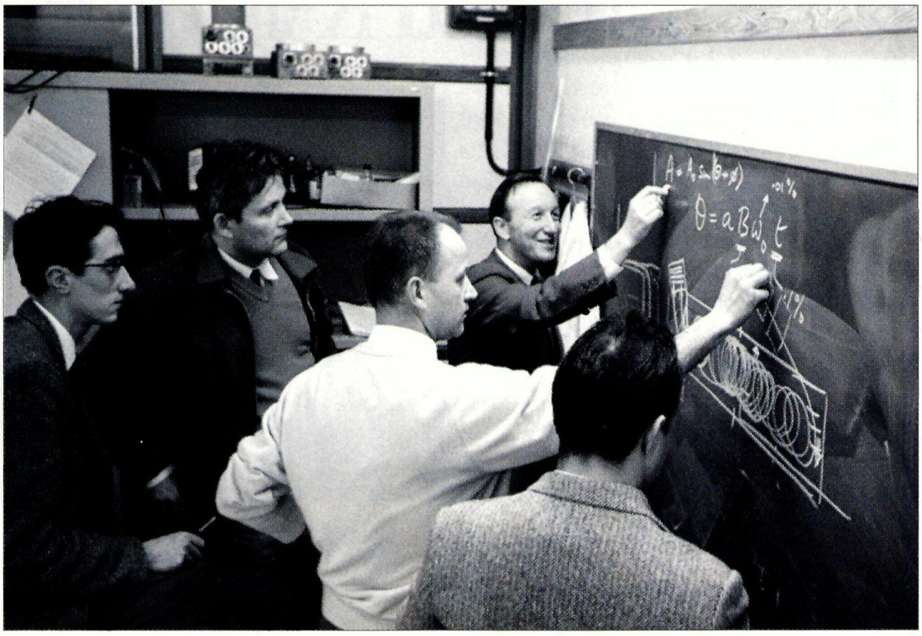
What happens when a galaxy falls in with the wrong crowd? Under the gravitational grasp of a large gang of galaxies, called the Fornax cluster, the irregular galaxy NGC 1427A is plunging into the group at 600 km s^{-1}. Located some 62 million light-years away from Earth in the direction of the constellation Fornax, NGC 1427A shows numerous hot, blue stars in this image obtained by the Hubble Space Telescope. While the Fornax cluster contains hundreds of individual galaxies, there is a considerable amount of gas lying between them. When the gas within NGC 1427A collides with the Fornax gas, it is compressed to the point that it starts to collapse under its own gravity. This leads to the formation of the myriad of new stars seen across NGC 1427A, which give the galaxy an overall arrowhead shape that appears to point towards the upper right, in the direction of the galaxy's high-velocity motion. (Courtesy NASA, ESA and the Hubble Heritage Team [STScI/AURA].)

CERN COURIER ARCHIVE: 1962

A look back to *CERN Courier* vol. 2, April 1962

g–2

The magnetic moment of the muon



Five members of the team of physicists that published the 1961 and 1962 g – 2 papers. From left: J C Sens, G Charpak, Th Muller, F J M Farley and A Zichichi. V L Telegdi also worked on the 1961 publication, and R L Garwin contributed to both papers.

One of the puzzles of present-day physics is that of the existence of the muon. An experiment recently completed at CERN has done much to clarify the problem, although the puzzle still remains.

Early in 1961 a scientific communication from CERN announced that the "anomalous magnetic moment" of the muon had been measured directly for the first time, and had been found to confirm theoretical predictions to within 2% (Charpak *et al.* 1961). This result showed, contrary to what many had hoped, or even expected, that the muon was indeed very similar to the electron, in spite of being some 200 times heavier.

During the year, the experiments were refined and continued, and recently a new result has been published, confirming the similarity with even greater accuracy (Charpak *et al.* 1962). Treating the muon as a simple "Dirac particle", that is just as a heavy electron, its anomalous magnetic moment is calculated from the theory of "quantum electrodynamics" as 0.001165. This latest experimental result shows the value to be 0.001162 ± 0.000005. *[The article continues for a time.]*

Some implications

The first part of this number is the most probable "answer" from the experiments; from the second part it can be said that the odds are 20 to 1 against a true value larger than 0.001172 or smaller than 0.001152.

Thus, it has been shown that the muon is best regarded simply as a "heavy electron", and not as some quite distinct particle. The closeness of the agreement with the calculated value shows in fact that, if the muon interacted with some unknown particle other than a photon, the "strength" of this interaction would be thousands of times weaker than the strong interaction of the proton.

The result is of great importance in itself, but also has a number of other implications of a more abstruse character. For example, although the theory of quantum electrodynamics has been remarkably successful in explaining very exactly many electromagnetic phenomena, it has often been suggested that it is really only valid down to a certain small, critical distance, in much the same way as classical dynamics is quite accurate enough for material bodies but breaks down for particles of nuclear size. If this were so, the value of the anomalous magnetic moment would be changed by a certain amount, depending on the value of this critical distance. Agreement between the experimental and theoretical values thus shows that there is no breakdown of quantum electrodynamics down to about 10^{-14} cm.

By combining the g – 2 results with the accurate value of the magnetic moment obtained by other experiments, the muon mass is now known with much higher precision than ever before. It is 206.768 ± 0.003 times the mass of the electron.

Conclusion

The successful completion of the g – 2 experiment has told us that the muon in itself has no unusual properties, and has extended the range over which the equations of quantum electrodynamics are certainly applicable. In doing so, it has highlighted the fundamental mystery of the muon. If these two particles, the electron and the muon, are not basically different, why should they both exist and what is the significance of their difference in mass? This remains a challenge for some future experiment.

Further reading

G Charpak *et al.* 1961 *Phys. Rev. Lett.* **6** 128.
G Charpak *et al.* 1962 *Physics Letters* **1** 16.

EDITOR'S NOTE

The *CERN Courier* came into being in August 1959, and in 1962 it became a regular monthly publication, appearing in something like its present form.

Following on from the selection of extracts published during 2004, CERN's 50th anniversary year, this regular archive feature will tell the story of particle physics through the pages of the *CERN Courier* from 1962 onwards.

Compiled by Hannelore Hämmerle and Nicole Crémel

WEB SERVICES

UNOSAT tackles tsunami challenge

The UN organization UNOSAT provides the international community with geographic information and access to satellite imagery to cope with natural disasters and post-conflict situations. UNOSAT has been based at CERN since 2002 in order to benefit from CERN's IT infrastructure and network connectivity. During the recent international crisis following the Asian tsunami, UNOSAT's website proved vital for ensuring that relief organizations had the necessary information to plan actions in the field.

When news of the earthquake and resulting tsunami reached UNOSAT on 26 December, the first major decision was whether to activate the international charter Space and Major Disasters, which allows satellites belonging to several major space organizations to be directed at specific sites. The UNOSAT team decided to wait until it had pieced together enough of the information arriving from various sources before choosing the most critical areas at which to point the satellites. This cautious approach proved wise, because the extent of the destruction became clear only gradually.

By the evening of 27 December key areas had been selected, and UNOSAT activated the charter. This ensured that 13 different satellites collected essential data in the ensuing days. In parallel with this, UNOSAT was busy making available on its website many maps based on archival data. These maps provided detailed measurements of the topography of affected coastal regions, enabling relief organizations to assess the most probable areas of damage and plan their interventions accordingly.

The unprecedented demand for images put the Central Web Services at CERN under considerable strain because downloads of maps required large files to be loaded into server memory for relatively long periods. This resulted in problems with memory capacity, which threatened to block access to websites supported by CERN; however, a way of avoiding such data jams was quickly found by CERN's Internet Services Group. As a result, and because CERN's computer centre is manned around the clock, the UNOSAT data remained available continuously despite the growing number of requests. This was not the case for some of the computing centres in the affected countries, where servers were not sufficiently robust and key data became inaccessible at times.

This map shows the extent of the tsunami destruction along the western coast of Aceh Province, Sumatra, and provides an estimate of the number of bridges and the length of primary roads that may have been damaged or destroyed. (Source: UNOSAT. Data sources: EastView Cartographic, US Department of State, Jet Propulsion Laboratory, and Global Insight LANDSAT data from the US Geographical Survey.)

To give a sense of the scale of the challenge, 200 000 maps were downloaded from the UNOSAT website during the whole of 2004, whereas this year this number was exceeded during the month of January alone. Moreover, UNOSAT, with a team of only 12 people, is already having to respond to new crises, such as the earthquake in Iran in February, while providing further analysis of the post-tsunami devastation. For example, UNOSAT recently prepared a detailed study of roads and bridges damaged by the tsunami, which is already being used by many organizations involved in rebuilding the affected regions.

Alain Retière, the head of UNOSAT, is confident that collaborating with CERN on advanced IT solutions can help facilitate the job of humanitarian organizations in responding to future natural disasters and complex crisis situations. Grid computing, which is being pioneered by the particle physics community, could prove particularly useful in handling the large amounts of data and significant data processing that UNOSAT's work involves.

The total amount of data UNOSAT is storing at CERN is relatively small at present – about 850 gigabytes (Gb) – but growing fast. NASA, the European Space Agency, the Centre National d'Etudes Spatiales and the Indian Space Research Organisation among others are giving UNOSAT access to archives containing terabytes of satellite images, and these need to be processed. Plans by some commercial companies to develop surveillance drones carrying arrays of digital cameras could one day result in the routine production of petabytes of image data from disaster zones, rivalling even the production of data at the Large Hadron Collider.

WEB DEVELOPMENT

W3C's character model promotes universal access

The World Wide Web Consortium (W3C) has published *Character Model of the World Wide Web: Fundamentals* as a W3C recommendation. The model provides a well defined and well understood way for Web applications on different platforms to transmit and process the various characters of the world's languages.

This recommendation gives authors of specifications, software developers and content developers a common reference to enable consistent, interoperable text manipulation on the World Wide Web. It builds on the Universal Character Set, which is defined jointly by the Unicode Standard and ISO/IEC 10646. Topics include use of the terms "character", "encoding" and "string", a reference-processing model, choice and identification of character encodings, character escaping and string indexing.

The character model is intended to facilitate use of the Web by all people, regardless of language, script, writing system and cultural conventions, in accordance with the W3C's goal of universal access.

This recommendation is the first in a set of three documents. Also in development are *Character Model for the World Wide Web 1.0: Normalization*, which will specify uniform normalization and string identity matching for text manipulation; and *Character Model for the World Wide Web 1.0: Resource Identifiers*, which will specify conventions for Internationalized Resource Identifiers.

PRODUCT INFORMATION

WEB TECHNOLOGY

Semantic Web boosts access to information

A new Semantic Web interface, mSpace, was launched in February. The interface improves access to information and presents search results in a categorized view in one window. The mSpace tool, developed by Southampton University's School of Electronics and Computer Science, offers powerful tools for organizing an information space to suit a person's interests, and enables the user to manipulate the presented categories.

A similar project, Esperonto, has been developing a toolkit to allow anyone to upgrade normal Web content into semantic content by making data machine-readable. The EC Information Society Technologies project finished at the end of February. Richard Benjamins, the director of R&D at Intelligent Software Components in Spain and co-ordinator of Esperonto, notes that the Semantic Web "will reduce information overload and make information more easily accessible to more people at lower cost".

Esperonto has gone further than just creating semantic content, and has provided tools to use the data effectively. The Semantic Web portal produces interlinked Web pages and a structured collection of data that users can navigate semantically, which is particularly useful in the case of large portals and databases with vast amounts of information.

The team behind mSpace. (Courtesy Steve Shrimpton/Southampton University.)

Further information
http://mspace.ecs.soton.ac.uk
www.esperonto.net/

E-SCIENCE

DOAR opens the way to research data

A new service providing open access to research information was launched in February. The Directory of Open Access Repositories (DOAR) will categorize and list the open-access research archives around the world. Such repositories have mushroomed over the past two years in response to calls by scholars and researchers worldwide to provide open access to research information.

DOAR will provide a comprehensive and authoritative list of institutional and subject-based repositories, as well as archives set up by funding agencies. Users of the service will be able to analyse repositories by location, type, the material they hold and other measures. This will benefit both users wishing to find original research papers and third-party "service providers", such as search engines or alert services.

The 18-month project is a joint collaboration between the universities of Nottingham in the UK and Lund in Sweden. The importance of the project and the wide support for it is reflected in its funders, led by the international Open Society Institute – a major player in advocating open access to the world's research findings. The Joint Information Systems Committee in the UK has also backed the project as part of a larger programme of funding for repository development in UK institutions. Additional contributory funding has come from the Consortium of Research Libraries and from the Scholarly Publishing and Academic Resources Coalition (SPARC) Europe – an alliance of research libraries, library organizations and research institutions.

For more details see www.opendoar.org.

