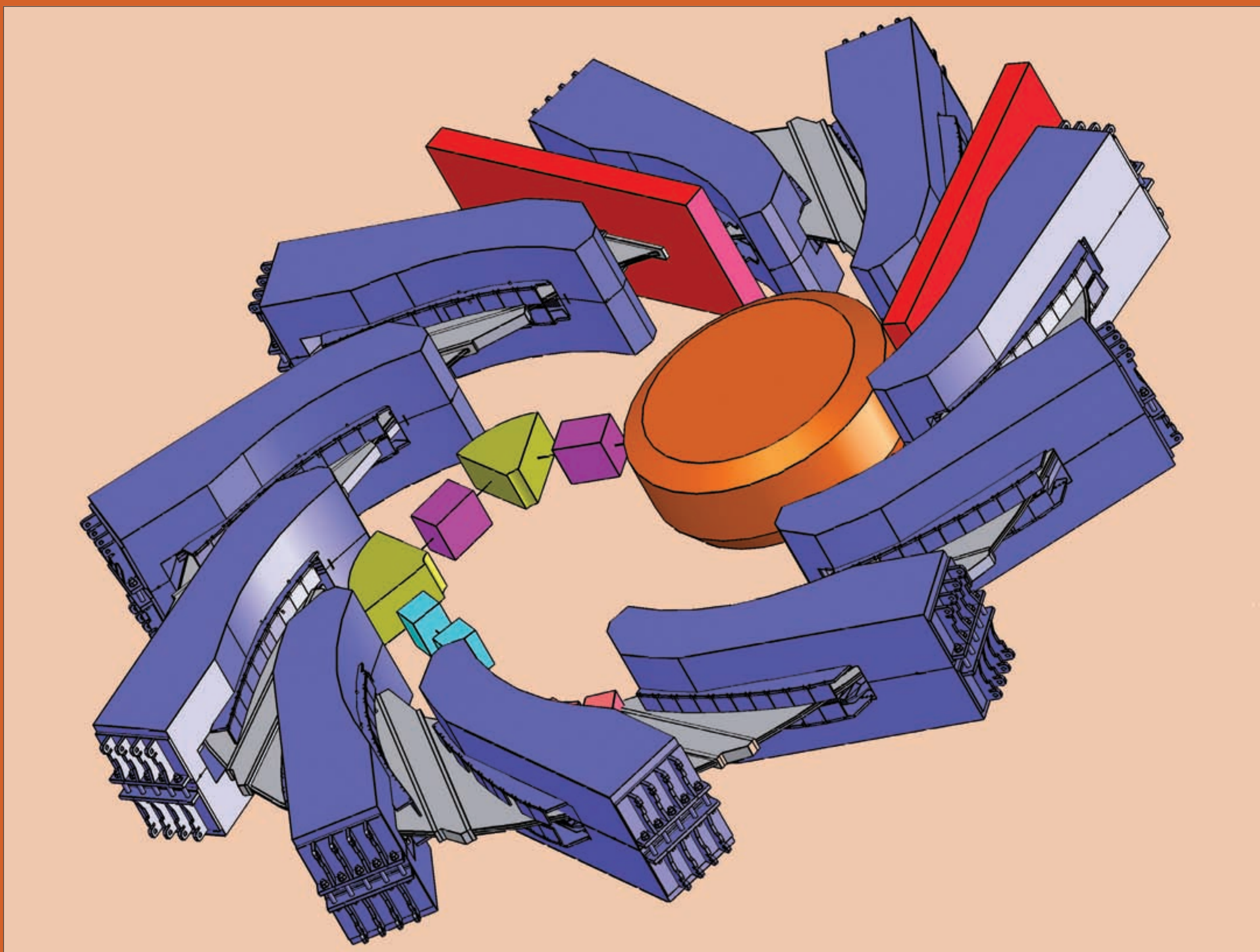
INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

CERN COURIER

VOLUME 48 NUMBER 7 SEPTEMBER 2008



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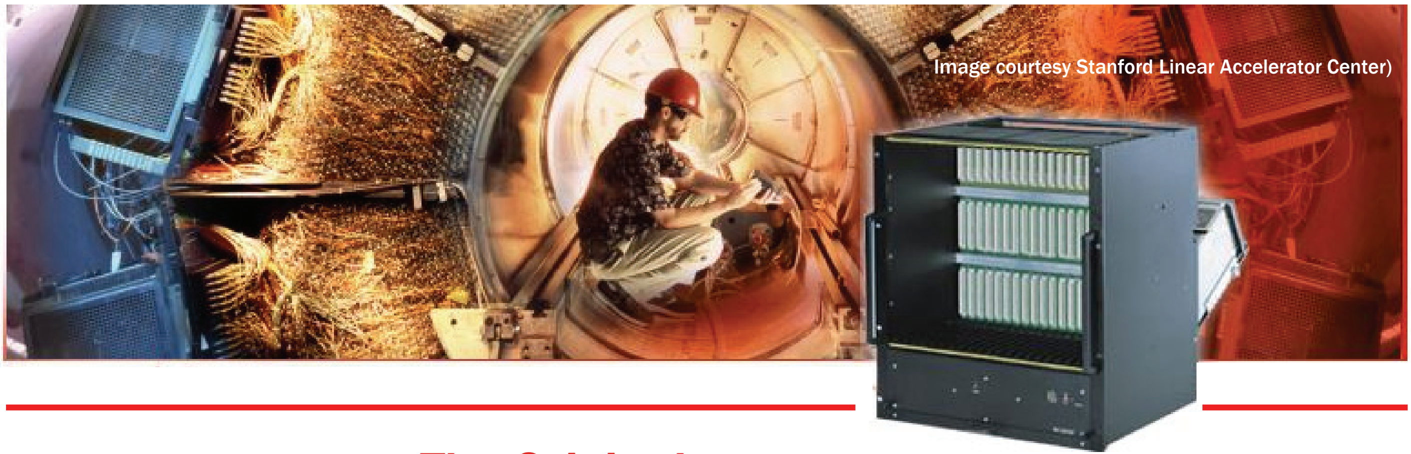

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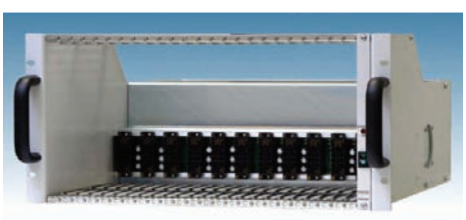

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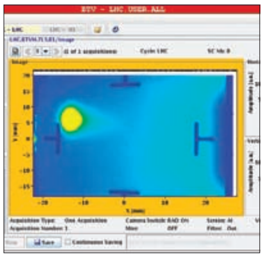

Counting down to the LHC p5

Laureates foresee LHC magic p30

Gas detectors prove worthy p35

Cover: Design of a variable-energy proton medical facility, based on an injector cyclotron followed by a spiral lattice fixed-field alternating-gradient (FFAG) ring, for the Recherche en Accélérateurs et Applications Médicales project (p21). (Courtesy SIGMAPHI Vannes.)

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

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Editor Christine Sutton
Editorial assistant Carolyn Lee
CERN, 1211 Geneva 23, Switzerland
E-mail cern.courier@cern.ch
Fax +41 (0) 22 785 0247
Web cerncourier.com

Advisory board James Gillies, Rolf Landua and Maximilian Metzger

Laboratory correspondents:
Argonne National Laboratory (US) Cosmas Zachos
Brookhaven National Laboratory (US) P Yamin
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IOP Publishing Ltd, Dirac House, Temple Back, Bristol BS1 6BE, UK
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Publisher Jo Nicholas
Art director Andrew Giaquinto
Production editors Lizi Brown, Jesse Karjalainen
Technical illustrator Alison Tovey
Advertising manager Ed Jost
Recruitment advertisement manager Moo Ali
Advertisement production Katie Graham
Marketing executive Anastasia Ireland

Advertising
Tel +44 (0)117 930 1026 (for UK/Europe display advertising), +1 215 627 0880 (for North American display advertising), or +44 (0)117 930 1027 (for recruitment advertising); e-mail sales@cerncourier.com; fax +44 (0)117 930 1178

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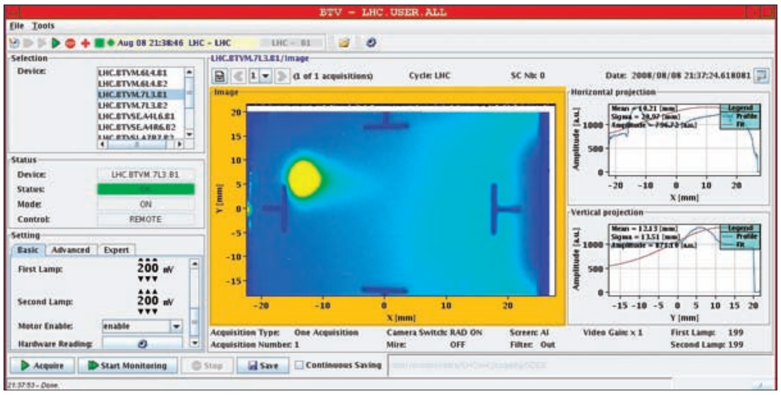
NEWS

CERN

LHC: countdown to beam begins



Particles in the LHC. The yellow spot shows a bunch of protons arriving at point 3 of the LHC ring on the very first attempt during synchronization tests on 8 August.

As the cool-down phase of commissioning the LHC came towards a successful conclusion at the beginning of August, CERN announced that the first attempt to circulate a beam in the LHC will be made on 10 September. The announcement was soon followed by the first sight of protons – albeit a small number – in the LHC during tests to synchronize the LHC's clockwise beam transfer system.

The LHC is unlike any other particle collider, being the first to have two beams of particles travelling in opposite directions in separate channels within the same magnetic structure, and it is the first to operate with superfluid helium at 1.9 K. It truly is its own prototype.

Starting up a machine like this is not as simple as flipping a switch. Commissioning is a long process that starts with the cooling down of each of the machine's eight sectors. This is followed by electrical testing of the 1600 superconducting magnet systems, and their individual powering to nominal operating current. Once these steps are completed, the powering together of all the circuits of each sector can begin. Only then can the eight independent sectors be powered up in unison to operate as a single machine.

There are around 1400 tests of varying complexity to be performed on each sector after it reaches 1.9 K. These include: electrical quality assurance to check that all the wiring is in place after the magnets have contracted during cool down; individual testing of protection systems; and power testing. These tests are done by the Operations Group together with teams of equipment experts from the Accelerators and Beams, Accelerator Technology and Technical Support Departments. A dedicated hardware commissioning team coordinates this effort.

After all these tests have been completed, the sectors are then handed over to the Operations Group to commence "dry runs", where the machine is run as it would be with the beam. There are also safety tests that must be done before the beam can circulate, to prevent people from being in the tunnel at the same time as the beam.

By the end of July, this work was approaching completion, with the whole machine fully loaded with 130 tonnes of liquid helium for the first time, and the final commissioning of the hardware progressing apace. All eight sectors were at or close to the operating temperature of 1.9 K required to reach the high magnetic-field strengths necessary to bend the beams at 7 TeV.

The next phase in the process is the synchronization of the LHC with the SPS accelerator, which forms the last link in the LHC's injector chain. Timing between the two machines has to be accurate to within a fraction of a nanosecond. The synchronization of the LHC's clockwise beam-transfer system was successfully achieved on the weekend beginning 8 August, when a single bunch of protons was taken down the transfer line from the SPS accelerator to the LHC. After a period of optimization, one bunch was kicked up from the transfer line into the LHC beam pipe and steered about 3 km around the LHC itself on the first attempt. The following day, the test was repeated several times to optimize the transfer before the Operations Group handed the machine back for hardware commissioning to resume. The anti-clockwise synchronization systems will be tested over the weekend of 22 August.

These tests will prepare the LHC for the first circulating beam on 10 September at the injection energy of 450 GeV. Once stable circulating beams have been established they will be brought into collision, and the final step will be to commission the LHC's acceleration system to boost the energy to 5 TeV per beam – the target energy for 2008. The decision to run the LHC at 5 TeV rather than 7 TeV this year is related to the need to re-train the superconducting magnets in the tunnel to reach the nominal field after some "de-training" occurred during transport and installation.

Sommaire

FERMILAB

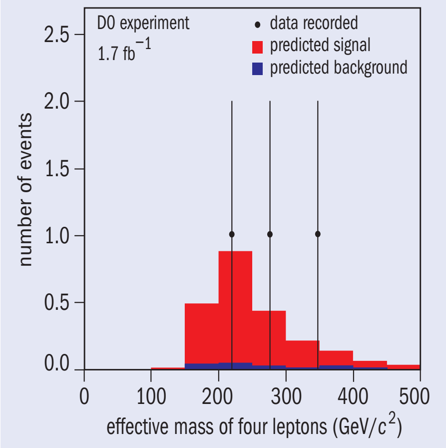
D0 snares last rare boson pair

The D0 collaboration at Fermilab has announced the observation of pairs of Z bosons produced in proton–antiproton collisions. This is the final and rarest state in the series of gauge boson pairs observed and studied by D0 and the CDF experiment at the Tevatron: Wγ, Zγ, WW, WZ and ZZ. Earlier this year CDF published evidence for ZZ production, but the D0 results presented on 25 July showed for the first time sufficient significance to rank as an observation.

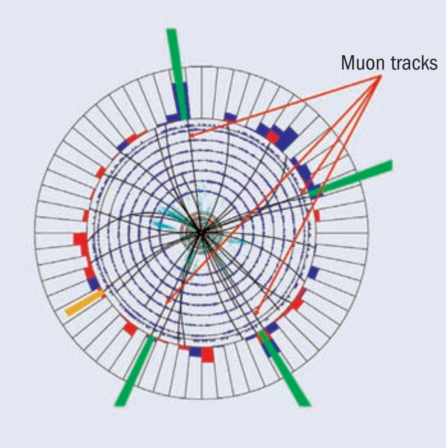
D0 observed ZZ production in 2.7 fb^{-1} of data with a combination of two analyses that look for Z decays into different final states. One analysis looked for a Z decaying into two electrons or two muons, the other for a Z decaying into neutrinos. The neutrino signature is challenging experimentally, but worthwhile to pursue because it occurs relatively frequently, although even this decay signature is predicted to occur less than once every 10^{12} collisions. The process of both Zs decaying to either electrons or muons is an even rarer process. In this analysis, three candidate events were observed with an expected background of less than 0.2 events. The statistical significance of the combined analysis is 5.7 σ, which firmly establishes the discovery of ZZ production at the Tevatron.

D0 measured a cross section for ZZ production of 1.5±0.6 pb, which is in excellent agreement with the prediction of the Standard Model. This is important as Z bosons in the Standard Model do not couple directly to one other. A higher rate would have implied anomalous self-couplings.

The observation of ZZ is connected with the search for the Higgs boson in several ways. The next rarest diboson production processes after ZZ are those involving Higgs bosons; seeing ZZ is an essential step in demonstrating the ability of an experiment to see the Higgs. Pairs of Z bosons also constitute one of the backgrounds to Higgs searches. At small values of the Higgs mass, ZZ can mimic the signature for a Higgs boson produced in association with a Z boson. At large values of the Higgs mass, the Higgs can decay into WW or ZZ. In more ways than one, ZZ observation is an essential prelude to finding, or excluding, the Higgs boson at the Tevatron.



Distribution of the four-lepton invariant mass in data, expected signal and expected background for a cross section of 1.6 pb.



One of the three ZZ events recorded by the D0 experiment. Each Z has decayed into a pair of muons, yielding four muon tracks in the detector.

Further reading

V Abazov *et al.* 2008 subm. *Phys. Rev. Lett.*, arxiv.org/abs/0808.0703v1.

SPECTROSCOPY

BaBar gets right to the bottom

The BaBar collaboration, working at SLAC has observed the ground state of the bottomonium family, the η_b meson. Bottomonium particles are bound states of a bottom quark and its antiquark. The first such state, the $\Upsilon(1S)$, was discovered 30 years ago and revealed the existence of the bottom quark. Physicists have been searching for the lowest-energy state of the system ever since.

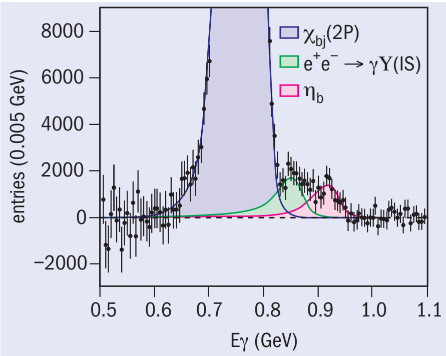
The η_b was observed in the energy distribution of the photons produced in the radiative decay of the $\Upsilon(3S)$. The two-body decay, $\Upsilon(3S) \rightarrow \gamma\eta_b$, produces a monochromatic line with an energy that can be used to determine the η_b mass. The crucial point of the analysis was to understand the photon backgrounds, especially those that form peaks in the spectrum. These include photons emitted in radiative processes such as $e^+e^- \rightarrow \gamma\Upsilon(1S)$, which produces photons with energies close to the expected η_b signal, and transitions to intermediate bottomonium states, $\chi_{bJ}(2P)$.

The team used more than 100 million

Υ(3S) events produced from e^+e^- collisions recorded with the BaBar detector at the PEP-II accelerator. These data were recorded in the final data-collection run of the experiment in 2008. After the analysis selection, approximately 19 000 η_b candidates were identified as forming a peak in the photon-energy spectrum at 921.2 MeV. The significance of this peak is 10 σ.

The corresponding mass of the η_b is 9388.9+3.1-2.1±2.7 MeV/c^2, giving a hyperfine mass splitting of 71.4+2.3-3.1±2.7 MeV/c^2 between the Υ(1S) and the η_b. This measurement represents the first experimental data on hyperfine mass-splittings in the heaviest meson system, and will allow for more precise tests of the role of spin–spin interactions in QCD.

The BaBar collaboration expects to release further results on bottomonium spectroscopy in the near future.



First signs of the η_b in data from BaBar.

Further reading

B Aubert *et al.* 2008 subm. *Phys. Rev. Lett.*, arxiv.org/abs/0807.1086.

COLLIDERS

BEPC II celebrates the first collision events

Champagne-bottle corks popped early on the morning of 20 July, as researchers at the Institute of High Energy Physics (IHEP) in Beijing celebrated the observation of the first particle collisions in the upgraded Beijing Electron Positron Collider (BEPC II) and the new Beijing Spectrometer, BES III. Although BEPC II and BE III had already been carefully tested separately, this was the first time that they had operated together.

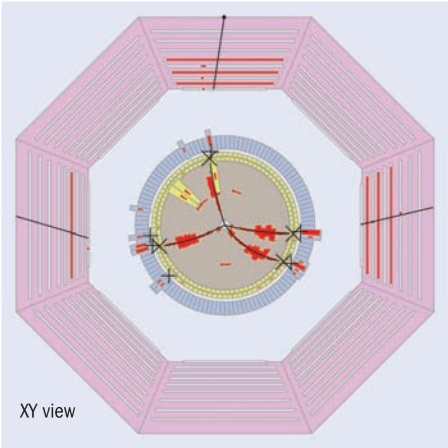
The first collisions, occurring late the previous afternoon, represent a new milestone for the project, which was nearly four years in planning and took another four and half years to construct. When fully operational, the BEPC II/BES III complex will be the world's premier facility for studying properties of charmed mesons and τ leptons.

BEPC II is a major upgrade of IHEP's previous e^+e^- collider, BEPC. The major change has been the addition of a second ring of magnets that allows the electron and positron beams to be stored separately. In the original machine, the electrons and positrons shared the same vacuum tube in a single ring of magnets, which limited the intensities of each beam and, therefore, the luminosity. The two separate rings of BEPC II will allow 93 bunches of electrons to collide with 93 bunches of positrons, with an expected increase in collision rate of more than 100-fold. Other improvements include a more powerful injection linac for electrons and positrons, and extensive use of superconducting technology, both for the RF-accelerating cavities and for the magnetic final focusing of the stored beams as they enter the interaction region.

The BES III detector in the interaction region of BEPC II. (Courtesy BES III/IHEP.)

The linac upgrade was finished in late 2004 and quickly reached its design goals. With the exception of the conventional focusing magnets in the interaction region, construction of the double rings was completed in October 2006. Beams were first stored the following month and synchrotron radiation running commenced soon after. The first collisions using conventional final-focus magnets were produced in March 2007 and collisions with the superconducting final-focus magnets followed in November, achieving 500 mA on 500 mA beam–beam collisions with a luminosity higher than $1 \times 10^{32}\ cm^{-2}s^{-1}$.

The assembly of the BES III detector was completed in January 2008 and it was moved into the interaction region in early May. A major improvement in this detector over its predecessor, BES II, is the huge superconducting solenoid magnet with a central field of 1 T. This magnet – the most powerful magnet in China – was built at IHEP by the laboratory's research staff. Together with the new helium gas-based tracking chamber, it provides a factor of five improvement in charged-particle momentum resolution over BES II. In addition, BES III contains an array of 6240 caesium iodide crystals to measure the energies of high-energy electrons and gamma rays. The crystal calorimeter provides



The first candidate charmed-meson pair event seen in BES III. The red slashes straddling some portions of the tracks indicate wire hits in small-angle-stereo layers. The yellow boxes are time-of-flight counters and the blue trapezoids indicate caesium iodide crystals in the barrel. The outer layers show muon chambers in the magnet yoke.

more than a factor of 10 improvement in the precision of measurements of electromagnetic shower energies.

To handle the huge, LHC-scale data rates expected when BES III operates at the J/ψ peak, the team has developed a specialized state-of-the-art, high-speed data-communication system. The figure (p7) shows an event display of the first candidate charmed-meson pair event in BES III, demonstrating that the detector and its associated software are performing well.

During the Saturday-night/Sunday-morning test run, operation of BEPC II proved stable, with a luminosity that hovered around $10^{30}\ cm^{-2}s^{-1}$, about a factor of 1000 times below the project's ultimate design goal of $10^{33}\ cm^{-2}s^{-1}$. This was partly because the operators used a 1-bunch-on-1-bunch collision mode to limit the intensity of the beam currents, avoiding possible damage to the sensitive detection elements of the BES III spectrometer, while the team also made sure that everything worked as expected. The next day, 20-bunch-on-20-bunch operation was quickly established, with a much higher luminosity. So far the beam-associated radiation background in the detector is manageable, even with the increased currents. During the coming months the intensity of the beams will be gradually increased while BES III's 2000 detection elements will be carefully adjusted and calibrated. When this process is completed, sometime in the early autumn, the BES III research programme will begin.

● BES III is run by a team from China, Hong Kong, Germany, Japan, Russia and the US.

DUBNA

GDE looks at proposed ILC site in Russia

JINR, Dubna, was host to the latest in the general meetings of the Global Design Effort (GDE) for a future International Linear Collider (ILC). The workshop on ILC Conventional Facilities and Siting (CFS) took place between 4–7 June 2008. It provided the opportunity for GDE members to take a look at the potential site near Dubna, first proposed in 2006.

The meeting focused on issues surrounding conventional facilities, such as water cooling and other cost drivers, which in turn depend on the eventual siting of a high-energy linear collider. (The conventional facilities account for about a third of the total estimated cost.) Parallel sessions at the workshop aimed at understanding the potential impact on the cost of various solutions, both for the current ILC Reference Design and alternative scenarios. The workshop also included discussions of CFS issues for a Compact Linear Collider, to try and identify common cost-effective solutions for both machines.

In preparing the reference design report issued in 2007, the GDE considered a deep site, about 100 m below ground. To proceed with the reference design, the GDE had asked the regional subgroups for "sample sites" in the three regions: the Americas, Asia and Europe; all three were deep. By contrast, the proposal submitted for the GDE's consideration by Grigory Shirkov, ILC project leader and chief engineer at JINR, is for a shallow site, requiring the construction of only one tunnel instead of two. This plan, which resulted from the joint discussions between JINR and the State Specialized

GDE workshop participants in Dubna also had a chance to see the potential site by air. (Courtesy JINR.)

Design Institute in Moscow, has a tunnel 20 m below ground in a thick layer of dry soil (loam). The collider infrastructure can be installed at or near the surface, avoiding the need for a second service tunnel. The region is seismically stable within almost 50 km of the site proposed for the collider and is practically uninhabited. The participants of the meeting had a chance to look at the suggested area from a helicopter, offered by the governor of the Moscow region, Boris Gromov.

While at Dubna, GDE members also met with representatives of the Russian State Project Institute, Moscow, which has a long history of designing and constructing nuclear power stations, nuclear centres and scientific accelerator centres, including those at JINR and at the Institute for High Energy Physics in Protvino. Discussions are now under way on work towards more detailed studies, including drilling a 1.6 m borehole near the proposed location of the interaction region. In addition to the Dubna site, the GDE plans to study other possible shallow sites, for example in a desert, and to study further the engineering options in deep sites, with a view to minimizing costs.

● For more about the Dubna site, see http://www.linearcollider.org/cms/?pid=1000548.

LINACS

PHIL: a new test facility for LAL

A new linac test facility is under construction at the Laboratoire de l'Accélérateur Linéaire (LAL), Orsay. The primary goal of the accelerator, called PHIL, is for testing photo-injection as part of research and development of advanced RF guns. The size of the machine is modest in comparison with the Photo Injector Test Facility at DESY Zeuthen (PITZ) or the CLIC Test Facility (CTF3) at CERN (p15). However, PHIL will also be used to train students and engineers, and the facility will be open to physics experiments that need low-energy, well-defined electron beams for detector calibration.

