INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

CERN COURIER

VOLUME 47 NUMBER 7 SEPTEMBER 2007

ILL celebrates first 40 years

ACCELERATORS
KEK demonstrates crab cavities p8

LHC FOCUS
ATLAS commissioning gathers speed p23

CENTENARY
The rich legacy of Hideki Yukawa p43

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

CERN Courier is distributed to member-state governments, institutes and laboratories affiliated with CERN, and to their personnel. It is published monthly, except for January and August. The views expressed are not necessarily those of the CERN management.

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Produced for CERN by IOP Publishing Ltd
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Tel +44 (0)117 929 7481; e-mail jo.nicholas@iop.org; web iop.org

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General distribution Courrier Adressage, CERN, 1211 Geneva 23, Switzerland. E-mail courrier-adressage@cern.ch
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UK Mark Swaisland, Chadwick Library, Daresbury Laboratory, Daresbury, Warrington, Cheshire WA4 4AD, UK.
E-mail m.r.swaisland@dl.ac.uk
US/Canada Published by Cern Courier, 6N246 Willow Drive, St Charles, IL 60175, US. Periodical postage paid in St Charles, IL, US. Fax 630 377 1569. E-mail vosses@aol.com
POSTMASTER: send address changes to: Creative Mailing Services, PO Box 1147, St Charles, IL 60174, US

Published by European Organization for Nuclear Research, CERN, 1211 Geneva 23, Switzerland. Tel +41 (0) 22 767 61 11
Telefax +41 (0) 22 767 65 55

Printed by Warners (Midlands) plc, Bourne, Lincolnshire, UK

 ISSN 0304-288X

IOP Publishing

CERN COURIER

VOLUME 47 NUMBER 7 SEPTEMBER 2007

Understanding flavour p29

Forty years of ILL p34

Yukawa's gold mine p43

Cover: An evening view of the Institut Laue-Langevin, which was founded 40 years ago (see p34) (Courtesy ILL/Artechnique.)

NEWS

LHC NEWS

First LHC sector and inner triplets pass the latest tests

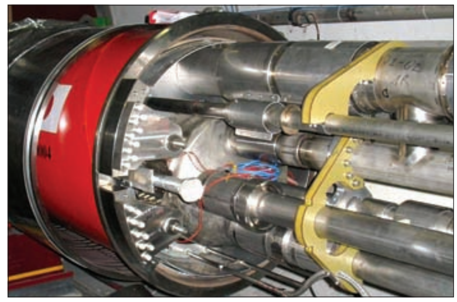
On 13 July, an inner triplet assembly of quadrupole magnets successfully completed a pressure test in the LHC tunnel, after installation of metal cartridges to reinforce internal support structures that broke in an assembly during an earlier pressure test in March. The triplet, which included three quadrupole magnets and the associated cryogenic and power distribution box (DFBX), met all test specifications at the requisite pressure of 25 atm for one hour.

The triplets will focus particle beams prior to particle collisions at the four interaction regions in the LHC. The pressure test is designed to verify the accelerator components in conditions that will occur during LHC operations. To withstand the asymmetrical forces generated, the Q1 and Q3 magnets at either end of the triplet assembly had each been fitted with a set of four metal cartridges to limit movement of the magnets inside their cryostats. The cartridges have a compound design consisting of an aluminium-alloy tube and an Invar rod to allow them to function over a broad range of temperatures.

To address design flaws that emerged during the March pressure test, a team from CERN, Fermilab, KEK and the Lawrence Berkeley National Laboratory also made changes to the DFBXs and the attachment of the triplet to the tunnel floor. These changes passed the test on 13 July.

Fermilab, in collaboration with CERN and KEK, supplied eight sets of triplets – one for either side of each of the interaction regions, plus one spare set. About half of the quadrupole magnets were repaired by the end of July, with the remaining repairs estimated to take six weeks to complete. This will be followed by the installation of assemblies and interconnections between quadrupole magnets, DFBXs and the rest of the accelerator. The inner triplets will then become part of the different sectors of the LHC and will be tested as part of the pressure tests of all sectors.

A set of four cartridges for the Q1 and Q3 repair, each consisting of an Invar rod inside an aluminum tube.



A Q1 magnet assembly with cartridges held in place by the four ear-like brackets bolted to the outer flange.

In the meantime, electrical tests have continued on the first sector to be commissioned (sector 7-8), which was initially cooled down in April (*CERN Courier* May 2007 p5). On 25 May, the dipole circuits were successfully powered up to several thousand amps, followed by the quadrupole circuits on 20 June. This was still below the nominal values. Depending on the type of superconducting magnet, the nominal current of the electrical circuits varies between 60 A and 12 kA. During the tests, however, some circuits were powered up to the nominal current and quenches triggered deliberately to test the protection system as well as the system for extracting the stored energy in the magnets.

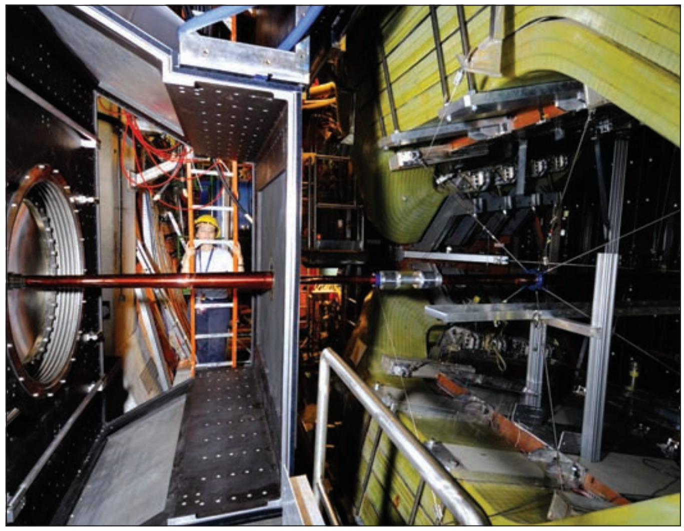
These power tests were the culmination of several weeks of electrical tests on sector 7-8. More than 100 electrical circuits for the superconducting magnets were checked one by one. An overall test, where all of the circuits were powered up overnight, also took place to ensure that they perform correctly over a prolonged period. Finally, a power cut was simulated at point 8 for the teams to verify that all of the systems were being supplied with power from the scheduled source – whether the normal or back-up power supply. Sector 7-8 will now be warmed up so that the triplet magnets to the left of point 8 can be connected up and some consolidation work can take place.

Sommaire

LHC EXPERIMENTS

ATLAS toroid endcaps and LHCb beam pipe take their final steps

The first giant toroid magnet endcap on its 80 m journey to the floor of the cavern housing the ATLAS detector.



Part of the newly completed LHCb beam pipe, close to the experiment's dipole magnet (right).

In the early hours of 13 June, the first of the two gigantic toroid magnet endcaps touched the ATLAS cavern floor. The second endcap followed suit on 12 July. With this delicate operation complete, the ATLAS collaboration has now finished lowering all of the large heavy pieces of detector into the cavern.

The last steps were not without challenges, particularly for the first endcap. These included removing a 5 m portion between the top of the main door and the roof to fit the 13 m high, 240 tonne endcap into the building. Once inside, it was lifted by a mobile crane and secured to two gantry cranes on either side of the entry shaft.

Another issue was that the endcaps were higher than the 2 × 140 tonne overhead travelling crane used to lower them down to the cavern floor. In order to secure an endcap to this crane, it first had to be suspended by the two gantry cranes and lowered 5 m to the correct height using a system of jacks. At the end of the 80 m journey down the shaft, each endcap was placed between the barrel part of the detector and the wheels of the endcap muon chambers with a precision of 2 mm and a margin of 10 cm on either side.

The LHCb collaboration has meanwhile completely installed, interconnected, pumped down and baked out all four sections of the LHCb beam pipe, which includes a section that connects to the vacuum vessel containing the VErtex LOcator (VELO). The largest of the four conical sections is composed of stainless steel and the others are made of beryllium to minimize background in the experiment. One of the more challenging tasks was the installation of the longest section of beryllium beam pipe (6 m) through the RICH2 detector in January, which used temporary rails to guide it through the inner tube with a leeway of only 4 cm. In February, a crane was used to lift the 160 kg stainless steel section and position it in the middle of the iron walls of the muon system on supports that align it with the beamline.

After all of the installation work, the next step was to pump the beam pipe down to a pressure of 10^{-7} mbar. During the following bake out and non-evaporable getter (NEG) activation, the VELO was heated to 150 °C and the NEG reached 220 °C to obtain an ultra-high vacuum inside the beam pipe. Once the bake-out was complete, the pressure had gone down to 10^{-11} mbar.

EXOTIC NUCLEI

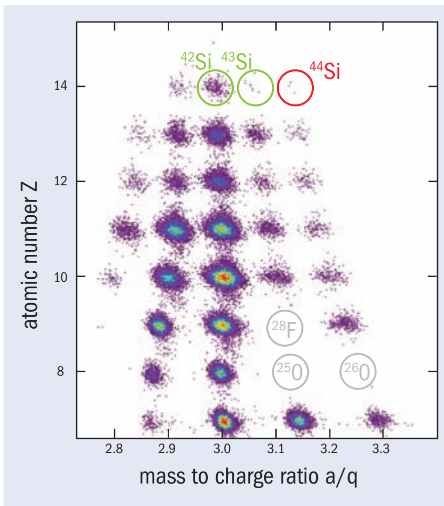
NSCL discovers the heaviest known silicon isotope to date

Researchers at the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University have produced the heaviest silicon isotope ever observed. The recent identification of ^{44}Si expands the chart of known isotopes and lays the groundwork for the future study of rare, neutron-rich nuclei.

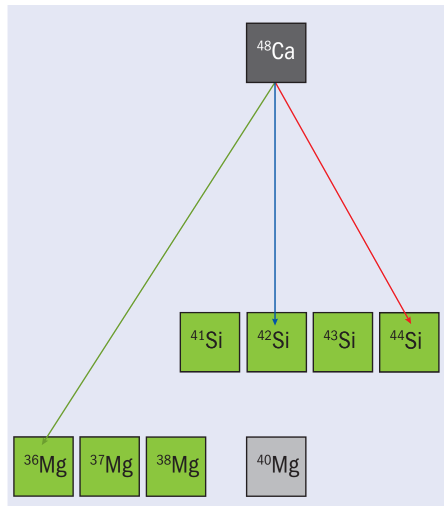
Beyond a certain range of combinations of protons and neutrons, nuclei cannot form at all, and additional nucleons will immediately leave the nucleus owing to zero binding energies. Pursuit of this limit, known as the drip line, has proved to be a scientific and technical challenge – particularly when it comes to neutron-rich nuclei. While the proton drip line has been mapped out for much of the chart of nuclei, the neutron drip line is known only up to oxygen (Z = 8). Producing isotopes at or near the neutron drip line remains a long-standing goal in experimental nuclear physics (*CERN Courier* May 2004 p26). For example, ^{43}Si was detected for the first time at Japan's Institute of Physical and Chemical Research (RIKEN) in 2002 (Notani *et al.* 2002). That same year, researchers at the GANIL laboratory in France detected the neutron-rich isotopes ^{34}Ne and ^{37}Na (Lukyanov *et al.* 2002).

In the ^{44}Si experiment conducted at the NSCL Coupled Cyclotron Facility in January, a primary beam of ^{48}Ca was accelerated to 142 MeV/u and directed at a tungsten target. Downstream from the target, the beam was filtered through NSCL's A1900 fragment separator. Eventually, some 20 different isotopes (including three nuclei of ^{44}Si) hit a set of detectors that could identify each ion as it arrived (Tarasov *et al.* 2007).

The study was intended to document the yield of isotopes containing 28 neutrons that lie between ^{48}Ca (the nuclei in the beam) and ^{40}Mg to extrapolate the expected yields in this region. ^{40}Mg is yet to be observed, and according to some theories should be on the drip line. Knocking out only protons from ^{48}Ca could create these isotopes, although this is a difficult feat because of the larger number of neutrons in the beam nuclei. The production of ^{44}Si is therefore an even greater feat, given that the collision must also transfer two neutrons from the tungsten target to the beam nucleus as it speeds past. The observation of ^{44}Si in the A1900 fragment separator stretches the limits of its single-stage separation. The excessive number of particles that come along with the rare nuclei can swamp the detectors used to identify the beam in the separator. The next-generation technique will use two-stage separation, delivering fewer particles to the detectors as more are filtered out travelling down the beamline.



Three ^{44}Si particles were identified after exposure for four hours to a total of 7×10^{15} primary beam particles of ^{48}Ca. Abundances of neighbouring isotopes were also recorded and used to estimate the cross-section for ^{40}Mg. The most abundant isotopes resulted from reactions that knocked out a combination of protons and neutrons.



Starting with a beam of ^{48}Ca nuclei, making the isotopes leading to ^{40}Mg entails knocking out only protons (blue line). But to produce ^{44}Si (red line), ^{48}Ca must acquire two neutrons in addition to losing six protons. The isotopes that are easiest to make (green line), such as ^{36}Mg to ^{38}Mg, are those that result from mixed proton-and-neutron knock-out.

Researchers are developing new two-stage separators that could run experiments with higher initial beam intensities, which offer a better chance of generating the sought-after, near-dripline nuclei. Preliminary testing on a new two-stage separator at NSCL has delivered promising results. Also, a new device has just been constructed at RIKEN in Japan, and one is planned for GSI in Germany. Nuclear scientists at NSCL hope that two-stage separation will help uncover the next generation of rare isotopes.

Further reading:

S Lukyanov *et al.* 2002 J. *Phys.* G **28** L41.
M Notani *et al.* 2002 *Phys. Lett.* B **542** 49.
O Tarasov *et al.* 2007 *Phys. Rev.* C **75** 064613 and arxiv.org/abs/0705.0349.