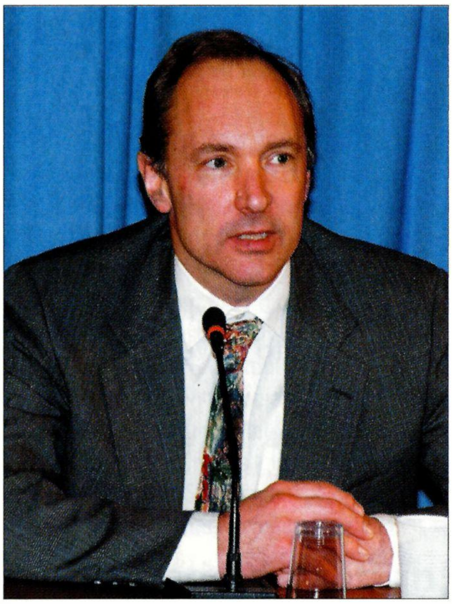
APPOINTMENTS

Tim Berners-Lee takes up chair...

The inventor of the World Wide Web, Sir Tim Berners-Lee, is to take up the Chair of Computer Science at Southampton University's School of Electronics and Computer Science. He will hold this position alongside his current appointments as senior research scientist at MIT's Computer Science and Artificial Intelligence Laboratory, and director of the World Wide Web Consortium (W3C).

"We are delighted that Tim Berners-Lee has accepted this appointment," said Wendy Hall, the head of the School of Electronics and Computer Science. "Many of the staff in the school have worked with him on the development of the World Wide Web over many years, and we are now closely involved with the evolution of the Semantic Web, which is Tim's vision for the future of the Web."

The Semantic Web has been described by Berners-Lee as "an extension of the current Web in which information is given well defined meaning, better enabling computers and people to work in co-operation". The Semantic Web provides a common framework that allows data to be shared and reused across applications, enterprises and community boundaries. It is a collaborative effort led by W3C with participation from many researchers and industrial partners.



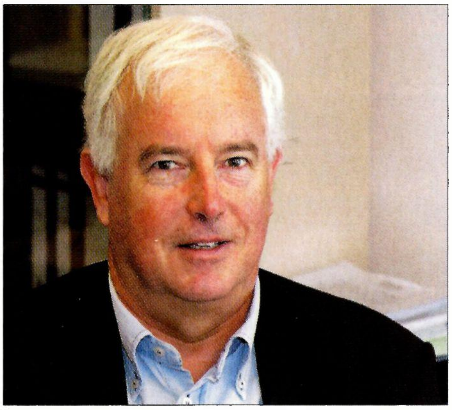
Berners-Lee will chair Computer Science.

In addition to the many honours he has received over recent years for his invention of the Web, Berners-Lee was named Greatest Briton 2004 at a ceremony at the Royal Courts of Justice, London, on 29 January. The judging panel awarded the prize to Berners-Lee based on his adaptability, modesty, strength, determination and sense of humour. On receiving his award and £25 000, Berners-Lee said it was an "amazing honour" and that he was just "in the right place at the right time".

...while David Williams gets professorship

The University of Edinburgh has appointed CERN's David Williams as an honorary professor in the School of Physics. This is in recognition of his work on particle physics, for promoting the development of networking across Europe to address the digital divide, and for his advice to the UK e-Science programme. Peter Clarke, from the School of Physics and the UK National e-Science Centre, said: "We are delighted with this move and look forward to David's association with Edinburgh."

Williams has worked for CERN in a variety of roles, including leading the Computing and Networks Division from 1989 until 1996. During that period Sir Tim Berners-Lee and collaborators created the World Wide Web. Williams is now responsible for the co-ordination of CERN's relations with the organizations of the European Union. Historically, his relations with Edinburgh have been with the Department of Physics, the Edinburgh Parallel Computing Centre, and, more recently, the National e-Science Centre and the associated e-Science Institute. He has been a fellow of the British Computer Society since 1981.



Williams accepts Edinburgh University post.

Williams was one of the initial European promoters of Grid computing, and is a member of the UK's e-Science steering committee and of the related technical advisory group. He is also a member of the UKLight steering committee, and chairs the e-Science advisory board of the Council for the Central Laboratory of the Research Councils.

Following his appointment at Edinburgh University he will work closely with the e-Science Institute, where he will act in an external advisory capacity for future planning activities. He will also be a visiting member of the Particle Physics Research Group in the School of Physics.

GRID PROJECTS

NorduGrid provides resources for ATLAS

Last year more than 20 sites of NorduGrid operated as a single resource to contribute about 30% of the total Data Challenge 2 (DC2) for the ATLAS experiment, which will run at CERN's Large Hadron Collider (LHC). This was the first attempt to harness large amounts of strongly heterogeneous resources in various countries for a single collaborative exercise using Grid tools.

NorduGrid has participated in the ATLAS Data Challenges since August 2002, and was the first Grid system to contribute to LHC computing in a production mode. NorduGrid develops, maintains and supports an open-source Grid middleware known as the Advanced Resource Connector (ARC). ARC consists of the Grid services running on the computing resources, an indexing service for resources and data, and clients making intelligent use of the distributed information and data available on the Grid. Since its first release in 2002 the ARC middleware has run without interruption, growing from its initial five sites to 50 sites today in 10 countries: Australia, Denmark, Estonia, Finland, Germany, Norway, Slovakia, Slovenia, Sweden and Switzerland.

For the ATLAS DC2, production was split across three Grid "flavours": Grid3 (in the US), LHC Computing Grid (LCG) and NorduGrid/ARC. The exercise lasted half a year and processed 10 million events in more than 300 000 jobs. Apart from providing data for the researchers, testing software, and validating the ATLAS computing model, DC2 demonstrated the interoperability between different Grid flavours at the application level.

Although originally designed to provide resources for ATLAS computing, NorduGrid has served many other sciences. It was first employed by theory groups, and today the infrastructure is used in many fields, ranging from biomedical sciences and pharmacology to climate modelling and space physics.

NorduGrid provides middleware for several national Grid projects, and will soon supply its middleware for a cross-Nordic Grid facility. DC2 proved that ARC can operate reliably in a heterogeneous environment, and, since it is free open-source software, interest is growing outside its Nordic cradle. Groups in Iceland, Latvia, Lithuania, Sri Lanka and Russia are involved in partnership projects with NorduGrid participation.

GridX1 project joins LHC Computing Grid

In December 2004 the Canadian GridX1 project joined forces with the world's largest international Grid project, the LHC Computing Grid (LCG). GridX1 makes the computing facilities at several Canadian research institutes appear as one resource in the LCG.

GridX1 interfaces with LCG through a centre at the Tri-University Meson Facility (TRIUMF) in Vancouver. Computers monitor and control jobs that are sent to the Canadian Grid, and can thus advertise the availability of the combined GridX1 resources. The details of the resources are hidden behind the interface layer, and only the interface machine needs to have the latest LCG release. This simplifies the management of the shared Canadian facilities; it also means that generic middleware can be used on the national Grid, and interference with other disciplines is minimized.

GridX1 is one of the first large research computing Grids in Canada and brings together researchers from the universities of Alberta, Calgary, Simon Fraser and Victoria, and from the National Research Council in Ottawa, TRIUMF, and CANARIE (Canada's advanced Internet development organization).

Canadian researchers are playing a key role in the ATLAS experiment at the LHC, and GridX1 played an important part in the ATLAS Data Challenge 2 in 2004. In the past nine months more than 3000 ATLAS jobs have run successfully on GridX1.

US COMPUTING

NSF release backs cyberinfrastructure

The US National Science Foundation Middleware Initiative (NMI) has issued its sixth release, NMI-R6, which offers several new components relating to end-user authorization services. The release, issued in December 2004, is designed to integrate with academic and research software and infrastructures such as Grids, and is available under open-source licences.

NMI, which began in late 2001, funds the design, development, testing and deployment of middleware, a key technology upon which customized applications are built. NMI is now part of the Shared Cyberinfrastructure (SCI) Division, which the National Science Foundation (NSF) established last year to bundle research and development in areas that enhance the computing infrastructure for scientific research and education.

The trigger for setting up the SCI was the report produced by a committee advising the NSF on infrastructure based on distributed computer, information and communication technology. The panel found that the progress in these technologies made a comprehensive "cyberinfrastructure" possible and that there was a need for distributed computing power and shared data-storage due to the increasing complexity, scope and scale of research challenges in different areas. It therefore recommended that the NSF should establish a programme to create, deploy and apply cyberinfrastructure.

The SCI supports the US national computation infrastructure for the academic research and education community. It also supports networks and networking technologies, from high-speed backbone networks to wireless networks that connect embedded sensor nodes in remote sites. The division also develops and supports software tools and services that hide implementation complexities and heterogeneity while offering clean logical interfaces to users.

To ensure interoperability between fragmented solutions already developed in certain areas, SCI supports initiatives to develop standards and programmes that make the sharing of data and resources as transparent as possible.

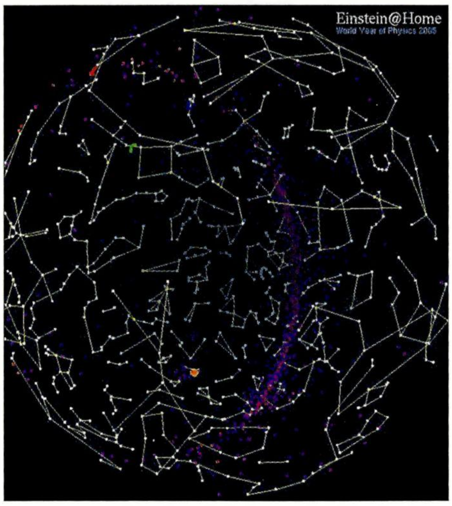
YEAR OF PHYSICS

@home with Einstein and the LHC

One of the most popular downloadable screensavers on the Web is SETI@home, which uses idle time on private PCs to analyse radio-astronomy signals in search of extra-terrestrial intelligence. The program has been downloaded by more than 5 million users, resulting in what is by many measures the most powerful distributed computer on Earth. Many similar projects have been launched in the past few years, and in February, as part of the Year of Physics activities, Einstein@home started operation.

This project is analysing gravitational wave data from the Laser Interferometer Gravitational Wave Observatory (LIGO) in the US and from the German–British GEO 600 gravitational wave observatory. The project is looking in particular at data coming from extremely dense, rapidly rotating stars, which are believed to be either quark stars or neutron stars. Some of these compact stars may not be perfectly spherical, and if this is the case they should emit characteristic gravitational waves that LIGO and GEO 600 should detect.

CERN has also been investigating this approach to distributed computing with a program called LHC@home. This was launched as part of the public outreach events for CERN's 50th anniversary last year, and was relaunched in February as part of the Year of Physics activities. LHC@home runs the program SixTrack, which simulates particles travelling around the Large Hadron Collider (LHC) to test the long-term stability of particle orbits. Since the particles in the LHC are relativistic, and indeed the whole purpose of the LHC is to use the famous equation $E=mc^2$ to generate new particles, LHC@home provides a good starting point to engage the public in a discussion of Einstein's special theory of relativity. This is one of his three major papers published in 1905 with a centenary being celebrated in this Year of Physics.



The Einstein@home starsphere screensaver is based on a rotating celestial sphere that shows the known constellations, along with the current zenith positions of three gravity wave detectors. Purple dots are pulsars and dark red dots are supernova remnants.

Both Einstein@home and LHC@home are based on the Berkeley Open Infrastructure for Network Computing (BOINC), an open-source platform launched by the team behind SETI@home. BOINC benefits from the experience of SETI@home, in particular concerning issues such as computer security and ensuring that users are properly credited for their contributions (*CERN Courier* September 2004 p62). This latter point is important because users are fiercely competitive about how much computer power they contribute, and this competition is part of what makes public resource computing so popular. The users also take considerable interest in the underlying science – the outreach part of the activity – and there is usually a lively discussion in the LHC Café, one of the project's user notice boards, which is moderated occasionally by people at CERN.

When LHC@home was made public last September the first 1000 users joined within less than 24 hours, and the project had to set a limit of 5000 users to ensure that the large flow of data being sent back could be handled adequately. The results so far are promising. Being able to increase computing power by one or two orders of magnitude, compared with what can be achieved with dedicated resources, will allow physicists at CERN to gain qualitatively new insight into the performance of the LHC, uncovering for example narrow regions of beam instability that would have been overlooked in coarser parameter searches.

BOINC allows users to decide how much of their PC's idle time they want to apportion to each project. You can join Einstein@home and LHC@home, and indeed several other projects that run on BOINC, by going to http://boinc.berkeley.edu/.

Calendar of events

April

2–8 HPC High Performance Computing Symposium San Diego, CA, USA, www.caip.rutgers.edu/hpc2005

5–6 PVSS Users Meeting CERN, Switzerland, www.etm.at/cern.htm

7–9 HealthGRID 2005 Oxford, UK, http://oxford2005.healthgrid.org

18–22 Third EGEE Conference Athens, Greece, http://eu-egee.org

May

2–6 GridAsia 2005 Singapore, http://gridasia.ngp.org.sg

9–12 Second International Workshop on Grid Computing and Peer-to-Peer Systems Singapore http://laurel.datsi.fi.upm.es/GPP05

9–12 Cluster Computing and Grid 2005 Cardiff, UK, www.cs.cf.ac.uk/ccgrid2005

June

20–24 Second International IEEE Symposium Sardinia, Italy, www.globalstor.org

21–24 International Supercomputer Conference ISC2005 Heidelberg, Germany, www.supercomp.de/

DESY becomes hub for Grid-based HERA events

To meet the computing challenges resulting from the upgrade of the HERA collider, scientists at DESY are employing Grid technology to increase simulation power.