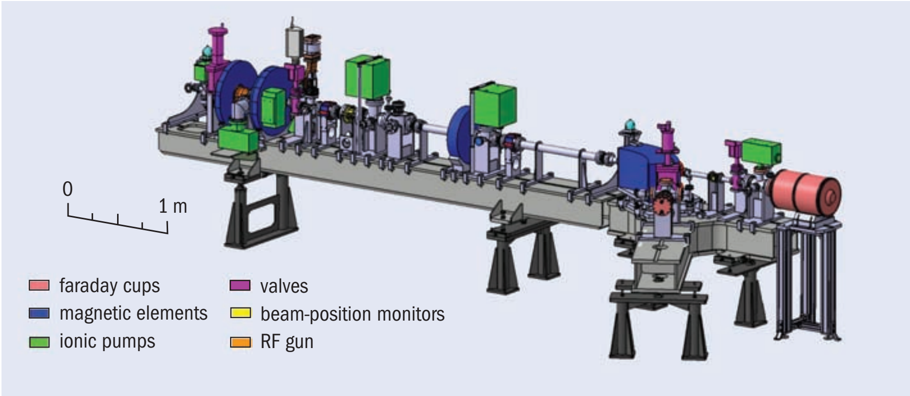
As civil engineering was required to reinforce the existing shielding to comply with current radiation safety requirements, the machine has been delayed and is now being constructed in two phases. Phase 0 consists of an RF gun with a copper photocathode, vacuum chambers, pump system, all magnetic elements, a dipole to analyse the energy distribution, and standard instrumentation (see figure). It uses a temporary 2.5 cell RF gun fed by a co-axial "doorknob" coupler. This is a copy of the gun constructed by LAL for the ALPHA-X accelerator at the University of Strathclyde in the UK.

For Phase I the laboratory will install a booster to bring the beam energy to 10 MeV and increase the diagnostic facilities. In parallel, a new RF gun will be constructed with a high-efficiency caesium-telluride photocathode prepared *in situ* in a special vacuum chamber. This will be directly derived from the type IV gun for CTF3.

The photocathodes in the new facility are illuminated by a Nd:YLF picosecond mode-locked laser, which delivers a single pulse at 5 or 10 Hz and is used on the fourth harmonic at 262 nm wavelength. The laser pulse-to-pulse stability is close to 1% for approximately eight hours. The optical path length is approximately 17 m and the laser light is injected at nearly normal incidence on the photocathode. Different spot sizes are obtained by changing the position of the last lens.

The table above summarizes the technical specifications for PHIL; in addition, the RF frequency is 2.998 MHz and the repetition rate limited to 10 Hz. A dedicated area of 20 m^2 for physics experiments has been planned at the downstream end of the accelerator.

All the infrastructure, water cooling, cabling, magnetic elements, RF gun, RF network and RF source are now ready and commissioned for Phase 0, and the control room is available and the software is in the process of completion. The main task remaining is the installation of the laser line optics. RF tests and conditioning should take place just after the summer shut down. The French radiation authority (Autorité de sûreté nucléaire) has authorized LAL to produce a first test beam run and, after a radiation control, the laboratory should obtain the permanent authorization for routine operations before the end of the year.



Schematic view of the new LAL beam line, phase 0, designed for testing photo-injection techniques.

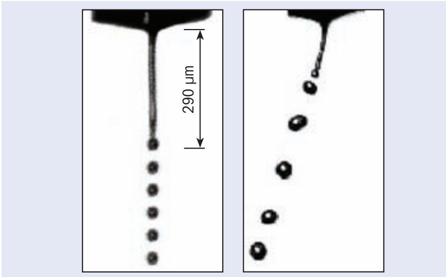
Table	Phase 0	Phase 1
Energy (MeV)	**6**	**10**
Charge (nC)	0.1	3
Rms bunch length (ps)	4	4
Rms energy spread(%)	0.3	<2
Normalized emittance (πmmmrad)	1	<20

PELLET TARGETS

Cryogenic jets defy Rayleigh's theory

Many technical and scientific applications, such as experiments with internal targets at particle accelerators, require the transport into an interaction zone of substances that are gaseous at room temperatures. At the same time, the pressure in the surrounding vacuum chamber must be kept as low as possible. One solution to this technological challenge are the so-called frozen-pellet targets, which provide fluxes of solid pellets produced from H_2, N_2, Ar or Xe, for example, with diameters in the 10 μm range. A new development not only provides more stable, narrow jets but also reveals some new phenomena in the process

The central part of such a target is a "triple-point chamber", where a jet of a cryogenic liquid is injected through a nozzle (with diameter roughly equal to the pellet diameter) into the same gaseous material close to triple-point conditions. Periodic excitation of the nozzle imposes oscillations along the jet's surface; the jet then disintegrates into drops downstream of the nozzle when the perturbation amplitude becomes equal to the radius of the jet. The drops then pass through a thin tube into vacuum. As they do so, they cool by surface evaporation to below melting point, producing a regular flux of stable frozen pellets.



First observation of satellite-free disintegration of a cryogenic jet in nitrogen (left). At low pressures the jets bend, spontaneously breaking the axial symmetry of the setup (right).

To produce narrow (diameters well below 1 mm), stable fluxes of pellets of the same size (monodisperse), the drop-production process must be carefully optimized and the production of satellite drops of varying size suppressed. Now a group from Forschungszentrum Jülich, Moscow's Institute for Theoretical and Experimental Physics, and the Moscow Power Engineering Institute has done just this with a patented cooling method that suppresses unwanted nozzle vibrations.

The team's technique has led to some surprising new findings. The breakup of jets of H_2 and N_2 reveals deviations from linear behaviour, indicating that Rayleigh's well established theory formulated in 1878 is not appropriate for thin jets that exchange energy and/or mass with the surrounding medium. Another new phenomenon, for which there is not even a rudimentary theoretical explanation, are jet modes where the axial symmetry of the dynamics is lost (see figure 1).

Further reading

A V Boukharov *et al.* 2008 *Phys. Rev. Lett.* **100** 174505.

NUCLEAR PHYSICS

Neutron-rich nuclei reveal new secrets

Two research teams at Michigan State University's National Superconducting Cyclotron Laboratory (NSCL) have reported fresh findings about neutron-rich nuclei. In separate experiments, groups measured a critical energy gap in oxygen nuclei and achieved their first-ever success using a new technique for finding isomers.

One important area of study with these nuclei focuses on the neutron drip line – the limit in the number of neutrons (N) that can bind to a given number of protons (*CERN Courier* December 2007 p37). For oxygen, that line was known to lie at 16 neutrons, and indeed indicated a new shell closure at N=16 in neutron-rich nuclei. However, theoretical calculations disagreed on the difference in binding energy between ^{24}O, with a closed shell of 16 neutrons, and ^{25}O, the first isotope beyond the drip line – in other words, the binding energy of the 17th neutron.

Calem Hoffman from Florida State University and colleagues have now pinpointed this quantity. The group used the NSCL's coupled cyclotrons to accelerate a beam of ^{26}F onto a fixed target, where they observed ^{25}O for the first time. The ^{25}O decays too quickly for direct detection, but the group was able instead to track its decay products: ^{24}O and a single free neutron, measured with the Modular Neutron Array. The team then used the angles, energies and momenta of the decay products to calculate the mass of the ^{25}O, which in turn allowed them to infer the difference in binding energy from ^{24}O, and ultimately the N=16 shell gap, which they find to be 4.86(13) MeV (Hoffman *et al.* 2008).

The second experiment, conducted by NSCL's Georg Bollen and colleagues, focused on nuclear isomers, in which neutrons are excited to a higher-energy arrangement for anywhere from fractions of a second to years. The team has discovered a previously unknown isomer of ^{65}Fe, a nucleus that is intriguing for its proximity in terms of proton and neutron numbers to ^{68}Ni, a particularly enigmatic isotope. ^{68}Ni displays some characteristics of doubly magic nuclei, but nuclei with slightly fewer protons and neutrons than ^{68}Ni reveal pronounced changes in structure – which generally is not the case for isotopes near others that are doubly magic. Researchers have little idea what is happening in this nuclear region, and so are keen to make more measurements.

These nuclei are a target for the Low Energy Beam and Ion Trap (LEBIT), which experimenters at NSCL use to collect high-speed products of cyclotron-spawned collisions. After firing a beam of germanium nuclei into a thin target, Bollen's team captured the products in LEBIT and directed them into a Penning trap, allowing them to make very precise mass measurements of the particles caught. The team measured two distinct masses for ^{65}Fe, indicating nuclei with different energy states – one the ground state and one a novel isomer at an excitation energy of 402(5) keV (Block *et al.* 2008) This is the first use of Penning trap mass spectrometry of this kind. Previous isomer studies have instead employed gamma-ray spectroscopy.

Further reading

M Block *et al.* 2008 *Phys. Rev. Lett.* **100** 132501.
C R Hoffman *et al.* 2008 *Phys. Rev. Lett.* **100** 152502.

SCIENCEWATCH

Compiled by Steve Reucroft and John Swain, Northeastern University

Frogs utilize ultrasonic skills

Everyone is familiar with the audible chirps and croaks of various frogs, but one particular tree frog in China turns out to be quite adept at using sound for localization, as Jun-Xian Shen of the Chinese Academy of Sciences in Beijing and Albert Feng of the University of Illinois at Urbana-Champaign and colleagues have discovered. Moreover, the same species can also tune its ear to different frequencies.

Females of the concave-eared torrent frog (*Odorrana tormota*), which lives around noisy rivers at the Huangshan hot springs, make chirps in the range 7.2–9.8 kHz, with harmonics up into the ultrasonic region to let males know they are ovulating. Males can locate them with an astonishing precision of less than 1°; a feat of localization comparable to dolphins, barn owls, elephants and humans (Shen *et al.* 2008).

In related studies, with Marcos Gridi-Papp of the University of California, Los-Angeles, Feng and colleagues examined the eardrums of the same species to examine whether they actually vibrate at the ultrasonic frequencies. What they found surprised them: it turns out that the frogs can deselect their sensitivity to ultrasound. Further studies revealed that when the Eustachian tubes in the frog's ears are closed, their ears are sensitive to high frequencies, but when the tubes are open the eardrums respond to low-frequency sounds (Gridi-Papp *et al.* 2008).

This remarkable frog, Odorrana tormota, *can tune in to ultrasound and use it to locate mates with great precision. (Courtesy Albert Feng.)*

Further reading

Jun-Xian Shen *et al.* 2008 *Nature* **453** 914.
Marcos Gridi-Papp *et al.* 2008 *PNAS* **105** 31 11014.

Spins entangle in room-temperature diamond

Dreams of a quantum computer all require a means to control and maintain entangled bits for long periods of time, a feat that is often imagined to require cryogenic temperatures. Now P Neumann of the University of Stuttgart and colleagues have shown that entangled states of two and three spins of carbon-13 nuclei can be maintained in diamond.

The researchers find that they can control the entangled states through their coupling to an electron in a nitrogen vacancy (a spot in the crystal where a nitrogen atom displaces one of the carbons). All this is at room temperature and over millisecond time scales. The dreams of a quantum computer just possibly have come a little closer to one day becoming a reality.

Further reading

P Neumann *et al.* 2008 *Science* **320** 1326.

Measuring fine structure by eye

There are only a handful of parameters that are known that depend on fundamental constants, and not on the details of a material sample. Now, joining the list of quantities such as the resistivity quantum and magnetic flux quantum is the opacity of suspended graphene, the material that consists of a one-atom-thick layer of carbon. R R Nair of the University of Manchester and colleagues have discovered that graphene's opacity depends only on the fine structure constant, α. They found that graphene absorbs about $\pi\alpha$, or 2.3% of incident white light, a result of the material's electronic structure. This leads to the surprising realization that the fine structure constant can essentially be measured by eye.

Further reading

R R Nair *et al.* 2008 *Science* **320** 1308.

Incense proves to calm the nerves

Frankincense – an aromatic tree resin – turns out to be more than just something that smells nice when burned. Arieh Moussaieff at the Weizmann Institute in Israel and colleagues have shown that one of the components of the resin, incensole acetate, has antidepressant and anxiolytic effects in addition to activating an ion channel related to the sensation of warmth in the skin. The same ion channel is also present in the brain, but its role there is not yet understood. After more than 4000 years of use, frankincense is starting to give up some of its secrets, and it looks as though its use by so many ancient cultures was far from accidental.

Further reading

Arieh Moussaieff *et al.* 2008 *The FASEB Journal* doi:10.1096/fj.07-101865.

Is non-Gaussianity set to spell trouble for cosmic inflation?

Inflation – the idea that the universe underwent an early period of extremely rapid expansion – may be in trouble. Amit Yadav and Benjamin Wandelt at the University of Illinois at Urbana-Champaign looked at the local non-Gaussianity of the temperature anisotropy of the cosmic microwave background using data from the Wilkinson Microwave Anisotropy Probe.

They discovered a value between 50 and 80 for the parameter f_{NL}, which describes this non-Gaussianity, with a disagreement of some 2.5 σ from the value between 0 and 1 that is expected in the simplest inflation models. Further data coming from the ESA's Planck satellite could make the result unambiguous and put significant pressure on inflationary models.

Further reading

A P S Yadav and B D Wandelt 2008 *Phys. Rev. Letts.* **100** 181301.

Compiled by Marc Türler, ISDC and Observatory of Geneva University

Polarization brings to light the accretion discs inside quasars

The extreme luminosity of quasars is thought to be generated by supermassive black holes accreting surrounding material at the heart of galaxies. If the accretion has a preferred rotation axis, the infalling gas and dust should eventually form an accretion disc round the black hole. An accretion disc is far too small for such distant objects to be seen in an image, but even its expected spectral characteristics have hitherto not been identified. A new study can now disentangle accretion-disc emission from that of dust, using infrared polarization measurements.

Quasars are the most luminous persistent sources of radiation in the universe. They radiate about 1000 times as much energy as all of the stars in their host galaxy. Such extreme luminosities can be achieved by the accretion of matter by a supermassive black hole. Gravitational accretion is indeed much more effective in radiating energy – typically about 10% of the accreted mass-energy – than the modest 0.7% yields of hydrogen fusion in stars. The accretion could be chaotic with no preferred direction, but the presence of jets stretching over millions of light-years in some quasars indicates a preferred direction, defined by the spin axis of the black hole and/or the rotation axis of an accretion disc (*CERN Courier* July/August 2006 p10).

Looking at sunset on Mauna Kea through the infrared polarimeter. (Courtesy UKIRT.)

Nikolay Shakura and Rashid Sunyaev derived the expected emission from an optically thick accretion disc back in 1973. The temperature gradient from the hot inner disc regions to the cooler external parts is expected to emit a spectrum characterized by a spectral index of +1/3 ($F_\nu \propto \nu^{+1/3}$), whereas the optical-ultraviolet spectra of quasars have an observed slope in the −0.2 and −1.0 range. This excess of emission in the red part of quasar spectra remained a puzzle for 35 years. Although it was usually ascribed to additional dust emission, it prevented astronomers from finding evidence for the accretion-disc origin of the dominant optical-ultraviolet emission of quasars.

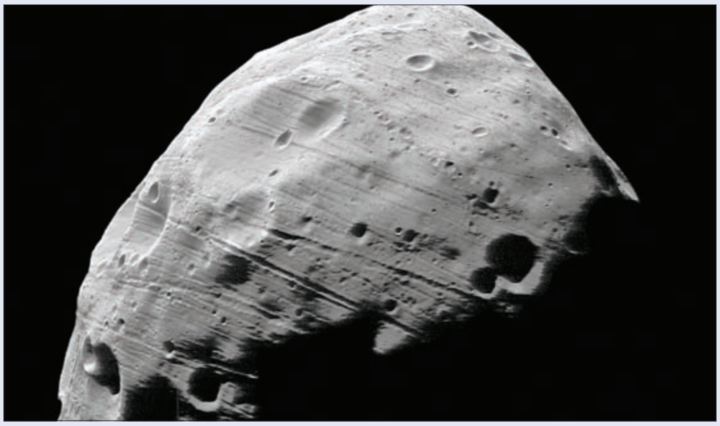
An international team of astronomers led by Makoto Kishimoto from the Max-Planck-Institut für Radioastronomie in Bonn and the Royal Observatory of the University of Edinburgh, has now found the characteristic spectral signature of an accretion disc in six quasars. It discovered a spectral slope consistent with the expected +1/3 index in the polarized near-infrared emission of these quasars. The team argues that the emission of the accretion-disc is revealed in polarized light because it is scattered by free electrons in the near vicinity of the black hole, whereas the emission of surrounding dust clouds is not scattered and thus not polarized. The infrared polarization observations have been made with the infrared polarimeter mounted on the UK Infrared Telescope on Mauna Kea in Hawaii.

These results provide evidence that the controversial accretion disc is truly there in quasars and has the expected properties in its outer regions where the observed infrared emission is thought to originate. The optical-ultraviolet emission from the inner regions of the disc closer to the black hole is, however, not yet well understood.

Further reading

M Kishimoto *et al*. 2008 *Nature* **454** 492.

Picture of the month



Does Mars have a moon? Yes, actually two moons, called Phobos and Deimos. However, they are tiny compared with our Moon and are more than likely objects from the asteroid belt extending between the orbit of Mars and Jupiter that ventured too close to the red planet and became trapped in its gravitational potential well. This new image captured by ESA's Mars Express mission shows the surface of Phobos in unprecedented detail. It was acquired by the high resolution stereo camera on 23 July 2008 at a distance of only 97 km. The irregular shape of this moon, which measures less than 30 km in any direction, is further altered by craters and grooves. The latter could be produced by ejecta thrown up from impacts on Mars or by soil slipping into internal fissures. (Courtesy ESA/DLR/FU Berlin (G Neukum).)

CERN COURIER ARCHIVE: 1965

A look back to *CERN Courier* vol. 5, September 1965, compiled by Peggie Rimmer

THE PROTON SYNCHROTON

The problem of CP invariance

A new experiment is being carried out at the end of the q_3 beam line. It is one of many in progress or planned in different laboratories to investigate the problem of CP invariance – roughly speaking, whether an antiparticle going backwards obeys the same rules as the corresponding particle going forwards. Interest in this problem is reflected in the presence already of four different groups around the PS engaged in related experiments.

From an observational point of view, there appear to be two neutral kaons, one with a comparatively long lifetime (5×10^{-8} s), called $K^0(L)$, the other with a shorter lifetime (10^{-10} s), known as $K^0(S)$. Until last year, the latter was identified with a particular combination of kaon and antikaon known as K^0_1, whilst the former was taken to be an associated combination called K^0_2 and the experimental observations were explained within the current theoretical framework.

This situation was rudely shattered by the discovery at Brookhaven that the longer-lived kaon sometimes decayed in a way thought to be possible only for the $K^0(S)$. After experiments at CERN and the Rutherford Laboratory (UK) had confirmed this fact and also ruled out the possibility that it could be caused by a particular kind of very weak but long-range cosmological force, attention turned more strongly to the idea that the law of CP invariance is in fact violated in this decay. If such is the case, the long-lived state $K^0(L)$ no longer has to be the "pure" state K^0_2 but can be a mixture of K^0_2 (CP = −1) and K^0_1 (CP = +1). It follows that interference should be observed between this K^0_1 component (which decays into two pions) and the "regenerated" K^0_1 mesons formed by passage of the K^0_2 component through matter. Evidence for such an effect was indeed obtained recently by the Princeton/Brookhaven group that made the original discovery.

Although the evidence now points strongly to an actual violation of the CP-invariance law, the source of the violation is still not at all clear.

For example, it seems that it could equally well be a direct result of a particular kind of weak interaction or an indirect result of the strong or electromagnetic interaction. Among the many ideas that have been put forward, some link the problem with the work on various particle classification schemes (SU_6 and so on), the general idea being that the same "force" that causes the particles of a given multiplet to have different masses, instead of one single mass, might give rise to small violations of the symmetry laws in some interactions.

Careful examination of the evidence for the symmetry laws has also shown that it is mostly indirect and a number of crucial experiments have been suggested to clear up the uncertainties.

High-intensity beam

The muon storage ring at the end of the South hall, photographed during installation of the electron counters (inside the ring on the far side) and before the shielding roof was put into place.

For the first time, an external proton beam has been brought into an experimental hall. The h_3 beam stretches right across the South hall to the muon storage ring in the far west corner. At the end of the line the protons strike a target inside the muon storage ring, producing pions which decay to give muons which then perform many revolutions of the ring before they in turn decay. By detecting the decay electrons a measure can be obtained of the precession of the muon spin in the magnetic field of the ring and in this way it is hoped to obtain a new value for the anomalous magnetic moment (g-2) of the muon an order of magnitude more accurate than the existing one obtained at CERN in 1962. This will test still further the region of validity of quantum electrodynamics and perhaps give some clue to the solution of the muon-electron puzzle: why are these two particles apparently identical except for their mass?

● Compiled from "Last month at CERN" on pp 131,132 and 136.

COMPILER'S NOTE

The indirect CP violation referred to is the CP symmetry violation of the decaying particle itself. Direct CP violation occurs during the decay and is a property of the force causing the decay. More difficult to observe, direct CP violation was first seen in 1999 at CERN and Fermilab for K^0 mesons, which are mixtures of down and strange quarks and antiquarks. Then in 2004 it was found at SLAC and KEK in B^0 mesons (containing the heavier bottom quarks and antiquarks) in which the effect is 10 000 times stronger. Now the LHCb experiment at CERN is ready to extend our understanding of this fundamental asymmetry. As for the muon-electron puzzle, in the intervening years it has become the electron-muon-tau puzzle. The mass differences of these three leptons, with the astonishing ratio of 1:200:3500, is still unexplained. Has this to do with the Higgs field? The LHC has a lot of questions to answer!

CLIC here for the future

What will the future be for accelerator-based particle physics at the high-energy frontier? The Compact Linear Collider study is developing an innovative option for an electron–positron collider.

CERN's latest and foremost accelerator, the LHC, is set to provide a rich programme of physics at a new high-energy frontier over the coming years. From 2008 onwards, the LHC will probe the new "terascale" energy region. It should above all confirm or refute the existence of the Higgs boson of the Standard Model and will explore the possibilities for physics beyond the Standard Model, such as supersymmetry, extra dimensions and new gauge bosons. The discovery potential is huge and will set the direction for possible future high-energy colliders. Nevertheless, particle physicists worldwide have reached a consensus that the results from the LHC will need to be complemented by experiments at an electron–positron collider operating in the tera-electron-volt energy range.

The highest centre-of-mass energy in electron–positron collisions so far – 209 GeV – was reached at LEP at CERN. In a circular collider, such as LEP, the circulating particles emit synchrotron radiation, and the energy lost in this way needs to be replaced by a powerful RF acceleration system. In LEP, for example, each beam lost about 3% of its energy on each turn. The biggest superconducting RF system built so far, which provided a total of 3640 MV per revolution, was just enough to keep the beam in LEP at its nominal energy. Moreover, the energy loss by synchrotron radiation increases with the fourth power of the energy of the circulating beam. So it is clear that a storage ring is not an option for an electron–positron collider operating at an energy significantly above that of LEP, as the amount of RF power required to keep the beam circulating becomes prohibitive.

Linear colliders are therefore the only option for realizing electron–positron collisions at tera-electron-volt energies. The basic principle here is simple: two linear accelerators face each other, one accelerating electrons, the other positrons, so that the two beams of particles can collide head on. This scheme has certain inherent features that strongly influence the design. First, the linacs have to accelerate the particles in one single pass. This requires high electric fields for acceleration, so as to keep the length of the collider within reasonable limits; such high fields can be achieved only in pulsed operation. Secondly, after acceleration, the two beams collide only once. In a circular machine the counter-rotating beams collide with a high repetition frequency, in the case of LEP at 44 kHz. A linear collider by contrast would have a repetition frequency of typically 5–100 Hz. This means that the luminosity necessary for the particle physics experiments can be reached only with very small beam dimensions at the interaction point and with the highest possible bunch charge. As luminosity is proportional to beam power, the overall wall-plug to acceleration efficiency is of paramount importance.

Global collaborations are currently developing two different technologies for linear colliders, each with different energy reach. The International Linear Collider (ILC) collaboration is studying a machine with a centre-of-mass energy of 500 GeV and a possible future upgrade to 1 TeV. This study is based on an RF system using superconducting cavities for acceleration, with a nominal accelerating field of 31.5 MV/m and a total length of 31 km for a colliding-beam energy of 500 GeV. The Compact Linear Collider (CLIC) study is aiming at a nominal energy of 3 TeV, and foresees building CLIC in stages, starting at the lowest energy required by the physics, with successive energy upgrades. The CLIC scheme is based on normal conducting travelling-wave accelerating structures, operating at very high electric fields of 100 MV/m to keep the total length to about 48 km for a colliding-beam energy of 3 TeV. Such high fields require high peak power and hence a novel power source – an innovative two-beam system, in which a drive beam supplies energy to the main accelerating beam. Initiated at CERN, CLIC is now a joint effort by a collaboration of 26 institutes. Although the acceleration technologies for ▷

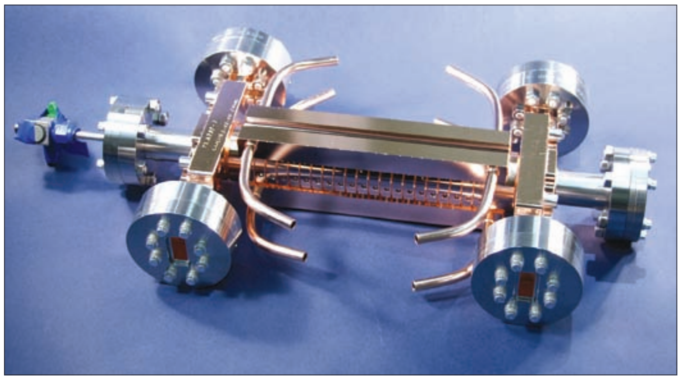


Fig. 1. An accelerating structure for CLIC that has been tested to 100 MV/m. Designed at CERN, the components were manufactured by KEK and the assembly and bonding as well as the testing with high-power RF was done by SLAC. (Courtesy SLAC.)