ACCELERATORS

KEK achieves first operation of crab cavities

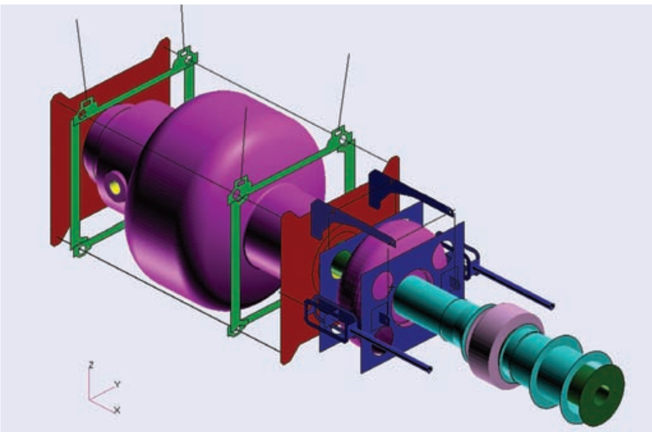


Fig. 1. A CAD drawing of a crab cavity. (KEK and MHI Ltd.)

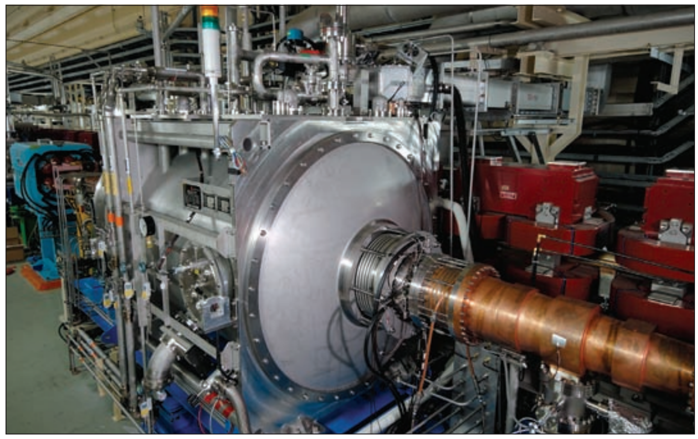


Fig. 2. A crab cavity installed at KEKB. (KEK and MHI Ltd.)

A team of accelerator physicists at KEK has achieved effective head-on collisions of electrons and positrons while retaining the crossing angle. They accomplished this at the KEKB collider using new devices called "crab cavities". This success will pave the way to increasing KEKB's luminosity – already the world's highest – to an unprecedented level.

At KEKB, the electron and positron bunches cross at an angle of 22 mrad (1.3 °). This non-zero crossing angle is one of the machine's novel design features: it provides effective beam separation at the collision point without a high level of background in the detector. However, it is necessary to tilt the bunches of electrons and positrons so that they collide head-on while still crossing at an angle to boost the luminosity further.

To accomplish this goal, the team at KEKB built several "crab cavities", special superconducting radio-frequency cavities that tilt each bunch sideways – somewhat like the way a crab walks. The concept was first suggested by R Palmer almost 30 years ago for linear electron-positron colliders, and K Oide and K Yokoya proposed the use of crab cavities in storage rings around 10 years later (Oide and Yokoya 1989). This was followed by designs and prototype models of the crab cavity by K Akai as part of a collaboration between the KEK and Cornell laboratories around 1992. Detailed engineering and prototyping were then done at KEKB by K Hosoyama's team, with the first full-size cavities being developed after a long struggle and installed in January 2007 (figure 1 and 2). Commissioning at KEKB started in February and continued until the end of June (Abe *et al.* 2007.)

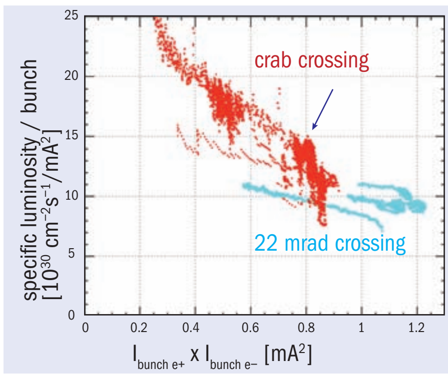


Fig. 3. The luminosity per bunch divided by the product of bunch currents. The red points show the results with crab cavities while the turquoise points show collisions without the crab cavities. A clear improvement is visible, especially at low bunch currents. The beam-beam tune shift reached a value of 0.088, comparable to the world record (near the arrow).

The crab cavities achieved a tune shift at low currents, comparable to the record achieved at LEP-II at CERN (figure 3). Proportional to the luminosity divided by the product of beam currents, this is a measure of luminosity potential. The team was recently able to operate the machine at high beam currents (1300 mA in the low-energy positron beam and 700 mA in the high-energy electron beam) at a luminosity above 10^{34}cm^{-2}s^{-1}.

These results from the first round of commissioning demonstrate the potential of the crab cavities, which according to simulations may eventually improve the luminosity by a factor of two. More commissioning runs and R&D will enable further increase in performance.

The KEKB collider operates at the Υ(4S) resonance and is used for studies of matter–antimatter asymmetry with beauty quarks and searches for new physics by the Belle experiment (*CERN Courier* June 2006 p22). For the future, a super-B Factory using crab cavities to achieve luminosities two orders of magnitude higher than existing accelerators is under discussion in Japan, and a competing proposal is also being discussed in Italy. Such a machine has the potential to discover physics beyond the Standard Model in rare decays (see p29). Crab cavities will also play a role in achieving high luminosity at other machines with a crossing angle, including the proposed International Linear Collider, upgrades of the LHC at CERN, and future synchrotron light sources.

Further reading:

T Abe et al. 2007 http://arxiv.org/abs/0706.3248.

K Oide and K Yokoya 1989 *Phys. Rev.* A **40** 315.

UNDERGROUND SCIENCE

NSF selects Homestake for deep lab site

The US National Science Foundation (NSF) has selected a proposal to produce a technical design for a deep underground science and engineering laboratory (DUSEL) at the former Homestake gold mine near Lead, South Dakota, site of the pioneering solar-neutrino experiment by Raymond Davis. A 22-member panel of external experts reviewed proposals from four teams and unanimously determined that the Homestake proposal offered the greatest potential for developing a DUSEL.

The selection of the Homestake proposal, which was submitted through the University of California (UC) at Berkeley by a team from various institutes, only provides funding for design work. The team, led by Kevin Lesko from UC Berkeley and the Lawrence Berkeley National Laboratory, could receive up to $5 m a year for up to three years. Any decision to construct and operate a DUSEL, however, will entail a sequence of approvals by the NSF and the National Science Board. Funding would ultimately have to be approved by the US Congress. If eventually built as envisioned by its supporters, a

Homestake DUSEL would be the largest and deepest facility of its kind in the world (*CERN Courier* December 2005 p5 and September 2006 p36).

The concept of DUSEL grew out of the need for an interdisciplinary "deep science" laboratory that would allow researchers to probe some of the most compelling mysteries in modern science, from the nature of dark matter and dark energy to the characteristics of microorganisms at great depth. Such topics can only be investigated at depths where hundreds of metres of rock can shield ultra-sensitive physics experiments from background activity, and where geoscientists, biologists and engineers can have direct access to geological structures, tectonic processes and life forms that cannot be studied fully in any other way. Several countries, including Canada, Italy and Japan, have extensive deep science programmes, but the US has no existing facilities below a depth of 1 km. In September 2006, the NSF solicited proposals to produce technical designs for a DUSEL-dedicated site. Four teams had submitted proposals by the January 2007 deadline, but in four different locations.

The review panel included outside experts from relevant science and engineering communities and from supporting fields such as human and environmental safety, underground construction and operations, large project management, and education and outreach.

Scientists from Japan, Italy, the UK and Canada also served on the panel. The review process included site visits by panellists to all four locations, with two meetings to review the information, debate and vote on which, if any, of the proposals would be recommended for funding.

STRATEGY

Europe's astroparticle physicists publish roadmap to the stars

The Astroparticle Physics European Coordination (ApPEC) consortium and the AStroParticle European Research Area (ASPERA) network have together published a roadmap giving an overview of the status and perspectives of astroparticle physics in Europe. This important step for astroparticle physics outlines the leading role that Europe plays in this new discipline – which is emerging at the intersection of particle physics, astronomy, and cosmology.

Grouped together in ApPEC and ASPERA, European astroparticle physicists and their research agencies are defining a common strategic plan in order to gain international consensus on what future facilities will be needed. This rapidly developing field has already led to new types of infrastructure that employ new detection methods, including underground laboratories or use of specially designed telescopes and satellite experiments to observe a wide range of cosmic particles, from neutrinos and gamma-rays to dark-matter particles.

Over the past few years, ApPEC and ASPERA have launched an important effort to organize the discipline and ensure a leading position for Europe in this field, engaging the whole astroparticle physics community. The roadmap is a result of this process, and though still in its first phase, it has started to identify a common policy.

In the process, ApPEC has reviewed several proposals and has recommended engaging in design studies for four large new infrastructures: the Cherenkov telescope array, a new-generation European observatory for high-energy gamma rays; EURECA, a tonne-scale bolometric detector for cryogenic research of dark matter; LAGUNA, a very large detector for proton decay and neutrino astronomy; and the Einstein telescope, a next-generation gravitational wave antenna. ApPEC has also iterated its strong support for the high-energy neutrino telescope KM3 in the Mediterranean region.

These projects – as well as proposals for tonne-scale detectors for the measurement of neutrino mass, dark-matter detectors and high-energy cosmic-ray observatories, will be discussed and prioritized further in a workshop in Amsterdam on 21–22 September. During the workshop, which 300 European physicists are expected to attend, Europe's priorities for astroparticle physics will be compared to those in other parts of the world.

● For the roadmap, see www.aspera-eu.org

SCIENCEWATCH

Compiled by Steve Reucroft and John Swain, Northeastern University

Nanotubes stick four times better than gecko feet…

Geckos manage to stick to almost any surface using tiny protrusions called setae on their feet. These can make close contact with more or less any surface – van der Waals forces then provide the stickiness that lets them walk on walls. Liehui Ge and colleagues at the University of Akron, Ohio, and Rensselaer Polytechnic Institute in Troy, New York, have now managed to replicate the basic structure with carbon nanotubes, making a tape that acts like an artificial gecko foot. The new material can support a shear stress of 36 N/cm^2 which is about four times better than a gecko can do and will stick to just about anything including Teflon. Since there is no chemical adhesion, the material can be used reversibly over and over again. It should find applications in almost any situation where things have to stick and then unstick.

(Courtesy Rustyphil/Dreamstime.com)

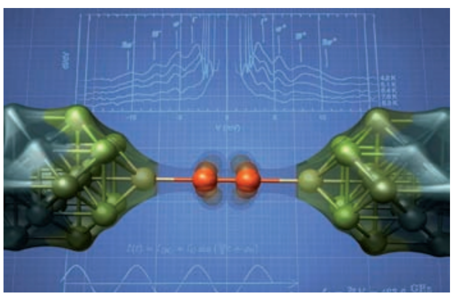
Further reading

Liehui Ge *et al.* 2007 *Proc. Nat. Acad. Sci.* **104** 10792.

…and AC Josephson effect makes nanowires vibrate

One of the remarkable effects that Brian Josephson predicted in his Nobel-prize winning work back in 1962 was that a constant voltage applied across an insulating tunnel gap separating two superconductors would give rise to a high-frequency current oscillation – the AC Josephson effect. Experiments have confirmed these oscillations in a variety of systems, and now, researchers at the Georgia Institute of Technology believe they have found that Josephson current oscillations also interact with mechanical motion on an atomic scale.

Alexei Marchenkov and colleagues made a niobium dimer (Nb_2) that acts as a weak link between two superconducting (bulk) niobium electrodes. They discovered features in the differential conductance through the dimer that seem to correspond to excitations of the dimer vibrational modes by Josephson oscillations. Their observations confirm the results of theoretical simulations and should have applications in studying structural and mechanical properties in a variety of nanomaterials.



Peaks in the measured conductance plotted versus applied voltage, shown in the top background, correspond to vibrational modes of a dimer of niobium atoms suspended between the left and right tip-electrodes. (Courtesy Georgia Tech/Alexei Marchenkov and Uzi Landman.)

Further reading

Alexei Marachenkov *et al.* 2007 *Nature Nanotechnology* **2** 481.

A new field of controllable optics?

Antennae in the radio-frequency range are often made out of numerous elements acting together to concentrate and direct electromagnetic energy in desired ways. René de Waele and colleagues at the FOM institute for atomic and molecular physics in Amsterdam now seem to have done the same with light at the nanometre scale. They not only managed to use chains of silver particles to direct light in a frequency-dependent fashion, but in ways that cannot be done at all with conventional optics.

The trick is to couple light to electrons in the silver to form quasiparticles called plasmons, which have smaller wavelengths than the free photons that go into them. A whole new field of controllable optics at the nanoscale could be just about to appear.

Further reading

René de Waele, A Femius Koenderink, and Albert Polman 2007 *Nano Lett.* **7** 2004.

Is this end for the game of draughts?

If you like a game of draughts, or checkers in the US, you may not want to continue reading. Jonathan Schaeffer and colleagues at the University of Alberta have used computing power to prove mathematically that if neither player makes a mistake, then the game ends in a draw every time.

A similar result is well known for noughts and crosses (or tic-tac-toe in the US), which usually kills interest in playing the game sometime in early childhood. The proof for checkers is trickier. It required dozens of computers for nearly 20 years to check a staggering number of configurations – the game involves some 5×10^{20} possible positions. Schaeffer has pursued the problem since 1989, when he began the Chinook project to develop a program capable of defeating the checkers world champion.

Further reading

Jonathan Schaeffer *et al.* 2007 *Science online* DOI: 10.1126/science.1144079.