The recent luminosity upgrade of the Hadron Electron Ring Accelerator (HERA) at DESY has led to a sizable increase in electron–proton interaction rates (*CERN Courier* March 2005 p17). This means that much larger samples of simulated events are now required to exploit the new reach in physics. The enhanced detectors are also much more demanding in terms of computing power, and insufficient simulation capacity could lead to significant uncertainties in the analysis of the data. It has therefore been essential to more than double the simulation resources for Monte Carlo production. Fortunately, Grid technology is an attractive way to meet this challenge.

The ZEUS experiment at HERA is one of the first projects not related to the Large Hadron Collider (LHC) to employ Grid-based simulation successfully for day-to-day data analysis on a mass-production scale. After one year of study and development the ZEUS group commissioned its automated production environment, which is built on top of the LHC Computing Grid 2 (LCG-2) middleware suite, and started production in November 2004. The core site at DESY acts as the central hub, while most of the production jobs are sent to Grid clusters outside DESY.

The number of connected sites running ZEUS production jobs has grown steadily and now amounts to 25, including sites in Canada, Germany, Italy, the UK and Spain. These countries also have strong groups participating in the ZEUS experiment. Production has recently reached a total of about 70 million events (figure 1), with weekly rates of up to 12 million events. Figure 2 on p20 shows the relative contributions of the individual sites.

The ZEUS collaboration had in fact been pioneering distributed Monte Carlo production since 1996 with a script-based system named Funnel. This system served all of the collaboration's production needs until 2003. The ZEUS Grid scheme is now seamlessly integrated with Funnel, and Grid-based jobs have dramatically enhanced the production capacity: they are contributing to more than 60% of the total production and the figure is still rising. Most importantly, the collisions the ZEUS team simulates on the Grid are not for testing purposes; they are immediately used by the physics groups in their analysis of the HERA data.

The routine operation achieved shows that Grid technology is ready for today's particle-physics projects and that a successful connection has been made to the end-users requesting the events. The H1 collaboration at HERA is now also preparing to launch Grid-based Monte Carlo production.

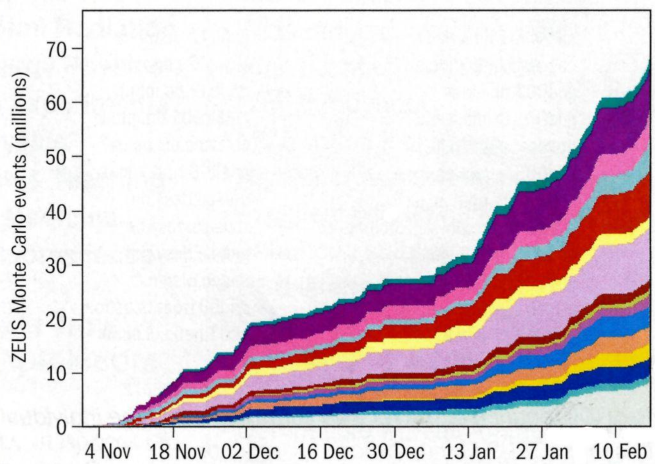


Fig. 1. Integrated yield of Grid-produced ZEUS Monte Carlo events between November 2004 and February 2005. The colours indicate the contributions of the different sites, which are shown in detail in figure 2.

Making it work

The DESY Grid infrastructure exploits the LCG-2 Grid middleware (a software suite developed for the global LHC data analysis), giving DESY a spot on the worldwide map of active LCG-2 sites. The DESY Production Grid provides core Grid services such as a resource broker, an information index, and replica and data management of the virtual organizations (VOs) maintained at DESY, including a basic level of computing resources; the bulk computing power is brought in by the experiments. The system enables opportunistic use of the resources to exploit CPU cycles and level out the peaks in demand. Computing resources at the University of Hamburg contribute to the worldwide computing effort for the Compact Muon Solenoid experiment at the LHC.

In addition to hosting and supporting dedicated VOs for the HERA experiments H1 and ZEUS, the infrastructure at DESY also fosters the Grid activities of the lattice quantum chromodynamics community in the framework of the International Lattice Data Grid and the International Linear Collider groups.

Storage is an important element of the DESY infrastructure. While the Grid infrastructures deployed today generally enable distributed scientific communities to collaborate and share resources, extra ▷

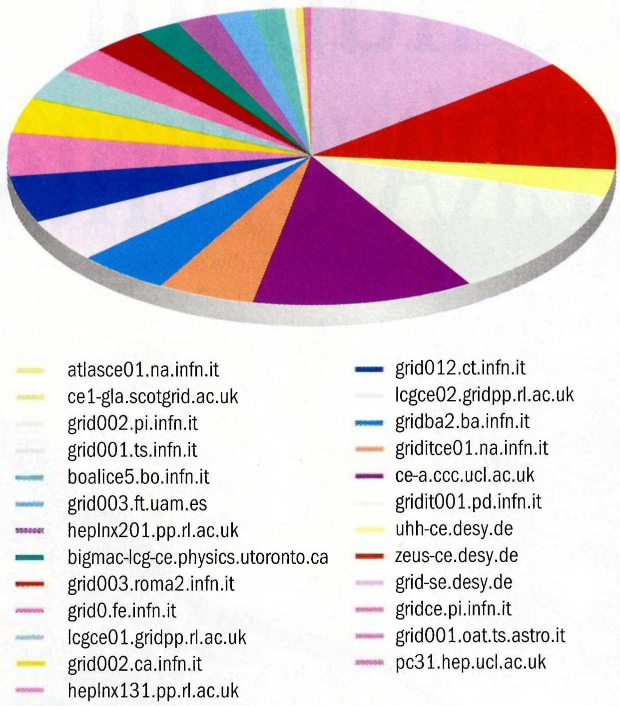


Fig. 2. Distribution of the relative contributions of the individual sites to the ZEUS Monte Carlo Grid production.

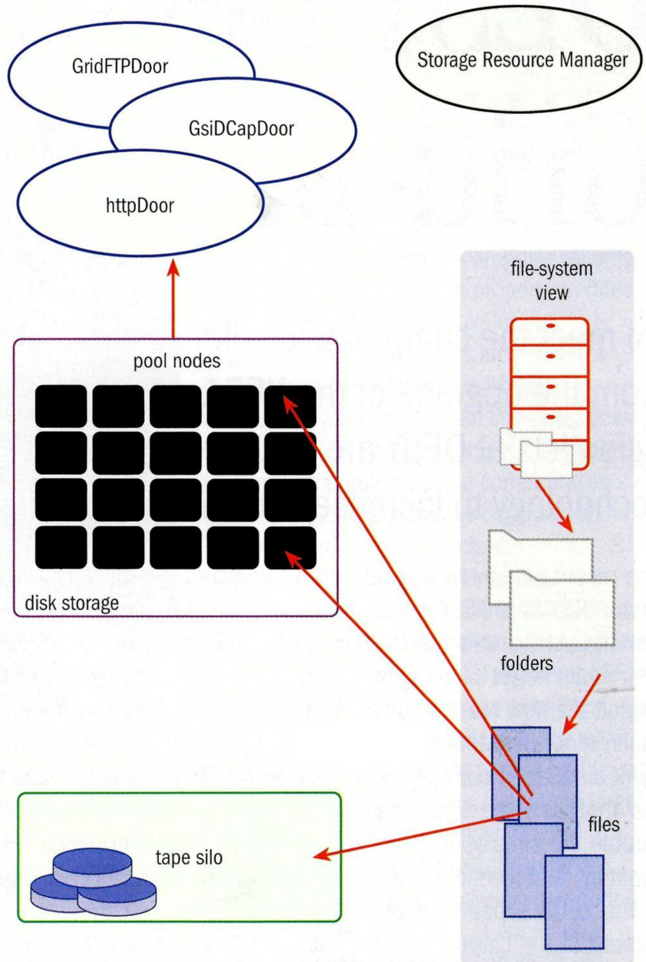


Fig. 3. Overview of the dCache component architecture. Maintaining a single file-system view, the file placement, including the creation of replicas, is determined by the system.

capabilities are needed to cope with the challenges associated with scientists accessing and manipulating very large, distributed collections of data. In co-operation with Fermilab, DESY has developed a Grid Storage Element (SE) that consists of dCache as the core storage system and an implementation of the Storage Resource Manager (SRM), which was developed by a collaboration between European and US Grid groups. The SE allows both local access (POSIX-like) and Grid access (GridFTP) to mass-storage facilities based on hierarchies of tape and disk technology as well as on disk-only configurations. The SRM protocol supports secure data transfers with protocol negotiation and reliable replication mechanisms over wide-area networks. It has become a standard for Grid interfaces to managed storage with existing implementations that have been deployed for production use at major high-energy physics laboratories including CERN, DESY and Fermilab. Many LCG sites are expected to follow soon.

Access to the entire DESY data space of 0.5 petabytes is provided by the SE based on dCache, a software-only Grid storage appliance that can manage the storage and exchange of hundreds of terabytes of data, transparently distributed among dozens of disk storage nodes (see figure 3). Although the location and multiplicity of data is autonomously determined by the system, the name space is uniquely represented in a single file-system tree.

Efficiency improvements

Designed as a caching system, dCache has been found to improve significantly the efficiency of back-end storage systems such as serial media (magnetic tape). Upon detecting hot spots, the aggregate throughput to client applications increases by dynamically replicating files over multiple storage nodes. The system will tolerate failures in its data servers, allowing administrators to use commodity computing and disk-storage components. The increasing number of sites using dCache technology demonstrates that it is well suited to solving many storage and data-distribution issues in large and small institutions.

The HERA experiments have shown that Grid technology is ready to be employed in ongoing research programmes, and it is being explored for use in applications beyond its present scope. Grid computing and the development of novel storage technologies are strategic components in DESY's research programme. They are viewed as essential ingredients for conducting high-energy physics experiments and for participating in future global projects, such as developing and operating an international linear collider within a worldwide collaboration.

Further reading

For details about dcache see www.dcache.org.
For more information about the Storage Resource Manager see http://sdm.lbl.gov/srm-wg.

Michael Ernst, **Andreas Gellrich** *and* **Rainer Mankel**, *DESY.*

Rewriting the rules on

For half a century, the synchrotron has been the workhorse of high-energy particle physics, from its first use with external beams to the modern particle colliders. The basic principle is to use the electric field in a radio-frequency (RF) wave to accelerate charged particles, the frequency varying to keep in time with particles on a constant trajectory through a ring of guiding magnets.

Now a team has demonstrated a different way of accelerating the protons in tests at the proton synchrotron (PS) at KEK, the Japanese High Energy Accelerator Research Organization in Tsukuba. For the first time, a bunch of protons in the synchrotron has been accelerated by an induction method (K Takayama *et al.* 2004). The technique may overcome certain effects that normally limit the intensity achieved in a synchrotron beam, and could prove to be an important advance for future proton colliders.

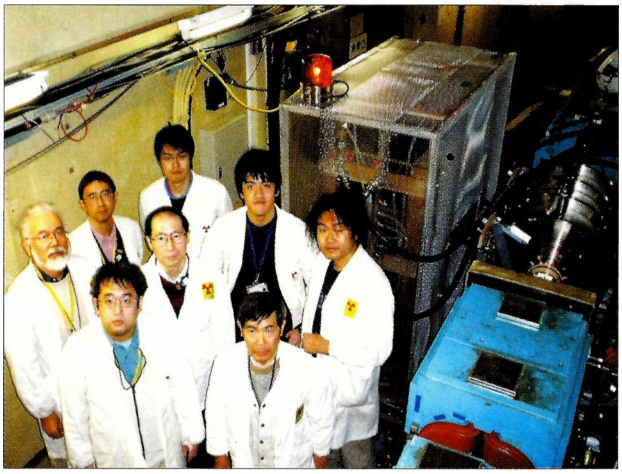
The concept of an "induction synchrotron" was first proposed about five years ago by the author and Jun-ichi Kishiro of KEK and the Japan Atomic Energy Research Institute (Takayama and Kishiro 2000). The idea was to overcome shortcomings of the RF synchrotron, in particular the limited longitudinal phase-space available for the acceleration of charged particles – in other words the distribution in energy and position around the ring of the particles being accelerated. In a conventional synchrotron, the particles are accelerated when they pass through an RF cavity, a device that contains the oscillating radio wave. The electric field naturally concentrates the particles into bunches in the direction of motion (i.e. longitudinally).

In the induction synchrotron, however, the accelerating devices are replaced with induction devices, in which a changing magnetic field produces the electric field to accelerate the particles. The basic device is a ferromagnetic ring, or core, through which the particles pass. A pulsed voltage sets up a magnetic field, and the changing magnetic flux in turn induces an electric field along the axis of the core (*CERN Courier* April 2003 p19). The induction-acceleration technique was first developed in the late 1960s and has a range of applications in linear accelerators, but the recent KEK experiment was the first time it was applied in a circular machine.

The system consists basically of an induction cavity with three cells driven by a pulse modulator as shown in figure 1. The cells developed for the experiment, which are rather like one-to-one transformers, use a nanocrystalline alloy as the magnetic-core material. The pulse modulator is connected to the acceleration cavity through a 40 m long transmission cable to keep the modulator far from the accelerator, where its solid-state switching elements would be exposed to high radiation. A matching resistance at the driver end reduces reflections. The pulse modulator can be operated in various modes from burst to 1 MHz continuous-wave via a system controlled by a digital signal processor (DSP).