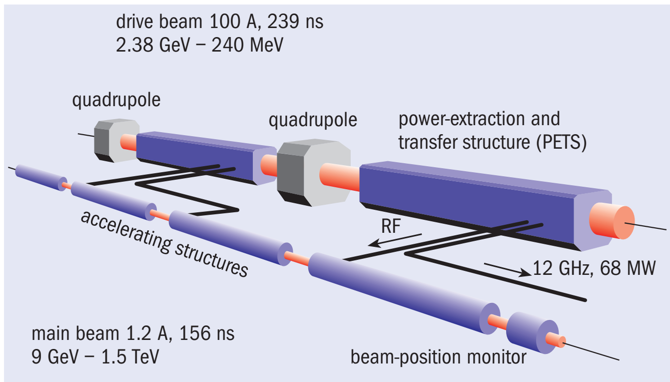


Fig. 2. The CLIC two-beam scheme, with the main beam accelerated by energy provided from the lower-energy, high-current drive beam.

ILC and CLIC are quite different, the two studies share many R&D issues and have developed a solid collaboration on these topics.

The linac design for CLIC is based on travelling-wave accelerating structures operating at a frequency of 12 GHz. These structures are one of the most challenging items being developed for CLIC. They have to be able to withstand the very high accelerating fields of 100 MV/m in pulses 239 ns long (see below) without being damaged by unavoidable RF breakdowns and pulsed RF heating. Figure 1 (p15) shows the best accelerating structure produced so far. It has been tested to fields of more than 100 MV/m at nominal pulse length and with an extremely low probability of RF breakdown of less than one in 10^7 pulses.

The peak RF power required to reach the electric fields of 100 MV/m amounts to about 275 MW per active metre of accelerating structure. With an active accelerator length for both linacs of 30 km out of the 48 km total length of CLIC, the use of individual RF power sources, such as klystrons, to provide such a high peak power is not really possible. Instead, the key innovative idea underlying CLIC is a two-beam scheme to produce and distribute the high peak RF-power (figure 2, p15). In this system, two beams run parallel to each other: the main beam, to be accelerated, and the drive beam to provide the RF power for the accelerating structures.

Providing the power

The drive beam is a high-current (100 A peak), low-energy (2.38 GeV) beam with a bunch repetition frequency of 12 GHz. It must contain all the energy required to accelerate the main beam, but how does it get this energy? In fact, the drive beam begins life as a long train of electron bunches (139 μs long) with large bunch spacing (60 cm). This is accelerated to an energy of 2.38 GeV using conventional klystron amplifiers at 1 GHz in a normal conducting linac. This acceleration can be made energy efficient, using the so-called fully-loaded acceleration mode, where a transfer efficiency from the RF to the beam of more than 95% has already been demonstrated in the CLIC test facility.

At this stage the drive beam contains all the energy necessary to accelerate one pulse of the main beam but with a beam current of 4.2 A. In order to get the high peak RF-power necessary for the main beam accelerating structures, the peak current of the drive beam has to be increased to 100 A. This occurs through bunch manipulations in a sequence of three rings that follow the linac: the delay loop and two combiner rings (figure 3). Here, in one of the important novel features of CLIC, the bunches in 239 ns long sub-trains are interleaved between each other by injection using RF deflectors. This leads finally to bunches spaced by 2.5 cm (12 GHz) in bursts 239 ns long, with an average current during the burst of 100 A. In total, 24 such bursts follow each other, with 5.8 μs intervals between bursts.

The tunnel for CLIC will contain the elements for both the main beam and the drive beam running parallel to each other about 65 cm apart. Transfer lines to transport both beams from the injectors to the far ends of the two linacs can be installed in the same tunnel, under the ceiling.

To transfer the energy to the main beam, the drive beam passes through novel "power extraction and transfer structures" (PETS), where it excites strong electromagnetic oscillations, i.e. the beam loses its kinetic energy to electromagnetic energy. This RF energy is extracted from the PETS and sent via waveguides to the accelerating structures in the parallel main beam. The PETS are travelling-wave structures like the accelerating structures for the main beam, but with different parameters (figure 4). One PETS with a different design has already been producing 30 GHz RF power in the CLIC test facility for three years.

A further challenge for CLIC, in common with the ILC, is to achieve the luminosity that the experiments demand. This requires beams of extremely small emittance. At CLIC, two damping rings in succession will provide the necessary reduction in each of the main beams. In the main linac itself, the RF accelerating structures have been carefully designed to control the wake fields induced by the bunches to avoid blow-up of the emittance. Finally, a sophisticated beam-delivery system focuses the beam down to dimensions of 1 nm rms size in the vertical plane and 40 nm horizontally. This requires the final focus quadrupoles to be stabilized to a vibration amplitude of less than 0.2 nm for oscillations above 4 Hz.

An important milestone will be the proof-of-principle demonstration that the major CLIC technologies are feasible. The CLIC Test Facility (CTF3), currently under construction, should demonstrate the main CLIC-specific issues by 2010.

CTF3 consists of a 150 MeV electron linac, followed by a series

Physics at a multi-TeV linear collider

The physics potential of a linear electron–positron collider is complementary to that of the LHC. Indeed, a 3 TeV collider can probe indirectly for new physics far beyond the reach of the LHC via precision measurements of two fermion production, for example. A high-energy linear collider would also allow for detailed complementary studies in the Higgs sector, such as measurements of rare Higgs decays, couplings of particles to the Higgs, the quantum numbers of the Higgs, and in particular, the Higgs self-coupling, which is needed to reconstruct the form of the Higgs potential.

Linear colliders will also complement the LHC's searches for supersymmetric particles – sparticles – by extending, for example, the discovery range in the lepton and gaugino sector. Physics studies for CLIC have demonstrated the potential to discover and make accurate measurements of smuons with masses larger even than a tera-electron-volt. If a sparticle can be produced at a linear collider, its mass and other properties can be determined much more accurately than at the LHC. Such studies will be important for the reconstruction of the exact parameters of the underlying theory from the measurements.

New gauge bosons such as a Z' can be studied up to the centre-of-mass energy range of the collider. If these exist in nature in the tera-electron-volt range – which the LHC will demonstrate – then CLIC could measure their properties with a precision only slightly less than LEP reached in the measurement of the Z.

In all, for essentially all scenarios of new physics discussed over the past decade, including, for example, extra dimensions, little Higgs, and new strong interactions, a collider such as CLIC could make significant and even conclusive contributions to disentangle the underlying new physics and considerably advance our understanding of space and matter.

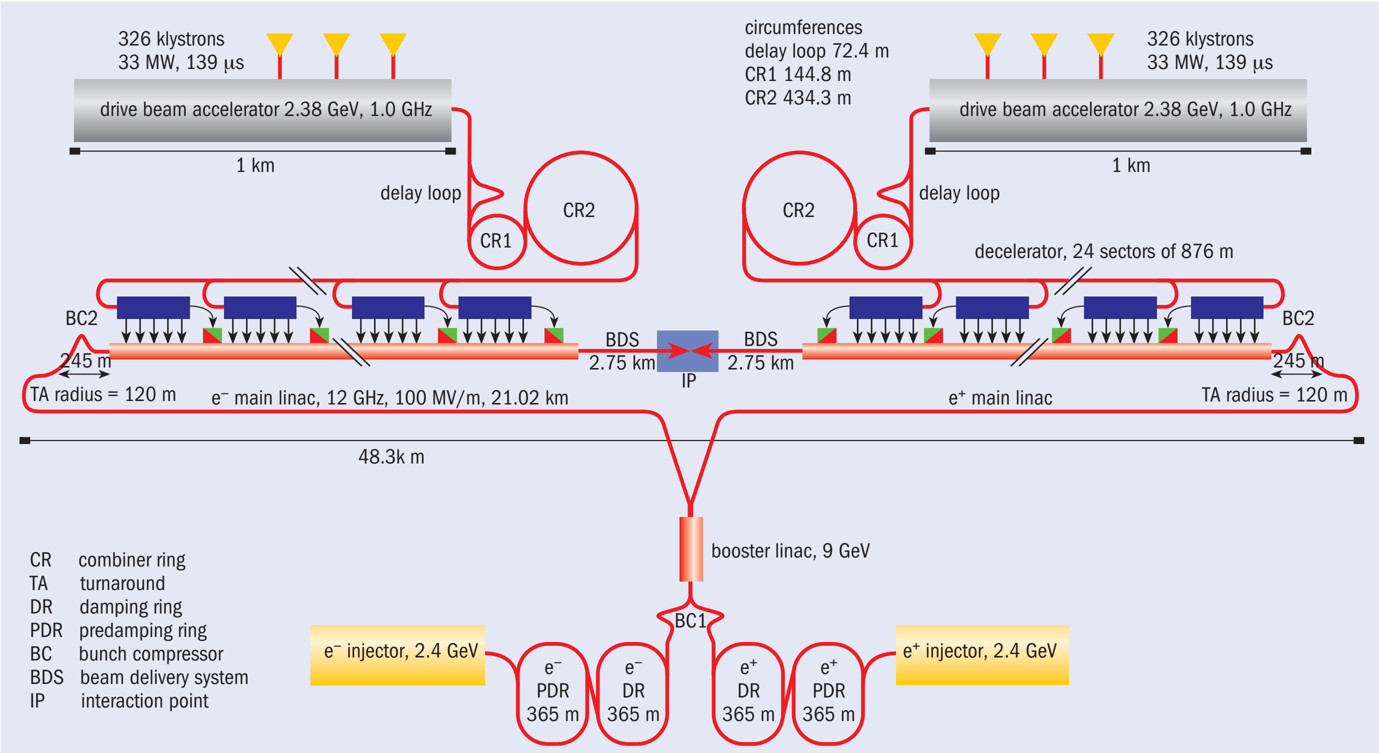
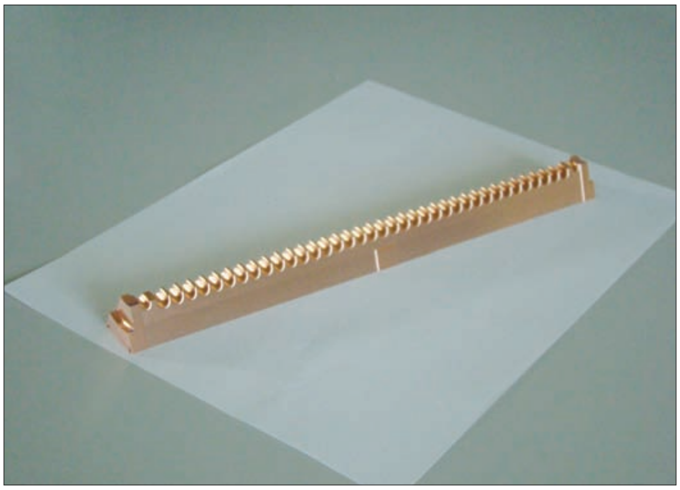


Fig. 3. The proposed layout for CLIC, showing the various components of the injection system and the drive-beam system (not to scale).



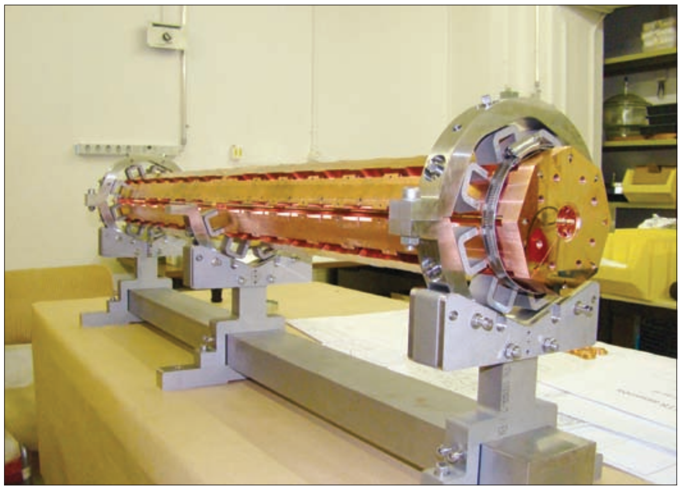


Fig. 4. A power-extraction and transfer structure (PETS). Eight octants like the one shown left form a closed structure (right). (Courtesy CLIC.)

of two rings, the delay loop and the combiner ring (figure 5). This part of CTF3 is a scaled-down version of the complex required to generate the CLIC drive beam. It will demonstrate the principle of the novel bunch-interleaving technique using RF deflectors to produce the compressed drive-beam pulses. In CTF3 the compressed beam is then sent into the CLIC Experimental Hall (CLEX). This houses several beam lines where the CLIC acceleration scheme will be tested, including the extraction of RF power from the drive beam and transfer of this RF power to the accelerating structure, which will accelerate a "probe beam" in a full demonstration of the CLIC acceleration principle.

Construction of CTF3 started after the closure of LEP in 2001, taking advantage of equipment from LEP's pre-injector complex. Its installation is on schedule: the linac, delay loop and combiner ring have already been operated with beam, and further commissioning is on going. The new CLEX building is now ready, with most of the equipment installed, and it should see beam from August 2008 onwards.

The first major milestone towards CLIC will be in 2010 when the most important new technologies should be shown to be feasible, so that a conceptual design report can be published. A technical design phase will follow, including industrialization and cost optimization. Pending a decision based on physics results from the LHC, construction, which is estimated to last seven years from the moment of project approval, could then begin.

● The R&D work towards CLIC is done by an international collaboration organized like those for the large particle physics experiments at CERN. It is managed by a collaboration board with ▷

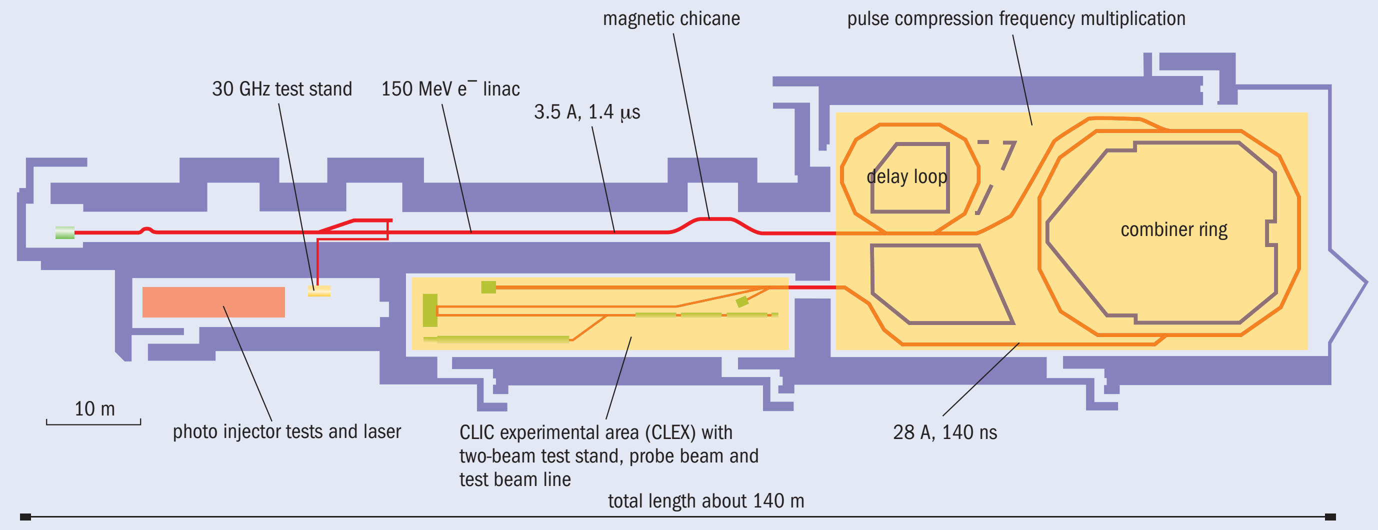


Fig. 5. Diagram of the CLIC test facility (CTF3), with 150 MeV linac, delay loop and combiner ring, together with the experimental area, CLEX.

representatives from the collaborating institutes, each one responsible for work packages and providing the necessary resources. The collaboration currently consists of 26 members from 14 countries: Ankara University Group (Ankara and Gazi), Budker Institute of Nuclear Physics (BINP), CEA (IRFU Saclay), CERN, CNRS IN3P3 (LAL, LAPP, LURE), DAE India (RRCAT), DOE USA (Northwestern University, Illinois, SLAC, JLAB), Helsinki Institute of Physics (HIP), IAP Nizhny Novgorod, INFN Frascati, JINR Dubna, MEC Spain (CIEMAT Madrid, IFIC Valencia, UPC Barcelona), NCP Pakistan, Norwegian Research Council (Oslo University), PSI Switzerland, STFC UK (John Adams Institute, Royal Holloway London), Ukraine Nat. Acad. Sci (IAP NASU), Uppsala University.

Further reading

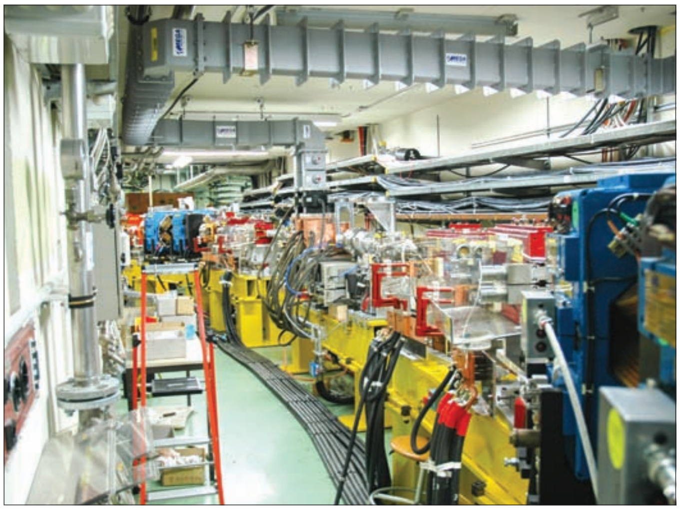
For more about CLIC, see http://clic-study.web.cern.ch/CLIC-Study/. For more about physics at CLIC, see E Accomando *et al*. 2004 CERN-2004-005, hep-ph/0412251.

Résumé

Un CLIC pour l'avenir

Le LHC promet d'offrir un riche programme de physique à la frontière des hautes énergies au cours des prochaines années. Les physiciens des particules sont toutefois d'avis que les résultats de cette machine devront être complétés par des expériences menées à un collisionneur électron–positon fonctionnant dans la gamme d'énergie du téraélectron-volt. L'étude sur la faisabilité du Collisionneur linéaire compact (CLIC) vise à atteindre une énergie nominale de 3 TeV, en utilisant des structures accélératrices résistives à ondes progressives fonctionnant à des champs électriques très élevés, de l'ordre de 100 MV/m. Ces champs exigent une puissance de crête élevée et, de ce fait, une source de puissance d'un nouveau type – un système novateur à deux faisceaux dans lequel un faisceau d'entraînement fournit de l'énergie au faisceau principal.

Hans Braun, **Jean-Pierre Delahaye**, **Albert De Roeck** *and* **Günther Geschonke**, *CERN.*



The injection area into the delay loop at CTF3. (Courtesy CLIC.)

The next CLIC workshop

The CLIC '08 workshop will be held at CERN on 14–17 October 2008. It is an accelerator and physics workshop, which provides a forum for those already participating in CLIC, those who are interested in joining, and any others interested in the physics and technology of CLIC. It follows the successful first workshop of this kind held in October 2007.

CLIC '08 will cover:

- The R&D towards CLIC feasibility demonstration and conceptual design in 2010. This includes items of ILC–CLIC common interest.
- Reflections on the R&D, facilities and engineering efforts needed in the period after 2010 to progress from a conceptual design to a technical design.
- Particle physics and detector issues of a multi-TeV linear collider.
- More information about CLIC '08 is available at http://project-clic08-workshop.web.cern.ch/.

Mission accomplished: a new hall for PETRA III

The grand experimental hall for the latest reincarnation of the PETRA storage ring at DESY involved some rather special civil engineering, as **Hermann Franz** explains.

Staff of the general contractor Ed. ZÜBLIN and members of the PETRA III project team at the handover ceremony in June (Photos courtesy DESY.).

With a handover ceremony at the end of June, an exciting year of hard work on DESY's new synchrotron radiation source, PETRA III, came to a successful conclusion for the construction team of general contractor Ed. ZÜBLIN and the DESY project team. They had completed the experimental hall within a year, exactly on schedule. As early as 7 April, DESY was able to take responsibility for the concrete slab on which the new part of the storage ring tunnel and the experiments are being set up. This latest project is the third reincarnation for the PETRA storage ring, which began life as a leading electron–positron collider in the 1980s and later became a pre-accelerator for HERA, the proton–electron collider. It will provide researchers at DESY with one of the most brilliant X-ray sources in the world.

The PETRA III project comprises the reconstruction of the PETRA accelerator to form a dedicated third-generation synchrotron radiation source together with 14 independent beamlines serving up to 30 experimental stations. An eighth of the ring (288 m long) has been completely remodelled within a new hall that also houses the experiments, and the remainder of the ring (some 2 km) has been completely refurbished. The overall budget of the project was €225 million, shared between the German Federal Government (90%) and the City of Hamburg (10%).

High brilliance guaranteed

PETRA III will have the lowest emittance – 1 nm rad – of all the high-energy (6 GeV) storage rings in the world. This will be achieved by installing 80 m of damping wigglers in two of the long straight parts of the ring. The high brilliance will be assured by undulators, where periodic magnetic fields force the beam to oscillate and emit intense radiation in a narrow energy band. To free space for the undulators in the new arc, the classic FODO lattice (the basic combination of quadrupole and dipole magnets) has been replaced by a Chasman-Green lattice, which is better optimized for light sources. There the magnets are mounted on girders carrying either two quadrupoles and one dipole, or three quadrupoles.

The project officially started in 2004 with the publication of the Technical Design Report (TDR). In the following years an increasing number of DESY staff worked on the detailed planning and preconstruction of accelerator and beamline components, and preparations for the construction activities on the DESY campus finally started in May 2007. However, disassembly of the old accelerator and preparation of the construction site could not start until 2 July 2007, after the last electrons and protons had been delivered to HERA. All the accelerator components had to be removed from the tunnel, an operation that was achieved in only three months. The magnets were refurbished, most of them receiving new coils, and magnetically characterized. They were then mounted again together with the new vacuum system, and in May 2008 the last dipole was installed in its old position. As the plan is for PETRA III to operate in top-up mode, where the storage ring current is kept almost constant with frequent injections of beam, the pre-accelerators and part of the general infrastructure also had to be refurbished.

The old PETRA tunnel had to be completely removed in the arc where the new experimental hall was being built. In designing the new hall, extreme care was taken to ensure optimum stability, both for the storage ring and the future X-ray beamlines. The hall floor is cast as a monolithic 1 m-thick concrete slab that will support all the components. This slab is mechanically isolated from its surroundings by soft vibration-damping material, and the framework of the hall is built on sleeved piles to minimize the influence it could exert through the ground on the floor of the hall.

The optimum design of the sleeved piles had to be tested by producing four prototype piles – in effect, the first experiment at PETRA III. Using bubble-wrap foil to sleeve the piles proved to be the most economic and efficient solution. Then for two months, a long procession of trucks removed the sand covering the old ▷

tunnel in the section where the new experimental hall was to be built before the remaining 95 piles could be lowered 20 m deep into the ground. At the same time, the 1 m-thick layer of recycled concrete material was brought into place and carefully densified (i.e. hardened). The layer forms the subsoil for the concrete slab. This period of construction ended with the foundation-stone ceremony on 14 September 2007.

It took only two months to erect the hall. By November 2007 the roof was closed and the teams celebrated with a topping-out ceremony attended by German research minister, Annette Schavan. The most exciting task followed in mid-December: the casting of the 1 m-thick base slab. Within 60 hours, 38 trucks brought 860 loads of concrete (some 6700 m^3) to the DESY campus where it was pumped into the hall. Half of the concrete (i.e. the upper half of the plate) is reinforced by steel fibres to minimize the number of cracks. The crucial part was the setting of what is possibly the longest single piece of concrete ever cast. During cool-down it performed exactly as predicted, shrinking by 8.2 cm and forming only one crack, which was cured by injecting epoxy resin. Preliminary measurements of the vibration and deformation properties gave promising results. In quiet periods the rms value of the vibrational amplitude at frequencies of above 1 Hz is as low as 20 nm. Finally, by 30 June 2008 work on the façade and the interior of the laboratories and evaluation rooms had finished on schedule.

Meanwhile, the first DESY groups have begun work inside the hall. All the points for the determination of the eventual beam position have been marked along the particle and X-ray beamlines. The laying of the cooling water pipes has started, and shielding stones for the tunnel have been set up inside the hall. Installation of the optics enclosures for the beamlines began in mid-July, and the erection of lead hutches to accommodate the experiments started at the beginning of August.

Experiments, which are organized in nine sectors, have been selected by an international advisory board based on the proposals collected in the TDR. All make use of the high brilliance of the PETRA III beam. Sector 1 will be dedicated to inelastic scattering of a few milli-electron-volts and nuclear resonant scattering with an energy resolution of nano-electron-volts, offering simultaneously a spatial resolution in the few or even submicron range. Sector 2 will be shared by a hard X-ray beamline, with one fixed energy end-station for powder diffraction and one for extreme conditions experiments, and one beamline for micro- and nano-small angle X-ray scattering applications. Sector 3 will house a variable polarization soft X-ray beamline equipped with an Apple-II type undulator and a selection of dedicated end-stations. Sector 4 is the imaging sector with one beamline for tomography (operated by the GKSS Research Centre, Geesthacht) and a hard X-ray nanoprobe beamline dedicated to spatially resolved absorption spectroscopy and fluorescence analysis.

In sector 5 GKSS and DESY will jointly operate a beamline for very hard X-rays (above 50 keV), dedicated mainly to applications in materials science. Sector 6 focuses on diffraction experiments with a very-high-resolution diffraction and a resonant scattering end-station. In addition, a station for electron spectroscopy will be included. Sector 7 makes special use of the high brilliance of PETRA III to perform experiments using the coherent flux. Both X-ray photon correlation spectroscopy and coherent imaging experiments are foreseen.

View of the experimental hall. The first optical enclosures are being set up in front of the storage ring tunnel, which is within the white shielding.

The last two sectors, 8 and 9, are dedicated to applications in life science, with four beamlines operated together with the Max Planck society, the Helmholtz Centre for Infection Research and, with the largest part of three experiments, the European Molecular Biology Laboratory. These beamlines will offer small angle scattering, macromolecular crystallography and bio-imaging end-stations.