Compiled by Marc Türler, INTEGRAL Science Data Centre and Observatory of Geneva University

Black holes appear to play a role in the evolution of the universe

Are black holes just a curiosity of nature or do they play a role in the formation and shaping of galaxies? The results of the most accomplished simulation to date show that the evolution of galaxies is influenced by the supermassive black holes at their centres.

Supercomputer simulations result in fascinating movies of the evolution of a portion of the universe over billions of years. They show how a uniform distribution of matter in the early universe progressively forms galaxies and clusters of galaxies – predominantly along a filamentary, sponge-like structure. This characteristic structure arises naturally from the mutual gravitational pull of matter making dense regions denser and voids emptier. However, a realistic simulation down to scales of single galaxies should include astrophysical processes that are related to the formation and evolution of stars and supermassive black holes.

The results of the first simulation to incorporate black hole physics have now been published by Tiziana Di Matteo from the Carnegie Mellon University in Pittsburgh and collaborators. This gives the best picture to date of how the cosmos formed. Called BHCosmo, this simulation tracks 230 million hydrodynamic particles in a cube the size of about 100 million light-years. It used the 2000 processors of the Cray XT3 system at the Pittsburgh Supercomputing Center over four weeks of run time.

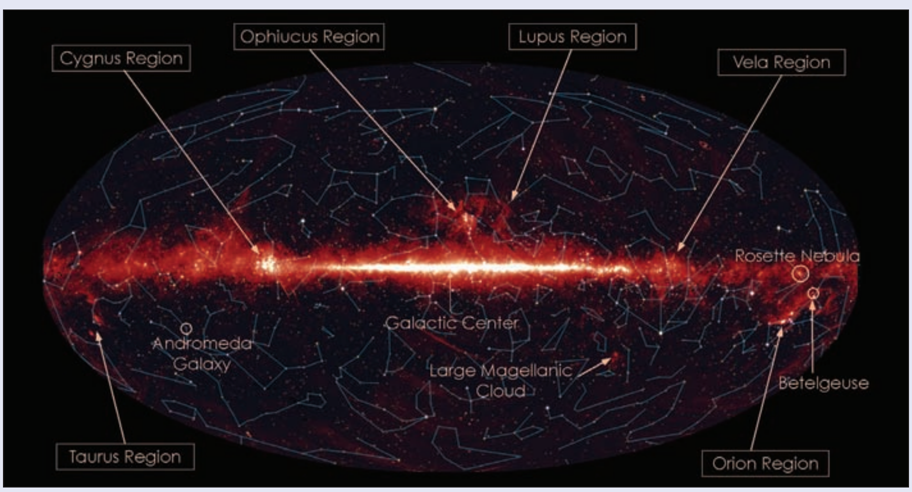
The BHCosmo simulation starts from initial conditions corresponding to the standard ΛCDM model of cosmology and self-consistently incorporates dark-matter dynamics, radiative gas-cooling, star formation, as well as black hole growth and associated feedback processes. It is not well understood how supermassive black holes form, so Di Matteo and colleagues circumvented this problem by inserting a black hole of 10^5 solar masses at the centre of each dark matter halo reaching a critical mass. These "seed" black holes can already form 300 million years after the Big Bang and their growth – by gas accretion and mergers with other black holes – depends very much on their environment. Strongly accreting black holes manifest themselves as quasars by emitting intense radiation that heats the surrounding gas. This heating in the BHCosmo simulation is found to be an important feedback process that expels the galaxy's interstellar gas into inter-galactic space and in the mean time extinguishes the quasar activity. This mechanism helps to explain why most elliptical galaxies are left with a low gas content and can therefore no longer form new stars. Past quasar activity of the supermassive black holes in their centres would thus be responsible for their old and reddish stellar populations. The BHCosmo simulation also confirms the observed relationship between the mass of the black hole and the mass of stars in galaxies. This suggests that black holes regulate galaxy formation and growth, but how this happens is not yet understood.

This work shows how the formation and evolution of about a million galaxies can be simulated in a representative portion of the universe with relatively simple assumptions. The good match between the simulated and observed properties of galaxies allows the prediction of what sort of galaxies will be seen at very high redshift by next-generation telescopes.

Further reading

T Di Matteo *et al.* 2007 *Astroph. Journal*, submitted.
See: http://arxiv.org/abs/0705.2269

Picture of the month



This image shows a projection of the entire sky in infrared light as obtained by the Japanese AKARI satellite launched in 2006.

With a lower resolution, but a larger field of view, the AKARI mission is complementary to NASA's Spitzer Space Telescope. The bright stripe extending from left to right is the disc of our own Milky Way Galaxy.

The infrared radiation at 9 μm shown here is emitted by heated interstellar dust in regions of intense star formation in the galaxy. The constellations are drawn in blue and regions of particular interest are labelled. (Courtesy JAXA.)

CERN COURIER ARCHIVE: 1964

A look back to *CERN Courier* vol. 4 September 1964, compiled by Peggie Rimmer

LAST MONTH AT CERN

Fundamental law doubted at Dubna

One of the most discussed topics at the 12th International conference on high-energy physics [at the Joint Institute for Nuclear Research, Dubna, 5–15 August] was the result of an experiment at the 33-GeV alternating gradient synchrotron in Brookhaven, US, by four physicists from Princeton University (one on leave from the Centre d'Études Nucleaires, Saclay) (Christensen *et al.* 1964). To the uninitiated, their discovery seemed of no special interest – a so-called K_2^0 meson had been found to decay sometimes into two particles (pions), instead of into the more usual three particles (pion + muon + neutrino, three pions, etc). To many high-energy physicists, however, and specialists in weak interactions in particular, the result was startling because it seemed to disprove one of the fundamental rules that are believed to cover the behaviour of matter: CP invariance.

This rule is connected with others by the so-called CPT invariance theorem. C represents "charge conjugation", changing the wave function of a particle into that of its corresponding antiparticle (or vice-versa); P is the parity operator, reversing the sign of all the space coordinates; T represents changing the sign of the time co-ordinate – running time backwards. Physically, CPT invariance implies that antiparticles (or particles), viewed upside down in a mirror with time running backwards, are subject to exactly the same forces and interactions as particles (or antiparticles) in the normal world. Moreover, for strong and electromagnetic interactions, systems of fundamental particles are invariant under C, P and T operations separately: for example (considering C alone) the force between an antiproton and a positron is the same as between a proton and an electron, so that an "anti" hydrogen atom would behave exactly as a normal hydrogen atom; considering P, the electron cloud is symmetrical about the proton nucleus so that the atom has no left and right or top and bottom. For weak interactions, however, P invariance does not hold: a particle undergoing spontaneous decay does show a kind of left and right side. But the "left" side is the "right" side of an antiparticle, so that until now it was accepted that the double action represented by CP introduced no change in any system. This was put in doubt by the Princeton/Brookhaven experiment.

A new force in the universe

The results were published just before the Dubna conference, and at the conference another group (from Illinois University) gave further evidence for the effect. There followed, as the rapporteur of the theoretical plenary session remarked, a great deal of agitated discussion, especially over the clinking sound of vodka glasses. Afterwards, at CERN and in many other laboratories, the discussion continued by letter and by telephone and new ideas were developed. At an early stage, three possibilities emerged: a) the experimental results were wrong; b) CP invariance could no longer be assumed to occur in all cases; c) an unknown effect transformed some of the K_2^0 mesons in the experiment into K_1^0 mesons, which then decayed into pions in the normal way.

The first explanation could be safely ruled out; the second was intriguing to many theoreticians, who busily began working out the possible consequences or tried to explain the cause in various ways; the third rapidly produced at least two independent postulates of a new, hitherto unsuspected, fundamental force in the universe.

At Stanford University (US), such an idea came from J S Bell, a CERN physicist on leave, and J K Perring (on leave from the Atomic Energy Research Establishment in England) (Bell and Perring 1964). At CERN, J Bernstein (on leave from New York University), N Cabibbo and T D Lee (on leave from Columbia University) evolved a similar notion. It seems that, apart from the four known forces (strong, electromagnetic, weak and gravitational), there may be a fifth, extremely weak but long-range, force that is different for antiparticles and particles. As a result, K_2^0 mesons would sometimes be changed to K_1^0 mesons and the experimental results could be explained without having to give up the principle of CP invariance.

Further reading

J H Christenson, J W Cronin, V L Fitch, R Turlay 1964 *Phys. Rev. Lett.* **13** 138.

J S Bell and J K Perring 1964 *Phys. Rev. Lett.* **13** 348.

● Compiled from "Last month at CERN" pp118–119.

COMPILER'S NOTE

In 1957 Richard Feynman lost a $50 bet when C S Wu and collaborators showed that weak interactions maximally violate parity P, acting only on left-handed particles (and right-handed antiparticles). Then in 1964 came the clear evidence that even the compound symmetry CP was broken in weak interactions.

Unlike parity violation, CP violation is a very small effect but this distinction between matter and antimatter may have profound consequences. Andrei Sakharov showed that CP violation (combined with other conditions very likely in the Big Bang) could account for the apparent lack of antimatter in the universe today. This led Val Fitch (of the Brookhaven experiment described here) to remark that the first evidence, ever, for CP violation was the fact that we exist.

For almost half a century, experiments and theory have failed to provide a fully satisfactory explanation of CP violation. Experiments continue in systems other than kaons and with ever-increasing accuracy, notably BELLE at KEK and BaBar at SLAC. The LHCb experiment at CERN is specially designed to study CP violation when the LHC starts up in 2008.

As far as is known, the combined CPT symmetry, a basic principle of relativistic quantum field theory, is an exact invariant in all processes. If experiments ever show that CPT is violated a lot more than $50 will be at stake.

COMPUTING NEWS

Compiled by Hannelore Hämmerle and Nicole Crémel

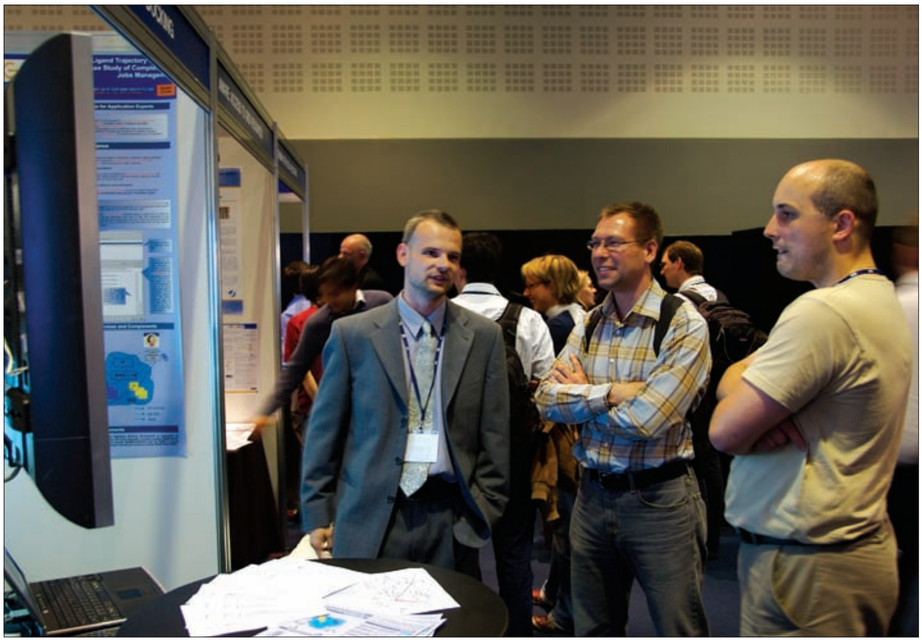
EVENT

Grid users meet standards at OGF20/EGEE User Forum

In May, the 2nd User Forum of the Enabling Grids for E-sciencE project was jointly organized with the 20th meeting of the Open Grid Forum in Manchester to bring current Grid users and standards bodies together. This event was Europe's biggest ever Grid event, with more than 900 registrations, and ensured that currently emerging standards are taking into account the experiences of the most challenging applications already using the Grid.

EGEE operates the largest multiscience Grid currently in production use and already works with OGF on several levels, providing input from the project's extensive knowledge of the deployment and management of large-scale infrastructures.

The sessions at the User Forum covered the different application domains on the Grid, ranging from astronomy and biology to Earth science and physics, as well as specific technical issues that affect users across domains, such as data management, monitoring and user interfaces.



The demonstration session at the 2nd EGEE User Forum attracted many people and resulted in lively discussions about the Grid In Action. (Courtesy Owen Appleton, EGEE.)

The Grid community increasingly includes business partners – both as users and service providers – as well as members of industry and academia, all of whom demonstrated best practices, introduced new developments and raised some unaddressed issues.

The event demonstrated how the Grid is routinely being used, with 20 live demonstrations of Grid usage in several scientific domains and a poster session to highlight key applications and technologies for the EGEE user communities. It is vital that scientists and technology experts exchange experiences and views to ensure a sustainable future development of the Grid.

Marcin Płóciennik from the Poznan Supercomputing and Networking Center won a prize for the best demonstration of a Grid application. On behalf of the Interactive European Grid project, he demonstrated an application for the visualization of plasma particles in fusion devices on the Grid. This showed how parallel applications, which may run remotely across several sites, can be supported on the Grid, including user-interactive access and visualization features.

Scientists in more than 200 virtual organizations now use the distributed computing infrastructure of EGEE, with a large user group coming from high-energy physics, in particular the LHC experiments at CERN. The number of jobs each month reported in the central accounting system totalled more than 1.5 million for the LHC experiments and more than 2 million for all users. Since some sites do not account all jobs, this is an under-estimate. In addition to the many different use cases of the Grid, a range of groups also showed tools that make using the Grid simpler, ranging from portals to application programming interfaces that can be used on several Grids.

The National e-Science Centre, the University of Manchester and the National Centre for e-Social Science hosted the joint event. Further information can be found at www.eu-egee.org/uf2.