In July 2004 the system was demonstrated to be capable of generating a step-pulse of 2 kV and a peak current of 18 A at 1 MHz with a duty cycle of 50%. It was then installed in the KEK PS in

Ken Takayama describes recent tests at KEK that have demonstrated induction acceleration in a proton synchrotron.



The induction acceleration team at KEK, with the induction cavity (to the right) and matching resistance (behind) installed in the KEK proton synchrotron.

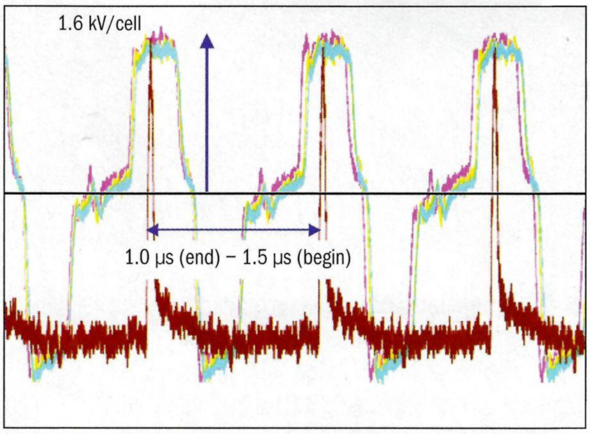


Fig. 2. The induction-pulse wave-form for each cell (pink, yellow and blue) and the proton bunch signal (brown). The revolution period is 1.5 µs at 500 MeV and 1.0 µs at 8 GeV.

September, ready to test induction acceleration.

For the experiment a single bunch of 6×10^{11} protons was injected into the main ring at 500 MeV, trapped in an RF bucket and accelerated up to 8 GeV. The aim was that the RF would simply capture the beam bunch while the induction voltage provided the acceleration. The timing of the master trigger for the pulse modulator was adjusted via the DSP so that the signal from the bunch

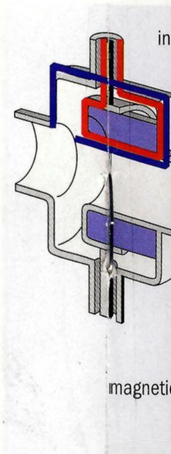


Fig. 1. The princi three-cell induct core acts like a c crea s an accel

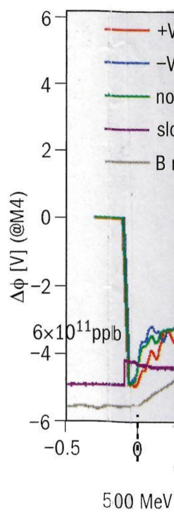
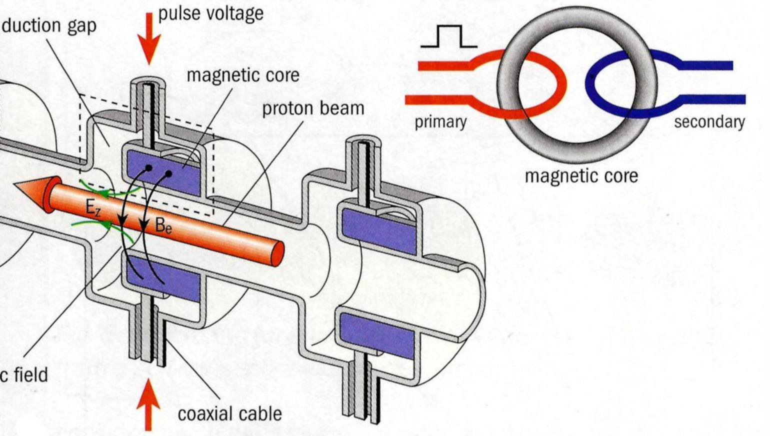
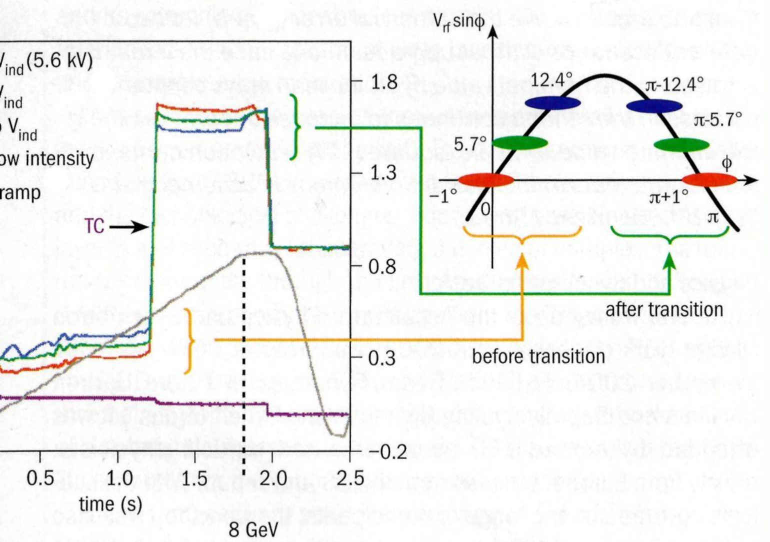


Fig. 3. Phase sig (red) and RF plus (purple) and mag energy crossing. relative to the RF

proton acceleration



iple of induction acceleration illustrated in a section through the ion cavity used in the experiment at KEK. Each ring-shaped magnetic one-to-one transformer (upper right). The changing magnetic field, B_e, lerating electric field, E_z.



nals for RF voltage alone (green), RF plus positive induction voltage s negative induction voltage (blue), together with beam intensity gnetic field (B), all as a function of time. TC indicates the transition- The diagram to the right shows the position of the proton bunch F voltage for the three cases, before and after transition.

stayed around the centre of the induction voltage pulse for the entire accelerating period. Figure 2 shows typical waveforms of the induction voltage signals for the three cells, plus the bunch signals.

To confirm the induction acceleration, the relative phase difference $\Delta\phi$ between the RF and the bunch centre was measured for three cases: with the RF voltage alone; with both the RF and positive induction voltages for acceleration; and with the RF and negative induction voltages. With both the RF and induction voltages, the centre of the bunch receives an effective voltage per turn of $V = V_{rf}\sin\phi + V_{ind}$, where V_{rf} and V_{ind} are the RF and the induction voltages respectively, and ϕ is the position of the bunch in the RF phase. A value for V of 4.8 kV is required for the RF bunch to follow the linearly ramping bending field of the synchrotron magnets.

Figure 3 shows the temporal evolutions of the measured phase for three cases. The results are in close agreement with the prediction from the equation for the voltage per turn of $\phi = 5.7°$, $-1.0°$ and $12.4°$ for the three cases, with $V_{rf} = 48$ kV and $V_{ind} = 5.6$ kV for the respective cases. The position of the proton bunch relative to the RF voltage for each case is also shown schematically on the right in the same figure. The plots indicate the successful acceleration of the bunch beyond the transition energy. This is the critical energy characteristic of a strong-focusing synchrotron at which the particles' revolution period becomes almost independent of energy and the stable phase position switches from one side of the RF pulse to the other, as indicated in figure 3.

These results are the first step in demonstrating the feasibility of an induction synchrotron, which could have important implications for future machines. A significant advantage of the induction technique is that the functions of acceleration and longitudinal focusing are achieved separately. This is not the case in the RF synchrotron where the gradient in the electric field provides the longitudinal confinement. In an induction machine voltage pulses of opposite sign separated by some time period can provide the longitudinal focusing forces. A pair of barrier-voltage pulses should work in a similar way to the RF barrier, which has been demonstrated at Fermilab, Brookhaven National Laboratory and CERN.

Separating the acceleration and focusing functions in the longitudinal direction brings about a significant freedom of beam-handling compared with conventional RF synchrotrons. In particular, it offers a means of forming a "superbunch": an extremely long beam bunch with a uniform density that would be most attractive in future hadron colliders and proton drivers for neutrino physics. In addition, crossing the transition energy without any longitudinal focusing seems to be feasible, and this could substantially mitigate undesired phenomena, such as bunch-shortening from non-adiabatic motion and microwave instabilities. The next step at KEK will be to test the barrier-voltage concept, proceeding further towards the formation of a superbunch in an induction synchrotron.

Further reading

K Takayama *et al.* 2004 in press *Phys. Rev. Lett.* http://www.arxiv.org/pdf/physics/0412006.
K Takayama and J Kishiro 2000 *Nucl. Inst. Meth. in Phys. Res. A* **451** 304.

Ken Takayama, *KEK*.

LHC upgrade takes shape with CARE and attention

Even before the Large Hadron Collider has accelerated its first beams, various groups have begun to plan an upgrade scheduled for around the middle of the next decade.

CERN's Large Hadron Collider (LHC), first seriously discussed more than 20 years ago, is scheduled to begin operating in 2007. The possibility of upgrading the machine is, however, already being seriously studied. By about 2014, the quadrupole magnets in the interaction regions will be nearing the end of their expected radiation lifetime, having absorbed much of the power of the debris from the collisions. There will also be a need to reduce the statistical errors in the experimental data, which will require higher collision rates and hence an increase in the intensity of the colliding beams – in other words, in the machine's luminosity.

This twofold motivation for an upgrade in luminosity is illustrated in figure 1, which shows two possible scenarios compatible with the baseline design: one in which the luminosity stays constant from 2011 and one in which it reaches its ultimate value in 2016. An improved luminosity will also increase the physics potential, extending the reach of electroweak physics as well as the search for new modes in supersymmetric theories and new massive particles, some of which could be manifestations of extra dimensions.

The timescale for an upgrade of 10 years from now turns out to be just right for the development, prototyping and production of new superconducting magnets for the interaction regions and of other equipment, provided that an adequate R&D effort starts now. It is against this background that the European Community has supported the High-Energy High-Intensity Hadron-Beams (HHH) Networking Activity, which started in March 2004 as part of the Coordinated Accelerator Research in Europe (CARE) project. HHH has three objectives:

- to establish a roadmap for upgrading the European hadron accelerator infrastructure (at CERN with the LHC and also at Gesellschaft für Schwerionenforschung [GSI], the heavy-ion laboratory in Darmstadt);
- to assemble a community capable of sustaining the technical realization and scientific exploitation of these facilities;
- to propose the necessary accelerator R&D and experimental studies to achieve these goals.

The HHH activity is structured into three work packages. These are named Advancements in Accelerator Magnet Technology, Novel Methods for Accelerator Beam Instrumentation, and Accelerator Physics and Synchrotron Design.

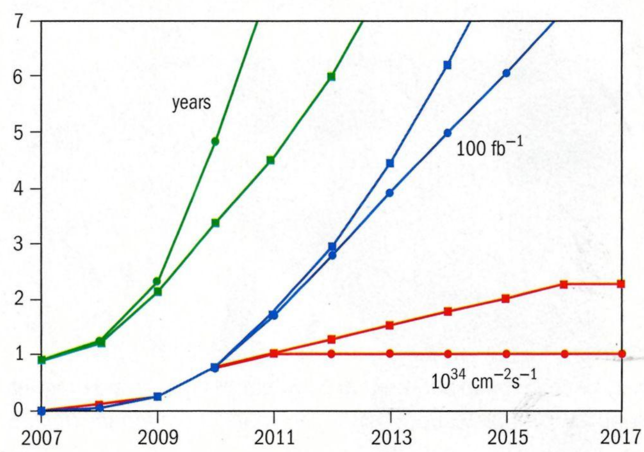


Fig. 1. Integrated luminosity (blue), peak luminosity of the year (red) and time to halve the statistical error (green) for two different scenarios without upgrade. In one case the luminosity is raised to the nominal value by 2011 then stays constant (circles); in the other it continues to increase linearly, reaching the ultimate value by 2016 (squares). The radiation damage limit for magnets in the interaction regions is assumed to be 700 fb^{-1}. (Courtesy J Strait.)

The first workshop of the Accelerator Physics and Synchrotron Design work package, HHH-2004, was held at CERN on 8–11 November 2004. Entitled "Beam Dynamics in Future Hadron Colliders and Rapidly Cycling High-Intensity Synchrotrons", it was attended by around 100 accelerator and particle physicists, mostly from Europe, but also from the US and Japan. With the subjects covered and the range of participants, the workshop was also able to reinforce vital links and co-operative approaches between high-energy and nuclear physicists and between accelerator-designers and experimenters.