The schedule dictates that the technical commissioning of the machine will start in October, with the first beam expected at the beginning of 2009. During the commissioning of the beamlines, scheduled for spring and summer 2009, DESY will invite already "friendly" users to participate in the characterization of the experiments at this exciting new facility.

Further reading

For more about PETRA III see http://petra3.desy.de.

Résumé

Mission accomplie: un hall pour PETRA III

À la fin juin, une cérémonie de mise à disposition a marqué l'achèvement, dans les temps, de la nouvelle source de rayonnement synchrotron de DESY, PETRA III, après une année de travail dur mais stimulant. C'est la troisième forme que prend l'anneau de stockage PETRA, au départ un collisionneur électron-positon, dans les années 80, puis un pré-accélérateur pour le collisionneur proton-électron HERA. Il devrait maintenant fournir à des chercheurs l'une des sources de rayons X offrant le plus de brillance. Le nouveau hall d'expérimentation, qui contient également une portion reconstruite de l'anneau de stockage, repose probablement sur la plus longue pièce de béton jamais coulée, et a exigé des travaux de génie civil particuliers.

Hermann Franz *on behalf of the PETRA III project team, DESY.*

The rise of the FFAG

Projects based on FFAG accelerators are beginning to flourish throughout the world.

The concept of fixed-field alternating-gradient (FFAG) accelerators was put forward in the early 1950s, as a possible way of applying the methods of strong focusing and phase stability to particle acceleration. An FFAG ring is a circular assembly of fixed-field magnets that strongly focus the accelerated beam, similar to that in an alternating-gradient synchrotron. However, as the magnetic field remains constant by definition, the beam spirals radially during the acceleration process, as in a cyclotron. Consequently, FFAGs feature magnets with a large transverse aperture and therefore high-beam acceptances in both momentum and space. Fast acceleration, high repetition rate and a large 6-D acceptance are the potential benefits of FFAGs that triggered their rebirth at the end of the 1990s, mainly in Japan (*CERN Courier* July/August 2004 p23). Since then the concept has been revisited in depth and this has led to a dual machine classification: scaling (invariant-focusing) FFAGs and non-scaling FFAGs.

In scaling FFAGs, the orbit shape and the optics of the beam are kept unchanged during the acceleration by applying a non-linear magnetic field of the form $B = B_0 (r/r_0)^k$, where k is the field index. Scaling FFAGs may be seen as an evolution of the synchrocyclotron concept, but offering more flexibility and potentially better performance in various application domains. The Japanese have recently constructed prototypes of radial-sector proton rings following this concept. They showed that modern 3D computer-aided methods allow accurate and reliable design of the sophisticated non-linear FFAG magnets. They also led to the development of a broadband and high-gradient RF cavity technology that makes fast acceleration and high repetition rates possible.

In non-scaling FFAGs, on the other hand, the betatron tunes are allowed to vary during the acceleration process. This freedom opens up new concepts that have been investigated with the help of modern particle-tracking computing techniques. Under the hypothesis that the total acceleration time is kept sufficiently short, the fast crossing of betatron resonances should have little effect on the beam stability. This new regime is sometimes referred to as "curved linear acceleration", meaning that there is no cyclic component in the beam motion equations. Non-scaling FFAGs tend to have much smaller transverse apertures than scaling machines.

FFAGs in Japan

The world's first proton FFAG accelerator, the Proof-of-Principle FFAG (POP-FFAG) was built at KEK in Japan in 2000 (*CERN Courier* October 2000 p11). At approximately the same time, researchers recognized that FFAG accelerators can feature rapid acceleration with large momentum acceptance. These are exactly the properties required for muon acceleration, for the production of medical

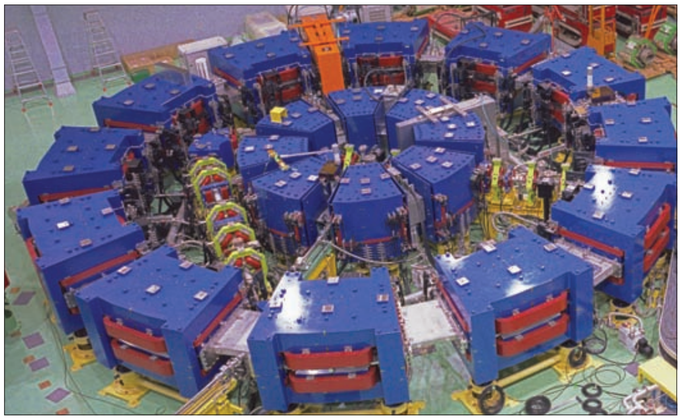


Fig. 1. The proton FFAG accelerator developed at Kyoto University Research Reactor Institute (KURRI), Japan, for a basic experiment on accelerator-driven systems. A third injector ring is located outside this image frame. (Courtesy KURRI.)

proton beams and for accelerator-driven systems (ADS) for nuclear energy. To investigate this potential, a team at KEK developed the first prototype of a large-scale proton FFAG accelerator. In 2004, it successfully accelerated a proton beam up to 150 MeV with a repetition rate of 100 Hz. Since then, intensive studies and discussions have taken place and various novel ideas have emerged that have led ultimately to new application projects for FFAG accelerators at several institutes in Japan.

A team at the University of Kyoto has developed a proton FFAG accelerator for basic research on ADS experiments. Here, the beam is delivered to the existing critical assembly of the Kyoto University Research Reactor Institute (KURRI). The whole machine is a cascade of three FFAG rings (figure 1). The beam was recently successfully accelerated up to 100 MeV and the first ADS experiment is due to start this summer.

Medical applications of FFAG accelerators have also been proposed in two different fields: hadron therapy and boron neutron-capture therapy (BNCT). For BNCT, an accelerator-based intense thermal or epithermal neutron source has been developed at KURRI, using an FFAG storage ring with a thin internal beryllium target (figure 2, p22). The growth of the beam emittance and the energy distortion caused by scattering in the target can be controlled using ionization cooling, a functionality that could not be used in a cyclotron owing to the lack of space. After completion of the whole system, recently the beam was successfully accumulated in the ring and neutron production has already been observed. This constitutes the first experimental demonstration of the efficiency of ionization cooling.

At the University of Osaka there is a proposal to build a highly intense muon source using the 50 GeV proton beam of the synchrotron at the Japan Proton Accelerator Research Complex. In the project, called PRISM, longitudinal phase-space rotation to narrow the initial energy spread of a muon beam by a scaling FFAG ▷

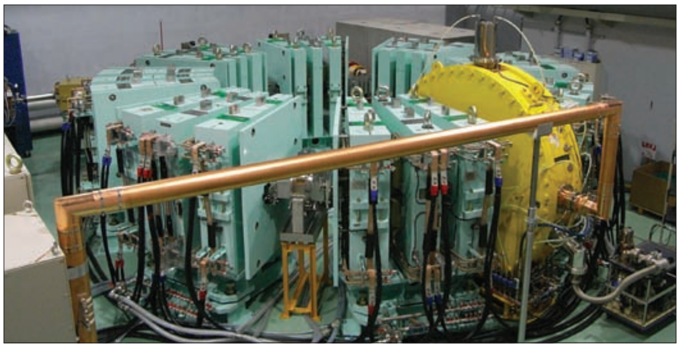


Fig. 2. The neutron source for boron neutron-capture therapy at KURRI uses an FFAG storage ring with an internal target. (Courtesy Y Mori.)

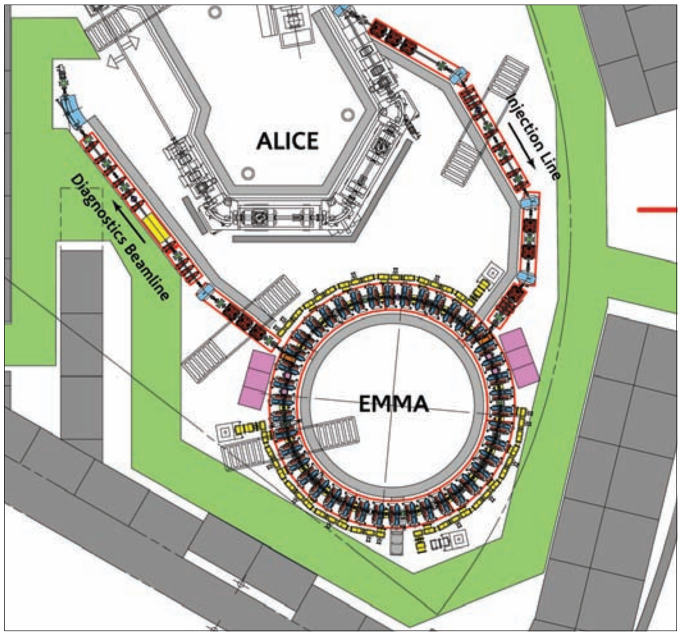


Fig. 3. The layout for EMMA, the non-scaling FFAG proof-of-principle project to be built at Daresbury in the UK. (Courtesy STFC.)

ring – featuring a large energy acceptance – has been developed to search for lepton-flavour violation in muon interactions. The ring consists of 10 magnets and 5 magnetic alloy RF cavities with a frequency and a gradient of 5 MHz and 200 kV/m, respectively.

The University of Kyusyu also has a new accelerator facility under construction. The main machine will be a 150 MeV proton FFAG accelerator whose design closely follows the one at KEK described above. This will be available for various applications, such as nuclear physics and material science.

EMMA in the UK

In the UK, non-scaling FFAGs are currently being studied for a variety of applications, including hadron therapy, ADS and the rapid acceleration of muons for a neutrino factory and a muon collider. The unique features of such machines mean that detailed development for these applications requires the construction of a proof-of-principle accelerator to explore in detail the beam dynamics to gain experience in the design and construction of non-scaling FFAGs, and to benchmark the computer codes employed in the studies.

This new machine, the Electron Model for Many Applications (EMMA) will be built at the Daresbury Laboratory of the Science and Technology Facilities Council (STFC). EMMA has been funded as part of the British Accelerator Science and Radiation Oncology Consortium (BASROC), which has also funded the design of a non-scaling FFAG, PAMELA, for the acceleration of carbon ions and protons for hadron therapy, and for studies of other potential applications of this technology.

EMMA will be a 10–20 MeV electron linear, non-scaling FFAG, designed with the necessary flexibility to allow the detailed studies required. In addition, it will use the linac for the Accelerators and Lasers In Combined Experiments (ALICE) project as an injector (figure 3). ALICE can deliver beams at any energy between 10 and 20 MeV, an important requirement for a complete study of resonance crossings in EMMA.

EMMA will use a doublet lattice and the ring will consist of 42 cells, each about 40 cm long. There will be 1.3 GHz RF cavities in every other cell, except around the injection and extraction regions. The intermediate cells will be used for diagnostics and pumps. The experimental nature of the accelerator means that it is important to have sufficient diagnostic devices. Within the EMMA ring, there will be two beam-position monitors in each cell, two wire scanners, two motorized screens and a wall current monitor. A beam-loss monitor, segmented into four sections, will surround the ring. A number of measurements can be made only outside the ring and hence an extraction line has been designed to include emittance, longitudinal beam profile and momentum measurements. There will also be instruments in the injection line to measure the beam properties on entrance to EMMA.

The designs of the ring and the injection and extraction lines are now complete, and detailed engineering studies are far advanced. Prototypes for some major systems have already been built and tested, and construction of the others will take place this year. Construction of the machine itself should be finished towards the end of 2009.

RACCAM in France

Scaling spiral-sector FFAGs are now seen as good candidates for hadron therapy applications, with various potential advantages, such as variable extracted energy and high repetition rates compared with cyclotrons, and simplicity of operation when compared with synchrotrons. These considerations have motivated the R&D project Recherche en Accélérateurs et Applications Médicales (RACCAM), which is based at the Laboratoire de Physique Subatomique et de Cosmologie (LPSC) in Grenoble and has received a grant for 2006–2008 from the French National Research Agency. The RACCAM project aims to produce a preliminary design study of a variable-energy proton installation, based on a 5–15 MeV H^- injector cyclotron followed by a spiral-lattice FFAG ring with an extraction energy of 70–180 MeV. This study is now close to completion. The project also includes the prototyping of a spiral magnet capable of delivering the required r^k field. A magnet of this type is now under construction at SIGMAPHI in France (figure 4).

RACCAM began in 2005 as a collaboration between LPSC, the radiotherapy department at the Grenoble University Hospital, and the magnet constructor SIGMAPHI. The collaboration has since rapidly expanded to include two more companies, IBA and AIMA, and the Antoine Lacassagne proton therapy clinic in Nice. Preliminary studies have led to a prototype proton therapy accelerator project, which could be hosted by the Antoine Lacassagne proton-therapy clinic (see cover). RACCAM has organized several international-scale meetings, including the FFAG 2007 workshop in Grenoble, and the Fixed-Field Synchrotrons and Hadrontherapy workshop, the first of the kind, in Nice in November 2007.

The international accelerator community is rapidly gaining knowledge of FFAGs and of their rich potential in several key applications. More than four large-scale prototypes are presently either under construction or commissioning in JAPAN and in the UK. There is no doubt that we are now getting close to the first real use of FFAGs for physics research or medicine.

Further reading

All details concerning the RACCAM collaboration can be found at: http://lpsc.in2p3.fr/service_accelerateurs/raccam.htm. For more about BASROC, see http://basroc.rl.ac.uk.

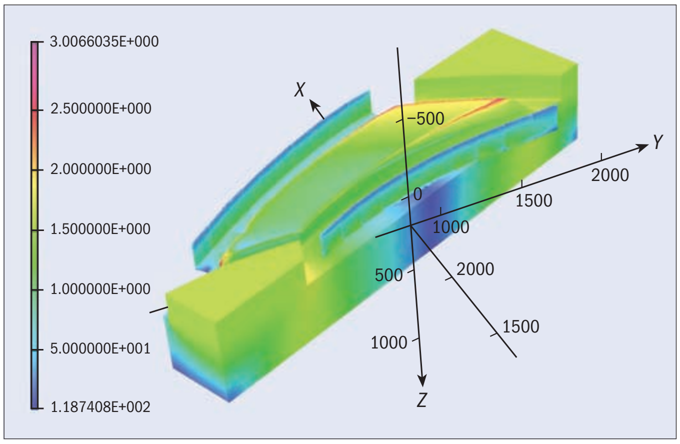


Fig 4. A prototype spiral dipole for the RACCAM project in France, which can deliver the field for a scaling FFAG. (Courtesy SIGMAPHI Vannes.)

Résumé

L'essor des FFAG

Le concept des accélérateurs à gradients alternés et à champ fixe (FFAG) a été proposé au début des années 50 dans l'idée d'appliquer les méthodes de la focalisation forte et de la stabilité de phase à l'accélération des particules. Ces machines permettent une accélération rapide, une fréquence de répétition élevée et une grande acceptance en impulsion et en espace. Ces avantages potentiels ont motivé la renaissance des FFAG dans les années 90, essentiellement au Japon. Depuis, la communauté internationale des accélérateurs apprend à les connaître et découvre leur important potentiel pour plusieurs applications clés. Plus de quatre grands prototypes sont en cours de construction ou de mise en service au Japon et au Royaume-Uni.

Johann Collot, *LPSC*, **Yoshiharu Mori**, *KURRI*, **Pierre Mandrillon**, *AIMA développement*, **François Méot**, *LPSC, and* **Rob Edgecock**, *STFC/RAL.*

London welcomes DIS international workshop

Topics varying from the developing legacy of the HERA collider to the subtleties of the game of cricket attracted enthusiastic audiences at the latest in the series of meetings on deep-inelastic scattering and related topics. **Matthew Wing** and **Robin Devenish** report.

This spring the XVI International Workshop on Deep-Inelastic Scattering and Related Subjects (DIS 2008) took place at University College London (UCL), and was jointly organized by the high-energy particle physics groups of the University of Oxford and UCL. Some 300 participants attended the workshop, which was held on 7–11 April and consisted of approximately 270 talks covering a multitude of subjects.

The provost and president of UCL, Malcolm Grant, opened the first day, which consisted mainly of plenary talks, with speakers detailing recent experimental and theoretical highlights, and looking at future developments in the field of deep-inelastic scattering (DIS), QCD and collider physics. The opening plenary speakers greatly helped to set the tone of the meeting with excellent overviews and positive outlooks. In the late afternoon, the workshop split into working groups with specialized talks, with up to six groups in parallel at any one time.

The parallel sessions covered a range of subjects, including structure functions and low-x; diffraction and vector mesons; electroweak measurements and physics beyond the Standard Model; hadronic final states and QCD; heavy flavours; spin physics; and future facilities. There were many excellent presentations, including high-quality results from both experiment and theory, together with extensive discussions. The parallel sessions continued throughout the next two days, culminating with a packed additional session organised by Hannes Jung from DESY on "What HERA can still provide". That so many people were prepared to forego an evening meal to participate in an extra session at the end of a busy day demonstrates the unique legacy of HERA, the world's first and only electron–proton collider, which ceased operation at DESY in June 2007 (*CERN Courier* January/February 2008 pp30 and 34). On the afternoon and morning of the final two days, the convenors of the working groups reported on the highlights of their sessions. Finally, Brian Foster of the University of Oxford beautifully summarized the whole workshop, again highlighting the vitality of both the field and the workshop.

Work on the structure of the proton – the main subject of the DIS workshop series – has seen tremendous advances recently. The H1 and ZEUS collaborations have made the first measurements of the longitudinal structure function, F_L, and have combined data on inclusive DIS cross sections from the HERA I run in a preliminary HERA fit of the parton density functions. The quantity F_L is an integral part of the description of the proton's structure and is directly sensitive to the gluon density and the QCD evolution with momentum transfer. Both collaborations have measured F_L using two special low-energy proton runs taken at the end of HERA data taking. While the data are consistent with QCD predictions of the parton densities, which are based on fits to the inclusive measurements of F_2, they cannot yet distinguish between different predictions, although significant improvements to the measurements are expected.

Participants outside UCL's main building. (Courtesy Simon Bevan/UCL.)

Taking advantage of the different detectors and their systematics, the combination of the F_2 measurements from H1 and ZEUS has produced results that are significantly more precise than the simple effect of doubling statistics. The effective "cross calibration" has led to uncertainties of 1–2% over a wide range in Bjorken-x and in photon virtuality, Q^2. The combined HERA data alone have in turn been used in a fit of the parton distributions in the proton and this leads to results that are competitive with global fits that use data from ▷

many different sources (see figure, right). Data from the Tevatron at Fermilab are also placing strong constraints on the structure of the proton. Results on the charge asymmetry of the W particle from the CDF experiment have a precision that is significantly better than the uncertainties on the parton distribution functions. Additionally, inclusive-jet cross sections from the D0 experiment yield constraints at the highest scales, up to 600 GeV. They also provide a wonderful verification of QCD predictions across 10 orders of magnitude in the cross section, differential in jet p_T and rapidity.

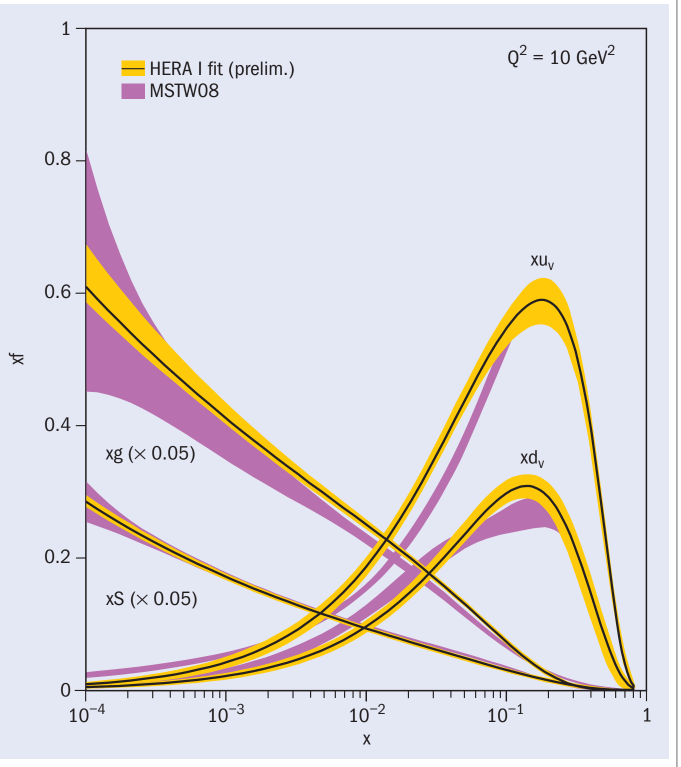
All of the above results are crucial inputs to our understanding of QCD, and in particular the structure of the proton, which is needed as the starting point for most of the physics at CERN's LHC. Along with the new measurements, theory is keeping pace with a number of advances that are either already made or planned. With the recent development of next-to-next-to-leading order QCD corrections (NNLO) for F_2, groups are working on the implementation of NNLO for general $2 \rightarrow 2$ parton scattering and the extension to the next order for F_2. Of course with every order in the perturbation expansion, the number of diagrams increases exponentially, but new approaches using formal mathematics developed for other applications, such as twistors, are helping to reduce the number of diagrams by over an order of magnitude.

Spin physics – fully polarized DIS – attracted many talks. The exquisite experiments of HERMES at HERA, COMPASS at CERN and those at RHIC and Jefferson Lab are matched by exotic new varieties of observables and dreams of reconstructing the proton structure in 3-D. Despite all this activity, however, the "spin crisis" remains. The quarks do not carry much of the proton's spin, and new results show that neither do the gluons (*CERN Courier* April 2006 p26). That leaves angular momentum – dubbed "dark angular momentum" by Xiangdong Ji of Maryland during his introductory talk on spin, because it will be so difficult to measure. Much remains to be done to clarify this area at the upgraded Jefferson Lab and/or RHIC.

The workshop programme made room for several social events including a welcome reception, held in the North Cloisters at UCL, and a brilliant concert at the Queen Elizabeth Hall by violinist Jack Liebeck and pianist Katya Apekisheva. The social highlight was the dinner held at Lord's Cricket Ground – "the home of cricket". After an excellent dinner, Norman McCubbin from the Science and Technology Facilities Council/Rutherford Appleton Laboratory gave a speech entitled "The scattering of balls: an English obsession". He explained the delights of this English game, such as its length, the many and complicated options for when tea can be taken and the history of Lord's. This was all supported by props showing how the game relates to physics and specifically deep-inelastic scattering.

DIS 2008 demonstrated how "DIS and Related Subjects" permeates almost all areas of high-energy physics, from hadron colliders to spin physics, neutrino physics and more. There is still much to be done and learnt in the field. Apart from the immediate excitement of the LHC start-up, another promising development for the future is the LHeC project, discussed on the last day, which would see the introduction of an electron ring in the LHC tunnel, allowing electron–proton collisions.

The European Committee for Future Accelerators has recently approved a conceptual design study and work is rapidly increasing on this project to assess its physics potential and technical realization, with a series of dedicated workshops starting this year. We are now all looking forward to seeing how this flourishing subject will be continued in Madrid at DIS 2009.



Parton densities (xf) in the proton as a function of Bjorken-x extracted from a HERA fit to combined structure function data from H1 and ZEUS, compared to a global fit using data from many sources (MSTW08).

● The workshop was generously supported by CERN, DESY, FNAL, Jefferson Lab, STFC, IPPP Durham, UCL Maths and Physical Sciences Faculty, John Adams Institute, Cockcroft Institute, Cambridge University Press and Oxford University Press. As co-chairs we would like to thank all members of the Local Organizing Committee, in particular Christine Johnston, who quietly and efficiently carried most of the administrative burden, and the student helpers who made the conference such a great success.

Résumé

L'atelier international DIS à Londres

Le XVIe Atelier international sur la diffusion profondément inélastique et les sujets connexes (DIS 2008) s'est tenu en avril à l'University College de Londres, avec quelque 300 participants. Les thèmes, qui allaient des impressionnantes contributions du collisionneur HERA aux subtilités du jeu de cricket, ont captivé le public. L'atelier a montré que la DIS et les sujets connexes ont leur place dans presque tous les domaines de la physique des hautes énergies, des collisionneurs de hadrons à la physique du spin, en passant par celle du neutrino. Les résultats obtenus à HERA constituent notamment un apport essentiel pour la compréhension de la CDQ et, en particulier, de la structure du proton, le point de départ de nombreuses études au LHC.

Matthew Wing, *UCL, and* **Robin Devenish**, *Oxford, co-chairs of the Local Organizing Committee for DIS 2008.*

Neutrino physicists get together down under

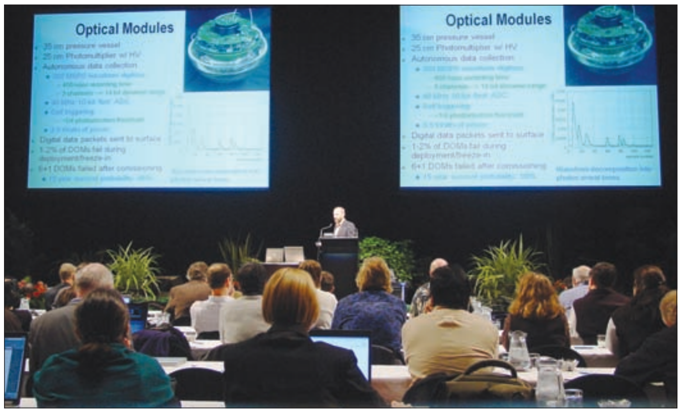
Christchurch in New Zealand provided an appropriate southern-hemisphere location for participants at Neutrino 2008 to hear the latest news from experiments that encompass the globe in more ways than one. **Jenni Adams** reports.

In recent years neutrinos have moved onto centre stage in both astrophysics and particle physics, and the latest developments were on show at the XXIII International Conference on Neutrino Physics and Astrophysics on 26–31 May. Supported by the International Union of Pure and Applied Physics, Neutrino 2008 took place in Christchurch, New Zealand, where it was organized by the University of Canterbury and the IceCube collaboration, which uses Christ church as its staging area and gateway to Antarctica. Conference-goers celebrated the 100th anniversary of the award of the Nobel Prize to a former undergraduate of the University of Canterbury, Ernest Rutherford, whose life was the topic of the opening presentation by Cecilia Jarlskog from Lund.