Les gros titres de l'actualité informatique

WORKSHOP

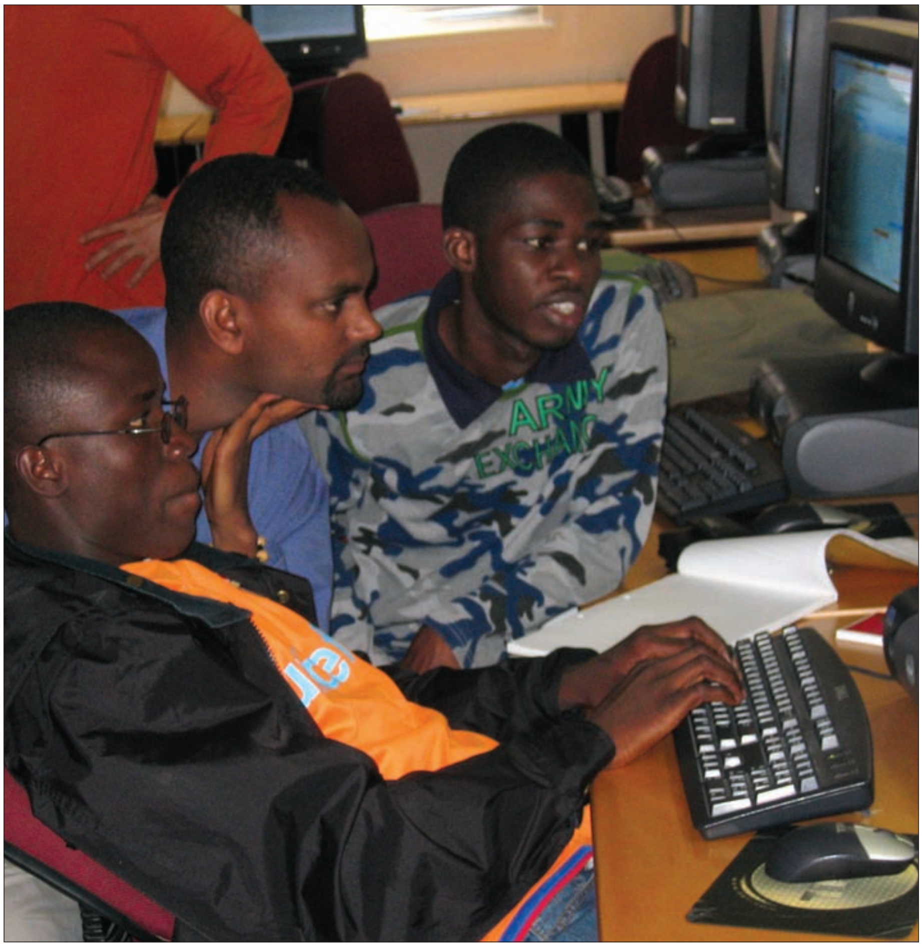
African scientists plug into volunteer computing projects

Volunteer computing projects like SETI@home use spare capacity on home and office computers to do scientific calculations. For African scientists with limited computing resources in their own institutes, volunteer computing is an opportunity to plug into global processing power at little cost. And for volunteers the world over, it is a chance to contribute directly to African science. This was the theme of a workshop that took place between 16–22 July at the African Institute for Mathematical Sciences (AIMS) in Muizenberg, South Africa. The workshop attracted 35 scientists from 18 countries across the African continent.

The workshop put a strong emphasis on practical know-how, with students spending most of each day – and well into the night – working in the AIMS computer lab, learning step-by-step how to install volunteer computing projects on servers that they had also installed themselves. Participants included mathematicians, computer scientists and epidemiologists who were encouraged to consider how science projects from their own universities could benefit from volunteer computing.

The framework for volunteer computing taught on the course was the open source software called BOINC (Berkeley Open Infrastructure for Network Computing). SETI@home and a range of other projects, including LHC@home, all use this framework. The instructors on the course included BOINC experts from CERN, the Niels Bohr Institute, the Swiss Tropical Institute, Extremadura University and Erasmus Medical Centre in Rotterdam. One keen tutor was a volunteer based in Botswana who has been helping projects like SETI@home for several years.

Not all scientific computing problems are suited to volunteer computing, and not all universities in Africa have sufficient bandwidth to manage even the rather modest needs of a BOINC server. But even for those not immediately able to launch a large-scale volunteer computing project, the course imparted skills across a range of useful open-source technologies that BOINC relies upon, while also introducing participants to more advanced concepts such as Grid technology.



Participants at the AIMS workshop in South Africa learnt how to use volunteer computing to advance science projects by using open-source software such as BOINC.

The workshop was a project of the Africa@home partnership, which includes CERN, the World Health Organization, the University of Geneva and the non-governmental organization IC Volunteers. The Geneva International Academic Network sponsors the partnership. Africa@home launched a volunteer computing project last year called malariacontrol.net, based on an epidemiological model developed at the Swiss Tropical Institute. The project has clocked-up more than 2000 CPU-years of simulations on 12 000 machines owned by more than 6000 volunteers. This proved an ideal platform to train the participants, who used the test-case as a model.

CONFERENCE

ACAT'07 tries to solve computing challenges

The 11th international workshop on Advanced Computing and Analysis Techniques in Physics Research (ACAT'07) took place on 23–27 April at NIKHEF in Amsterdam. Chaired by Jos Vermaseren, a group of more than a hundred computer scientists, experimental and theoretical physicists from all corners of the globe attended the workshop. The meeting included no fewer than 83 talks, providing a broad overview in three distinct series of talks: theory, analysis and computing technology. In addition, the conference featured a discussion forum on Grid computing and also included a social outing to the Van Gogh museum, followed by a tour of the Amsterdam Canals.

Topics in the plenary sessions ranged from software engineering to higher-order corrections in perturbation theory and included presentations from industry. Jeroen Vink, from Royal Dutch SHELL, gave an impression of the computing challenges faced in the oil and gas industry. Ronald van Driel demonstrated how the commitment of Philips to current Grid-computing initiatives is already generating promising results.

During the series of talks on computing technology, summarized by Federico Carminati (CERN), it became clear that Grid computing has become a necessity for the high-energy physics community. Jeff Templon (NIKHEF) stressed that the most challenging problems are to do with heterogeneity and system complexity. Experiments and middleware developers presented many solutions to overcome these problems. Although particle physicists run one of the largest Grids for scheduled production applications, stability remains a concern for large-scale user analysis – as required beyond 2008. Lenore Mullin (National Science Foundation) discussed the challenges faced by computational physics from an organizational perspective.

The analysis series of talks included presentations on many different kinds of algorithms, ranging from genetic algorithms to multivariate analysis (MVA) methods. A nice overview was presented by Thomas Speer (Zürich). A number of speakers presented the implementation of these algorithms in experiment software, in online as well as offline applications, including trigger studies, commissioning and reconstruction. Jürgen Schmidhuber (TU München) gave an overview of recent progress in machine learning. During the interesting round-table discussion, the participants agreed that a methodology to study MVA methods is needed, as well as a set of standardized benchmarks for comparisons.

Stefan Weinzierl (Mainz) reviewed the status of automated theoretical calculations for LHC observables. Progress on this front, from many-particle zero-loop to two-particle two-loop calculations, has been very impressive in recent years. In the parallel sessions, Sven-Olaf Moch (DESY-Zeuthen) summarized this and made it more explicit. Significant progress took place both for automated Monte-Carlo type cross-section evaluators such as MadGraph/MadEvent, GRACE, SANC and the CEDAR project. In addition, there were reviews of developments in powerful tools for loop calculations such as FeynArts/LoopTools, AMBRE, SIGMA and the parallelized and multi-threaded version of the FORM computer algebra programme (parFORM and tFORM).

Les Hatton (Kingston University) gave a memorable presentation by focusing on the reliability of software and numerical results. His solution: independent verification, open sources and variation in languages and compilers. He recommends that every scientific paper should not only publish the science and methodology, but also the code and the environment in which it was run.

● More information on the conference is available online at www.nikhef.nl/acat07/.

Calendar of Events

September
2–7 Computing in High Energy and Nuclear Physics (CHEP'07)
Victoria, British Columbia, Canada
www.chep2007.com/

10–14 GridKa School
Karlsruhe, Germany
www.fzk.de/gks07/

September
10–17 XXI International Symposium on Nuclear Electronics and Computing (NEC'2007)
Varna, Bulgaria
nec2007.jinr.ru/

4–7 Parallel Computing 2007
Jülich, Germany
www.fz-juelich.de/conference/parco2007/

17–21 Cluster 2007 and **Grid 2007**
Austin, TX, US
http://cluster2007.org/
www.grid2007.org/

October
1–5 EGEE'07
Budapest, Hungary
www.eu-egee.org/egee07/

15–19 ICALEPCS'2007
Knoxville, TN, US
www.sns.gov/conf/icalepcs07/

15–19 OGF21
Seattle, WA, US
www.ogf.org/

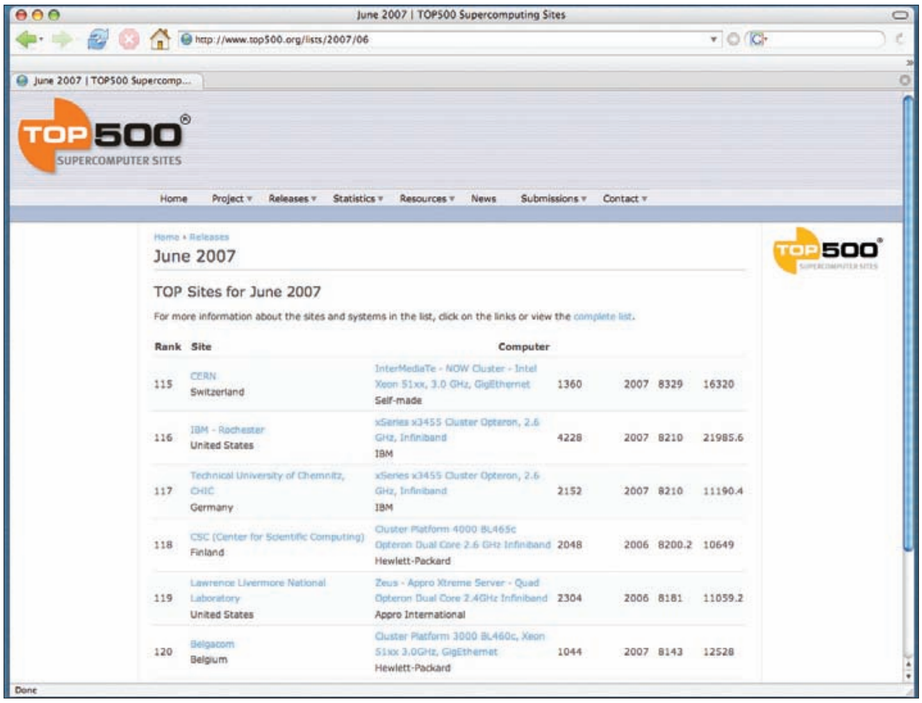
November
5–9 HEPiX Fall 07
St Louis, MO, US
www.hepix.org/

10–16 SC'07
Reno, NV, US
http://sc07.supercomputing.org/

24–26 e-Challenges
The Hague, The Netherlands
www.echallenges.org/e2007/

COMPUTER RANKING

CERN makes it into supercomputing TOP500



Supercomputers are normally large dedicated machines tuned to solve computationally intensive scientific challenges. Grid computing, on the other hand, pools thousands of ordinary PCs at computing centres around the world to tackle problems that can be split up into many relatively small chunks. Yet the processing power of individual computing centres on the Grid is growing rapidly, reaching levels comparable with top supercomputers. This was illustrated recently, when CERN for the first time entered the prestigious TOP500 Supercomputing Sites list, which ranks the fastest supercomputers in the world.

CERN reached a respectable 115th position in the TOP500 list released at the end of June. CERN's cluster, consisting of 340 servers with two Intel Xeon 5160 (Woodcrest) processors, with a total of 1360 cores, is one of only a few commodity clusters in the list. It reached a performance in the standard benchmark used for the TOP500 of just over 8.3 teraflops. The fastest supercomputer, an IBM BlueGene machine at Lawrence Livermore Laboratory, managed 280 teraflops with 131 072 cores. However, apart from the top three, all machines were rated below 100 teraflops.

It is significant that CERN achieved this result using only about 20% of the computing power available in its computer centre, which in turn is only a fraction of the computing power available on the EGEE Grid infrastructure. Another important feature of the result is that no special tuning of the CERN computers was required to achieve this result using the TOP500 benchmarks, even though the high-throughput requirements of Grid computing are very different from the low-latency requirements of normal supercomputers.

The TOP500 project was started in 1993 to provide a reliable basis for tracking and detecting trends in high-performance computing. Twice a year, a list of the sites operating the 500 most-powerful computer systems is assembled and released. The best performance on a benchmark, known as LINPACK, is used as a performance measure for ranking the computer systems. The full rankings list is available at www.top500.org/lists/2007/06.

HIGH-PERFORMANCE COMPUTING

European cluster project for supercomputing is completed

In May, the Forschungszentrum Jülich (FZJ) Research Centre in Germany announced that the JULI project was successfully completed. In one year, the project developed a next-generation, high-performance cluster computer in close co-operation between researchers at FZJ and companies from Germany and the US.

Cluster computers are built modularly, using standard PC technology and very fast networks. As ideal instruments for a wide range of simulation problems, they now make up a large proportion of the most powerful computers in the world (see article above). The decisive factor for such a collection of computers working in parallel is the fast transmission of signals across the computing network.

The Jülich Linux cluster JULI connects fast processors in IBM's JS21 blades, which are equipped with two PowerPC 970MP dual-core processors with a top speed of 2.5 GHz, which are three times faster than any of the previous blade generations. These blades are connected over the "InfiniPath" InfiniBand network, developed by the US company Qlogic, providing a particularly high bandwidth even for small reports with a latency time of less than 2 μs.