The first session provided overviews of the main goals. Robert Aymar, director-general of CERN, reviewed the priorities of the laboratory until 2010, mentioning among them the development of technical solutions for a luminosity upgrade for the LHC to be commissioned around 2012–2015. The upgrade would be based on a new linac, Linac 4, to provide more intense proton beams, together with new high-field quadrupole magnets in the LHC interaction regions to allow for smaller beam sizes at the collision-points – even with the higher-intensity circulating beams. It would also include rebuilt tracking detectors for the ATLAS and CMS experiments. Jos Engelen, CERN's chief scientific officer, encouraged the audience to

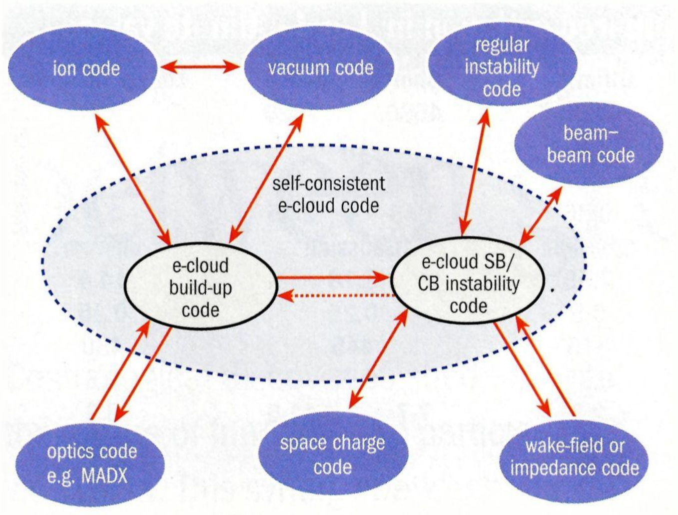


Fig. 2. Schematic for a universal simulation code, emerging from a self-consistent electron-cloud core.

consider the upgrade of the LHC and its injector chain as a unique opportunity for extending the physics reach of the laboratory in the areas of neutrino studies and rare hadron decays, without forgetting the requirements of future neutrino factories.

For the GSI laboratory, the director Walter Henning described the status of the Facility for Antiproton and Ion Research project (FAIR), and its scientific goals for nuclear physics. He pointed to the need for wide international collaboration to launch this accelerator project and to complete the required R&D.

Further talks in the session looked in more detail at the issues involved in an upgrade of the LHC. Frank Zimmermann and Walter Scandale from CERN presented overviews of the accelerator physics and the technological challenges, addressing possible new insertion layouts and scenarios for upgrading the injector-complex. The role of the US community through the LHC Accelerator Research Program (LARP) was described by Steve Peggs from the Brookhaven National Laboratory, who proposed closer coordination with the HHH activity. Finally, Daniel Denegri of CERN and the CMS experiment addressed the challenges to be faced if the LHC detectors are to make full use of a substantial increase in luminosity. He also reviewed the benefits expected for the various physics studies.

The five subsequent sessions were devoted to technical presentations and panel discussions on more specific topics, ranging from the challenges of high-intensity beam dynamics and fast-cycling injectors, to the development of simulation software. A poster session with a wide range of contributions provided a welcome opportunity to find out about further details, and a summary session closed the workshop.

The luminosity challenge

The basic proposal for the LHC upgrade is, after seven years of operation, to increase the luminosity by up to a factor of 10, from the current nominal value of 10^{34} cm^{-2} s^{-1} to 10^{35} cm^{-2} s^{-1}. The table compares nominal and ultimate LHC parameters with those for three upgrade paths examined at the workshop.

The upgrade currently under discussion will include building essentially new interaction regions, with stronger or larger-aperture "low-beta" quadrupoles in order to reduce the spot size at the collision-point and to provide space for greater crossing angles. Moderate modifications of several subsystems, such as the beam dump, machine protection or collimation, will also be required because of the higher beam current. The choice between possible layouts for the new interaction regions is closely linked to both magnet design and beam dynamics; different approaches could accommodate smaller or larger crossing angles, possibly in combination with an electromagnetic compensation of long-range beam–beam collisions or "crab" cavities (as described below), respectively. A more challenging possibility also envisions the upgrade of the LHC injector chain, employing concepts similar to those being developed for the FAIR project at GSI.

The timescale for an upgrade of 10 years from now is just right for the development, prototyping and production of new superconducting magnets for the interaction regions.

The workshop addressed a broad range of accelerator-physics issues. These included the generation of long and short bunches, the effects of space charge and the electron cloud, beam–beam effects, vacuum stability and conventional beam instabilities.

A key outcome is the elimination of the "superbunch" scheme for the LHC upgrade, in which each proton beam is concentrated into only one or a few long bunches, with much larger local charge density. Speakers at the workshop underlined that this option would pose unsolvable problems for the detectors, the beam dump and the collimator system.

For the other upgrade schemes considered, straightforward methods exist to decrease or increase the bunch length in the LHC by a factor of two or more, possibly with a larger bunch intensity. Joachim Tuckmantel and Heiko Damerau of CERN proposed adding conventional radio-frequency (RF) systems operating at higher-harmonic frequencies to vary the bunch length and in some cases also the longitudinal emittance of the beam, while Ken Takayama promoted a novel scheme based on induction acceleration (see p22).

Experiments at CERN and GSI, reported by Giuliano Franchetti of GSI, have clarified mechanisms of beam loss and beam-halo generation, both of which occur as a result of synchrotron motion and space-charge effects due to the natural electrical repulsion between the beam particles. These mechanisms have been confirmed in computer simulations. Studies of the beam–beam interaction – the electromagnetic force on a particle in a beam of all the particles in the other beam – are in progress for the Tevatron at Fermilab, the Relativistic Heavy Ion Collider (RHIC) at Brookhaven, and the LHC.

Tanaji Sen of Fermilab showed that sophisticated simulations can reproduce the lifetimes observed for beam in the Tevatron, and Werner Herr of CERN presented self-consistent 3D simulations for beam–beam interactions in the LHC. Kazuhito Ohmi of KEK conjectured on the origin in hadron colliders of the beam–beam limit – the current threshold above which the size of colliding beams increases with increasing beam intensity. If the limit ▷

Parameters for various LHC upgrade options compared with nominal and ultimate values

Parameter	Symbol	Nominal	Ultimate	Shorter bunches		Longer bunches
number of bunches	n_b	2808	2808	4680	7020	936
protons per bunch	N_b (10^{11})	1.15	1.7	1.7		6.0
bunch spacing	Δt_{sep} (ns)	25	25	15	10	75
average current	I (A)	0.58	0.86	1.43	2.15	1.0
longitudinal profile	–	Gaussian	Gaussian	Gaussian		uniform
rms bunch length	σ_z (cm)	7.55	7.55	3.78		14.4
beta at IP1 and IP5	β^* (m)	0.55	0.5	0.25		0.25
crossing angle	θ_c (μrad)	285	315	445		430
Piwinski parameter	$\theta_c\sigma_z/(\sigma^*2)$	0.64	0.75	0.75		2.8
luminosity	L (10^{34} cm^{-2} s^{-1})	1.0	2.3	7.7	11.5	8.9
events per crossing	–	19	44	88		510

in the LHC arises from diffusion related to the crossing angle, then RF "crab" cavities, which tilt the particle bunches during the collision process, thus effectively providing head-on collisions despite the crossing angle of the bunch centroids, could raise the luminosity beyond the purely geometrical gain in making the beams collide head-on.

Another effect to consider in the LHC is the electron cloud created initially when synchrotron radiation from the proton releases photoelectrons at the beam-screen wall. The photoelectrons are pulled toward the positively charged proton bunch and in turn generate secondary electrons when they hit the opposite wall. Jie Wei of Brookhaven presented observations made at RHIC, which demonstrate that the electron cloud becomes more severe for shorter intervals between bunches. This may complicate an LHC upgrade based on shorter bunch-spacing. Oswald Gröbner of CERN also pointed out that secondary ionization of the residual gas by electrons from the electron cloud could compromise the stability of the vacuum.

The wake field generated by an electron cloud requires a modified description compared with a conventional wake field from a vacuum chamber, as Giovanni Rumolo of GSI discussed. His simulations for FAIR suggest that instabilities in a barrier RF system, with a flat bunch profile, qualitatively differ from those for a standard Gaussian bunch with sinusoidal RF. Elias Metral of CERN surveyed conventional beam instabilities and presented a number of countermeasures.

The simulation challenge

In the sessions on simulation tools, a combination of overview talks and panel discussions revisited existing tools and determined the future direction for software codes in the different areas of simulation. The tools available range from well established commercial impedance calculations to the rapidly evolving codes being developed to simulate the effects of the electron cloud. Benchmarking of codes to increase confidence in their predicative power is essential. Examples discussed included beam–beam simulations and experiments at the Tevatron, RHIC and the Super Proton Synchrotron at CERN; impedance calculations and bench measurements (e.g. for the LHC kicker magnets and collimators); observed and predicted impedance effects (at the Accelerator Test Facility at Brookhaven, DAFNE at Frascati and the Stanford Linear Collider at SLAC); single-particle optics calculations for HERA at DESY, SPEAR-3 at the Stanford Linear Accelerator Center, and the Advanced Light Source at Berkeley; and electron-cloud simulations.

Giulia Bellodi of the Rutherford Appleton Laboratory, Miguel Furman of Lawrence Berkeley National Laboratory, and Daniel Schulte of CERN suggested creating an experimental data bank and a set of standard models, for example for vacuum-chamber surface properties, which would ease future comparisons of different codes. New computing issues, such as parallelization, modern algorithms, numerical collisions, round-off errors and dispersion on a computing Grid were also discussed.

The simulation codes being developed should support all stages of an accelerator project that has shifting requirements; communication with other specialized codes is also often required. The workshop therefore recommended that codes should have toolkits and a modular structure as well as a standard input format, for example in the style of the Methodical Accelerator Design (MAD) software developed at CERN.

Frank Schmidt and Oliver Bruning of CERN stressed that the MAD-X program features a modular structure and a new style of code management. For most applications, complete, self-consistent, 3D descriptions of systems have to co-exist with the tendency towards fast, simplified, few-parameter models – conflicting aspects that can in fact be reconciled by a modular code structure.

The workshop established a list of priorities and future tasks for the various simulation needs and, in view of the rapidly growing computing power available, participants sketched the prospect of an ultimate universal code, as illustrated in figure 2 (see p25).

● The HHH Networking Activity is supported by the European Community-Research Infrastructure Activity under the European Union's Sixth Framework Programme "Structuring the European Research Area" (CARE, contract number RII3-CT-2003-506395).

Further reading

http://care-hhh.web.cern.ch/CARE-HHH/HHH-2004.

Walter Scandale *and* **Frank Zimmermann**, *CERN.*

Exploiting the synergy between great and small

Cosmological discoveries shed new light on the nature of fundamental particles, and vice versa. This synergy between the greatest and the smallest components of the universe was the subject of the 2004 DESY Theory Workshop, held in Hamburg.

Alexander Vilenkin (left) of Tufts University in Massachusetts talks with Christof Wetterich of the University of Heidelberg.

There are a number of astrophysical phenomena, notably in connection with cosmology and ultrahigh-energy cosmic rays, that open a new window onto particle physics and lead to a better microscopic understanding of matter, space and time. On the other hand, particle physics is often exploited to great depths for an ultimate understanding of astrophysical phenomena, in particular the structure and evolution of the universe. These frontier-physics issues attracted a record number of 188 participants to Hamburg for the latest annual DESY Theory Workshop, held on 28 September – 1 October 2004 and organized by Georg Raffelt.

The workshop started with the traditional day of introductory lectures aimed at young physicists, which covered the main topics of the later plenary sessions. Most of the participants jumped at this opportunity. At the end of the day, they had learned much about Big Bang cosmology, including the thermal history of the universe; about the evolution of small fluctuations in the early universe, and their imprints on the cosmic microwave background (CMB) radiation and the large-scale distribution of matter; and about how these initial fluctuations may emerge during an inflationary era of the universe. They were also up to date in ultrahigh-energy cosmic-ray physics. Thus the ground was laid for the workshop proper.

Highlighting the dark

In recent years, significant advances have been made in observational cosmology, as several plenary talks emphasized. Observations of large-scale gravity, deep-field galaxy counts and Type Ia supernovae favour a universe that is currently about 70% dark energy – accounting for the observed accelerating expansion of the universe – and about 30% dark matter. The position of the first Doppler peak in recent measurements of the CMB radiation, by for example the Wilkinson Microwave Anisotropy Probe (WMAP) satellite, strongly suggests that the universe is spatially flat. These values for the cosmological parameters, together with today's Hubble expansion rate, are collectively known as the "concordance" model of cosmology, for they fit a wide assortment of cosmological data. Indeed, we have entered the era of precision cosmology, with the precision set to continue increasing in the coming decade as a result of further observational efforts. It is now the turn of theoretical particle physicists to explain these cosmological findings, in particular why the dominant contribution to the energy density of the present universe is dark and what it is made of microscopically.

Dark matter

Successful Big Bang nucleosynthesis requires that about 5% of the energy content of the universe is in the form of ordinary baryonic matter. But what about the remaining non-baryonic dark matter?

This 25% cannot be accounted for in the Standard Model of particle physics: the only Standard Model candidates for dark matter, the light neutrinos, were relativistic at the time of recombination and therefore cannot explain structure formation on small galactic scales. Studies of the formation of structure – as observed today by the Sloan Digital Sky Survey, for example – from primordial density perturbations measured in the CMB radiation yield an upper ▷

Discussing the fate of the universe: from left to right – Sidney Bludman, Slava Mukhanov and Dominik Schwarz.

bound of about 2% on the energy fraction in massive neutrinos. This translates into an upper bound of around 1 eV for the sum of the neutrino masses. Observations, by means of the forthcoming Planck satellite, of distortions in the temperature and polarization of the CMB will improve the sensitivity in the sum of neutrino masses by an order of magnitude to 0.1 eV. This is comparable to the sensitivity of the future Karlsruhe Tritium Neutrino Experiment (KATRIN), which measures the neutrino mass via the tritium beta-decay endpoint spectrum, and of the planned second-generation experiments on neutrinoless double beta-decay.