The question "Where are we?" is beloved of neutrino physicists. Alexei Smirnov of the Abdus Salam International Centre for Theoretical Physics in Trieste noted that a quarter of the papers found on the SPIRES high-energy physics database with this title are in neutrino physics. With the discoveries of neutrino masses and lepton-flavour mixing now established, there is a standard neutrino scenario in which neutrinos have masses in the sub-electron-volt range and there are two large mixings and one small or zero mixing between the three neutrino flavours. Neutrino experiments have moved into an era of precision measurements, motivated by the belief that neutrino mass and mixing are manifestations of physics beyond the Standard Model. However, as Smirnov noted, despite many years of effort and many trials, the physics underlying neutrino mass and mixing remains unidentified.

Roadmap of theoretical possibilities

Understanding neutrinos is a two-step process. The first step is to determine the values of the three mixing angles, the masses of the three mass eigenstates, and the value of the CP-violating phase. It is also necessary to find out whether the neutrino is its own antiparticle, that is whether it is as described by the physics of Paul Dirac or of Ettore Majorana. The second step is to try to understand why the neutrino matrix elements and the neutrino masses are what they are and what they tell us about physics well beyond the Standard Model. Stephen King from Southampton presented a roadmap of theoretical possibilities, including extra dimensions and possible grand unified theories, with each theoretical path linked to future experimental results.



Spencer Klein from Lawrence Berkeley National Laboratory talks about IceCube, which is under construction at the South Pole to observe cosmic high-energy neutrinos. (Courtesy University of Canterbury.)

Two of the mixing angles are now well determined: one through the solar-neutrino experiments and the other through the atmospheric- and accelerator-neutrino studies. The third angle, θ_{13}, is much less constrained but is no less important because it determines how close the mixing matrix is to the theoretically interesting, highly symmetric "tribimaximal" configuration. The best limits on θ_{13} are currently from the Double Chooz experiment. If θ_{13} is large enough, it may be possible to observe CP violation with neutrinos, and Yosef Nir from the Weizmann Institute explained how a large value for the CP-violating parameter, δ, could explain the observed baryon asymmetry in the universe via the process called leptogenesis.

Speakers from solar-neutrino experiments were the first to present their results, beginning with reports from the Borexino detector located at Gran Sasso National Laboratory in Italy, and from the third and final phase of the Sudbury Neutrino Observatory (SNO) in Canada. SNO's third phase included ^{3}He proportional counters to measure the rate of neutral-current interactions in the detector's heavy water. The Borexino experiment has results from 192 days of data taking and, as with earlier solar-neutrino measurements, these are ▷

best described by neutrino-flavour oscillation. The electron-neutrino flavour eigenstate, to a good approximation, is a linear combination of two mass eigenstates with masses m_1 and m_2. Neutrinos from the same energy range but at a much shorter baseline are detected by the KamLAND experiment in Japan, which observes antineutrinos from nuclear reactors. A combined analysis of the solar and KamLAND data now gives precise results for the mixing angle, Δ_{12}, and mass difference Δm_{12}^2, of the two mass eigenstates. The result of analysis with two flavours gives $\Delta_{12} = 33.8 + 1.4 - 1.3$ ° and $\Delta m_{12}^2 = 7.94 + 0.42 - 0.26 \times 10^{-5}$ eV^2.

The Super-Kamiokande experiment in Japan is now fully recovered from the accident in 2001, which destroyed around half of the original photomultiplier tubes. It has provided a high-precision measurement of neutrino oscillations by detecting atmospheric neutrinos in an energy range of hundreds of millions of electron-volts to a few tera-electron-volts. Jennifer Raaf from Boston gave the results from a combined analysis of the pre-accident and post-accident data taking. These include a mixing angle with $\sin^2 2\theta_{23} > 0.94$ at 90% confidence, which is the best constraint so far obtained for this parameter. The experiment also places limits on non-oscillation physics, such as neutrino decoherence, which is excluded at 5.0 σ, and neutrino decay, which is excluded at 4.1 σ.

Neutrino beams produced at particle accelerators offer the greatest control over the neutrino sources. They have been used to study the same neutrino oscillations that take place in atmospheric neutrino oscillation. The KEK-to-Kamioka (K2K) experiment was the first long-baseline neutrino experiment to operate, using neutrinos sent from the KEK laboratory to the Super-Kamiokande detector 250 km away. The K2K collaboration has previously reported results consistent with the Super-Kamiokande atmospheric neutrino results using data collected between 1999 and 2004. At the conference Hugh Gallagher from Tufts University presented new results from the Main Injector Neutron Oscillation Search (MINOS) experiment. This uses a muon–neutrino beam that is produced at Fermilab and observed at two sites: a near detector at Fermilab and a far detector 734 km away at the Soudan Underground Laboratory in Minnesota. MINOS now has the tightest constraint on the mass difference, finding $\Delta m_{23}^2 = 2.43 \pm 0.13 \times 10^{-3}$ eV^2 and a result for the mixing angle that is consistent with that for Super-Kamiokande.

The conference also heard reports on future experiments that aim to measure θ_{13}. These include the reactor-neutrino experiments Double Chooz in France, Daya Bay in China and the Reactor Experiment for Neutrino Oscillation at Yonggwang in Korea, as well as the accelerator-neutrino experiments T2K, OPERA at the Gran Sasso National Laboratory, and NOvA at Fermilab.

Many efforts are under way to determine directly the absolute neutrino mass scale in laboratory experiments through nuclear beta-decay or neutrinoless double beta-decay, which is possible if the neutrino is Majorana. Beta-decay experiments can be categorized by the detector type and there were reviews of tracking, solid-state, calorimetric and scintillator detectors, with energy resolution being the crucial common ingredient. The neutrino mass scale can also be probed through cosmology; the relic neutrino density influences the evolution of large-scale structure in the universe. Richard Easther from Yale presented the latest results obtained by combining cosmic microwave background and supernova observations. The best fit constrains the mass sum from all neutrino flavours to be less than 1 eV, with better precision obtainable if the Hubble constant is known independently.

Neutrinos also probe a range of physical processes, from the heat source of the Earth to the location of high-energy cosmic accelerators. Bill McDonough of Maryland discussed how the detection of geoneutrinos can put limits on the amount of heat generated by uranium and thorium inside the Earth. KamLAND has already placed limits on this but is restricted by the background from reactor neutrinos. The next step may be the Hawaii Anti-Neutrino Observatory, HANOHANO – a proposed 10 kilotonne liquid scintillation detector designed to be transportable and deployable in the deep ocean. Its goal is to measure the neutrino flux from the Earth's mantle for the first time.

Cosmic neutrinos may also unveil the very high-energy, cosmic-ray accelerators. Unlike photons or charged particles, neutrinos can emerge from deep inside their sources and travel across the universe uninterrupted. Julia Becker of Gothenberg University discussed some potential sources of cosmic neutrinos, including some of the most energetic objects in the universe, such as supernova remnants, microquasars and active galactic nuclei. To date, no experiment has observed extraterrestrial high-energy neutrinos, but cubic-kilometre telescopes (e.g. KM3Net, which is planned for the Mediterranean, and IceCube, under construction at the South Pole) are expected to be large enough to observe these cosmic neutrinos. Spencer Klein from the Lawrence Berkeley National Laboratory gave an update on the IceCube neutrino observatory, which uses the ice at the South Pole as a Cherenkov medium for the detection of high-energy neutrinos. The observatory comprises an in-ice, three-dimensional array of photomultiplier tubes and a surface air shower array. In February, half of the detector had been deployed, bringing the instrumented volume to roughly 0.5 km^3.

Although the field of neutrino physics has moved into a precision era, many puzzles remain and there is still much to be explained. A number of experiments are anticipating new results in the near future, so we can look forward to the next Neutrino conference, to be held in Athens in 2010.

Further reading

For the Neutrino 2008 programme and presentations, see www.neutrino2008.co.nz.

Résumé

Des physiciens des neutrinos en Nouvelle-Zélande

La XXIIIe Conférence internationale sur la physique des neutrinos et l'astrophysique a fait le point sur les dernières évolutions dans le domaine. Elle s'est tenue à la fin mai à Christchurch (Nouvelle-Zélande) et a été organisée par l'Université de Canterbury et la collaboration IceCube, qui utilise Christchurch comme ville de transit pour l'Antarctique. Les résultats présentés ont montré que les expérimentateurs neutrino sont maintenant passés aux mesures de précision. Ils pensent que la masse et le mélange des neutrinos sont des manifestations de la physique au-delà du modèle standard. Il demeure cependant encore bien des zones d'ombre et des incertitudes.

Jenni Adams, *University of Canterbury, New Zealand.*

Nobel dreams at Lindau

This year's annual meeting of Nobel laureates on the edge Lake Constance had more than a touch of CERN about it, taking place only weeks before the start up of the LHC.

Every summer since 1951 a large number of Nobel laureates gather in Lindau, Germany, at Lake Constance (the Bodensee) and meet with talented young scientists from around the world. These annual meetings, today a permanent institution supported by a foundation, were initiated by the late Count Lennart Bernadotte, a member of the Swedish royal family who had settled on the nearby Island of Mainau in Lake Constance. Count Bernadotte, an outstanding personality with philanthropic, ecological, cultural and scientific interests, established these meetings of Nobel laureates with young scientists with the intention of fostering scientific excellence as well as international cooperation in the spirit of pacifism. Today the foundation is headed by Countess Sonja Bernadotte, assisted by Wolfgang Schürer, visiting professor for public affairs at St Gallen University.

Initially only young scientists from Germany were invited, but over the years the meetings were expanded to participants from Europe and then the world. Some 550 students, postgraduates and fellows currently take part each year, selected by the scientific board of the Foundation Lindau Nobel Prizewinners Meetings. The delegates come from more than 60 countries, of which about 40% are from outside Europe. The proportion of young female scientists has been constantly increasing, reaching 50% last year.

The Lindau meetings usually focus on one of the Nobel prize fields in the natural sciences – physics, chemistry, and physiology or medicine – and rotates between them; a separate meeting on economic sciences with winners of the Bank of Sweden Prize in Economic Sciences in Memory of Alfred Nobel is held every two years. The one-week programme of the meeting of Nobel laureates consists of lectures by the laureates, scientific discussions between them and the young scientists, a round table and social events. The informal contacts are of course a crucial element.

This year the Meeting of Nobel Laureates – the 58th in the series – was on physics, with 24 participating laureates, including several particle physicists with close links to CERN, namely David Gross, Gerardus 't Hooft, Carlo Rubbia, Jack Steinberger, and Martinus Veltman. The lectures included talks by Veltman on "The development of particle physics", Gross on "The Large Hadron Collider and the Super World", Steinberger on "What future for energy and climate?" and 't Hooft on "Humanity in the cosmos". Also from the field of particle physics, Donald Glaser, who received the Nobel prize for the invention of the bubble chamber, talked about the role of cortical noise in vision, and cosmologist George Smoot described the beginning and development of the universe. The round table centred on energy and climate, following on from talks by three chemistry laureates, and featured contributions from both Rubbia and Steinberger.

Beyond these eminent names, CERN participated this year with a highly visible press event in which Jos Engelen and Lyn Evans talked about the LHC start up and where several laureates discussed questions on the expected results of the LHC (p30). During the event a video link was established to the CERN control centre so that the audience could observe the ramp up of sector 7/8 of the LHC to 8500 A (5 TeV) as it happened.

The round-table discussion on energy and climate included CERN Nobel laureates Jack Steinberger, second from left, and Carlo Rubbia, fourth from right. (Courtesy Lindau Nobel Laureate Meetings/C Flemming.)

CERN was also represented among the young scientists attending the meeting. In 2007, I had established contacts with the Lindau Foundation, and as a result, CERN was invited to nominate a candidate with a link to medicine, the field of last year's meeting. Benjamin Frisch, a student on the Austrian doctoral student programme, working at CERN on the medical applications of microelectronics, was selected. This year CERN was again invited to nominate young scientists. The four candidates selected were a good representation of the range of science and technology at CERN, as well as the laboratory's international nature (p32).

The annual Nobel meeting in Lindau was once again an outstanding event, full of enthusiasm and brilliant ideas. For the young scientists it was a unique opportunity to exchange ideas and network beyond and outside their scientific subject, making it a veritable feast of science. The international context and the commitment to scientific excellence are basic elements that are common to both the Nobel foundation and to CERN – a good reason to maintain and intensify the links between both organizations.

Maximilian Metzger, *secretary-general, CERN.*

Nobel expectations for

What do leading figures in particle physics expect from the LHC, a few weeks before the machine's start-up? There couldn't be a better opportunity to ask them than at the 2008 physics meeting of Nobel laureates. Paola Catapano went to Lindau to find out.

The opportunity for young scientists to meet with Nobel laureates makes the Lindau meeting a very special occasion. This year it was even more special for CERN, with four young participants from the laboratory and a press event where several of the laureates spoke of their expectations for the LHC. The following extracts give some flavour of their opinions.

LINDAU NOBEL LAUREATE MEETINGS/C FLEMMING

David Gross: "a super world"

Gross shared the 2004 Nobel Prize in Physics with David Politzer and Franck Wilczek "for the discovery of asymptotic freedom in the theory of the strong interaction". He is currently director of the Kavli Institute of Theoretical Physics at the University of California, Santa Barbara.

I expect new discoveries that will give us clues about the unification of the forces, and maybe solve some of the many mysteries that the Standard Model (SM) leaves open. I personally expect supersymmetry to be discovered at the LHC; and that enormous discovery, if it happens, will open up a new world – a super world. It will give the LHC enough to do for 20 years and will help us to understand some of the deepest problems in the structure of matter and elementary particles physics and beyond. Supersymmetry is not just a beautiful speculative idea, it has three incredibly strong vantage points in the LHC energy range: the unification of forces, the mass hierarchy and the existence of dark matter, where its abundance is observed. These three indirect hints from experimental observations all point to a TeV regime that can be naturally accommodated in extentions of the SM that were invented long before these indications appeared.

V STEGER

Gerardus 't Hooft: "a Higgs, or more"

't Hooft shared the 1999 Nobel Prize in Physics with Martinus Veltman "for elucidating the quantum structure of electroweak interactions in physics". He is currently professor of theoretical physics at the Spinoza Institute of Utrecht University.

The first thing we expect – we hope to see – is the Higgs. I am practically certain that the Higgs exists. My friends here say it is almost certain that if it exists, the LHC will find it. So we're all prepared and we're very curious because there's little known about the Higgs except some interaction signs. There could be more than one Higgs, several Higgs, and there could be a composite Higgs, but most of us think it should be an elementary particle... My real dream is that the Higgs comes up with a set of particles that nobody has yet predicted and doesn't look in any way like the particles that all of us expect today. That would be the nicest of all possibilities. We would then really have work to do to figure out how to interpret those results.

LINDAU NOBEL LAUREATE MEETINGS/C FLEMMING

Douglas Osheroff: "lots of new particles"

Osheroff shared the 1996 Nobel Prize in Physics with David Lee

new physics at the LHC

and Robert Richardson for "their discovery of superfluidity in helium-3". He is currently professor of physics and applied physics at Stanford University.

The LHC is an incredible piece of engineering, there is no doubt about that; 27 kilometres of superfluid helium is a mind-boggling thing. However, if you look at any little piece of that, it is a simple technology, carried to the absolute limit of what we could imagine that man would ever do. But of course the most fascinating part of CERN isn't the cryogenics, it's the particles that we hope the LHC will produce... If we don't get the Higgs, that would in fact be a bit more interesting, but I am hoping that there will be lots of new particles and resonances that no one ever expected. That will be really exciting.

V STEGER

Carlo Rubbia: "Nature will tell"

Rubbia shared the 1984 Nobel Prize in Physics with Simon van der Meer for their work that led to the discovery of the W and Z bosons at CERN. Rubbia was director-general of CERN from 1989 to 1993 and is still based mainly at CERN, pursuing a variety of research projects in the fields of neutrino physics, dark matter and new forms of renewable energy.

I think Nature is smarter than physicists. We should have the courage to say: "Let Nature tell us what is going on." Our experience of the past has demonstrated that in the world of the infinitely small, it is extremely silly to make predictions as to where the next physics discovery will come from and what it will be. In a variety of ways, this world will always surprise us all. The next breakthrough might come from beta decay, or from underground experiments, or from accelerators. We have to leave all this spectrum of possibilities open and just enjoy this extremely fascinating science.

V STEGER

George Smoot: "the nature of dark matter"

Smoot shared the 2006 Nobel Prize in Physics with John Mather "for their discovery of the blackbody form and anisotropy of the cosmic microwave background radiation". He currently works in the field of cosmology at the Lawrence Berkeley National Laboratory and is a collaborator on the Planck project.

For a cosmologist, one of the great things is that cosmology and high-energy physics are merging – they begin to overlap and are necessary for each other. For the LHC, I am very excited because it turns out that one of the missions I am doing, the Planck mission, has had the same schedule as the LHC for 14 years. We'll probably launch a little later... I am looking forward to hearing about the Higgs, because I'd like to see the Standard Model completed and understood. I'm also hoping that the LHC will begin to unveil extra dimensions, and that will have huge applications across the board. But what I am really looking forward to is supersymmetry or something that shows what dark matter is made of, so I have really high hopes, perhaps too high hopes.

LINDAU NOBEL LAUREATE MEETINGS/C FLEMMING

Martinus Veltman: "the unexpected"

Veltman shared the 1999 Nobel Prize in Physics with his student ▷

Gerardus 't Hooft "for elucidating the quantum structure of electroweak interactions in physics". He is professor emeritus at the University of Michigan, Ann Arbor.

What I expect from the LHC? That's a big problem. What I would like to see is the unexpected. If it gives me what the Standard Model predicted flat out – the Higgs with a low mass – that would be dull. I would like something more exciting than that. I sincerely hope that we do not find something strictly according to the Standard Model because that will make it a closed thing of which we see no door out, though it is still full of questions. Anything except the two-photon decay of the Higgs… But there is also the possibility that other products might come up because the machine, after all, enters a new domain of energy and will perhaps show us things we didn't know existed. It's a very exciting thing for me and my guts can't wait…

Résumé

LHC : Les Nobel disent leurs attentes

Tous les étés depuis 1951, un grand nombre de prix Nobel se réunissent à Lindau (Allemagne), au bord du lac de Constance, pour rencontrer de jeunes et brillants scientifiques du monde entier. Cette année, à l'occasion de la 58ème de ces rencontres, il a beaucoup été question du CERN, à quelques semaines du démarrage du LHC. Plusieurs prix Nobel ayant des liens étroits avec le CERN ont participé et quatre boursiers du CERN faisaient partie des quelque 500 jeunes scientifiques invités. Lors d'une rencontre consacrée au démarrage du LHC, des prix Nobel ont évoqué leurs attentes à l'égard de la physique que le LHC permettra de découvrir. On trouvera ici des extraits de ces interventions.

Paola Catapano, *CERN.*

The first presence at Lindau

CERN was first officially present at Lindau in 1971, when I was sent there to talk to Werner Heisenberg about the latter's future attitude towards CERN. My boss Edwin Shaw, head of the Public Information Office, picked me because I spoke German. This was no easy mission. I was very fearful of speaking to Heisenberg because, in 1969, the Nobel laureate had advised the German government not to finance "Supercern" – a more powerful accelerator at a new site in Europe. For Heisenberg, the era of ever-larger machines continuing to yield important discoveries was ending. A universal formula would answer all outstanding questions in particle physics. His peers strongly disagreed with him and he was persuaded to back the lower-cost 300 GeV project at the existing CERN site (*CERN Courier* August 1971 p221).

Simon Newman, celebrating the discovery of the W boson, which earnt Rubbia the Nobel prize in 1984.

Simon Newman, *CERN (1968–1985).*

First impressions

For a second year, CERN was offered the opportunity to send young scientists to Lindau. The four selected candidates represented the diverse range of the laboratory's research. Here are some of their impressions of the event:

M KOWALSKA

"It's just my second day here in Lindau… We already heard four Nobel lectures and all of them were different and extremely interesting. Some of them were more quiet, some more ready to give advice and even joked during their talks. But even meeting so many students from so many countries is incredibly interesting, to exchange ideas and experiences. I am sure that I am going to learn a lot and remember Lindau for a long time."
– Magda Kowalska, ISOLDE.

"Lindau is a very nice experience. There are many students from all over the world and many Nobel Laureates from different fields in physics. It is a unique opportunity to meet them and talk in an informal way about many subjects. It is very encouraging for us students to have such role models for our future."
– Rafael Ballabriga, Medipix/ Technology Transfer.

"I've had very little time so far to talk to the Nobel laureates, but it's been really great to talk to other students and learn about what they're doing and how they work on their research. Generally, when I go to conferences in particle physics, I only talk with particle physicists. Here I get exposed to a lot of other different fields like superconductors and plasma physics. I just had a discussion at lunch about it and that was really fun."
– Bilge Demirkoz, ATLAS.

"In Lindau, what I find interesting is to learn physics that is actually outside my field of research and to be aware of what other fields of research do in other areas. Yesterday, for instance, we learnt about quantum optics and today, biophysics. It is very interesting to be exposed to all these new ideas – in case we don't find anything at the LHC and I'll have to change field!"
– Geraldine Servant, Theory Unit.

Energy options and the role of nuclear fusion

Will nuclear physics provide a solution to the world's energy shortage? Former director-general of CERN, **Chris Llewellyn-Smith**, talks to **Antonella Del Rosso**.

Chris Llewellyn-Smith is no stranger to CERN. He served five years as director-general, from 1994 to 1998. During his mandate, LEP was successfully upgraded and the LHC project was approved. On his most recent visit to CERN, however, Llewellyn-Smith did not address the audience gathered in the main auditorium on particle physics or high-energy accelerators. Instead, he talked about the shortage of energy sources in the world, a popular topic these days.

With the price of oil fluctuating, subjects such as "hydrogen-driven" cars, "solar-fed" devices and "biomasses" appear increasingly in newspapers and magazines, with various experts constantly presenting new scenarios. According to the International Energy Agency, a huge increase in energy use is expected in the coming decades. Most of it is needed to lift billions of people out of poverty, including more than 25% of the world's population who still lack electricity.

According to Llewellyn-Smith: "Fossil fuels supply 80% of the world's primary energy. When they are exhausted, it currently looks as if much of their role will have to be taken over by nuclear fission (conventional nuclear reactors at first, then fast breeders when the cheaper uranium is exhausted), and possibly solar power, but this will need technological advances to decrease the cost, and in storage and transmission. And then, of course, we should use any alternative energy that works such as wind, biomasses and hydro. We also must become much more economical. For large-scale production power plants, we hope that a major role will be played by fusion."

The idea of producing energy using nuclear fusion dates back to the early 1950s. About 20 years after its discovery, at the first Conference on the Peaceful Uses of Atomic Energy held in Geneva in 1955, Homi Bhabha said: "I venture to predict that a method will be found for liberating fusion energy in a controlled manner within the next two decades." (Vandenplas and Wolf 2008). Unfortunately, after the first enthusiastic moments, major technological hurdles prevented fusion from becoming the easy option for energy supply that was originally expected.

Now the future of fusion is ITER, the joint international research and development project that aims to demonstrate the scientific and technical feasibility of fusion power. "The biggest fusion device in the world at the moment is the Joint European Torus, JET, at Culham in the UK," explains Llewellyn-Smith. "In order to show that fusion can really work, we need to build something that is twice as big in every dimension and that will be ITER. There are other devices currently being built in the world but they are all smaller, so there is no competition for ITER." Europe, Japan, Russia, US, China, South Korea and India are all involved in the ITER project. "Between them," continues Llewellyn-Smith, "these countries are home to more than half the population of the world. So, this is really a global response to a global problem."

Llewellyn-Smith: from CERN to nuclear fusion. (Courtesy UKAEA.)

CERN is directly contributing to support ITER through some recently signed agreements (*CERN Courier* May 2008 p26). "ITER is starting from nothing," says Llewellyn-Smith, who is currently chairman of the ITER Council. "They need experts in a large number of areas and CERN can help by making expertise available. Some of these areas, such as superconductivity, have been used in fusion but not on the scale that has been used at CERN. The expertise of CERN people will certainly help to build up the project and make it work quickly."

Strong links between CERN and the fusion facilities also exist at a more managerial level. Llewellyn-Smith was called to lead the UK nuclear fusion programme after his mandate at CERN and then obtained the chair of the ITER Council, whereas CERN's current director-general, Robert Aymar, did quite the opposite and came to CERN after having led the ITER project. "The first example of exchange between CERN and fusion dates back to John Adams in the 1960s," confirms Llewellyn-Smith. "He was an engineer who went from building the PS to founding the Culham fusion laboratory, which I now direct, and then went back to CERN to build the SPS."

Particle physics and fusion use similar techniques, such as ▷

superconducting magnets, high-vacuum systems, RF systems, and detectors that have to work with high levels of radiation. However, it is not only the development of new technologies that Llewellyn-Smith brought from CERN to the fusion projects; it is also the experience of big international scientific projects. “I joined fusion at a time when Europe was trying to reach agreement to build ITER with the other members,” he continues. “The experience that I had negotiating to get the Americans, Japanese, Russians, Indians, Canadians etc involved at CERN, was valuable; I had dealt with many of the governments in ITER before, and even many of the same people.”

Big projects have high potential but they also bring a great deal of uncertainty concerning their feasibility, the huge amount of money they cost and their actual duration. ITER is not even a real fusion reactor yet, it is an experimental device. It will take at least 10 years to build it and another decade to understand its results, and only then might people start building an actual prototype power station. “The time-scale is slow,” confirms Llewellyn-Smith. “It is slow because we are dealing with very difficult, large-scale, first-of-a-kind projects. In fact, it will take considerably more than 30 years before fusion can be rolled out on a large scale. A very good question is if it will still be needed. The answer is ‘yes’, because the energy need is going to increase and – even forgetting about CO_2 and climate change – at a certain point there will be no oil, no coal, and no gas, and we will really need additional options. So we have to go on with fusion as fast as we can.” As it seems inevitable that the world’s remaining fossil fuels will be used, “developing the technology to capture and store the CO_2, and then deploying it on a large scale, must be a priority” according to Llewellyn-Smith.