The Munich-based company ParTec developed ParaStation, the cluster operating-system for JULI, and the experts at Jülich are responsible for ensuring high levels of availability, performance and reliability of the system – as well as providing the ParaStation Grid monitor.

50 years of Fortran

With its 50th anniversary this year, the Fortran programming language is one of the oldest programming languages and is still widely used in the scientific community. **Eric McIntosh** looks back at the usage and development of Fortran at CERN.

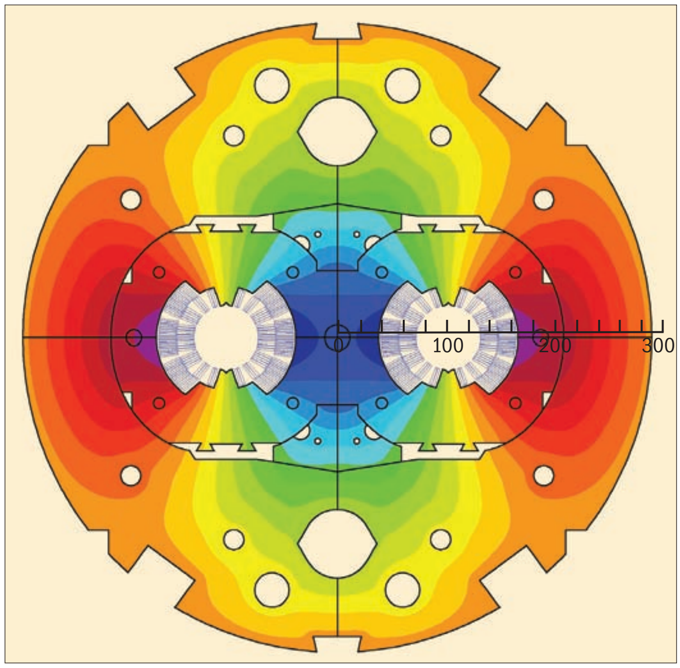
In February 1957, the Fortran programming language was formally announced to the world. FORTRAN was an acronym for the IBM Mathematical FORmula TRANSlating System and was developed by an IBM project team, whose leader John Backus sadly died earlier this year. This compiler was one of the first high-level language compilers ever developed. Before that time, computers had been programmed in the machine language itself or in a simple higher-level language like Alphacode, User Code or Autocode for the Ferranti Mercury at CERN.

Fortran came to CERN in 1961 when the laboratory acquired an IBM 709 computer that came with a free Fortran compiler. This language was quickly recognized to be a significant step forward in programming capability and allowed collaboration and program interchange with the US laboratories. The only alternative high-level language at this time was ALGOL, which was more structured but not as adaptable to the data-handling requirements of a high-energy physics institute. In addition, attempts to define a standard for ALGOL dragged on and Fortran quickly became the language of choice for scientific and technical programming.

Fortran was developed and extended through several dialects: FORTRAN I, II, III, IV and 66, 77, and more recently, Fortran 90/95. Fortran 2003 is coming soon and discussions are under way to define 2008. CERN's own Fortran dialect was never widely adopted and was superseded by the agreed International Standards.

Several machine-specific Fortran-callable routines (in Assembler or later the C language) always had to be provided, for example for bit and byte manipulation of physics data or for the numeric conversion of the multiple character, integer and floating-point representations. Thus, even a well-written program conforming to standards was not really portable between big-endian, little-endian, 32-bit, 60-bit or 64-bit machines with different character sets. Indeed, this was so much the case that the first CERN benchmark suite developed in the 1970s to evaluate performance of computer processors ran on IBM-compatible machines only.

On the other hand, the Fortran language was well-suited to building libraries of useful subroutines, packages and complete programs, which were widely distributed. One of the most successful of these was the CERN Program Library, a large collection of general-purpose programs that were orientated towards the needs of high-energy physics. However, since they were nearly all of a general mathematical or data-handling nature, these programs were applicable to a wide range of problems. The library contains about 2500 subroutines grouped into 450 program packages, with 80% being written in Fortran – mostly FORTRAN 77 – and the remainder in C or assembly code (but usually still with a Fortran version available). The library was ported to nearly all computers in use within high-energy physics and distributed in binary and source form to most collaborating institutes, as well as to hundreds of non-high-energy physics institutes. It reached its peak in the LEP era and while frozen for some years, is still widely used today.



Magnetic field in the LHC main dipole simulated with the ROXIE program that comprises about 100 000 lines of FORTRAN code. (Courtesy S Russenschuck, CERN.)

Indeed, the wide adoption of FORTRAN 77 – the ASCII character set and the IEEE standard for floating-point arithmetic with 32-bit and 64-bit words – has greatly facilitated program portability. Fortran was *the* language at CERN until well into the last decade of the 20th century, while other languages like PL/1, PASCAL, BASIC, Modula-1 came and went. All this changed with the advent of the first PCs in the 1980s and the World Wide Web; computing was no longer dominated by scientific and technical applications. CERN recognized that, to produce and maintain the huge amount of software required by the experiments, it needed object-orientated and fully structured programs for the LHC era.

Also in the 1980s, discussions on the next version of the Fortran standard – known as 8X at the time – were blocked in ▷

The Cray supercomputer (blue and yellow, in the background) at CERN in 1988 used mainly Fortran programs.

Fortran code today

```
Program cubes
Implicit none
Double precision x
Do
       Write (*,'(A)',advance0"NO") 'Please enter a number X: '
       Read (*,*) x
       Write (*,*) 'X cubed 0 ', x*x*x
End do
End program cubes
```

The sample program "cubes" written in today's Fortran code (above) and 1950s' machine code (right).

the committees involved. The US committee X3J3, with around 50 members, manufacturers, large laboratories and other users, expected the ISO WG5 committee to adopt its recommendations. Instead, a stalemate ensued over the content and a compromise Fortran 90 was not reached until 1991.

Michael Metcalf, formerly of CERN and co-author of *Fortran 90/95 Explained*, was a member and significant contributor to X3J3 and must have been appalled at the delays. CERN therefore adopted C++ in the 1990s as the recommended programming language for the LHC experiments. Nonetheless, the accelerator and engineering communities at CERN continue to use Fortran. The LHC magnet design program ROXIE, accelerator design tools like SixTrack and MAD-X (the MAD 8 successor) or the PS operational tool for phase space tomography are recent developments in modern Fortran. Even the LHC experiments still continue to use some existing Fortran applications for simulated-event generation.

Today, Fortran 95 provides all desirable object-orientated and structured programming features, pointers and overloaded operators, and is extremely efficient in the handling of arrays. There are free gfortran and g95 compilers, as well as the excellent NAG f95 library and a variety of other commercial products.

Finally, there is no need to be a religious extremist; these days, procedures in different languages can be intermixed (which will only become easier). Different subsets of applications can be written in the most appropriate language, e.g. Java for the web, and all can be glued together in a PYTHON framework. On the other hand, it is also possible to misuse almost any language: C++ includes C, and Fortran still has the GO TO function.

Fortran is the language of high-performance technical computing – even if this is an increasingly smaller segment of today's computing activities. In 1990, the former IT division leader Paolo Zanella wrote: "If I had to pick one thing likely to still be alive 30 years from now, I would choose Fortran."

Résumé

50 ans de FORTRAN

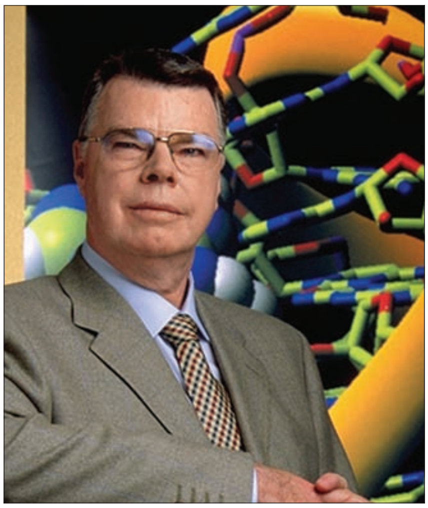
En février 1957, la création du langage de programmation FORTRAN était formellement proclamée. Nommé selon un acronyme du Mathematical FORmula TRANslating System d'IBM, le FORTRAN a été élaboré par une équipe de projet d'IBM. C'était l'un des tout premiers compilateurs de langage de haut niveau développés et il reste très utilisé au sein de la communauté scientifique. Au fil des ans, il a été perfectionné et a trouvé des extensions dans plusieurs dialectes: FORTRAN I, II, III, IV et 66, 77 puis, plus récemment, Fortran 90/95. La version FORTRAN 2003 sortira bientôt et les discussions sont en cours pour définir la version 2008. Dans cet article, Eric McIntosh retrace l'utilisation et le développement du FORTRAN au CERN, où ce langage est arrivé en 1961.

Eric McIntosh, *CERN.*

The greatest challenge: computing the brain

After nearly 40 years at the top end of scientific computing, Bob Bishop is bringing his considerable experience to bear on a project to unravel the extremely complex system of the mammalian brain. Here he talks to **Beatrice Bressan**.

Bob Bishop began his scientific life as a physicist, earning a BSc in mathematical physics from the University of Adelaide and an MSc from the Courant Institute of Mathematical Sciences at New York University. He spent an intervening three years in Australia as a research scientist in the developmental phase of medical ultrasonics and nuclear magnetic resonance techniques. Progressively, he developed an interest in technical and scientific computing and eventually took employment with Digital Equipment Corporation in 1968 at its headquarters in Maynard, Massachusetts, from where he advanced through various global management positions.



Bishop became the international vice-president for Apollo Computer Inc in 1982, and then joined Silicon Graphics Inc in 1986 as founding president of the SGI World Trade Corporation. He was chair and CEO of Silicon Graphics from 1999 to 2005. Today, he is involved in a broad range of global initiatives, but arguably none as ambitious at the Blue Brain Project. This project is a collaboration between the École Polytechnique Fédérale de Lausanne (EPFL) and IBM, and has the ambitious goal of attempting to reverse-engineer the mammalian brain in order to understand human brain function and dysfunction through detailed simulations. The project is headed by Henry Markram, a brilliant young neuroscientist of South African origin with research credentials from the Weizmann Institute, Israel, who founded and directs the Brain Mind Institute at EPFL.

The Blue Brain Project aims to produce biologically accurate, functional computer models of the brain and will explore solutions to problems in mental health and neurological disease towards a new generation of information-based medicine.

How and when did you become involved in the project?
I spent a 45-year professional career working with people who were at the leading edge of science. Most of my work has been in the application of high-performance computing to science. During this time, computing made many inroads in medicine, especially imaging – the brain, the cardio-vascular system and indeed the whole human body. It has always seemed miraculous to me how various non-invasive scanning methods reveal one's inner condition. Today, we can build high-resolution images that "fuse" together some 10 different modalities of data collection to generate a complete inner vision of the human body.

Then, along came genomics – enabled by computing, X-ray crystallography and electron microscopy – and finally we could discover and interpret the complex molecular structure of the living cell. The double helix of DNA was unravelled, as was the transcription formula for building cells. However, the functioning of one part of our bodies remained a mystery: the brain.

It is now more than 100 years since Santiago Ramon Y Cajal, the Spanish scientist, won the Nobel Prize in Medicine for his revelation that the neuron, the fundamental cell of the brain and central nervous system, is a discrete cell and not a continuum. We have more than a hundred billion (10^{11}) neurons in our brain. And like the trees in a forest, the neurons of our brain touch on average a thousand other neurons. The point of touching, where the communication takes place, is called a synapse. With a hundred billion (10^{11}) neurons and, on average, a thousand synapses, we have in total a hundred trillion (10^{14}) connection points. It is the passing of chemicals – neurotransmitters – across these connection points that account for our consciousness and thinking processes.

Is it possible to accurately model, simulate and visualize the functioning of the human brain, beginning from the neuron level? This is a challenge of enormous proportions that has been taken up by the Blue Brain Project at the Brain Mind Institute, EPFL. In July 2005, the institute demonstrated some very interesting macro effects that derived from the modelling and simulation of the neo-corti- ▷

cal column of a rat brain with approximately 10 000 neurons and 30 million synapses. This proved to be a successful "proof of concept" and constituted the first phase of the project. In November 2006, after further evidence had been accumulated and long-term funding commitments achieved, Prof. Markram decided to take the more ambitious step of extending the research to include a range of mammalian brains: from rat, to mouse, to cat, to primate and finally, to human. He asked me to be chairman of his advisory board.

What are the objectives and the most important milestones of this project?

The ultimate mission, by the year 2015, is to successfully reverse-engineer the human brain and then to forward-engineer it through computational simulation to predict how dysfunction can occur. If you look at the world today, every society is paying a huge premium for such dysfunctions as Alzheimer's, Parkinson's, epilepsy, depression, schizophrenia, addiction, autism and dyslexia. All of these complex brain dysfunctions are not well understood and their treatment is costing society a vast amount of money each year. We believe, that if we could model and simulate the underlying neuronal and synaptical behaviour accurately, then there would be a greater possibility of designing pharmaceuticals that exactly pinpoint and correct these dysfunctions. We expect that such knowledge would lead to a huge transition in the medical and pharmaceutical industries over the next 20 years.

Let me point out however, that this is a project for humanitarian purposes funded by private humanitarian sources and with ground rules that call for it to be open source. We will actively seek cross-institutional, cross-national and cross-religious contributions to the project, and share our knowledge as it emerges.

The past 20 years have seen significant advances in the development of instrumentation for scientific investigation. Can you identify important technologies that have contributed to the development of the Blue Brain project?

Prof. Markram's group has successfully developed a "patch clamp" method for tapping into the firing behaviour of neuron cells and calibrating the behaviour of up to 12 such cells connected together. This data enables neurons to be classified into various types, based upon firing and spike-train behaviour patterns. The amazing thing is that all mammals share the same fundamental neurons, but the neurons are arranged differently, with different architectures, and this creates different behaviour patterns.