In theories beyond the Standard Model, there is no lack of candidates for the dominant component of dark matter. Notable viable candidates are the lightest supersymmetric partners of the known elementary particles, which arise in supersymmetric extensions of the Standard Model: the neutralinos, which are spin-$\frac{1}{2}$ partners of the photon, the Z-boson and the neutral Higgs boson, and the gravitinos, which are spin-$\frac{1}{2}$ partners of the graviton. Showing that one of these particles accounts for the bulk of dark matter would not only answer a key question in cosmology, but would also shed new light on the fundamental forces and particles of nature.

While ongoing astronomical observations will measure the quantity and location of dark matter to greater accuracy, the ultimate determination of its nature will almost certainly rely on the direct detection of dark-matter particles through their interactions in detectors on Earth. Second-generation experiments such as the Cryogenic Dark Matter Search II (CDMS II) and the Cryogenic Rare Event Search with Superconducting Thermometers II (CRESST II), which are currently being assembled, will provide a serious probe of the neutralino as a dark-matter candidate.

Complementary, but indirect, information can be obtained from searches for neutrinos and gamma rays from neutralino–antineutralino annihilation, coming from the direction of particularly dense regions of dark matter, for example in the central regions of our galaxy, the Sun or the Earth. Ultimately, however, the proof of the existence of dark matter and the determination of its particle nature will have to come from searches at accelerators, notably CERN's Large Hadron Collider (LHC). Even the gravitino, which is quite resistant to detection in direct and indirect dark-matter searches because it interacts only very feebly through the gravitational force, can be probed at the LHC.

Dark energy

In contrast with dark matter, dark energy has so far no explanation in particle physics. Apart from the observed accelerated expansion, the fact that we seem to be living at a special time in cosmic history, when dark energy appears only recently to have begun to dominate dark and other forms of matter, is also puzzling. Explanations put forth for dark energy range from the energy of the quantum vacuum to the influence of unseen space dimensions. Popular explanations invoke an evolving scalar field, often called "quintessence", with an energy density varying in time in such a way that it is relevant today. Such an evolution may also be linked to a time variation of fundamental constants – a hot topic in view of recent indications of shifts in the frequencies of atomic transitions in quasar absorption systems, which hint that the electromagnetic fine-structure constant was smaller 7–11 billion years ago than it is today.

Depending on the nature of dark energy, the universe could continue to accelerate, begin to slow down or even recollapse. If this cosmic speed-up continues, the sky will become essentially devoid of visible galaxies in only 150 billion years. Until we understand dark energy, we cannot comprehend the destiny of the universe. Determining its nature may well lead to important progress in our understanding of space, time and matter.

The first order of business is to establish further evidence for dark energy and to discern its properties. The gravitational effects of dark energy are determined by its equation of state, i.e. the ratio of its pressure to its energy density. The more negative its pressure, the more repulsive the gravity of the dark energy. The dark energy influences the expansion rate of the universe, which in turn governs the rate at which structure grows, and the correlation between redshift and distance. Over the next two decades, high-redshift supernovae, counts of galaxy clusters, weak-gravitational lensing and the microwave background will all provide complementary information about the existence and properties of dark energy.

Inflationary ideas

The inflationary paradigm that the very early universe underwent a huge and rapid expansion is a bold attempt to extend the Big Bang model back to the first moments of the universe. It uses some of the most fundamental ideas in particle physics, in particular the notion of a vacuum energy, to answer many of the basic questions of cosmology, such as "Why is the observed universe spatially flat?" and "What is the origin of the tiny fluctuations seen in the CMB?".

The exact cause of inflation is still unknown. Thermalization at the end of the inflationary epoch leads to a loss of details about the initial conditions. There is, however, a notable exception: inflation leaves a telltale signature of gravitational waves, which can be used to test the theory and distinguish between different models of inflation. The strength of the gravitational-wave signal is a direct indicator of what caused inflation. Direct detection of the gravitational radiation from inflation might be possible in the future with very-long-baseline, space-based, laser-interferometer gravitational-wave detectors. A promising shorter-term approach is to search for the signature of these gravitational waves in the polarized radiation from the CMB.

Matter matters

The ordinary baryonic matter of which we are made is the tiny residue of the annihilation of matter and antimatter that emerged from the earliest universe in not-quite-equal amounts. This tiny imbalance may arise dynamically from a symmetric initial state if baryon number is not conserved in interactions that violate the conservation of C (C = charge conjugation) and the combination CP (P = parity), which produce more baryons than antibaryons in an expanding universe.

There are a few dozen viable scenarios for baryogenesis, all of which invoke more or less physics beyond the Standard Model. A particularly attractive scenario is leptogenesis, according to which neutrinos play a central role in the origin of baryon asymmetry. Leptogenesis predicts that the out-of-equilibrium, lepton-number violating decays of heavy Majorana neutrinos, with an exchange responsible for the smallness of the masses of the known light neutrinos, generate a lepton asymmetry in the early universe that is transferred into a baryon asymmetry by means of non-perturbative electroweak baryon- and lepton-number violating processes. Leptogenesis works nicely within the currently allowed window for the masses of the known light neutrinos.

Heavenly accelerators

The Earth's atmosphere is continuously bombarded by cosmic particles. Ground-based observatories have measured them in the form of extensive air showers with energies up to 3×10^{20} eV, corresponding to centre-of-mass energies of 750 TeV, far beyond the reach of any accelerator here on Earth. We do not yet know the sources of these particles and thus cannot understand how they are produced. Astrophysical candidates for high-energy sources include active galaxies and gamma-ray bursts. Alternatively, a completely new constituent of the universe could be involved, such as a topological defect or a long-lived superheavy dark-matter particle, both associated with the physics of grand unification. Only by observing many more of these particles, including the associated gamma rays, neutrinos and perhaps gravitational waves, will we be able to distinguish these possibilities.

Identifying the sources of ultrahigh-energy cosmic rays requires several kinds of large-scale experiments, such as the Pierre Auger Observatory, currently under construction, to collect large enough data samples and determine the particle directions and energies precisely. Dedicated neutrino telescopes of cubic-kilometre size in deep water or ice, such as IceCube at the South Pole, can be used to search for cosmic sources of high-energy neutrinos. An extension of their sensitivity to the ultrahigh-energy regime above 10^{17} eV will offer possibilities to infer information about physics in neutrino–nucleon scattering beyond the reach of the LHC.

● For the programme and presentations at the workshop see www.desy.de/desy-th/workshop2004/.

Connecting quarks with the cosmos: Michael Turner presents the 2004 DESY Heinrich-Hertz Lecture on Physics.

Further reading

The Committee on the Physics of the Universe, Board on Physics and Astronomy, National Research Council 2003 *Connecting Quarks with the Cosmos: Eleven Science Questions for the New Century* (The National Academies Press, Washington, DC).

Andreas Ringwald, *DESY.*

STAR has silicon at its core

Fig. 1. The silicon strip detector installed on the support cone, which was built in France for the STAR silicon vertex tracker.

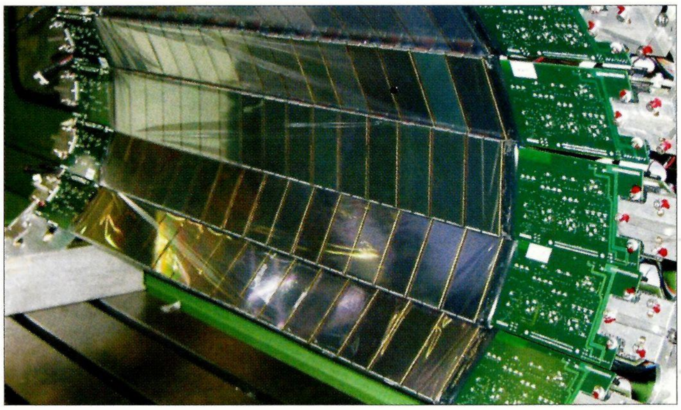


Fig. 2. A section of the silicon strip detector (comprising five ladders each with 16 detector modules) installed on a coordinate-measuring machine to determine the relative locations of the silicon wafers on the ladders.

A silicon strip detector is providing more power for particle detection in Brookhaven National Laboratory's STAR experiment.

An important milestone has been reached in the STAR experiment at Brookhaven's Relativistic Heavy Ion Collider (RHIC) with the integration of the silicon strip detector (SSD). The installation completes the STAR ensemble, which is dedicated to tracking the thousands of charged particles that emerge at large angles to the colliding beams. The SSD has been fully commissioned and is now collecting data.

The completion of the STAR SSD is the result of a multi-year French research and development effort that began shortly after STAR started taking data in 2000, and which was led by the Laboratoire de Physique Subatomique et des Technologies Associées (Subatech) in Nantes, and the Institut de Recherche Subatomique (IreS) in Strasbourg. The detector incorporates state-of-the-art bonding technology as well as front-end electronics and control chips designed and developed by the Laboratoire d'Electronique et de Physique des Systèmes Instrumentaux (LEPSI) in Strasbourg.

The SSD makes extensive use of double-sided silicon microstrip sensors and has a total sensitive area of about 1 square metre. The detector consists of 320 detector modules arranged on 20 ladders (see figures 1 and 2). These form a barrel at a radius of 23 cm from the beam, inserted between the silicon vertex tracker (SVT) and the time projection chamber (TPC).

The detector enhances the tracking capabilities of the STAR experiment in this region by providing information on the positions of hits and on the ionization energy loss of charged particles. Specifically, the SSD improves the extrapolation of tracks in the TPC to the hits found in the SVT. This increases the average number of space points measured near the collision vertex, significantly improving the detection efficiency for long-lived meta-stable particles such as those found in hyperon decays. Moreover, the SSD will further enhance the SVT tracking capabilities for particles with very low momentum, which do not reach the TPC.

The SSD was based on an early proposal for the Inner Tracking System of the ALICE experiment at CERN's Large Hadron Collider; however, the design of the detector has evolved and matured considerably after several years of research, development and prototyping. To fulfil the constraints of the STAR environment, innovative solutions were required for electronics, connections and mechanics.

The detector module comprises one double-sided silicon microstrip sensor and floating electronics on two hybrid circuits of very low mass (see figure 3, p32). The silicon sensor contains 1536 analogue channels (768×2) and has a resolution of 17 μm in azimuth ($R\varphi$) and 700 μm in the beam direction (z). Each of the hybrid circuits is dedicated to one side of the sensor and hosts six A128C front-end chips and a Costar chip for control purposes. The hybrids are connected to the outer boards via a low-mass Kapton-aluminium bus, manufactured at CERN.

The A128C front-end chip, developed in a collaboration between LEPSI and IReS, shows an extended input range corresponding to ±13 MIPs (minimum ionizing particles) and an extra-low power consumption of less than 350 μW per channel. A dedicated multipurpose application-specific integrated circuit is in charge of the hybrid controls and temperature measurements.

Kapton-copper microcables and state-of-the-art tape automated bonding (TAB) technology connect the silicon readout strips to the input channels of the front-end electronics chip, and the chips to ▷

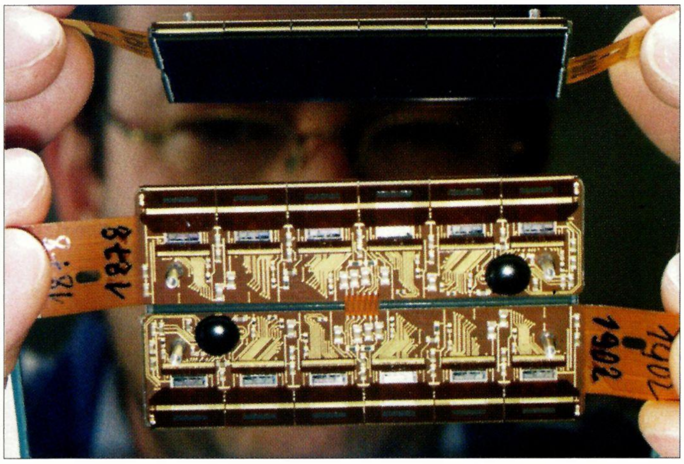


Fig. 3. Each detector module features a double-sided silicon microstrip sensor (top) backed by its onboard front-end electronics (bottom). The module extends slightly beyond the silicon surface (7.5 × 4.2 cm) and is a few millimetres thick.

their hybrids. TAB enables a flexible connection, which acts as an adapter between the different pitches of the detectors and the chips. The technology is also testable and it provided a good yield during production. It was essential to make the detector modules small enough to be integrated into STAR.

Another unique feature of the SSD is its air-cooling system. The carbon-fibre-based structure on the ladder that supports the detector modules, analogue-to-digital converters, and control boards is wrapped with a Mylar foil and defines a path to guide the flow of air induced by transvector airflow amplifiers. This design avoids the use of liquid coolant, cooling pipes and heat bridges, and provides a material budget with a total radiation length very close to 1%.