A particular attraction of fusion is that it is environmentally responsible. “Fusion doesn’t produce CO_2, and it’s not possible to have some sort of runaway reaction or explosion,” explains Llewellyn-Smith. “Fusion reactors can have all sorts of problems but it is very difficult to imagine accidents that will harm people. Fusion uses tritium, which is of course radioactive, but the active amount in a fusion power station will be less than a gram. The walls of the reactor become radioactive, but by choosing the materials correctly, we can make sure that the radioactivity has a half-life of around 10 years. So, a fusion reactor will become radioactive but 100 years later you could recycle the material. Unless you burn it, the waste from a conventional nuclear reactor is radioactive for many thousands of years.”

Changes in energy sources in the long-term future will alter the political balance of the world. Wealthy countries whose internal economy depends on the oil trade may become less wealthy, and western economies based on the use and transformation of oil derivatives may suffer from the change in the global energy scene. “The problem we face today is that the very poor countries generally have very limited energy resources,” says Llewellyn-Smith. “One quarter of the world’s population has no electricity at the moment. They need more energy to enjoy anything like what we would regard as an acceptable standard of living. We need some sort of solidarity, and equity.” He adds: “At the moment 80% of our energy comes from oil, coal and gas, which are going to end in the next decades. So the world is going to be different. I can’t predict what it will be like but the concern is to make sure that it is viable for everybody. It is unlikely that very high-tech solutions like fusion will become widely available in less wealthy countries. So maybe we in the developing world should be adopting such high-tech solutions and they should be using fossil fuels as long as they last. That is a political problem.”

Politics and the role of science: this is an interesting point. How much are scientists driven by politicians and vice-versa? “In the end politicians must make the decisions,” says Llewellyn-Smith. “The responsibility for scientists is to make sure that decisions are made on the basis of true facts. Long-term projects are very difficult to deal with because politicians only tend to look until the next election. They are beginning to say the right things about climate change, but words are not enough. We cannot stop the consequences of the things we are already doing, which will happen (e.g. rising temperatures) during the next 20 to 30 years. As scientists, it is our duty to make sure that governments understand what the potential solutions are and what alternative solutions should be developed. Our responsibility is providing information in an easy and understandable form.”

The primary concern of scientists is to understand the world, not change it, but as Llewellyn-Smith concedes: “As a by-product they can help to change and shape it; in fusion we are trying to help shape the world by providing another major energy option.”

Further reading

For Llewellyn-Smith’s talk, “Energy, Sustainability and Development”, see http://indico.cern.ch/conferenceDisplay.py?confId=30324.
Paul Vandenplas and Gerd H Wolf 2008 *Europhysicsnews* **39** 21.

Résumé

Les options énergétiques et le rôle de la fusion nucléaire

Chris Llewellyn-Smith n’est pas un inconnu au CERN ; il y a été directeur général pendant cinq ans, de 1994 à 1998. En 2003, on lui a confié la direction du programme de fusion nucléaire du Royaume-Uni et il est actuellement président du Conseil du projet international commun de R&D ITER. Il a récemment présenté au CERN une conférence sur un thème d’actualité : l’énergie, la durabilité de l’environnement et le développement. Il répond ici aux questions d’Antonella Del Rosso sur le défi de produire dans les prochaines années l’énergie nécessaire pour extraire des milliards de personnes de la pauvreté, sachant que plus de 25% de la population mondiale vit encore sans électricité.

Antonella Del Rosso, *CERN.*

Gas detectors advance into a second century

A recent workshop at Nikhef looked at the latest developments in a detection technique that dates back to the early days of particle physics, and saw the beginnings of a new research collaboration.

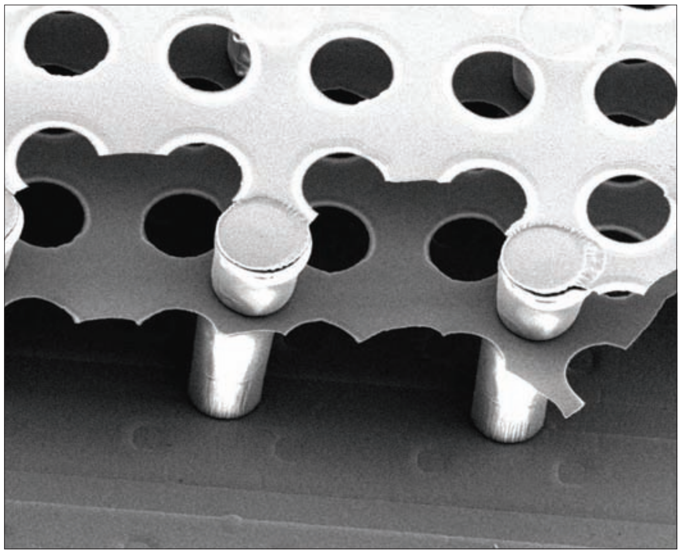


Fig. 1. A "twingrid": a double MicroMegas cathode grid grown with silicon wafer technology on top of a CMOS pixel detector, which has the benefit of rapid signal development. (Courtesy University of Twente.)

In 1908, Rutherford was the first to use a gas-filled wire counter to study natural radioactivity. To celebrate 100 years of gas counters, and in particular to look ahead to new developments in gas-based detectors, some 100 physicists gathered at Nikhef, Amsterdam, on 16–18 April. They were on a mission: to work towards the foundation of the RD51 collaboration, devoted to further research and development of micropattern gas detectors (MPGDs).

Fabio Sauli from the TERA Foundation and CERN reviewed how, in 100 years, gas detectors developed from Geiger counters to multiwire proportional chambers, drift chambers and time-projection chambers (TPCs) – detectors that are now widely used in high-energy and nuclear physics experiments. The need for gas detectors that could operate at high counting rates led to the development of micro-strip gas chambers. However, they proved difficult to operate in challenging conditions and were prone to aging and sparking. Nevertheless, the gas-detector community stood up to the challenge. The invention of MPGDs, such as the micromesh gaseous structure chamber (the MicroMegas) and gas-electron multiplier (GEM) detector, appears to have solved these problems.

Progress in MPGDs

These detectors have small avalanche gaps and therefore a rapid signal development, implemented in slightly different ways. In MicroMegas detectors the electron multiplication takes place in the narrow gap between a thin cathode mesh with holes and the anode. GEMs, on the other hand, have an insulating polymer foil with thin metal coatings on both sides, and the multiplication takes place in the holes in the foil. Such MPGDs are already in use in difficult environments, such as in the COMPASS experiment at CERN, and various ideas exist to develop MPGDs further into robust, economic, fast and, potentially, large-area tracking detectors with a low material budget (one-fifth to one-tenth of that in typical silicon detectors).

The workshop heard about progress towards various further improvements for MPGDs. Ioannis Giomataris of DAPNIA-Saclay presented new developments in MicroMegas detectors, such as bulk and large-area construction, and also spoke about various applications. Recent advances in thick GEM detectors formed the focus of the talk by Amos Breskin of the Weizmann Institute, while CERN's Serge Duarte looked at how to make large GEMs. In a slightly different vein, Vladimir Peskov from CERN described work on resistive-electrode thick GEMS, which are designed to give higher gain without sparking (*CERN Courier* May 2007 p35).

With recent developments in silicon wafer processing technology it is now possible to grow the thin cathode grid of a MicroMegas detector right on top of a silicon pixel chip (figure 1). Such a set-up (known as "Ingrid") integrates detector and read-out electronics optimally in one structure, as Victor Blanco Carballo from Twente University and Lucie de Nooij from Nikhef demonstrated (figure 2, p36). Sparks in the narrow gap between the cathode and the anode can destroy the pixel chip, but Nicolas Wyrsch of the Institute of Microtechnology, Neuchatel, showed that with a layer of amorphous silicon on the pixel chip, the detector can withstand sparking.

There are numerous applications of MPGDs, a few of which were discussed during the workshop. In R&D studies, thick GEMs are used for the detection of single photons in Cherenkov imaging counters. At Jefferson Lab, a new multipurpose spectrometer is being developed, where GEMs could be used in particle tracking at high rates. ▷

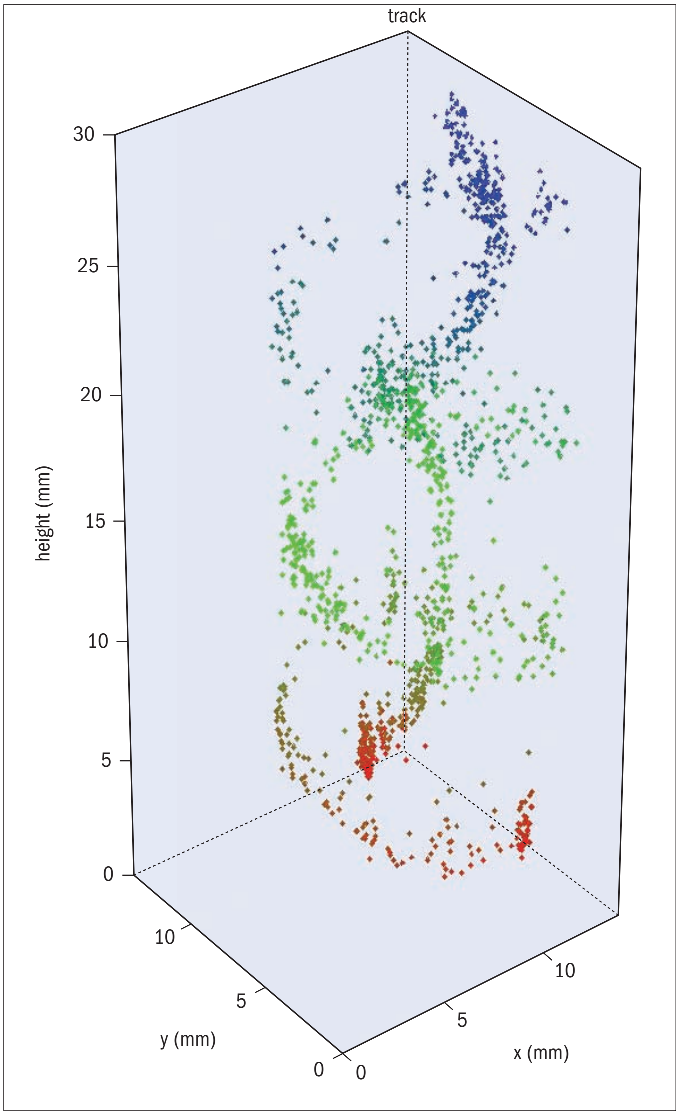


Fig. 2. Two tracks from a strontium source in a magnetic field, captured in a drift chamber read out by an integrated MicroMegas and pixel detector that also measures time (a TimePix chip). The points are individual hits, and the colours indicate drift time, converted to distance on the vertical axis. (Courtesy M Fransen and L de Nooij/Nikhef.)

GEMs are also being developed for digital hadron calorimetry in experiments proposed for the International Linear Collider (ILC) – a very high granularity can be achieved with small cells that are either "on" or "off". Groups working on experiments for the ILC have in addition designed large TPCs with MPGD read-out, and both GEMs and MicroMegas are being considered for this role.

In other developments, MicroMegas detectors could read out a TPC for the Tokai-to-Kamioka experiment in Japan, or be used as muon detectors at high counting rates, such as in the upgrade of the ATLAS detector at CERN for the upgraded LHC, the Super-LHC (SLHC) (*CERN Courier* July/August 2008 p17). A gas-pixel transition-radiation tracker based on MicroMegas is under study, and MicroMegas detectors are excellent technology choices for experiments that aim to detect rare events, such as searches for weakly interacting massive particles and solar axions, and studies of neutrinoless double beta-decay. MPGDs also have applications in astronomy and medicine as X-ray imaging detectors, and in neutron detection.

The workshop also discussed future read-out chips. The TimePix chip is derived from the Medipix2 chip, but with a time measurement for each pixel, which is an important asset for gas detectors. Michael Campbell from CERN talked about the Medipix3 chip, which is now under development, and Jan Timmermans of Nikhef discussed the requirements of TimePix-2, a successor of TimePix, and how this chip could be a general purpose read-out chip.

The RD51 collaboration

In a workshop at CERN in September 2007, participants realized that future progress in MPGDs would be best served by tighter collaboration. This led to the formation of a protocollaboration, working towards an R&D proposal: "Development of micropattern gas detectors technologies." Now some 50 institutes in Europe, the US and Asia have declared an interest, and a proposal for this collaboration, RD51, was submitted to the LHC committee on 2 July, following the workshop at Nikhef where Leszek Ropelewski from CERN was elected spokesperson, and Maxim Titov of CEA-Saclay was elected co-spokesperson.

The objectives of RD51 are to form a technology-oriented collaboration; to share common investments and infrastructure, such as test beams, radiation facilities and production lines; to develop common standards; to optimize the communication and sharing of knowledge; and to collaborate with industrial partners. The collaboration intends to perform technological studies for the optimization and industrialization of each manufacturing technology, and to develop radiation-hard devices that can operate beyond the limits of present devices (e.g. for detector upgrades for the SLHC). In addition, RD51 will work towards the integration of detector-simulation software, such as Garfield and Magboltz, with Geant4. It will also study the synthesis of MPGD front-end electronics into a number of read-out approaches, optimize read-out integration with detectors, and develop large-area MPGDs with CMOS read-out.

● Slides from the workshop are available online at Indico: see http://indico.cern.ch/conferenceDisplay.py?confId=25069. The next RD51 workshop will take place in Paris on 13–15 October 2008. For further details, visit http://indico.cern.ch/conferenceDisplay.py?confId=35172.

Résumé

Les détecteurs gazeux fêtent leurs cent ans

En 1908, Ernest Rutherford était le premier à utiliser un compteur à fil dans un tube contenant du gaz pour étudier la radioactivité naturelle. Pour fêter les 100 ans des compteurs gazeux et pour anticiper les nouveaux développements des détecteurs à gaz, une centaine de physiciens se sont réunis à Nikhef (Amsterdam) du 16 au 18 avril. Ils ont passé en revue les divers développements dans le domaine, en particulier depuis l'invention des détecteurs gazeux à microstructures (MPGD), qui semblent pouvoir fonctionner dans les conditions exigeantes des expériences modernes de physique des particules. Les participants ont cependant aussi réfléchi à la fondation de la collaboration RD51, qui sera consacrée à la R&D sur les MPGD.

Paul de Jong, *Nikhef.*

FACES AND PLACES

APPOINTMENT

Joël Mesot becomes director at PSI

Joël Mesot, an internationally acknowledged solid-state physicist, has become the new director of the Paul Scherrer Institut (PSI). His term of office began on 1 August, the Swiss national "birthday", in the year that PSI is celebrating its 20th anniversary. He takes over from the interim director, Martin Jermann (*CERN Courier* October 2007 p37).

Mesot was elected to the post by the Swiss Federal Council at the end of 2007. He was also elected to a joint professorship in physics at the two Swiss federal polytechnics, ETH-Zurich and EPF-Lausanne, by the ETH Council in April 2008.

Mesot's career in solid-state physics, which started with neutron scattering at ETH-Zurich/PSI and the Institut Laue-Langevin, continued with synchrotron radiation studies while a guest scientist at Argonne National Laboratory.

His work, with an emphasis on materials with unusual electronic properties, has made him well known in the fields of neutron scattering and photoelectron spectroscopy in connection with high-temperature superconductivity. He holds two patents associated with his research, and in 2002 was awarded the European Science Foundation's Latsis Prize for outstanding and innovative contributions in a selected field of European research.

Since December 2004 he has been head of the Laboratory of Neutron Scattering of PSI and ETH-Zurich, based at the Swiss Spallation Neutron Source (SINQ) at PSI.

Mesot will take over an active multidisciplinary "user laboratory" with world-class research facilities for material science, elementary particle physics, biology, medical science and energy and environmental research – a legacy promoted by previous directors. This, together with the foreseen realization of a compact X-ray free-electron laser at PSI, will guarantee an exciting and ambitious challenge for the next decade.

Joël Mesot, who took over at PSI on 1 August. (Courtesy Markus Fischer/PSI.)

VISIT

French research minister comes to CERN

On 6 June Valérie Pécresse, the French minister for higher education and research, visited CERN. The main objective of the visit was to obtain input on the organization of large research infrastructures, based on information concerning CERN's administrative and scientific configuration and the experiment collaborations.

After a tour of the CMS experiment and the LHC tunnel, with the president of the French National Assembly, Bernard Accoyer, the delegation took part in a round-table discussion attended by a dozen physicists. This included the director-general, project leaders, deputy spokespeople, members of the experiments, CERN personnel and users. The minister commented that fields of biomedical research, such as Alzheimer's disease and cancer, could benefit from pooling resources at the European level following CERN's example.

The French minister for higher education and research, Valérie Pécresse, with CERN's director-general, Robert Aymar. She visited CERN to learn more about the organization of large research infrastructures.

AWARDS

CERN receives Duke's Choice Award for Java development

CERN was honoured by Sun Microsystems at the JavaOne conference in May, with a gold Duke's Choice Award for the collection of Java applications that CERN developed for the installation and operation of the LHC. James Gosling, inventor of Java and vice-president of Sun Microsystems, presented the award to CERN's Derek Mathieson, who collected it on behalf of the organization.

Mathieson also had the opportunity to give live demonstrations of four of CERN's Java applications during Gosling's keynote presentation. These started with EDH, an application used by the administration as part of its Advanced Information Systems project. This was followed by the Technical Infrastructure Monitoring application used to monitor critical systems such as electricity, water supplies and cooling, 24 hours a day throughout the CERN site. The third application was the GraXML event viewer, which provides three-dimensional visualization of the ATLAS detector geometry with event data overlaid, allowing researchers to see the reconstructed particle tracks as they traverse the detector. The demonstrations finished with the GridPP real-time monitoring tool developed at Imperial College, London, which provides real-time views of Grid activity, visualized on a three-dimensional view of the Earth.

Derek Mathieson, right, receives the Duke's Choice Award from James Gosling, on behalf of CERN. Mathieson also gave demonstrations at the ceremony. (Courtesy John Todd/Sun Microsystems.)

All-ion accelerator scoops 21st Century Invention Prize

Ken Takayama and Yoshio Arakida of KEK and Yoshito Shimosaki of the Japan Synchrotron Radiation Research Institute and Kota Torikai Gunma University, have been awarded the 21st Century Invention Prize for 2008 by the Japan Institute of Invention and Innovation (JIII) for their work on an all-ion accelerator, based on the induction synchrotron concept. Atsuto Suzuki, director-general of KEK, has also been awarded the 21st Century Contribution to Invention Prize. They received their awards from Prince Masahito, president of JIII, at a ceremony on 17 June.

The invention is based on the induction synchrotron concept, proposed by Takayama and the late Junichi Kishiro in 2000 and fully demonstrated using the KEK 12 GeV PS in 2006 after the first partial demonstration in 2004 (*CERN Courier* April 2005 p22). In the all-ion accelerator, all ions, including cluster ions and radioisotope ions, are captured from the ion source and accelerated in the induction acceleration cells with pulsed voltages generated by transformers.

The transformers are energized by corresponding switched power supplies. Solid-state power conductors act as switching elements controlled by gate signals digitally manipulated from the signal of the circulating beam. This guarantees the synchronization of the acceleration with the revolution of the ion beam, whatever the ion and its possible charge state.

The KEK 500 MeV Booster is currently under renovation to become the world's first injector-free all-ion accelerator.

Left to right: Yoshito Shimosaki, Ken Takayama, Kota Torikai, and Yoshio Arakida at the award ceremony. (Courtesy KEK.)

Centennial Markov Prizes honour neutrino and accelerator physics

The centenary of Russian physicist Moisey Markov was celebrated on 14–16 May at the 6th Markov Readings held in Moscow and Dubna. In honour of the anniversary, the event saw the award of two Markov Prizes for 2008, to specialists in neutrino physics and accelerator physics.

Markov (1908–1994) made pioneering contributions to research in neutrino physics, as well as to studies of fundamental problems in elementary particle physics and quantum gravity, and on the borderline between particle physics and cosmology. The academician secretary of the Nuclear Physics Division of the Academy of Sciences of the USSR for two decades (1967–1988), Markov played a big role in the country's development of nuclear, particle and cosmic-ray physics and neutrino astrophysics. The Markov Prize was established by the Institute for Nuclear Research (INR) of the Russian Academy of Sciences in his memory as one of the founders of the Institute.

One Markov Prize for the centennial year was awarded to Stanislav Mikheev of INR and Alexei Smirnov of the Abdus Salam International Centre for Theoretical Physics and INR. They received the prize "for their outstanding contributions to the theory of neutrino oscillations and neutrino astrophysics that has made major impact on the interpretation of data from the institute's unique experiments at Baksan, the Large Volume Detector and the Liquid Scintillator Detector, as well as from other experiments". They are especially well known for their work on neutrino oscillations, particularly in matter. Sergei Esin, Leonid Kravchuck and Alexandr Feschenko, all from INR, received the second centennial Markov Prize "for the outstanding contribution to the development of physics and technology of accelerators, construction and upgrade of the high current linear accelerator of the Moscow Meson Factory".

From left to right: Victor Matveev, director of INR, with prize-winners Stanislav Mikheev, Leonid Kravchuck, Alexandr Feschenko, Sergei Esin and Albert Tavkhelidze, chairman of the Markov prize committee. Markov's portrait is in the background. (Photos courtesy INR-RAS.)

Alexei Smirnov shared the prize with Mikheev but was unable to be in Moscow. He will receive his prize later.

SCIENTIFIC INFORMATION

Workshop tackles scientific dissemination via open access

We hear the phrase "it's all on the Internet" more and more frequently, but it is not true for everyone. In the western world most of the information that scholars access for research is restricted to subscribers, with subscriptions only affordable by wealthy institutions. Moreover, access to the Internet is not necessarily easy – in several countries there is extremely limited bandwidth combined with a power supply that may be highly irregular.

Open access has begun to address the first of these problems. In particle physics, for example, use of the preprint service arXiv.org means that there is basically always one version of any paper written in the last 15 years available to anyone with access to the Internet.

On 7–16 July the Science Dissemination Unit (SDU) of the International Centre for Theoretical Physics (ICTP), in collaboration with CERN and the International Network for the Availability of Publications, organized a workshop on how to use open-access models for scientific dissemination. Some 60 participants attended, coming from 35 different countries, mainly from the less advantaged parts of the world.

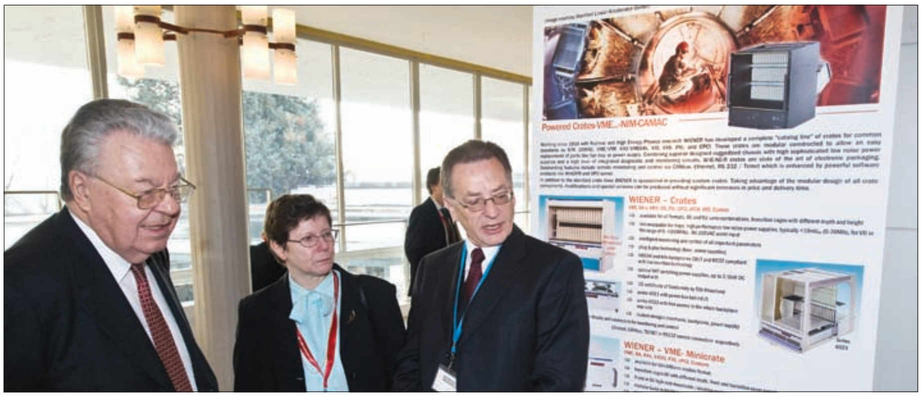
The stimulating discussions at the workshop showed that open access should not only provide an opportunity for improving access to information but also be used to augment the visibility of results from research carried out in less wealthy countries. There are still many practical issues to be solved, but there is no doubt that open access offers a level playing field to researchers across the world for accessing and disseminating scientific results.

Further reading

For more about the workshop, see http://sdu.ictp.it/openaccess. The ICTP SDU has published a free book *Science Dissemination, using open access*. This is available at http://sdu.ictp.it/openaccess/book.html.

INDUSTRY

CERN and German ministry host first Innovation Forum



Beatrix Vierkorn-Rudolph (centre), head of the BMBF Directorate and German delegate to the CERN Council, and Robert Aymar (left), CERN's director-general, visiting the industry exhibition. (Courtesy BICOM.)

This year the Federal Ministry of Education and Research (BMBF), together with CERN, held the first ever Innovation Forum at CERN in parallel with the 10th industrial exhibition in the series "Germany at CERN". Open to participants from all CERN member states, the forum aimed to provide researchers, innovators, chief technology officers and entrepreneurs the opportunity to learn more about CERN's technological know-how and expertise, accumulated through building the LHC, its detectors and the Worldwide LHC Computing Grid. In addition, participants could find out about the applications and benefits of CERN technology in many different domains beyond high-energy physics.

After a preliminary contact and networking evening on 28 January, both events were opened the following day by Beatrix Vierkorn-Rudolph, head of the BMBF Directorate and German delegate to the CERN Council, and Robert Aymar, CERN's director-general. They then toured the industrial exhibition, which provided a state-of-the-art picture of German industry. Some 30 German companies presented their products at the exhibition, in the main areas of mechanical and electrical engineering, electronics, data processing, radiation protection, vacuum and low-temperature technology, civil engineering and buildings. As with other exhibitions of this kind, it provided a platform for companies to offer their services to scientists and purchasing officers at CERN, to establish contacts and to find out about future purchasing opportunities.