The neuron behaviour patterns are stored in a database and retrieved on demand. The key software challenge is then to manipulate the cell morphology in 3D such that the synaptical touch points are representative of reality. This entails some very sophisticated computational visualization techniques.

With this, we have reached another important part of the project: how to upgrade the volume of experimental data. This is possible using neuroscience laboratories around the world as partners. But, if they only have research-level capability, it will not be possible to have enough data about neuron behaviour. As in the Human Genome project, which finished ahead of time through the industrialization of data capture, we have the same goal in the Blue Brain Project: to industrialize data capture from many different laboratories and assist them to develop instrumentation for that purpose.

One aim of the project is to build a global academic network and commercial service industry across all fields of life science. Do you think this is realistic?

I think we are more focused than that – even though it is true: the brain and its central nervous system have a very broad impact on all aspects of life. The reason we use a global network of partners incidentally is, first to accelerate data capture and second, to have researchers who are focused on certain aspects of the simulation, such as on Alzheimer's, addiction, autism, and ageing. However, we think that in all cases, in spite of such specialized partners, a holistic full-brain model and simulation will be necessary to accurately study and demonstrate the desired effects. The EPFL Blue Brain team will attempt to coordinate this activity, worldwide. Most people would say that the mission we are on is a hundred-year mission, not only a 10-year project. For this reason, we want to collaborate with, and possibly co-fund, any activity or technology that will get the job done sooner.

You started your career as a mathematical physicist before becoming professionally known around the world in scientific computing, especially as chair and CEO of SGI. But why did you decide to leave scientific research?

Well, I really haven't – but I am at a point where I have retired from direct corporate line management. For 40 years, I built the international operations of three scientific computer companies – each with about 40 subsidiaries. During that process I lived in five countries; always supporting scientists and their research ambitions. I was privileged to see many new areas of science evolve. The computer became the scientist's most valuable instrument. It was enjoyable to watch science embrace computing in every dimension – personal computing, real-time computing and super computing. Commercial computing eventually emerged from the early roots of scientific computing, in a similar way that the commercial World Wide Web emerged from CERN's data-sharing.

Although I was a researcher in the early days of my career, and have since carried a strong interest in every dimension of science, I did not in fact stay long "in the trenches". I grew up in Australia building short-wave radios and other "ham" activities. I still collect radios and still have some basic unanswered questions regarding the fundamentals of electromagnetic radiation. In my view, the 21st century will see a higher degree of integration in science from particle physics, to medicine, biology, the environment and out to planetary science and cosmology. I see more and more the possibility that all sciences will be underpinned by mathematical modelling, simulation and visualization, because these are the horizontal "power tools" that now propel scientists into the unknown. Comparing computer simulations and predictions with reality will become the main way forward.

How has your work brought you to interact with CERN?

I have been a frequent visitor to CERN for 30 years with the companies that I managed. Recently, I observe that CERN has become a leader in Grid computing. By tying thousands of PCs together one can resolve parallel, loosely-coupled problems cheaply and easily. My view however, is that physics around the world is short on knowledge when it comes to deploying high-performance computers and building truly interactive 3D models of fundamental underlying physical phenomena. Nature is indeed complex, non-linear and multi-disciplinary, and therein lies our greatest challenge – understanding it holistically.

CERN is extremely professional at collecting petabytes of data online and processing it offline. So, the collection cycle and the analysis cycle are separated. Myself, I am interested in having these two cycles come closer together such that there can be real-time analysis during the experiment and so that the experiment can be computationally steered as phenomena emerge and become visible. Real-time interactive physics is my dream – running computational simulations and experiments simultaneously, and in parallel.

How, in your experience, does CERN drive computing requirements?

Grid computing is its first priority, such as the LHC Computing Grid. There is no effort that I observe to have integrated real-time 3D modelling of the collision processes – it is pieced together afterwards, balancing the energy and momentum equations. As yet, there is no real interest in visualizing the particle interactions as they take place. Therein lies an opportunity for the future, I believe. Of course, there are some ambiguities as to how we would even model fundamental particles – as waves, as point mass and charge, or as strings, for example – and these questions are still critical and unresolved. I would like to see a return to supercomputing in the high-energy world sometime in the future, but for now, it is all Grid computing.

Having spent more than 40 years in the private sector, what is your vision for scientific research in the future?

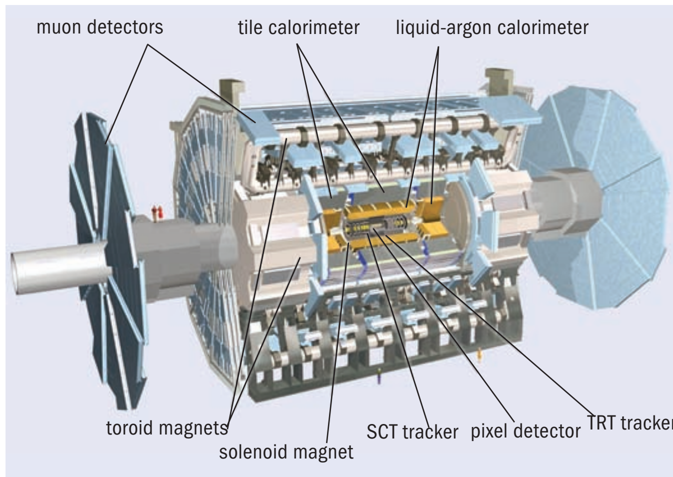
Science and technology drive the economy, but they are funded in a manner that does not represent their importance. The world must develop a better way with more long-term guaranteed funding for science and discovery. Not at the end of the stream as it is now, after all the lawyers, administrators and the marketers have drunk their share; it must have the first "bite of the cherry". Only 2% of the GDP of industrial nations goes to research. We can argue that the entire economy is underpinned by research and that's not a good percentage. To feed the foundations with 2% is a mistake. At least I would give the first 2%, and not the last!

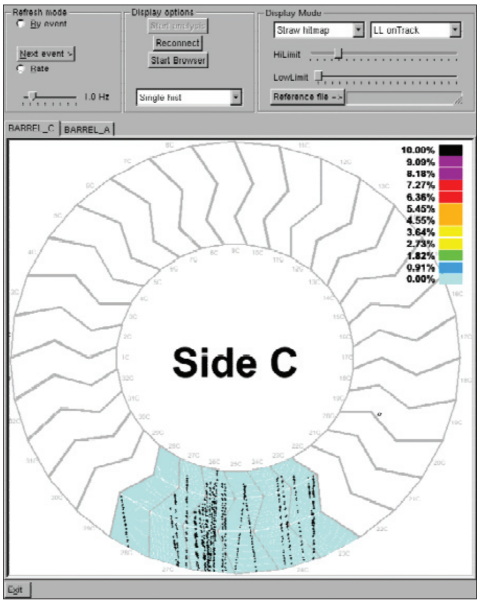
Résumé

Le grand défi : modéliser le cerveau

Bob Bishop a travaillé près de 40 ans à la pointe du calcul scientifique, tout d'abord chez Digital, puis chez Apollo Computer et chez Silicon Graphics. Aujourd'hui, il participe à divers projets planétaires, dont le plus ambitieux est très probablement « Blue Brain ». Ce projet, une collaboration entre l'École polytechnique fédérale de Lausanne et IBM, vise à réaliser une réplique numérique du cerveau des mammifères afin de comprendre son fonctionnement et ses dysfonctionnements à l'aide de simulations. Dans cette interview, Bishop décrit cette entreprise passionnante et évoque l'avenir de l'informatique pour la physique des hautes énergies.

Beatrice Bressan, *CERN.*


muon detectors
tile calorimeter
liquid-argon calorimeter
toroid magnets
solenoid magnet
SCT tracker
pixel detector
TRT tracker



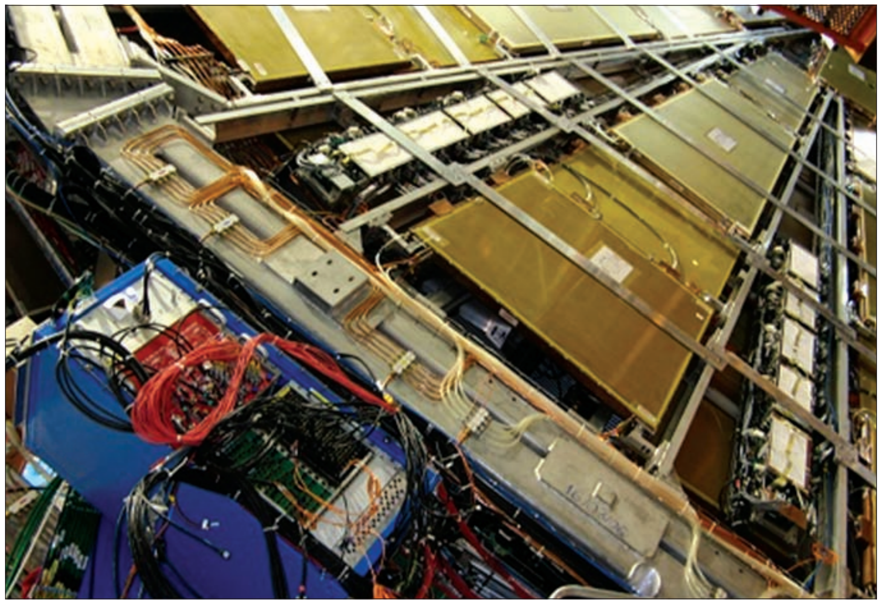


Fig. 2. (left) Cosmic-ray tracks recorded in the barrel TRT during the M3 tests. Fig. 3. (right) The TGC sector used in the tests.

absorber in the forward direction (less than 5°). Liquid argon also figures in the electromagnetic calorimeter, which is optimized for electrons and photons. However, in this case, lead (rather than copper) is used to initiate particle showers.

For the M3 tests, around 75% of the tile calorimeter and 50% of the liquid argon calorimeter were powered with high voltage and included in the final digital read-out. The tile calorimeter will provide a fast read-out for triggering when finally operational at the LHC, adding together calorimeter cells into trigger towers that point to the interaction point. In the M3 set-up, 500 trigger towers (around 25% of the final number) were used to provide a first-level trigger on cosmic muons, supplying signals to special trigger electronics for commissioning, which in turn delivered a trigger signal to the central trigger processor. This yielded a couple of cosmic events per minute that were read out by the central data acquisition (DAQ). During the run, a dozen or so non-expert "shifters" looked after routine operations, such as data and hardware monitoring, testing procedures as well as the detector systems.

The muon system for ATLAS is based on the huge toroid magnet system, with several different kinds of detector to register and track muons as they pass beyond the layers of calorimetery. Monitored drift tubes (MDTs) provide the precision measurements in the bending region of the magnetic field in both the barrel and the endcap region of the detector. They are complemented by trigger chambers – resistive plate chambers (RPCs) in the barrel and thin gap chambers (TGCs) in the endcap regions – which provide fast signals for the muon trigger and the second co-ordinate for the measurement of the muon momentum.

For the barrel muon detectors, sections of both the MDTs and the RPCs took part in the M3 tests using the final set-up for the high-voltage, low-voltage and gas systems, and all monitored by the central DCS. Some 27 000 drift tubes were read out during the run, which is more than the barrel muon read-out of the LEP experiments (e.g. ALEPH had approximately 25 000 muon channels) but is less than 10% of the final total for ATLAS. Two sectors of RPCs were used to provide a trigger on cosmic muons.

The integration of new components into the global system formed the main goal of week two, which saw the addition of detectors from the inner tracking system and more trigger equipment. The inner detector uses three different systems for tracking particles within the volume of a superconducting solenoid magnet inside the calorimeters. The tracking systems form three layers, the outermost being the transition radiation tracker (TRT) based on "straws" (4 mm diameter drift tubes). Silicon strip detectors in the semiconductor tracker (SCT) are used at radii closer to the beam pipe, while silicon pixel detectors form the innermost layer.

The barrel TRT was successfully installed and tested in October 2006. Since then a number of stand-alone and system tests combined with the SCT have taken place to characterize the detector. For M3, six TRT barrel modules – altogether 20 000 channels or 19% of the TRT barrel – were connected to the back-end read-out electronics and successfully integrated into the central DAQ. Steps were also taken towards the integration of the TRT DCS into the ATLAS DCS, and cosmic-ray data were collected in combination with other detectors by the end of the M3 period (figure 2).

Cooling for the SCT was not available during the M3 run, so this detector could not take part fully. However, its DAQ was nonetheless successfully integrated using some test modules installed adjacent to the SCT read-out driver (ROD) crates. Despite using only a small number of modules, M3 provided a valuable opportunity to exercise the final DAQ infrastructure and the functionality of the trigger timing in preparation for running with the full SCT.