A high level of serialization has been reached by incorporating the analogue-to-digital converters and control boards close to the detector modules. This enables the data from the half million channels of the SSD to be transported to the STAR data acquisition system using only four giga-link optical fibres. In the future, additional parallelization of the readout will enable the readout speed of the SSD to be increased to match the trigger and data-taking rates foreseen for STAR in the high-luminosity era of RHIC II.

The SSD project has been funded by the IN2P3/CNRS, the Ecole des Mines de Nantes, the metropolitan district of Nantes, the Loire-Atlantique department, and the regions of Alsace and Pays de la Loire. Financial support has also been provided by the US Department of Energy through the STAR collaboration.

Further reading

L Arnold *et al.* 2003 *Nucl. Instr. Meth.* **A499** 652.
See also the SSD Web site: http://star.in2p3.fr.

Lilian Martin, *Laboratoire Subatech, Nantes, for the SSD group.*

PRIZES

French physics society recognizes Blondel with 2004 research award

The Société Française de Physique has awarded the 2004 Jean Richard prize to Alain Blondel of the University of Geneva and the Ecole Polytechnique. The prize is given annually to a French researcher for his or her exceptional and original work in the field of theoretical or experimental physical sciences.

Blondel was a major driving force behind the phenomenal success of electroweak precision measurements at the Large Electron–Positron Collider (LEP), not least by pioneering the resonant depolarization technique of accurately measuring the beam energy. These measurements have probed the Standard Model to unprecedented precision. Blondel is now working on neutrino physics, thus continuing his contribution to electroweak physics.

Alain Blondel, left, with the polarization team at the Large Electron–Positron Collider in 1993.

INDUSTRY

German companies on display at CERN

For the first two days of March, CERN's main building was transformed into a showcase for German industry. Twenty-nine companies from sectors related to particle physics attended the ninth Germany at CERN exhibition, organized by the German Federal Ministry of Education and Research (BMBF). The exhibition enabled the companies to meet scientists, engineers and other potential purchasers.

Left to right: Hermann Schunck, director of the BMBF, and Robert Aymar, CERN's director-general, speak with a representative of a German company.

APPOINTMENTS

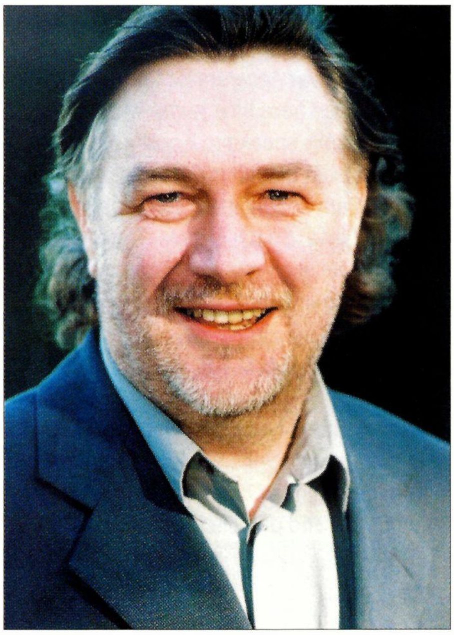
PPARC welcomes new chief executive

Keith Mason, a leading space scientist, has been appointed as the new chief executive and deputy chair of the UK's Particle Physics and Astronomy Research Council (PPARC). Mason will take up the post on 1 August for a period of four years, succeeding Ian Halliday who retired as chief executive on 31 March.

Mason is now the head of University College London's Department of Space and Climate Physics and director at the Mullard Space Science Laboratory. He is also the UK's lead investigator for the Ultra-Violet/ Optical Telescope on the NASA Swift space mission, which was launched last November to study the explosive phenomena of gamma-ray bursts.

"It is an honour to have the opportunity to build on the legacy left by Ian Halliday," Mason commented following the announcement. "This is a time of great opportunity for the UK in astronomy, particle physics and space science."

Richard Wade, deputy chief executive and director of programmes at PPARC, will take over as interim chief executive and accounting officer for the period from 1 April to 31 July.



Keith Mason, appointed head of PPARC.

YEAR OF PHYSICS

Online diaries demystify physics

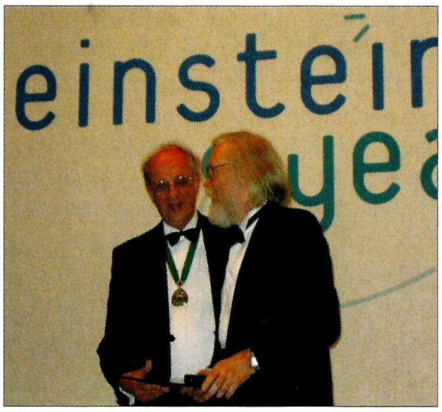
Quantum Diaries is a website that follows physicists from around the world as they experience the World Year of Physics 2005. In their own words, in photos, blogs and videos, they tell the real-life stories of real physicists in real time.

The project, set up by the InterAction Collaboration of communicators from particle physics laboratories around the world, is not just about physics; it aims to show what it is to be a physicist. That means that the diarists write about their families, hobbies and interests, as well as their latest research findings and the challenges that face them in their labs.

The diarists, mainly nominated by their home laboratories, represent a cross-section of working physicists, from graduate students to senior researchers. They speak nine languages and represent 15 countries. Outside the lab they are jazz musicians, parents, amateur astronomers, photographers and athletes.

- See http://interactions.org/quantumdiaries.

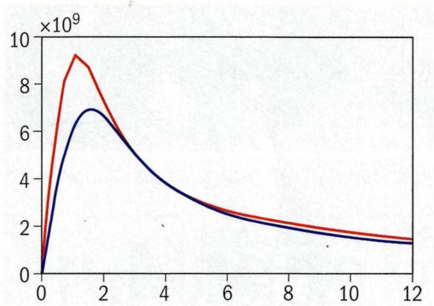
Caolionn O'Connell is writing a diary about working as a researcher at SLAC.



Theorist John Ellis, right, receives the Dirac Medal wearing a "borrowed dinner jacket".

Extracts from Quantum Diaries

Caolionn O'Connell, graduate student in advanced accelerator technologies, at the Stanford Linear Accelerator Center (SLAC):
"31 January: I have hit a bump in the road, metaphorically speaking. A really big bump, such that even though my car might have lost a wheel, I am hoping it will still drive me to the thesis defense. So it is simple. The blue and the red curve should be the same. As much as you might squint, look at the graph askew or jump up and down, there is no way those two curves are going to match. The red curve is the simulation and the blue curve is physics. It becomes a moment of concern when your simulations do not obey the laws of physics. Consequently, the many, many hours I have spent baby-sitting computers have been for nothing, nada, zilch. That's right, worthless."



O'Connell expresses "concern when your simulations do not obey the laws of physics".

John Ellis, theorist at CERN:
"20 January: Off to London today with my family to receive the Dirac Medal, which was awarded to me by the Institute of Physics at a swish ceremonial dinner at the Savoy Hotel in London. The photo shows me in a borrowed dinner jacket and 20 Swiss Franc dress shoes.

"Back in 1983, the Institute of Physics awarded me their Maxwell medal, and I almost missed the presentation. However, I was saved by the Falklands war, which was raging at the time. I arrived late for the ceremony, getting there just as the German ambassador was presenting the Born medal. He apologized for having to jump ahead of the Maxwell medal, the reason being that he had to hurry back to his embassy for some urgent war-related message. By the time he had finished, I had finally reached my place and was available to receive my medal."

NEW PRODUCTS

Electron Tubes has a new website for scientists and engineers working in imaging and non-imaging optics, scintillation counting, and nuclear and particle physics. New features include an interactive search facility for selecting photomultipliers. See www.electrontubes.com.

ACT/Techno has announced a new development system based on the VITA 31.1 Ethernet fabric implementation. The VITA 31.1 standard defines the pin assignments and connector to implement a standard switched Ethernet fabric on a VME64x backplane, without use of cables. For further information see www.acttechnico.com, e-mail sales@acttechnico.com or call +1 215 957 9102.

Leica Microsystems has introduced a new mask metrology tool, the LMS IPRO3. The new device is designed to support mask metrology for 65 nm and provides measurement precision with a short-term repeatability of better than 1.5 nm (3σ). For further information tel +49 6441/29 2229 or see www.semiconation.com.

PI (Physik Instrumente) has announced the new P-540 series nanofocusing Z-stages, designed for easy integration into high-resolution microscopes and other probing instruments. They provide fast motion to 100 μm in the z direction with subnanometre resolution. For more details call +1 508 832 3456, e-mail stefanv@pi-usa.us or see www.pi.ws.

SCHOOLS

ICTP summer school reviews latest findings in astroparticle physics

The seventh School on Non-Accelerator Astroparticle Physics was held at the Trieste Abdus Salam International Centre for Theoretical Physics (ICTP) from 26 July to 6 August 2004. The school, which is sponsored by the ICTP and the Istituto Nazionale di Fisica Nucleare (INFN), is held every three years. Non-accelerator astroparticle physics is a rapidly growing field that is often modified significantly by exciting new results, so the general picture presented at each of the schools has been considerably different.

Last year marked the 40th anniversary of the foundation of the ICTP (*CERN Courier* November 2004 p30). During that period the centre has grown in size and complexity. For example, it now has several buildings, a large library, guest houses and well equipped computer rooms. Located about 10 km from the centre of Trieste, it is close to Miramare Castle and Grignano Bay. Besides theoretical research carried out at the centre by staff and visitors, summer schools and workshops are held every year and these represent one of the centre's main activities.

About 100 people from 38 nations participated in the seventh astroparticle physics school.

Around 100 participants, including 80 students and 16 lecturers, attended the seventh astroparticle physics school. The participants came from 38 nations, mainly from developing countries although a significant number also came from western countries. The lectures were given by well known theoretical and experimental physicists involved in intensive research in the fields covered by the school. Four sessions were devoted to discussion and participants proved to be very motivated, so the atmosphere was lively. Three poster sessions were organized and students presented 32 posters, which gave a broad view of activities in the field in general and in developing countries in particular.

The main building of the ICTP in Trieste.

After a few introductory lectures on basic particle physics, the school covered the status of the field and the future perspectives of astroparticle physics in detail, from both the experimental and theoretical points of view.

A first set of lectures introduced the fundamentals of particle physics with a review of the Standard Model and beyond. A comprehensive section on neutrino physics and astrophysics covered neutrino masses and oscillations, short- and long-baseline neutrino experiments, atmospheric and solar neutrinos, and neutrino telescopes.

Theoretical aspects as well as current and potential dark-matter searches were extensively discussed. Several lectures dealt with searches for axions, magnetic monopoles and nuclearites. Cosmic rays and astrophysics were covered, with reviews on experiments in space, extreme-energy cosmic rays and photons and antimatter in space. The theory of gravitational waves was introduced, and current and future searches for gravitational waves were reviewed.

A session was devoted to the legacy of the Large Electron–Positron Collider (LEP) at CERN and future accelerators and superbeams. Large-scale facilities, detectors and data acquisition, and large-scale computing were a significant part of the programme. Other sessions concerned the world of science, with reviews on 100 years of science, science and society, and the universe.

Further reading

Copies of the lecture transparencies are available on the ICTP website http://cdsagenda5.ictp.trieste.it/full_display.php?ida=a0355 and at www.bo.infn.it/~giacomellir/ictp/ (see under School Agenda and Documents). The proceedings, edited by R A Carrigan Jr, G Giacomelli and N Paver, are to be published by World Scientific, Singapore.

CELEBRATION

Symposium honours Lee Teng's career in accelerator physics

A symposium and banquet, organized by the Argonne National Laboratory and Fermilab, was held on 24 February to celebrate the retirement of accelerator physicist Lee Teng. Since his first job with accelerators as a graduate student in 1949, where he developed a beam extraction system in the Chicago cyclotron for Enrico Fermi and others, Teng has been active on some of the most important problems in accelerator physics. The extraction system, worked out with James Tuck, was later used at Liverpool University and then at Chicago University, and was the basis for resonant extraction used almost everywhere.

Teng later became the principal designer of the Argonne Zero Gradient Synchrotron and then director of the Argonne Particle Accelerator Division. When the National Accelerator Laboratory (later the Fermi National Accelerator Laboratory, FNAL) was formed, he was there on "day one" in 1967 and became head of accelerator theory. He was busy with a variety of activities at FNAL, such as the design of components and colliders including the Tevatron, and he also was able to find time to contribute to projects at CERN, Los Alamos National Laboratory, Lawrence Berkeley Laboratory, Brookhaven National Laboratory and TRIUMF in Canada.

Lee Teng at the symposium held to honour his retirement. (Courtesy Mike Borland.)

Teng helped design the proton therapy facility at the Loma Linda University Medical Center, California, and the Taiwan Light Source, located at Taiwan's National Synchrotron Radiation Research Center, where he served as its first director. He returned to Argonne in 1989 to help design the 7 GeV light source, and later served as head of the Accelerator Physics group of the Advanced Photon Source.

At the symposium, Teng and others noted the many responsibilities he still has as a member of various boards and committees. It will be an active retirement.

MEETINGS

The **10th LNF Spring School in Nuclear, Subnuclear and Astroparticle Physics** will take place at the INFN National Laboratories in Frascati, Italy, on 16–20 May. The school is directed at graduate students, postgraduate and post-doctoral fellows, and young researchers from the EU Euridice Network. The 2005 school will be mainly devoted to theoretical and experimental developments in meson spectroscopy, kaon physics, neutrino physics and cosmology. It will also include a historical session, special seminars and short presentations by young researchers attending the school. For further information, see www.lnf.infn.it/conference/lnfss.