More than 200 participants from Germany and other CERN member states representing about 100 research institutes and companies attended the Innovation Forum, which, like the exhibition, was on from 29–30 January. Members of the CERN Technology Transfer Group were first to talk at the forum, presenting technology transfer at CERN and the conditions for accessing technology developed at CERN, together with an overview of the technology-transfer opportunities for applications in, for example, microelectronics, cryotechnology, surface treatment and mechanics. Experts from CERN also presented specific state-of-the-art technologies developed in domains such as accelerators, material and surface technology, ultra-high vacuum and microelectronics. As an illustration of a successful application, Germany's Raytest GMBH presented its ClearPET small-animal PET system for imaging in pharmaceutical research. This is based on detector technology developments carried out within the Crystal Clear Collaboration (*CERN Courier* July/August 2005 p27).

Following the presentations, "matchmaking talks" took place between experts from CERN and industry representatives interested in specific technologies. These provided participants from both industry and research with excellent networking opportunities. Many discussions took place to present products, know-how and expertise available from industry for CERN, as well as to raise awareness of CERN as a centre of excellence for innovative technologies and expertise. The talks evaluated co-operation possibilities between fundamental research and industry.

In the evening, participants were able to continue discussions and networking in a relaxed atmosphere inside CERN's Globe of Science and Innovation.

The forum continued the next day with the exchange of ideas and exploration of network opportunities, followed by a visit to the underground areas of the CMS and ATLAS experiments. This gave the participants an idea of the challenges, complexity and performance of the LHC and its experiments, all of which have never been achieved before.

In general, the participants recognized the benefits of fundamental research, in particular particle physics, for society and could see the commercial prospects and competitive advantages that particle physics offers to high-tech industry. Participants from industry showed a strong interest in the presentations on CERN's technologies and their potential for application outside high-energy physics.

For follow-up and similar events in the future, all participants will be contacted and asked to fill in a questionnaire about the importance and impact of this event.

● For more about the programme, participants and company profiles, and all presentations, see the BICOM GmbH website www.innovationsforum-cern.de.

Heinrich Rohrer (centre), the 1986 Nobel Laureate who shared the prize in physics with Gerd Binnig for the design of the scanning tunnelling microscope, visited CERN on 25 June. Welcomed by ATLAS spokesperson Peter Jenni (right) and head of the former IT Communications Team, Francois Grey, he visited the cavern of the ATLAS experiment. Afterwards he toured the ATLAS control room, the Computer Centre, the Unosat project, the Antimatter Decelerator and ISOLDE.

NEW PRODUCTS

Aerotech has announced new Motion Designer software that provides an easy-to-use graphical user interface for generating and analysing motion trajectories, as well as improving the performance of complex motion profiles. The software simplifies trajectory programming and reduces development time where an exact motion profile needs to be generated. It can be used with Aerotech's PC-based A3200 Automation Platform motion and machine-control system, as well as with the EnsembleT or single-axis SoloistT motion controllers. For more information, contact Cliff Joliffe, tel +44 118 940 9400 (fax +44 118 940 9401), e-mail cjolliffe@aerotech.co.uk.

AMS Technologies now has the small, ultra fast Sudden Fault Fuse Resistors (SFFR) in IGBT driver circuits from Caddock Electronics available up to 1100 V. The SFFR technology eliminates the catastrophic damage in the gate driver circuit caused by sudden breakdown in gate isolation in the IGTB. In the SFFR the sudden application of a high voltage fault instantaneously causes distributed multiple interruptions along the length of the SFFR element, opening the high voltage fault. For more information, tel +49 898 957 7514, e-mail salesinfo@ams.de or see www.ams.de.

HamaTech Advanced Process Equipment has shipped its 30th MaskTrack photomask-cleaning system for 45 nm photolithography processing. This combines the capability to control process parameters dynamically, allowing an unparalleled variety of surface materials to be cleaned with a single tool and thereby eliminating adjustment downtime, together with innovative inspection and repair feedback for the targeted cleaning of specific areas of the mask. For more information, tel +49 704 5418 or fax +49 704 454 1239.

Heason Technology has announced the EDGE Motor from Nanomotion, a micro sized, sub micron resolution ceramic servomotor, just 13.5 mm long, 7.6 mm wide and 3.15 mm high. The EDGE can deliver a dynamic stall force of 300 mN at speeds of up to 120 mm/s – sufficient to position focusing mechanisms and other small optical devices, and devices such as miniature pumps. The motor is rated for a temperature range of –20 °C to +60 °C. For more information, contact Jon Howard, tel +44 140 375 5800 (fax +44 140 375 5810), e-mail jhoward@heason.com or see www.heason.com.

HiTek Power has introduced a series of 600 W ultraslim, lightweight high-voltage power supplies housed in a 1U high chassis. These new supplies measure 430 mm wide, 500 mm long, and 42 mm high, and they offer double the power available from other similar-sized supplies. The series provide full digital front-panel control and monitoring. The units offer output voltages of 1 kV to 80 kV, using air as the primary insulation medium. Output currents range from 7.5 mA to 600 mA. For more information, contact Michelle Quiggan, tel +44 190 371 2400, e-mail MQuiggan@hitekpower.com or see www.hitekpower.com.

OBITUARIES

Peter Schlein 1932–2008

Friends and colleagues were shocked and deeply saddened by the unexpected death of Peter Schlein on 26 February 2008. He was a highly respected particle physicist who started his long career on emulsion experiments and moved on to bubble-chamber, fixed-target and hadron-collider experiments. His best-known efforts include his role in founding two fields: the partonic structure of the pomeron and forward B-particle production.

Peter was born in Brooklyn, New York, on 18 November 1932, the eldest of four sons. His father, Irving Schlein, was a neoclassical composer, Broadway musical conductor and teacher. After graduating from Union College in Schenectady, New York, Peter received his PhD from Northwestern University in Evanston, Illinois. He worked as a postdoctoral researcher at the University of California, Berkeley, and Johns Hopkins University before joining the physics department at University of California Los Angeles (UCLA) in 1962.

Peter's research was unique. Had he not pursued it, much of the work in his field would probably not have been done or would have been undertaken at a much later date – and it would certainly have lacked his distinctive style. He took sabbatical leave from UCLA in 1969 at CERN to work at the ISR. The experiment was so fascinating for him that he continued the collaboration, dividing his time between CERN and UCLA. He went on to construct the first wide-aperture forward spectrometers at the ISR in 1973–1974, and this was to influence much of his future research. In the mid-1970s Peter returned to the US, where he collaborated on the fixed-target experiment E260 at Fermilab. He later returned to CERN to build the second-generation forward spectrometer to observe the Λ_c baryon and to study forward systems.

After the closure of the ISR, and excited by the results of his R608 experiment on diffractive dissociation of protons, Peter and Gunnar Ingelman proposed that the pomeron, which is exchanged in such interactions, should have partonic structure. Like any other strongly interacting particle, this partonic structure could be measured experimentally by observing jets in this class of interactions. He proposed and constructed the UA8 experiment at the $Sp\bar{p}S$ Collider at CERN to observe the jets produced in diffractive interactions. This saw the first use of Roman pots to trigger a central collider experiment. A very clean signal for jets in diffractive dissociation was observed with the first year's data, and so the new field of "hard diffraction" was born.

Peter Schlein. (Courtesy Lonnie Schlein.)

Before data-taking on the UA8 experiment was completed, Peter started thinking about studying B mesons and CP violation in hadron colliders, at a time when many physicists were planning to build e^+e^- colliders to study the same physics. During the next few years he directed the R&D programme that developed the topology trigger and the silicon system deployed a few millimetres from the circulating beams, two major obstacles for studying B mesons in hadron colliders. His series of proposals for a B experiment at the SPS, Fermilab and RHIC at Brookhaven eventually formed the basis of the plan for the LHCb experiment that will start data taking at the LHC this year. He left the LHCb experiment because of a lack of US support and, along with his UCLA colleagues, joined another LHC experiment, CMS, where he again concentrated on forward physics.

Peter spent four decades with the UCLA physics department, where he left a strong impression. Throughout his career he brought several notable faculty members to the department, and his impact was evident on the younger generation of faculty who were regularly asked by outside colleagues: "How is Peter doing?"

Near the end of his career and during his retirement, Peter turned his boundless energy towards reviving the legacy of his father's classical music. He catalogued hundreds of old scores and recovered lost pages from a variety of musical sources. He befriended many of the top musicians and musicologists in St Petersburg, Russia, transcribing all of the scores into digital form, and he commissioned performances and recordings by members of the St Petersburg Philharmonic. In all, Peter produced 14 CDs of his father's works, which are now being performed by musicians around the world. He was as proud of his accomplishments in creating "a new page in American music" as he was of his career as a physicist. With boundless energy and unstinting enthusiasm, he brought the beauty and originality of his father's musical works to the attention of an audience that never knew of their existence. This new work of musical discovery remains a work in progress and will add to his legacy.

Peter Schlein was a devoted family man and he leaves behind his wife, Lisa, his children, Oren and Ilana, five grandchildren and three brothers.

Samim Erhan, David Saltzberg and Rainer Wallney, UCLA.

Hiromi Hirabayashi 1934–2008

Hiromi Hirabayashi, a leading figure and professor emeritus of KEK, passed away on 11 April 2008. He was an internationally renowned pioneer in the field of applied superconductivity and cryogenics for high-energy physics.

Hirabayashi was born in Gifu Prefecture, renowned for the Shirakawa-go world heritage site. He was educated in nuclear engineering at the graduate school of Tokyo Institute of Technology, where he gained his PhD in 1966, before becoming a research associate at the Institute of Nuclear Study at the University of Tokyo. He worked on preparations for the National Laboratory for High Energy Physics, or KEK, now the High Energy Accelerator Research Organization, in particular in developing a hydrogen bubble chamber, essential for high-energy physics experiments in Japan. At the same time he established cryogenics – the necessary basic engineering – as a new academic discipline in Japan, and contributed to the development of applied superconductivity and cryogenics in collaboration with Japanese industry.

Moving as an associate professor to KEK when it was set up in 1971, Hirabayashi became a key person in the development of the KEK 1-m bubble chamber. From 1979, as professor, he led the construction of the primary proton and secondary (kaon and pion) beam lines at the KEK 12-GeV proton synchrotron. With excellent foresight, he advocated the importance of applied superconductivity and cryogenic engineering for accelerator science at the energy frontier of particle physics and was able to develop these areas through his strong leadership. His activities in these fields extended internationally through the developments of a superconducting secondary beam line at KEK, superconducting magnets for the TRISTAN project, a challenging 10-T dipole magnet for future accelerators, and collaborations on superconducting magnet development for the Superconducting Super Collider project, the g-2 experiment at Brookhaven, the WASA experiment at Uppsala University and the LHC project at CERN. He made Japanese superconducting magnet technologies for accelerator and particle physics highly appreciated throughout the world.

Hiromi Hirabayashi. (Courtesy KEK.)

Hirabayashi went on to become head of the Experiment Management Division, head of the Cryogenics Center, and director of the Applied Research Laboratory at KEK. In 1995 he was invited to head the Safety and Environment Research Center at the National Institute for Fusion Science, where he used his extensive experience and knowledge to advise on the construction of the Large Helical Device.

He contributed to several boards and committees, as a member of the international cryogenic engineering committee in 1990–1999, chairman of the cryogenic society of Japan in 1992–1994, and a member and chairperson of the superconductivity and cryogenics panel of the international committee for future accelerators in 1987–1995. He was also the Asian editor of *Cryogenics* from 1987–1996. His exceptional work in the field was recognized with the IEEE Award for Continuing and Significant Contributions in the Field of Applied Superconductivity and the special award for superconducting technology from the Society of Non-Traditional Technology.

After retirement in 1998, with a view to the environment and energy saving, Hirabayashi highlighted the need for the "convergence of liquid hydrogen and superconducting technology". His ideas for future society and technology leave an important legacy.

Hirabayashi's most important contribution was to devote energy to train the next generation to work in the fields of superconductivity and cryogenics and the development of these technologies. He trained many young scientists who now work actively in accelerator science and particle physics.

Hirabayashi's sudden death has been received with deep sadness not only by people in Japan but worldwide.

Takakazu Shintomi and Akira Yamamoto, KEK.

Uwe Timm 1924–2008

Uwe Timm, a senior physicist at the DESY Laboratory, died aged 84 on 1 May 2008.

Coming from the University of Hamburg, Timm joined DESY in 1958, before its official foundation in 1959. He was among a group of idealistic and enthusiastic young people whom Willibald Jentschke had attracted to build a 6 GeV electron synchrotron. The group succeeded in building a superb accelerator, even though they had all been amateurs in the field. Timm's responsibility was the 40 MeV electron linac injector which performed well from the beginning when the first electron beam was accelerated on 25 February 1964.

Timm subsequently turned to experimental high-energy physics. His unique contribution to this field was building a beam of high-energy coherent bremsstrahlung: an electron beam hitting a diamond target under precise conditions produces coherent gamma radiation with high linear polarization. For this achievement Timm received the Röntgen award from the University of Giessen in 1966. The polarized photon beam offered new ways to study photoproduction and Timm's group used it to measure ρ photoproduction and Compton scattering on the proton with polarized gamma rays, producing spectacular early results at DESY. The polarized gamma beam was also used by other DESY groups and helped the F35 group, for example, to study pion photoproduction and win the "Physikpreis" of the German Physical Society in 1970.

When DESY turned to storage-ring physics, Timm became spokesman of the PLUTO collaboration at the DORIS storage ring. PLUTO soon had good data on the total hadronic cross-section and on inclusive muons, which confirmed the existence of the τ lepton. The collaboration's pioneering work on gamma–gamma physics is still quoted today. The investigation of the Υ resonance decaying into three gluons established early indirect evidence for the existence of the gluon and for its spin. The PLUTO detector moved to the PETRA storage ring where the collaboration saw the first clear two-jet events and took part in the first round of experiments connected with the discovery of the gluon.

Uwe Timm. (Courtesy DESY, Hamburg.)

Yet another challenge awaited Timm at the end of his career, with the approval in April 1984 of the electron–proton storage ring HERA. Its construction required an enormous coherent effort from the DESY staff. Many physicists and engineers from the experimental groups joined the teams building HERA. As one of them, Timm again did a great service to the laboratory by, perhaps not surprisingly, building a 50 MeV proton linac (Linac III) of the Alvarez-type. It was ready for duty in November 1988, well in time before Timm retired officially in April 1989.

Timm was one of those people who do not seek the limelight, but who are vital to keep a laboratory successful. In collaborations he provided the necessary leadership and saw to it that consensus and harmony prevailed, and that the collaboration remained on a successful course. He will be remembered by his colleagues and friends at DESY as a personality who was instrumental in shaping the physics and the spirit of the laboratory.

Erich Lohrmann, DESY.

RECRUITMENT

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Wilson Fellowship in Experimental Physics

The Wilson Fellowship program at Fermilab seeks applications from Ph.D. physicists of exceptional talent with at least two years of postdoctoral work. The fellowships are awarded on a competitive basis and support physicists early in their careers by providing unique opportunities for self-directed research in experimental physics. Fellows will work on the Fermilab particle physics experiment of their choice. The Fermilab experimental program includes collider physics at both the Tevatron and the LHC, studies of neutrino and astroparticle physics, as well as R&D for future colliders and high intensity beams.

The Wilson Fellowships are tenure track positions with an annual salary fully competitive with university assistant professorships. The appointment is for an initial term of three years and can be renewed for an additional two years upon the completion of a successful review after the first two years.

Each candidate should submit a research statement describing a proposed research program, a curriculum vitae, and should arrange to have four letters of reference sent to the address below. Application materials and letters of reference should be received by October 31, 2008.

Materials, letters, and requests for information should be sent to:

Wilson Fellows Committee
Fermi National Accelerator Laboratory
MS 122, Attention: Cathryn Laue
P.O. Box 500, Batavia, IL 60510-0500
or Email: wilson_fellowship@fnal.gov

Additional information is available at:
http://www.fnal.gov/pub/forphysicists/fellowships/robert_wilson/

Fermilab

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RUPRECHT-KARLS-
UNIVERSITÄT
HEIDELBERG

The **Faculty of Physics** of the Ruprecht-Karls-University at Heidelberg, Germany, invites applications for a

Akademische Ratsstelle

„Lectureship“ (A13) (Tenure-track/Tenured)

We are looking for a theoretical physicist active in the field of mathematical physics, for example string theory or supergravity. The successful candidate is expected to demonstrate a commitment to teaching excellence in theoretical physics, including the undergraduate level (theoretical mechanics, electrodynamics, quantum mechanics and statistical physics). In the long run, part of the teaching is expected to be done in German.

Applicants are expected to have a Ph.D. in physics, an excellent research record and teaching experience.

The Ruprecht-Karls-University Heidelberg wishes to increase the proportion of female faculty and, for this reason, especially welcomes applications from women. Handicapped persons with the same qualifications will be given preference.

Qualified candidates are invited to submit their application **until October 30th** with the usual documents and a research plan to **Prof. A. Hebecker, Institut für Theoretische Physik, Philosophenweg 16, D-69120 Heidelberg**

CCIN2P3
Centre de Calcul de l'Institut National de Physique Nucléaire et de Physique des Particules

CNRS
CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

The IN2P3/CNRS Computing Centre (CC-IN2P3) is a national facility which provides storage and computing services for scientific research needs, mainly in the fields of nuclear, high-energy and astro-particle physics. More than 40 international scientific experiments regularly use its services. (For more information see: **http://cc.in2p3.fr**)

CC-IN2P3 hosts and operates one of the WLCG tier-1s centres and is responsible for the reception, long-term storage and initial processing of data produced by the 4 LHC experiments at CERN.

Job Opportunities for Engineers

At CC-IN2P3, Lyon, France

Scientific Data Storage Engineer (M/F)

Within a context of rapid growth and increased diversity of the storage services, CC-IN2P3 is looking for candidates to reinforce its Storage group. Currently composed of 7 engineers experts in data storage systems and working closely with the Systems and Operations groups, the Storage group is responsible for researching, designing, building, troubleshooting, operating and maintaining several storage systems in use within the computing centre.

The installed storage capacity of the computing centre is currently more than 10.000 Terabytes (both disk- and tape-based) and is planned to steadily grow in the coming years. Several software systems are currently in use for managing scientific data, including HPSS, GPFS, dCache, SRB, iRods, xrootd and Tivoli Storage Manager.

The ideal candidate must have a degree in computer science or a related scientific field. Interested in the usage of advanced technologies for the massive storage of scientific data, he/she will acquire the necessary proficiency through the provided training and on-site practical experience. He/she is expected to become an expert of one or several of the storage systems in use.

More information: **http://cc.in2p3.fr/article1625.html**

Software Engineer – Web Application Development (M/F)

The selected candidate for this full-time job will join a project within the Developments team. He/she is expected to effectively contribute to the development and deployment of an advanced platform for collecting, organising, correlating and reporting on information extracted from multiple independent data sources.

Mechanisms for efficient storage and retrieval of the collected data complemented by an advanced web-based interface for the visualisation of custom-selected information are essential components of this platform.

The ideal candidate must have a degree in computer science or a related scientific field with at least 3 years of experience in software development. A strong interest for advanced technologies for web-based application is essential to be successful in this position.

More information: **http://cc.in2p3.fr/article1633.html**

cerncourier.com

Lecturer in Accelerator Physics

Salary: £36,927 - £43,679 per annum inclusive of London Allowance

Royal Holloway University of London (RHUL) and the UK Science and Technology Facilities Council (STFC) intend to make a joint Lecturer appointment in Accelerator Physics.

RHUL is part of the John Adams Institute for Accelerator Science; a joint venture between Oxford University, RHUL and STFC. The RHUL accelerator physics group is currently involved in projects at the ATF2 at KEK, CTF3 at CERN, PETRA3 at DESY and is building up activity in DIAMOND at STFC Harwell and the LHC at CERN. Our projects are currently built around expertise in laser based beam diagnostics, advanced RF systems, radiation physics and advanced simulation.

We are looking to make a Lectureship appointment to establish a vibrant joint programme of accelerator physics at Royal Holloway and STFC. You should have at least three years postdoctoral research experience and be developing an international reputation in the field. This is an excellent opportunity to be part of a growing joint programme and would suit someone who aspires to a leading role in a major national laboratory, while establishing a strong academic profile in one of the larger colleges of the University of London.

For an informal discussion about the post contact Professor Grahame Blair (g.blair@rhul.ac.uk).

Further details and an application form are available on line at www.rhul.ac.uk/personnel or from the Personnel Department, Royal Holloway, University of London, Egham, Surrey TW20 0EX; Tel: 01784 414241; Fax: 01784 274900; E-mail: recruitment@rhul.ac.uk
Please quote the reference KB/4583.
The closing date for receipt of applications is the 26th September 2008.
It is expected that interviews for this position will be held on 21st October 2008.

We positively welcome applications from all sections of the community.

Royal Holloway
University of London

SCANTECH

Lead physicist – Le Bourget du Lac, France

Scantech is an international company specialized in advanced on-line measurement and control systems for industrial applications. Our head office is located in France, about 1 hour drive from CERN, with additional sites in the Peoples Republic of China and the US.

We require a Physicist/Engineer with a suitable background in radiation sensors and detection systems to head our research and development department. The successful candidate will be qualified preferably to PhD level.

Working on our French site, in direct collaboration with company management, you will contribute to the creation of a new generation of innovative, market leading products. An important part of our product range is based on X-ray interactions: photoelectric absorption, fluorescence and backscattering. Therefore, the successful candidate should posses a real understanding of the underlying physics of ionizing radiation and in particular of x-rays. Experience in software development is also desirable.

You will have a degree in physical science or equivalent experience with a proven track record of successful development. You will intervene on the complete development cycle: design, dimensioning and specification of the equipment, choice and follow-up of suppliers, machine reception and support to end-customers. Knowledge of French and/or English is required.

Negotiable salary and benefits package.

To apply, please e-mail your CV and contact details to jan.gaudaen@scantech.fr or send them to Jan Gaudaen, Scantech, Savoie Technolac - BP244 , 73374 Le Bourget du Lac, France
Phone +33(0)479252265

Technische Universität München

The Faculty of Physics of the Technische Universität München invites applications for a

Full Professorship (W 3) for Experimental Astroparticle Physics

to be filled as soon as possible in an early replacement of an existing chair.

Position

The Position will have a focus on astroparticle physics and be embedded both in the Cluster of Excellence “Origin and Structure of the Universe” and the Physics Department of the TU München. The current research activities in the Excellence Cluster Universe include low energy neutrino-astronomy, neutrino-oscillations and the search for dark matter. The successful candidate is expected to have an internationally recognized expertise in astroparticle and/or neutrino physics and should complement the scientific interests of existing groups working in experimental particle and nuclear physics at accelerators. In addition, a strong and active engagement within the cooperative research center SFB/TR 27 “Neutrinos and Beyond” is anticipated. Furthermore, an active participation in the research program of the Maier-Leibnitz-Laboratory is desirable. The research campus Garching offers a range of possibilities for cooperation with internationally leading research institutions, such as the research reactor and local Max Planck Institutes.

Active participation in the teaching program of the Physics Department of the TU München will be required, including introductory courses as well as specialized lectures on particle/astroparticle physics.

Requirements

Formal requirements for the professorship are a diploma from a university or university of applied sciences, pedagogical qualifications and a PhD degree. Excellent research accomplishments that may have been gained also outside academia are obligatory. Postdoctoral teaching experience or a formal lecturing qualification is required. Applicants should not have passed the age of 52 at the time of nomination. Under certain circumstances, however, this age limit can be neglected.

Persons with disabilities will be given preference over other applicants with comparable qualifications.

The TUM is striving to increase the proportion of women in research and education. Therefore, female scientists are especially encouraged to apply for this position.

Application

Applicants should complete the web form found on **www.universe-cluster.de (->jobs)** or submit their application (including CV, credentials and documents, publication list and a short overview of research interests) before 15 October 2008 to the following address:

Technische Universität München
Dean of the Faculty of Physics
James-Franck-Straße
D-85748 Garching

Excellence Cluster Universe · www.universe-cluster.de

BESSY

***BESSY** operates one of the world's most modern synchrotron radiation sources for VUV and soft X-rays, delivering high quality synchrotron radiation to more than 1.300 international users annually. We are further planning for a Free Electron Laser (BESSY-FEL) to generate ultimate quality VUV and soft X-rays for future short pulse and high brilliance experiments.*

To have the continuing ability to guarantee world class beam conditions paired with a competitive availability of the source we are developing an accelerating cavity with damped higher order modes and a new kind of injection magnets. To support the accelerator group in this field we look for a

Ph.D. Physicist

Ref. No: M-EF 08

The position is to calculate electromagnetic fields in frequency and time domain for complex accelerator components and perform experiments for their verification.

Candidates should have experience in the numerical calculation of electromagnetic fields using the most advanced 3D computer codes. Fundamentals in accelerator physics or experiences in accelerator operation are appreciated.

Enquiries should be directed to Dr. Ernst Weihreter,
Tel: +4930-63924634, E-mail: weihreter@bessy.de

Initially, we offer a three year appointment funded according to the German TVöD. Women are especially encouraged to apply. Handicapped persons will be given preference to other applicants with the same qualification.

E-mail applications will not be accepted. To apply, please send a cover letter and other application documents to:

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www.bessy.de

Leibniz Gemeinschaft

Universität Karlsruhe (TH)
Forschungsuniversität · gegründet 1825

KIT
Karlsruhe Institute of Technology

The **Fakultät für Physik** at the Universität Karlsruhe (TH) invites applications for the position of a

Junior-Professor for Theoretical Physics (W1, tenure track)

at the Institute for Theoretical Physics. Promotion to a tenured W3 position is possible after successful evaluation.

The applicant should conduct an active research program in theoretical particle physics. Expected are experience and significant achievements in physics beyond the standard model, in the development of novel field-theoretic techniques or in the phenomenology of elementary particle physics, with emphasis on collider physics.

The position offers excellent opportunities for collaboration within the Department of Physics, with other departments of the University and with the Forschungszentrum Karlsruhe in the framework of the Karlsruhe Institute of Technology (KIT). This includes the "KIT Centre for Elementary Particle and Astro-Particle Physics" (KCETA), the Transregional Collaborative Research Center SFB/TR9 "Computational Particle Physics" and the Research Training Group GRK 742 "High Energy Physics and Particle Astrophysics".