On the second week of the run, the first-level calorimeter trigger (L1Calo) also joined the data collection, taking part for the first time in a milestone run, although not yet providing real triggers. For this initial test, the system consisted of one-eighth of the final set of preprocessor modules and one ROD. The pre-processor modules perform the analogue-to-digital conversion for L1Calo and will also identify the bunch-crossing that the signals have come from when there is beam in the LHC. Running this system was smooth and provided valuable experience of stable running with parts of the final

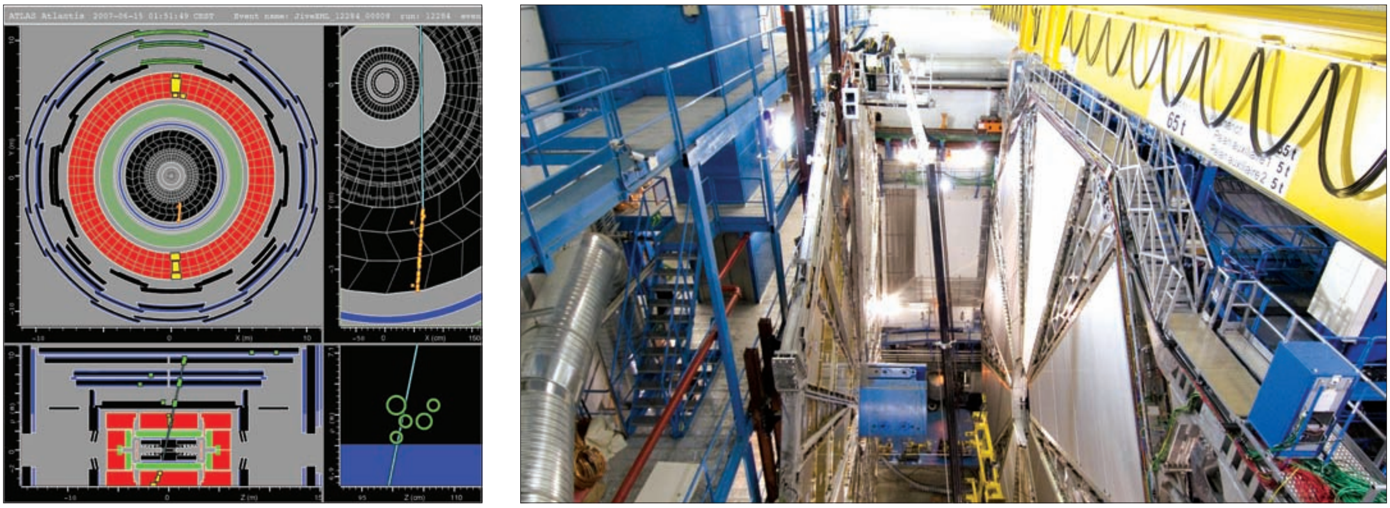


Fig. 4. (left) A muon track recorded during the M3 tests. Clockwise: X-Y view of the full detector including from top to bottom MDTs (green), calorimeters (red and green), and TRT hits (yellow); zoom to centre of the detector with details of TRT track; R-Z view of MDT sector hit by muons with MDT radii; R-Z view with hits and the muon track. (right) Installation of a big wheel of muon TGCs, on the left, prior to the cosmic tests in June, with the corresponding wheel of MDTs visible to the right.

trigger hardware integrated with the other ATLAS subsystems.

For the muon system, elements of the endcap wheels were brought into the trigger during the second week. The TGCs, which provide the level-1 trigger for the muon-endcaps, had already been integrated into the central trigger and DAQ system, but on 13 June some of them were used for the first time to provide a cosmic-ray trigger to other subdetectors, in particular endcap monitored drift tube chambers. This involved 1 out of the 72 sectors of TCGs, using final chambers, electronics equipment and DCS (figure 3). The alignment of the TGCs was sufficiently well known that triggers from cosmic rays were produced with good efficiency at a rate of 3 Hz.

The region of interest builder (RoIB) was another component of the final trigger hardware that was successfully integrated during M3. Although the first-level trigger decision is based on the multiplicity of objects, and not on their position, the first-level trigger processors do remember where they encountered objects passing their thresholds, and, for events accepted by the first-level trigger, they pass this information on to level 2. The role of the custom-built electronics forming the RoIB is to receive these region of interest fragments from the first-level muon and calorimeter trigger subsystems and the central trigger processor, and then to combine them into a single record that is passed on to the level-2 trigger supervisor. The initial hardware for the high-level trigger (level-2 and Event Filter) was also successfully integrated. This consisted of 20 level-2 nodes running cosmic algorithms (but not rejecting events) and 10 event filter nodes (without algorithm processing), which passed data to one of six subfarm output units (SFOs) in the final system. The SFO was able to write events to disk at a rate of up to 70 MB/s and subsequently transferred these files to CASTOR, the data storage on the CERN site, at a rate of around 35 MB/s.

M3 provided the first opportunity for Tier-0 processing to take part in a real data-taking exercise. The existing Tier-0 infrastructure, so far only used in large-scale tests decoupled from the online world, was adapted to the needs of M3 and run during almost the whole data-taking period. Its tasks were to pick up the data files written to CASTOR by the DAQ and to run the offline reconstruction. For the first time, the complete offline software chain could reconstruct cosmic-ray events from data in the calorimeters, the inner detector and part of the muon system (figure 4).

The full monitoring chain was also running, taking the different reconstructed objects as input and producing the relevant monitoring histograms for each subdetector in order to check its correct performance. In a subsequent processing step, monitoring histograms produced as outputs of the individual reconstruction jobs were also merged to allow data quality monitoring over longer periods of time.

Progress during M3 – the third "mile" – has demonstrated that almost all of the subsystems of ATLAS can work together in at least a fraction of their final size, and, in the case of the calorimeters, a large fraction. There are still a few more miles to go. The challenge will be to increase the system in size as commissioning continues while keeping the running-efficiency high and the failure-rate low.

Résumé

ATLAS franchit une nouvelle étape.

Depuis son achèvement, la grande caverne souterraine où sera logée l'expérience ATLAS du LHC se remplit progressivement des divers éléments qui formeront le détecteur le plus volumineux jamais construit pour un collisionneur. Parallèlement, la mise en service en souterrain des divers sous-détecteurs va bon train. Au mois de juin s'est achevée avec succès la troisième semaine d'essais avec rayons cosmiques pour tester simultanément plusieurs sous-systèmes dans une configuration aussi proche que possible de la configuration définitive. Pour la première fois, les tests ont porté sur des éléments du système de trajectographie, des calorimètres et des systèmes de détection des muons.

Giuseppe Mornacchi, *CERN, and* **Thorsten Wengler**, *Manchester, on behalf of the ATLAS Collaboration.*

Electron cooling: challenges at RHIC

A team at Brookhaven has established a scheme to provide electron cooling for the ion beams at RHIC in order to increase luminosity and the physics potential.

Discoveries at RHIC, at the Brookhaven National Laboratory (BNL), have captured worldwide attention. These findings have raised compelling new questions about the theory that describes the interactions of the smallest known components of the atomic nucleus. To address these questions at RHIC, we need to study rare processes. To do this, we must increase the collider's luminosity, which is the rate at which ions collide inside the accelerator. BNL's Collider-Accelerator Department (C-AD) is therefore investigating various upgrades, including the possibility of a luminosity upgrade through a process of electron cooling.

The electron-cooled RHIC, known as RHIC-II, would use low-emittance ("cool"), energetic and high-charge bunches of electrons to cool the ion bunches. This would increase the density of the ion bunches and lead to a higher luminosity. Achieving the necessary characteristics for the electron bunches will require using advanced accelerator techniques such as a high-brightness, high-current energy-recovery linac (ERL). A linac of this type may have other applications, including in an eRHIC (energetic electron ion collider at RHIC) and future light sources.

As RHIC operates, its luminosity goes down because of intra-beam scattering (IBS), which causes the bunches of gold ions to increase their longitudinal emittance and transverse emittance. This means that the bunches "heat up" and become more diffuse. A variety of other mechanisms can also induce emittance growth, regardless of IBS. These include instabilities of the ions' motion, mechanical vibration of the magnets and the collisions themselves. Whatever the cause, more diffuse beams will produce lower luminosity and fewer collisions. So to improve luminosity, accelerator physicists at RHIC aim to eliminate, or reduce, the buildup of heat within the bunches by using electron cooling.

In 1966 Gersh Budker, of what is now the Budker Institute of Nuclear Physics (BINP) in Novosibirsk, invented electron cooling, which has been applied at numerous storage rings around the world. The idea is very intuitive: bring cold electrons into contact with the ions so that heat can flow from the warmer ions to the colder electrons. Cold electrons are produced by an electron source and are then accelerated to match precisely the speed of the ions in a straight section of the ring. Here, the two beams overlap and have a chance to exchange heat. The electrons are discarded after one pass and replaced by fresh electrons to continue the cooling process. At RHIC, which has two 3800 m rings, this straight section will be more than 100 m long. There are other differences between RHIC and previous electron-cooled rings: RHIC will be the first collider to be cooled during collisions and will be the first cooler using bunched electron beams.

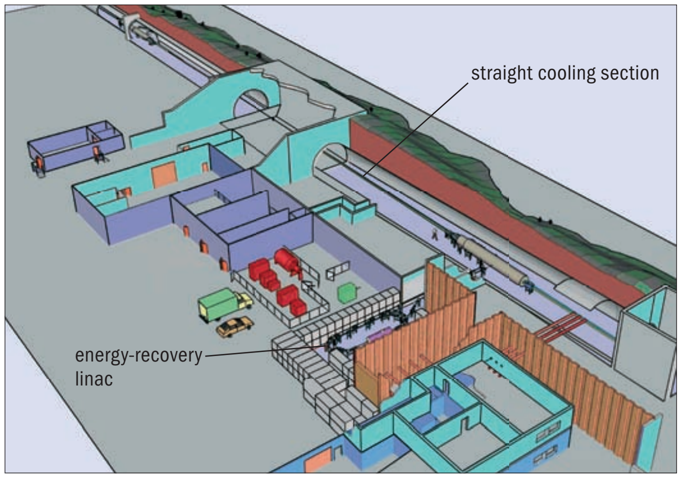


Fig. 1. A possible layout of the electron cooler of RHIC at the "2 o'clock" interaction point. (Images courtesy BNL.)

To gain confidence in the calculated performance of the RHIC electron-cooler, the team at BNL has strived to develop dependable simulation techniques and benchmark them in experiments. Many institutes have helped in this challenge: BINP, JINR, Tech-X Corporation, Jefferson Laboratory, Fermilab, and the Svedberg Laboratory. The last two laboratories also helped in benchmarking experiments on their electron coolers.

One of the challenges of cooling RHIC lies with the machine's high energy, which is around 10 times higher than any previous electron cooler (54 MeV electron energy for RHIC's gold ions at 100 GeV per nucleon). This slows electron cooling because the cooling time is approximately proportional to the cube of the energy. The cooler therefore requires an electron beam that has

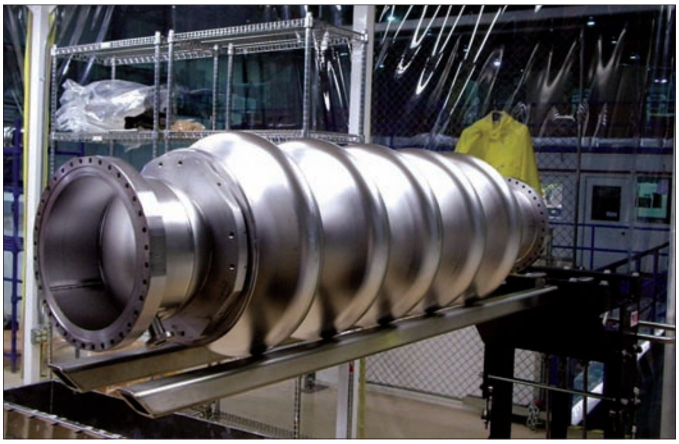


Fig. 2. The 703.75 MHz ampere-class ERL superconducting cavity provided 20 MeV acceleration at low-power investment.

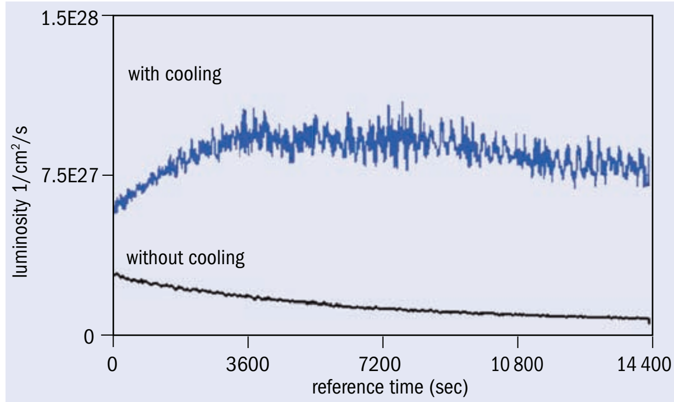


Fig. 3. A plot of results from a simulation of the luminosity of gold–gold collisions at 100 GeV/A per beam over a 4-hour store, shown without and with electron cooling.

a high energy and a high current. It must also cool over a long straight section, which means that a conventional DC electron accelerator cannot be used for cooling RHIC. For this reason, an ERL electron accelerator was adopted by BNL to produce electron bunches with a high charge (about 5 nC), a low emittance (under 3 μm normalized rms) and a high energy of 54 MeV. Another challenge is matching precisely – in position, speed and angular deviation – the electrons to the ions.

Figure 1 shows a possible layout of an electron cooler at RHIC. The cooling will take place in a 100 m straight section in the RHIC tunnel between two superconducting RHIC quadrupoles. The electron beam, generated by a 54 MeV superconducting RF ERL, will first travel with the beam in the anticlockwise ring and then loop back and travel with the beam in the clockwise ring. In doing so, the electron beam cools both rings.

The task of producing the necessary low-emittance and high-charge (high-brightness) electron bunches is even more difficult. The BNL team is currently working on a laser-photocathode superconducting radiofrequency source for the continuous production of a high-brightness electron beam that is capable of about 0.1 A. The design aims for a 0.5 A continuous average current. To make the ERL work without beam breakup, a superconducting accelerator cavity has been developed, which is capable of more than 3 A without beam-breakup, together with other technologies for accelerating a very high current efficiently.

Following several years of intensive R&D, we are confident that, according to our calculations, these techniques will increase the luminosity at RHIC and allow more sensitive, precision studies of the substructure of matter.

Figure 2 shows an ERL superconducting cavity and figure 3 gives the results of a cooling simulation. The five-cell cavity, developed by the C-AD and built by local industry (Advanced Energy Systems), is the first dedicated ERL cavity to be developed. After chemistry and testing at Jefferson Laboratory, it demonstrated 20 MeV acceleration at low-power investment.

The accelerator technologies that we are developing may also have applications at BNL beyond the RHIC-II upgrade. For example, the eRHIC upgrade would add electrons from an ERL to collide with the ion beams of RHIC. Another possible application could be at future "light source" facilities, using very high brightness X-rays to study the properties of materials and biological samples.