The **International School of Physics Enrico Fermi** on CP Violation: From Quarks to Leptons is to be held in Varenna, Italy, on 19–29 July. The school, organized by the Italian Physical Society, is aimed at advanced postgraduate level and is based on lecture courses plus seminars. Topics will range from the theory and phenomenology of CP violation to perspectives for future experiments. The deadline for applications is 20 May. Further details are available at http://varenna05.pi.infn.it/.

The **12th Euro Summer School on Exotic Beams** will be held at Mainz, Germany, on 25 August – 2 September. Organized this year by GSI-Darmstadt, the school is intended for PhD students and young post-docs starting work in fields related to radioactive ion beams. The school consists of several lecture courses given by specialists in the field, starting from a basic level. The deadline for registration is 1 June. For further information and online registration see www-linux.gsi.de/~scheid/euroschool-05/home.htm. Enquiries can be sent by e-mail to euroschool@gsi.de.

MSM05, the **4th International Conference on Magnetic and Superconducting Materials**, is to be held at Ibn Zohr University, Agadir, Morocco, on 5–8 September. The aim is first to review information on the most recent scientific and technological advances in the fields of superconductivity and magnetism, and second to create the opportunity for scientists from all parts of the world to discuss and share their research findings and explore the possibilities of mutual co-operation. For further information see http://msm05.esta.ac.ma.

PHYSTAT05, a conference on Statistical Problems in Particle Physics, Astrophysics and Cosmology, will be held in Oxford, UK, on 12–15 September. This is the fifth in a series that started with the Confidence Limits Workshop at CERN in January 2000. As well as contributions from physicists, there will be invited talks by an ensemble of distinguished statisticians. Attendance is limited to 120 participants. Further information is available at www.physics.ox.ac.uk/phystat05, or by e-mail from l.lyons@physics.ox.ac.uk.

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BOOKSHELF

Very High Energy Cosmic Gamma Radiation: A Crucial Window on the Extreme Universe by Felix A Aharonian, World Scientific. Hardback ISBN 9810245734, £65 ($107).

Astronomy – the study of all kinds of cosmic radiation – meets particle physics at the highest gamma-ray energies. This book offers the opportunity for particle physicists to cross the bridge between the two disciplines. They will discover the nature and properties of the extreme sources in the universe able to emit photons at energies higher than 10 GeV.

Very-high-energy astrophysics is entering a new era with the recent achievement by the High Energy Stereoscopic System (HESS) of the first spatially resolved high-energy gamma-ray image of an astronomical object, the supernova remnant RX J1713.7-3946 (*CERN Courier* January/February 2005 p30). This image confirms that supernova remnants are at the origin of cosmic rays.

Supernova remnants, such as the Crab Nebula, figure among the many high-energy gamma-ray sources described by Aharonian. (Courtesy European Southern Observatory.)

The lead author of the paper in *Nature* that described the HESS results was Felix Aharonian, the author of this book. Here he uses his expertise to provide a broad and comprehensive overview of the study of cosmic gamma rays, from energies of about 10 GeV to 10 TeV. In nearly 500 pages, he covers all aspects of the field including the theoretical ground of gamma-ray emission and absorption mechanisms, as well as the status of detection facilities. The main part of the book is, however, devoted to the phenomenology of the various sources of very-high-energy gamma rays.

With more figures than equations, the author guides us through the world of supernova remnants, pulsars, jets of quasars and microquasars, and clusters of galaxies. He even discusses the implications for cosmology, as derived from the interaction of very-high-energy gamma rays with the diffuse extragalactic background radiation. As complete as this book tends to be, however, I am a little surprised to find notable omissions, including gamma-ray bursts and the possible annihilation-radiation of weakly interacting massive particules (WIMPs), which are mentioned but not discussed.

Nevertheless, this book with its extensive list of references is a very valuable introduction to the astrophysics of high-energy gamma-ray radiation. Well structured and with its more mathematical parts left for the appendix, it is also suitable for a quick search for a specific topic. It can therefore be used as a reference book for this fascinating "last electromagnetic window" on the cosmos, a topic destined to evolve very rapidly in the coming years.

Marc Türler, INTEGRAL Science Data Centre and Geneva Observatory.

The Essential Turing by B Jack Copeland (ed.), Oxford University Press. Hardback ISBN 0198250797, £50 ($98). Paperback ISBN 0198250800, £14.99 ($24.95).

At high school I once received a mathematics prize in the form of two volumes on calculus. I was very pleased until I discovered that they contained not a single diagram or figure. Everything was explained with words and mathematical formulae only. Alan Turing's most important paper, "On computable numbers, with an application to the Entscheidungsproblem", similarly lacks any diagram of his famous tape-manipulating machine.

Turing was of course the father of modern computing, and the aim of Jack Copeland's book is to present some of his important papers in three ways: the original, a guide to the original, and some historical critiques. The guides prove to be very useful since they are not bound by the inhibition against figures that seems to have existed in Turing's time.

First a health warning is in order. This is not a book for armchair reading by the faint-hearted! I'm not a mathematician and despite Copeland's efforts I became lost several times. To get the best out of this book, read it at a desk and have a notepad and pencil handy – and an eraser. It was said of Gauss's published proofs that one had to thaw them before they could be read. This is what you have to do here, even with some of Copeland's own material. And there are still too few diagrams.

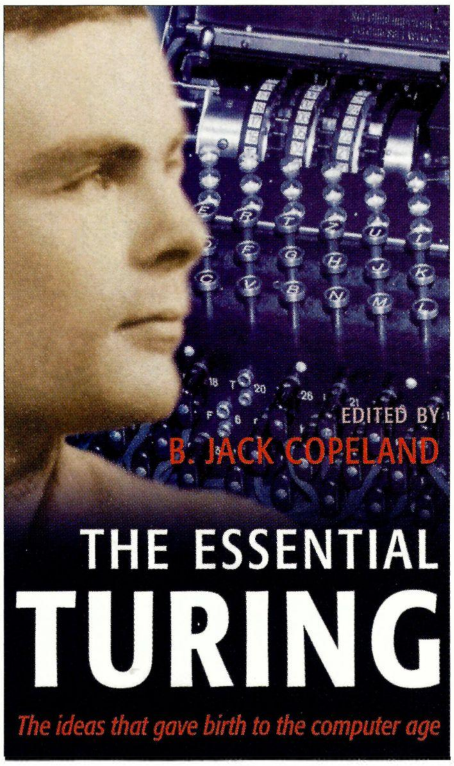
That said, this is an utterly interesting book. Be prepared for some hard work, but you will be rewarded with a fascinating new view on the birth of the computer.

Here, for the first time, are bundled together the most influential papers of Turing in the original. Reading "On computable numbers..." I could not help but wonder what the reviewers of the London Mathematical Society must have thought when they received it in 1936. There is plenty of maths in the paper, to be sure, but this business of computing machines, tapes, erasing stuff, moving left and right, and all the strange conventions – could this be a serious research topic? The paper is very compact given that it exposes all the fundamental questions of computing in a mere 40 pages. Studying it is a most thrilling experience: it gave me a glimpse into the mind of the genius, struggling with a totally new concept, feverishly trying to compress into a single article all the miraculous stuff he sees with his mind's eye.

A minor complaint is that Turing's papers have been re-typeset and this gives an odd feeling. I think I would have preferred a good facsimile of the originals to this immaculate computer-crafted output. It would also have made the book even more attractive.

There is, however, much more to the book than just the papers and Copeland's guides. A great deal of history is woven into it, creating a somewhat strange hybrid between a biography, a history book and a textbook for a course on the philosophy of computing. There are letters from Turing to his mother about the strangeness of life in America, and other material that almost clashes with the very mathematical treatment of proofs in logic. But the historical-biographical intermezzos are welcome passages where you can relax.

I was pleased with the the book's high accuracy and the exposure of the real roles of Turing and John Von Neumann in the development of computing. There is also plenty of previously unpublished material here, based on war archives that were released only in 1996. Transcripts of BBC radio debates on machine intelligence in which Turing took part are fascinating reading.



Copeland, like other biographers of Turing, shows a slight bias in favour of his hero. But what a hero he was: we get the seminal papers plus the best explanation of the Enigma episode I have read, and also the much less known work on artificial intelligence and artificial life that kept Turing preoccupied in the last years of his life. Of this phenomenal work most of us know only the famous Turing Test – how many know he also worked on neural networks and simulation of morphogenesis at a time when computers ran at 1 MHz with a few kilobytes of memory?

Strangely, the book contains no references to websites. There is www.turingarchive.org/, where scans of the original papers can be viewed, and www.alanturing.net/, Copeland's own site about Turing.

Robert Cailliau, CERN.

SUPPLIER INFORMATION

VIEWPOINT

In need of the human touch

Software development is more than engineering and still needs the human factor to be successful, says **Federico Carminati**.

I have led software projects since 1987 and have never known one, including my own, that was not in a crisis. After thinking and reading about it and after much discussion I have become convinced that most of us write software each day for a number of reasons but without ever penetrating its innermost nature.

A software project is primarily a programming effort, and this is done with a programming language. Now this is already an oxymoron. Programming is writing before; it entails predicting or dictating the behaviour of something or someone. A language, on the other hand, is the vehicle of communication that in some ways carries its own negation because it is a way of expressing concepts that are inevitably reinterpreted at the receiver's end. How many times have you raged "Why does this stupid computer do what I tell it [or him or her according to your momentary mood toward one of the genders], and not what I want!?" A language is in fact a set of tools that have been developed through evolution not to "program" but to "interact".

Moreover every programmer has his own "language" beyond the "programming language". Many times on opening a program file and looking at the code, I have been able to recognize the author at once and feel sympathy ("Oh, this is my old pal...") or its opposite ("Here he goes again with his distorted mind..."), as if opening a letter.

Now if only it were that simple. If several people are working on a project, you not only have to develop the program for the project but you also have to manage communication between its members and its customers via human and programming language.

This is where our friends the engineers say to us "Why don't you build it like a bridge?" However, software engineering is one more oxymoron cast upon us. We could never build software like a bridge, no more than engineers could ever remove an obsolete bridge with a stroke of a key without leaving tons of scrap metal behind. Software engineering's dream of "employing solid engineering processes on software development" is more a definition than a real target. We all know exactly why it has little chance of working in this way, but we cannot put it into words when we have coffee with our engineer friends. Again, language leaves us wanting.

Attempts to apply engineering to software have filled books with explanations of why it did not work and of how to do it right, which means that a solution is not at hand. The elements for success are known: planning, user-developer interaction, communication, and communication again. The problem is how to combine them into a winning strategy.

Then along came Linux and the open source community. Can an operating system be built without buying the land, building the offices, hiring hundreds of programmers and making a master plan for which there is no printer large enough? Can a few people in a garage outwit, outperform and eventually out-market the big ones? Obviously the answer is yes, and this is why Linux, "the glorified video game" to quote a colleague of mine, has carried a subversive message. I think we have not yet drawn all the lessons. I still hear survivors from recent software wrecks say: "If only we had been more disciplined in following The Plan..."

Is software engineering catching up? Agile technologies put the planning activity at the core of the process while minimizing the importance of "The Plan", and emphasize the communication between developers and customers.

Have the "rules of the garage" finally been written? Not quite. Open source goes far beyond agile technologies by successfully bonding people who are collaborating on a single large project into a distributed community that communicates essentially by e-mail. Is constraining the communication to one single channel part of the secret? Maybe. What is certain is that in open source the market forces are left to act, and new features emerge and evolve in a Darwinian environment where the fittest survives. But this alone would not be enough for a successful software project.

A good idea that has not matured enough can be burned forever if it is exposed too early to the customers. Here judicious planning is necessary, and the determination and vision of the developer is still a factor in deciding when and how to inject his "creature" into the game. I am afraid (or rather I should say delighted) we are not close to seeing the human factor disappear from software development.

Federico Carminati, CERN.

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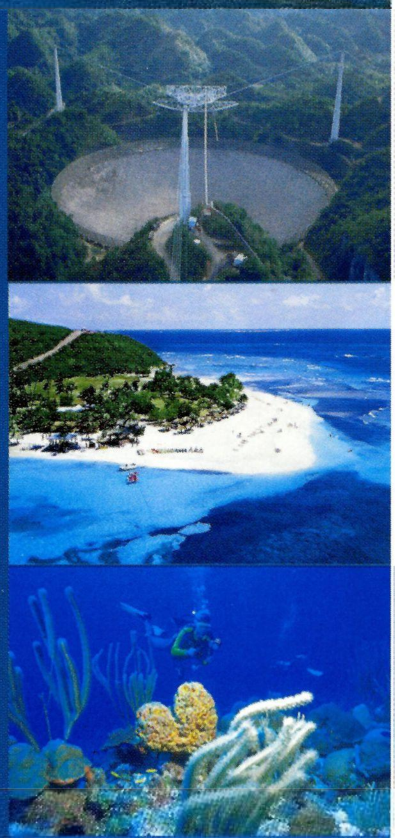

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