Applicants should have completed a course of studies in physics and should hold a PhD in physics. Teaching duties include lecture courses in physics for students of physics and also for students of other natural sciences or engineering disciplines.

Initially, the position is a limited term appointment for a three-year duration which can be renewed for a second three-year period after successful evaluation. After six years and positive final evaluation, advancement to a W3 professorship is possible.

The University aims to increase the number of female professors and especially welcomes applications from women. Handicapped persons with equal qualifications will be preferred.

Applications with the usual credentials as well as information on the five most important publications and a statement about past and planned research and teaching activities should be sent before **October 10, 2008** to: **Universität Karlsruhe (TH), Dekan der Fakultät für Physik, D-76128 Karlsruhe, Germany.**

HIC for FAIR

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

www.uni-frankfurt.de

The Institute for Applied Physics, Johann Wolfgang Goethe-University Frankfurt, invites applications to fill the following position:

Full Professorship (W3) in the Field of Experimental Astrophysics

The successful candidate is expected to have established an international reputation in this field of research and have a publication record in at least one of the following areas: 1.) Observational cosmology, 2.) Star phenomena and nucleosynthesis in stars, 3.) Development of novel particle and radiation detectors, as well as data analysis for astrophysics.

The research facility GSI in Darmstadt, with their current project FAIR, and the intense neutron generator FRANZ in Frankfurt provide the successful candidate with possibilities to participate in high-level experiments with astrophysical relevance. In addition, there are many potential collaboration partners, both on-site with the Institute for Theoretical Physics and the Institute for Nuclear Physics, as well as with the astrophysicists at GSI Darmstadt. The Institute for Applied Physics is currently conducting the construction of FRANZ and offers cooperation via research activities in accelerator and plasma physics, in image processing and properties extraction as well as with the technical infrastructure in the areas of mechanics and electronics. The candidate is expected to be very interested in the accelerator-based astrophysical experimental program. Moreover, the candidate should have obtained a habilitation or equivalent achievements in the field of experimental astrophysics and should document a successful active participation in international collaborations. Good social and teaching skills will be required to take part in teaching programs at all levels (Bachelor, M.Sc, PhD), with emphasis on developing the courses in the field of astrophysics (currently very well attended).

This position is initiated by the new Helmholtz International Center -HIC for FAIR- within the Hessian initiative of excellence LOEWE. An active contribution to this research activity is necessary.

The designated salary for the position is based on "W" on the German university scale or equivalent. The Goethe University is committed to a pluralistic campus community through affirmative action and equal opportunity. For details see: www.uni-frankfurt.de/aktuelles/ausschreibung/professuren/index.html.

Applications accompanied by the usual information (CV, degrees and certificates, list of publications, details on teaching and international experience, information on successful grant applications, all as pdf-files), should be sent via e-mail within **four weeks** of publication of this announcement to **Johann Wolfgang Goethe-Universität, Dean of the Faculty of Physics, Max-von-Laue-Str. 1, D-60438 Frankfurt am Main, Germany,** dekanat@physik.uni-frankfurt.de.

UNIVERSITY OF Cincinnati

The HEP group at the University of Cincinnati has an opening for a

POSTDOCTORAL RESEARCH ASSOCIATE ON THE BELLE EXPERIMENT AT KEK.

The initial appointment is for two years with the possibility of renewal. The Cincinnati Belle group (two faculty members, two postdocs, students) is involved in numerous analyses: measurement of the CKM angle alpha via b-to-u decays; measurements of D0-D0bar mixing; measurements of polarization in B- VV decays; and studies of Bs decays using data taken at the Upsilon(5S) resonance. Belle has the world's largest samples of reconstructed B and D decays. The experiment will take data until 2009, when Belle/KEKB is scheduled to be upgraded to a "Super B-factory."

Applicants should apply at **https://www.jobsatuc.com**, posting 28UC0175, and arrange to have three letters of recommendation sent to:
Prof. Alan Schwartz, Physics Department, University of Cincinnati,
P.O. Box 210011, Cincinnati, Ohio 45221.

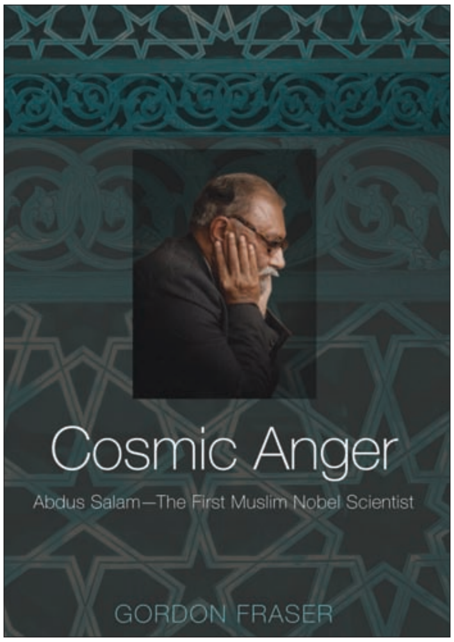
Cosmic Anger: Abdus Salam – The First Muslim Nobel Scientist by Gordon Fraser. Oxford University Press. Hardback ISBN 9780199208463 £25 ($49.95).

The late Abdus Salam – the only Nobel scientist from Pakistan – came from a small place in the Punjab called Jhang. The town is also famous for "Heer-Ranjha", a legendary love story of the Romeo-and-Juliet style that has a special romantic appeal in the countryside around the town. Salam turned out to be another "Ranjha" from Jhang, whose first love happened to be theoretical physics. *Cosmic Anger*, Salam's biography by Gordon Fraser, is a new, refreshing look at the life of this scientific genius from Pakistan.

I have read several articles and books about Salam and also met him several times, but I still found Fraser's account instructive. What I find intriguing and interesting about *Cosmic Anger* is first the title, and second that each chapter of the book gives sufficient background and historical settings of the events that took place in the life of Salam. In this regard the first three chapters are especially interesting, in particular the third, where the author talks about Messiahs, Mahdis and Ahmadis. This shows in a definitive way the in-depth knowledge that Fraser has about Islam and the region where Salam was born.

In chapter 10, Fraser discusses the special relationship between Salam and the former President of Pakistan, Ayub Khan. I feel that more emphasis was required about the fact that for 16 years, from 1958 to 1974, Salam had the greatest influence on the scientific policies of Pakistan. On 4 August 1959, while inaugurating the Atomic Energy Commission, President Ayub said: "In the end, I must say how happy I am to see Prof. Abdus Salam in our midst. His attainments in the field of science at such a young age are a source of pride and inspiration for us and I am sure that his association with the commission will help to impart weight and prestige to the recommendations." Salam was involved in setting up the Atomic Energy Commission and other institutes such as the Pakistan Institute of Nuclear Science and Technology and the Space and Upper Atmosphere Research Commission in Pakistan.

Finally, I find the book to be a well written account of the achievements of a genius who was a citizen of the world, destined to play a memorable role in the global development of



science and technology. At the same time, in many ways Salam was very much a Pakistani. In the face of numerous provocations and frustrations, he insisted on keeping his nationality. He loved the Pakistani culture, its language, its customs, its cuisine and its soil where he was born and is buried.

Hafeez Hoorani, National Centre for Physics, Quaid-E-Azam University.

Gravitational Waves Vol 1: Theory and Experiments by Michele Maggiore, Oxford University Press. Hardback ISBN 9780198570745 £45 ($90).

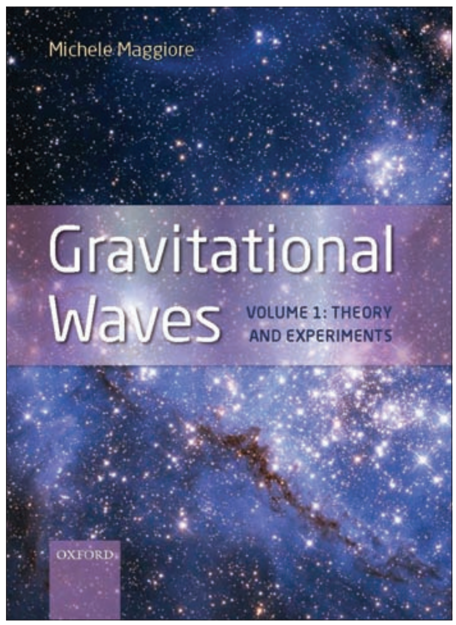
This is a complete book for a field of physics that has just reached maturity. Gravitational wave (GW) physics recently arrived at a special stage of development. On the theory side, most of the generation mechanisms have been understood and some technical controversies have been settled. On the experimental side, several large interferometers are now operating around the world, with sensitivities that could allow the first detection of GWs, even if with a relatively low probability. The GW community is also starting vigorous upgrade programmes to bring the detection probability to certitude in less than a decade from now.

The need for a textbook that treats the production and detection of GWs systematically is clear. Michele Maggiore has succeeded in doing this in a way that is fruitful not only for the young physicist starting to work in the field, but also for the experienced scientist needing a reference book for everyday work.

In the first part, on theory, he uses two complementary approaches: geometrical and field-theoretical. The text fully develops and compares both, which is of great help for a deep understanding of the nature of GWs. The author also derives all equations completely, leaving just the really straightforward algebra for the reader. A basic knowledge of general relativity and field theory is the only prerequisite.

Maggiore explains thoroughly the generation of gravitational radiation by the most important astrophysical sources, including the emitted power and its frequency distribution. One full chapter is dedicated to the Hulse-Taylor binary pulsar, which constituted the first evidence for GW emission. The "tricky" subject of post-Newtonian sources is also clearly introduced and developed. Exercises that are completely worked out conclude most of these theory chapters, enhancing the pedagogical character of the book.

The second part is dedicated to experiments and starts by setting up a background of data-analysis techniques, including noise spectral density, matched filtering, probability and statistics, all of which are applied to pulse and periodic sources and to stochastic backgrounds. Maggiore treats resonant mass detectors first, because they were the first detectors chronologically



to have the capability of detecting signals, even if only strong ones originating in the neighbourhood of our galaxy. The study of resonant bar detectors is instructive and deals with issues that are also very relevant to understanding interferometers. The text clearly explains fundamental physics issues, such as approaching the quantum limits and quantum non-demolition measurements.

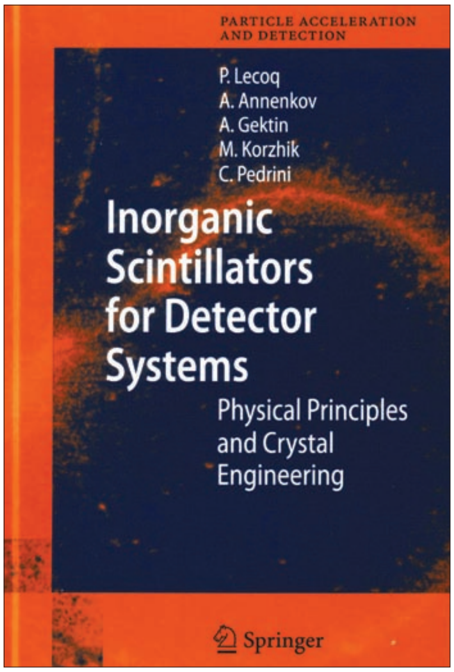
The last chapter is devoted to a complete and detailed study of the large interferometers – the detectors of the current generation – which should soon make the first detection of GWs. It discusses many details of these complex devices, including their coupling to gravitational waves, and it makes a careful analysis of all of the noise sources.

Lastly, it is important to remark on a little word that appears on the cover: "Volume 1". As the author explains in the preface, he is already working on the second volume. This will appear in a few years and will be dedicated to astrophysical and cosmological sources of GWs. The level of this first book allows us to expect an interesting description of all "we can learn about nature in astrophysics and cosmology, using these tools".
Carlo Bradaschia, INFN/Pisa.

Inorganic Scintillators for Detector Systems by P Lecoq *et al.*, Springer. Hardcover ISBN 9783540277668, £79 (€105.45).

This book covers a highly topical area of modern detector physics – scintillators. Initially developed as a tool for scientific exploration, scintillation detectors rapidly migrated into applications in our day-to-day lives, such as in energy production, security applications and the medical sector. The development of high-quality scintillators is an example of how demanding technological requirements in high-energy physics drive development and optimization processes that eventually benefit the general public. In this book the authors tell the story of two decades of major progress, largely motivated by building the largest electromagnetic calorimeter in high-energy physics with lead tungstate ($PbWO_4$), and by the development of a scintillator, lutetium aluminium perovskite (LuAP), for medical applications.

The introductory chapter deals with the terminology, key aspects and basics of the scintillation process, and it finishes by giving a table based on a combined



classification of scintillators. This is most informative for the end-users of scintillators, but caution must be exercised as some of the information is out of date. For example, a rather optimistic light yield for zinc tungstate ($ZnWO_4$) of 21 500 photons/MeV is given (taken from a reference from 1962), whereas around 9300 photons/MeV would be more appropriate. There are also some typos. For example, the scintillation time-constant of calcium tungstate ($CaWO_4$) is given as "600 ns", whereas it should read 6000 ns.

The next chapter discusses how scintillator development is influenced and guided by user requirements. The authors review five main areas of scintillator applications and set the scene for dealing with the often conflicting demands on scintillator characteristics. Then follows a substantial chapter that discusses the scintillation mechanisms of inorganic scintillators in great detail. The text is well written so that newcomers to the field and experts alike will enjoy it.

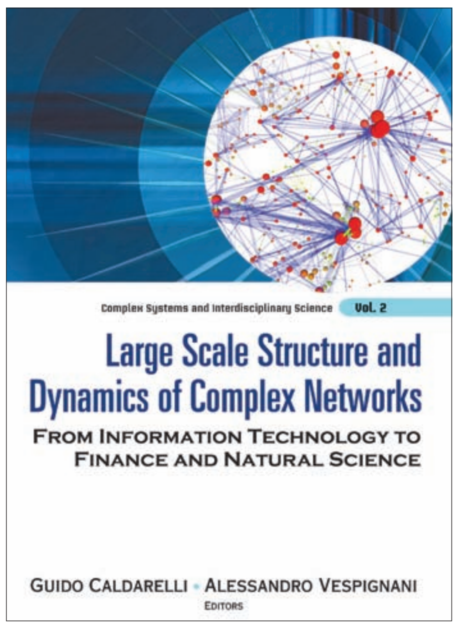
Producers of scintillating crystals are the main target audience for the next two chapters, which deal with the influence of crystal structure defects on the scintillation process and on crystal engineering. They give valuable information about crystal production, for $PbWO_4$ in particular, as well as useful recipes and ideas for solutions to various issues. Such information is often absent, or at best summarized, in short publications. A description of strategies that are common to developing scintillators for high-energy physics and for medical applications forms the final chapter.

Overall, the book is interesting and informative for the user – novice and expert – with sections at the right level for each.
Hans Kraus, Oxford University.

Large Scale Structure and Dynamics of Complex Networks: from Information Technology to Finance and Natural Science edited by Guido Caldarelli and Alessandro Vespignani, World Scientific. Hardback ISBN 9789812706645 £49 ($98).

Networks are everywhere, in social institutions as well as in economic, biological and technological systems. They are not a new phenomenon, but our understanding has not kept up with their influence and our increasing dependence on them. The complexity of networks has now become a central issue in characterizing, modelling and understanding them in many different disciplines, from physics, biology and mathematics to engineering and computer science. It is therefore important to seek the development of a methodological and theoretical framework, in order to define the general principles underlying the dynamics and structures of complex networks.

Researchers are now discovering the general concepts and properties of highly diversified networks, from living cells to electric power grids, and, thanks to progress



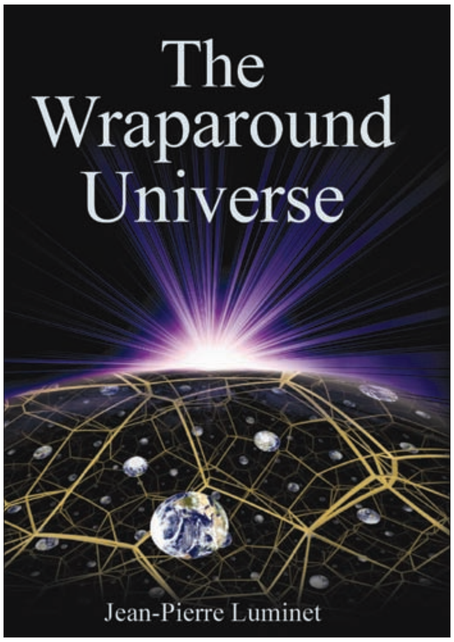
in information technologies, it is possible to analyse the large-scale statistical properties of networks. It is also evident that many complex evolving networks share a sophisticated topology. Intrinsic properties of complex systems, such as robustness to disturbances or information transmission time, are a direct consequence of this underlying network topology, which, in some cases, could be explicitly engineered.

The authors of this volume intend to show both a snapshot of forefront research activities in the field of complex systems and the achievements of the European project on Coevolution and self-organization in dynamical networks (COSIN; see www.cosinproject.org). The wide interdisciplinary approach is emphasized by the various chapters, which start with an introduction to the basic notation and definitions, based on graph theory, followed by an overview of the main classes of models: static random networks and evolving random networks.

Chapters three to six deal mainly with various aspects of complex networks, from the topological properties that may impact a variety of related topics, to the state of the art in network visualization – a challenging issue. The remaining four chapters focus on more specific fields. "Modeling the webgraph: how far we are" considers the graph induced by the hyperlink structure of the web, the nodes of which are the HTML pages with the edges being the links among them. "The large scale structure of the Internet" reviews the results obtained in the characterization of this large-scale complex network. Chapter nine looks at two of the most commonly used characterizations of a community of biological species: the food web and the taxonomic tree. The final chapter reviews some of the main general findings about social networks and then focuses on a specific case of an economical network: the boards of directors of large corporations.

The book also includes a detailed list of references, spanning a wide spectrum of disciplines, which underline the importance of the interdisciplinary approach in this field.
Gian Piero Siroli, University of Bologna and CERN.

The Wraparound Universe by Jean-Pierre Luminet, A K Peters. Hardback ISBN 9781568813097 $39.



The first thing that impressed me about this book by Jean-Pierre Luminet is the way that the text is organized. Although the author seems to suggest that the reader uses the references as a way to jump between different chapters – rather like hyperlinks on the web – what I really appreciated is that the book has 45 short chapters, each just a few pages long. This allows the reader to taste and digest it bit by bit, following their own rhythm.

Luminet has done his best to explain everything in a simple but never simplistic way, so it may take different people a different amount of time, and this structure makes it easier to adapt to each reader's needs. This could be one of the reasons why the book has had two editions in the original French as well as this English translation, and will probably be translated into other languages.

If you know a little of modern cosmology, you will read this book avidly from the first page to the last. I should admit that I felt ignorant at the beginning because I had never realized the importance of topology when discussing cosmic evolution (the fact that apparently I was not alone is not a good excuse). Consequently I'm grateful to Luminet for having made the role of topology in modern cosmology clear.

For example, I learned that the finite or infinite character of space depends both on its curvature and on its topology, though the latter is often neglected, even in refereed papers published by important journals. In addition, I realized that Einstein's equations do not set constraints *a priori* on the universe's topology. Rather, they can be solved for different boundary conditions, which include the specification of the three-dimensional space topology.

Space may have positive, null or negative curvature – a property of the "metric" that encodes the machinery to measure distances. We say that the geometry is spherical, Euclidean or hyperbolic in these three cases. The metric is the subject of Einstein's equations, which express it as a function of the total energy content of the universe through the energy-momentum tensor and the cosmological constant. On the other hand, the equations do not constrain the topology of the universe at all.

The simplest topology is "simply connected" (i.e. we can shrink all closed loops down to points without "exiting" from the space), and this is often implicitly assumed in books and articles about cosmology. However, "multiply connected" topologies are also possible (with any curvature), and if their "volume" is smaller than the visible universe, they may leave distinct signatures on the cosmic microwave background radiation, which could be experimentally detectable.

In general, a multiply connected universe would produce several images of each galaxy, and different topologies would produce different patterns, although searching for them is not an easy task. Luminet shows that the most recent data about the cosmic background radiation from the Wilkinson Microwave Anisotropy Probe are fitted better by "well-proportioned spaces", among which the best seems to be the "spherical dodecahedral Poincaré space", the volume of which is a 120th of the hypersphere (i.e. the simply connected topology) with the same curvature. This conclusion has been criticized by many researchers, but cannot be falsified with the present data. However, the Planck satellite should be able to provide measurements precise enough to discard this possibility if wrong and, possibly, identify the topology of our universe.

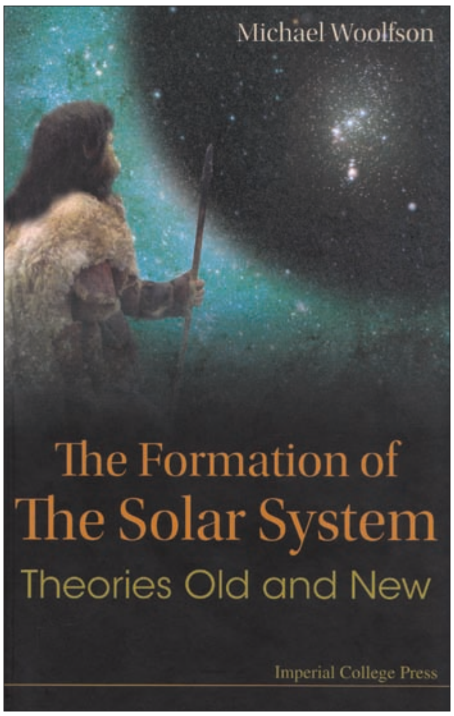
Luminet also considers the sociology of science. Comments about the impact of different ideas or even about the same ideas in different historical and geographical conditions are scattered throughout, but especially occur at the end. In conclusion, the book is well within the reach of the general public but still offers valuable insights to more

expert people. It raises a number of questions and tries to provide a few answers in one of the most fascinating subjects of modern research.
Diego Casadei, New York University and CERN.

The Formation of the Solar System: Theories Old and New by Michael Woolfson, Imperial College Press. Hardback ISBN 9781860948244, £49 ($95).

Starting from ancient times, this book looks at various ideas about the solar system, and details how theories about planet formation evolved over time. The author spells out the constraints that each theory had to fit (and which observations were less crucial), along with the problems and benefits of each model. With observations continually improving, some theories were discarded, others were refined and revisited decades or centuries later, and new ones also emerged. The past 100 to 200 years especially have seen much more detailed observations and new insights into what bodies are to be found in our solar system and the different features that they exhibit.

The author looks in particular at the solar nebula theory, which has been developed extensively during the past decades and now offers mechanisms for many aspects of planet formation. However there are still theoretical difficulties and some new observations that do not fit with this model. The author has therefore developed a different model, the capture theory, which he first proposed in 1962 and has since developed. Although this model describes the detailed structure of the solar system and its formation, the author does not claim to have the found the final answer, only a plausible one.



The book is written for a lay audience: the author avoids formulas – only in the second half are there a few – and uses simple illustrations and two-dimensional models to explain the concepts that he is describing. He also tries to connect to the reader's everyday experience. For example, he realises that zodiacal light cannot usually be seen in cities because of light pollution, and that the term "isotopes" usually appears in articles about nuclear reactors rather than astronomy. I also very much appreciated that he tried to put a face to the different theories by having many portraits of astronomers.

All in all, the book gives a good overview for both specialist and non-specialist readers. The non-specialists will need to invest some effort towards the end, where the author describes the current dominating theories in detail; and for those who want to go deeper into the field there are extensive references for each chapter.
Hannelore Hämmerle, MPG Munich.

Books received

The Light Fantastic: A Modern Introduction to Classical and Quantum Optics by Ian R Kenyon, Oxford University Press. Hardback ISBN 9780198566458 £59.95 ($120). Paperback ISBN 9780198566465, £29.95 ($60).

This book presents a thorough and self-contained introduction to modern optics, covering in full the three components of ray optics, wave optics and quantum optics. Digital cameras, LCD screens, aircraft laser gyroscopes and the optical-fibre-based Internet illustrate the penetration of optics into 21st-century life. These and many more modern applications are presented from first principles. The self-contained material allows the reader to select specific themes, which are grouped in the following way: paraxial ray optics with matrix methods and aberrations; interference, coherence and interferometers; diffraction, spectrometers and Gaussian beams; fourier optics, holography and information processing; Maxwell's theory; scattering, absorption and dispersion in bulk materials; and interface behaviour, etc.

Simple Models of Magnetism by Ralph Skomski, Oxford University Press. Hardback ISBN 9780198570752, £39.95 ($80).

For hundreds of years, models of magnetism have been pivotal in the understanding and advancement of science and technology, from the interpretation of the Earth as a magnetic dipole to quantum mechanics, statistical physics and modern nanotechnology. This book is the first to envision the field of magnetism in its entirety. It complements a rich literature on specific models of magnetism and provides an introduction to simple models, including some simple limits of complicated models. Written in an easily accessible style, with a limited amount of mathematics, it covers a range of quantum-mechanical, finite-temperature, micromagnetic and dynamical models and deals not only with basic magnetic quantities but also with modern areas, such as nanomagnetism and spintronics, and with "exotic" themes, as exemplified by the polymer analogy of magnetic phase transitions.

Introduction to Quantum Effects in Gravity by Viatcheslav Mukhanov and Sergei Winitzki, Cambridge University Press. Hardback ISBN 9780521868341 £45 ($85).

This is the first introductory textbook on quantum field theory in gravitational backgrounds intended for undergraduate and newly graduated students in the fields of theoretical astrophysics, cosmology, particle physics and string theory. It covers the basic (but essential) material of the quantization of fields in an expanding universe and quantum fluctuations in inflationary space–time. It also contains a detailed explanation of the Casimir, Unruh and Hawking effects, and introduces the method of effective action used for calculating the back-reaction of quantum systems on a classical external gravitational field. The broad scope of the material covered will provide the reader with a thorough perspective on the subject, every major result being derived from first principles and thoroughly explained. The book is self-contained, assuming only a basic knowledge of general relativity, and it provides exercises with detailed solutions throughout.