Further reading

For more information about the Collider-Accelerator Department's electron cooling group see www.bnl.gov/cad/ecooling.

Résumé

Refroidissement par électrons au RHIC

Une équipe du laboratoire national de Brookhaven a procédé avec succès aux premiers essais d'un système visant à assurer un refroidissement par électrons pour les faisceaux du collisionneur d'ions lourds relativistes (RHIC). Le but est d'accroître la luminosité du collisionneur pour étudier des processus rares. Pour obtenir les caractéristiques nécessaires pour les paquets d'électrons utilisés dans le processus de refroidissement, il faudra utiliser des accélérateurs très perfectionnés, en particulier un linac à récupération d'énergie à haute brillance et à intensité élevée. Un tel linac peut avoir d'autres applications, par exemple dans un collisionneurs électron-ion énergétiques au RHIC et dans de futures sources de lumière.

Ilan Ben-Zvi, *BNL.*

Understanding flavour is the key to new physics

The physics related to the different types (or flavours) of quark has had an important impact on particle physics research. A series of extended workshops held at CERN has examined the possibilities for the future of flavour physics in the LHC era.

The LHCb detector at CERN will focus on heavy-flavour physics, an essential element in further testing the Standard Model.

For many years, the interactions between quarks of different flavour and the phenomenon of CP violation – the non-invariance of weak interactions under combined charge-conjugation and parity transformations – have played an important role in particle physics. In 1963, a year before the observation of CP violation in $K_L \rightarrow \pi^+\pi^-$ decays, Nicola Cabibbo introduced the concept of flavour mixing. Ten years later, Makoto Kobayashi and Toshihide Maskawa discovered that quark-flavour mixing allows the accommodation of CP violation in the framework of the Standard Model, provided that there are at least three different replicas – or generations – of the fermion content of this theory. Sheldon Glashow, John Iliopoulos and Luciano Maiani had already introduced the charm quark in 1970 to suppress the flavour-changing neutral currents, and Mary K Gaillard and Benjamin W Lee in 1974 estimated the mass of that quark with the help of the K^0–$\bar{K}^0$ oscillation frequency. Then, in the 1980s, the large value of the top-quark mass was first suggested by the large B^0_d–$\bar{B}^0_d$ mixing seen in the ARGUS and UA1 experiments at DESY and CERN, respectively.

Flavour physics has since continued to progress, and flavour-changing neutral-current processes and CP-violating phenomena are still key targets for research because they may be sensitive to physics lying beyond the Standard Model. Experiments have ▷

revealed the particles of all three generations, and have established non-vanishing neutrino masses, leading to a rich flavour phenomenology in the lepton sector, pointing towards new physics. Studies on how the field will continue to progress formed the basis for the five meetings in a series of workshops on Flavour Physics in the LHC Era, which were held at CERN between November 2005 and March 2007.

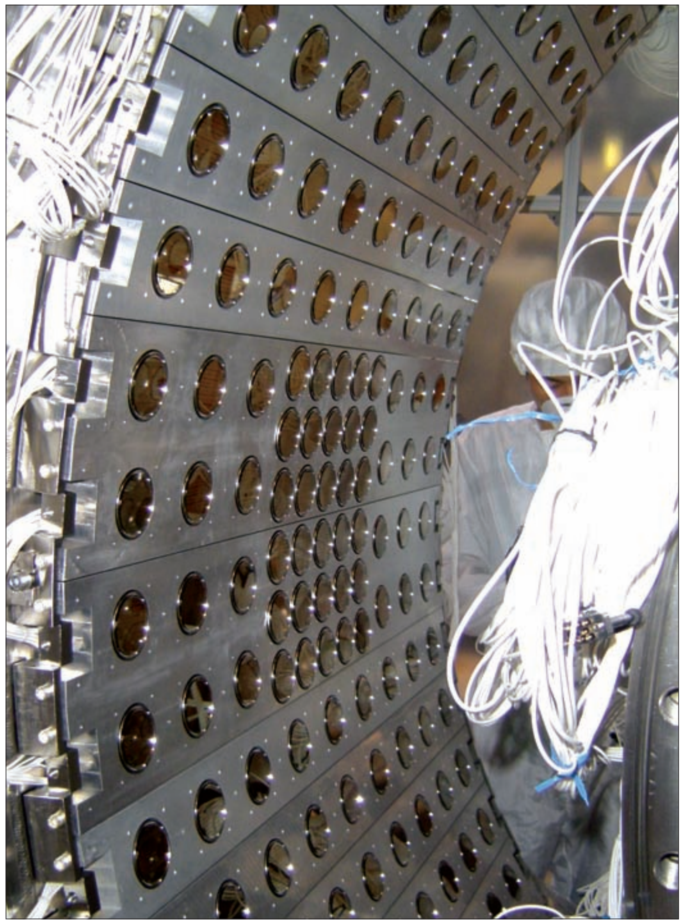
The rise of the B meson

The kaon system dominated the exploration of the quark-flavour sector for more than 30 years. For the past decade, however, the B-meson system has been the key player. Thanks to the B-factories based on e^+e^- colliders at SLAC and KEK, with their detectors BaBar and Belle, respectively, CP violation is now also definitely seen in B decays, where the "golden" decay $B^0_d \to J/\psi K_S$ shows CP-violating effects at the 70% level. These effects can be translated into the angle β of the unitarity triangle, which characterizes the Kobayashi–Maskawa mechanism of CP violation. Several strategies to determine the other angles of the triangle, α and γ, have been proposed and successfully applied to the data from the B-factories. After important first steps in experiments at LEP and at the SLAC Large Detector, the CDF and DØ collaborations at Fermilab's Tevatron collider last year eventually measured the B^0_s–$\bar{B}^0_s$ oscillation frequency ΔM_s. This spring, the B-factories reported evidence for D^0–$\bar{D}^0$ mixing – the last missing meson–anti-meson mixing phenomenon.

So far, these results – together with intensive theoretical work – have shown that the Kobayashi–Maskawa mechanism of CP violation works remarkably well. This complements the precision tests of the gauge sector of the Standard Model and therefore highly constrains any scenario for new physics beyond the Standard Model. On the other hand, neutrino oscillations and the baryon asymmetry of the universe require sources of flavour mixing and CP violation beyond what is present in the Standard Model. This demands the continued exploration of flavour phenomena, improving the current accuracy and probing new observables.

When the LHC at CERN starts up next year, these efforts will be boosted because B-decay studies will be the main theme of the LHCb experiment (*CERN Courier* July/August 2007 p30). The ATLAS and CMS experiments will mostly focus on the properties of the top quark and on the direct search for new particles, which could themselves be the mediators of new flavour and CP violating interactions. The B_s-meson system is the new territory of the B-physics landscape that can be fully explored at the LHC; this was not accessible at the e^+e^- B-factories operating at the $\Upsilon(4S)$ resonance. The experimental value of ΔM_s is consistent with the Standard Model prediction, although this suffers from lattice QCD uncertainties and still leaves much room for CP-violating new-physics contributions to B^0_s–$\bar{B}^0_s$ mixing, which could be detected at the LHC with the help of the $B^0_s \to J/\psi\varphi$ decay. B_s-physics will also open new ways to determine the angle γ of the unitarity triangle.

These methods make use of pure "tree" decays (e.g. $B^0_s \to D^{\pm}_s K^{\mp}$), on the one hand, and of decays with penguin contributions (e.g. $B^0_s \to K^+K^-$) on the other. Moreover, the $B^0_s \to \varphi\varphi$ channel will shed more light on possible new-physics contributions to the CP asymmetries of various $b \to s$ penguin modes, which may be indicated by the current B-factory data for $B^0_d \to \pi^0 K_S$, $B^0_d \to \varphi K_S$



The photomultipliers of the liquid-xenon calorimeter of the MEG experiment, due to start the search for $\mu \to e\gamma$ decays in September at PSI. (Courtesy MEG collaboration.)

and similar modes. Another key aspect of the LHC B-physics programme will be studies of strongly suppressed rare decays, such as $B_s \to \mu^+\mu^-$, which could be highly enhanced through the impact of physics beyond the Standard Model.

Investigations of the extremely rare decays $K^+ \to \pi^+\nu\bar{\nu}$ and $K_L \to \pi^0\nu\bar{\nu}$ will complement the studies of B_s-physics. These are very clean from a theoretical point of view, but unfortunately hard to measure. Nevertheless, there is a proposal to take up this challenge and to measure the former channel at CERN's SPS, and there are efforts to explore the latter – even more difficult decay – at the Japan Proton Accelerator Research Complex (J-PARC).

There are many other fascinating aspects of flavour; the D-meson system is an interesting example. The recently observed D^0–$\bar{D}^0$ mixing can be accommodated in the Standard Model, but suffers from large theoretical uncertainties. New physics may actually be hiding there and could be unambiguously detected through CP-violating effects. Other important flavour probes are offered by the physics of top and by flavour violation in the neutrino and charged-lepton sectors. For the latter, an investigation of the lepton-flavour-violating decay $\mu \to e\gamma$ is about to start this year with the MEG experiment at the Paul Scherrer Institute (*CERN Courier* July/August 2004 p21). In addition, studies of $\mu \to e$ conversion are proposed at Fermilab and J–PARC. Further studies using τ decays at the LHC and at a possible future super-B-factory will be important in this area. Finally, continued searches for electric dipole moments and measurements of the anomalous magnetic moment of the muon are essential parts of the future experimental programme.

Towards the LHC era

As the start of the LHC rapidly approaches, there is one burning question: what is the synergy between the plentiful information following from analyses of the flavour sector with the high-Q^2 programme of the ATLAS and CMS experiments? The extended workshop at CERN focused on this topic and received remarkable interest from the particle-physics community, attracting more than 200 participants from around the world. The workshop followed the standard CERN format with three working groups devoted to the flavour aspects of high-Q^2 collider physics; the physics of the B, K and D meson systems; and flavour physics in the lepton sector. This framework allowed many new studies to be performed. The goals of the workshop were to outline and document a programme for flavour physics for the next decade, to discuss new experimental proposals and to address the complementarity and synergy between the LHC and the flavour factories with respect to the potential for discovery and the exploration of new physics. In this context, detailed discussions took place on two proposals for an e^+e^- super-B-factory, one at KEK and one near Frascati. Such a "super-flavour factory" would allow for precision experiments in quark and lepton flavour physics by accessing the B, the τ and the charm sector. The final meeting complemented this discussion with a review of upgrade plans for LHCb.

The workshop confirmed that flavour physics is an essential element in the further testing of the Standard Model, which should reveal inconsistencies in an unambiguous manner. Should particles associated with new physics be produced at the LHC, studies of flavour physics will play a key role, helping to uncover the underlying new physics, to study the properties of the new-physics particles and to detect or exclude new sources of CP violation and flavour structures.

● The detailed results and conclusions of the workshop will be published as a CERN report (in preparation). For further information, see the workshop homepage at: http://cern.ch/flavlhc.

Résumé

Comprendre la saveur pour accéder à la nouvelle physique

La physique portant sur les divers types (ou saveurs) de quarks a un fort impact sur la physique des particules et elle pourrait s'avérer cruciale pour accéder à la physique au-delà du modèle standard. L'atelier « Flavour Physics in the LHC Era » a tenu cinq sessions au CERN entre novembre 2005 et mars 2007 pour examiner la manière dont la branche va évoluer à l'avenir. Le but était d'esquisser un programme pour la physique de la saveur dans la prochaine décennie, d'examiner de nouvelles propositions d'expérimentation et de s'intéresser à la relation entre le LHC et les « usines » à saveurs du point de vue du potentiel de découvertes et de l'exploration de la nouvelle physique.

Robert Fleischer, **Tobias Hurth**, **Michelangelo Mangano**, *CERN.*

Polarized hyperons probe dynamics of quark spin

Researchers at Jefferson Laboratory demonstrate how two analyses of the same data provide two plausible models of spin transfer in exclusive hyperon production, yielding quite different pictures of quark spin dynamics and challenging existing theories.

A continuing mystery in nuclear and particle physics is the large polarization observed in the production of Λ hyperons in high-energy, proton–proton interactions. These effects were first reported in the 1970s in reactions at incident proton momenta of several hundred GeV/c, where experiments measured surprisingly strong hyperon polarizations of around 30% (Heller 1997). Although the phenomenology of these reactions is now well known, the inability to distinguish between various competing theoretical models has hampered the field (Zuo-Tang and Boros 2000).

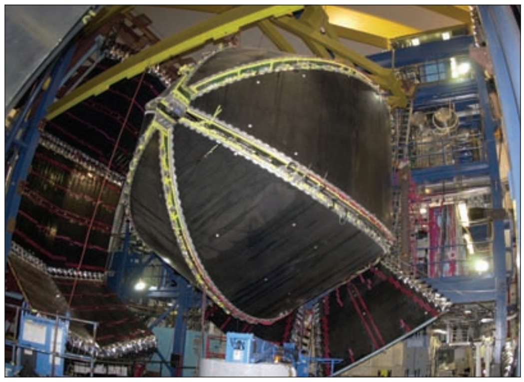


Fig. 1. The CLAS spectrometer, shown with the outer detector arrays moved away from the inner tracking detectors. (Courtesy Jefferson Lab.)

Two new measurements from the US Department of Energy's Jefferson Lab in Virginia are now challenging existing ideas on quark spin dynamics through studies of beam-recoil spin transfer in the electro- and photoproduction of $K^+\Lambda$ final states from an unpolarized proton target. Analyses of the two experiments in Hall B at Jefferson Lab using the CLAS spectrometer (figure 1) have provided extensive results of spin transfer from the polarized incident photon (real or virtual) to the final state Λ hyperon.

The results indicate that the Λ polarization is predominantly in the direction of the spin of the incoming photon, independent of the centre-of-mass energy or the production angle of the K^+. Moreover, the photoproduction data show that, even where the transferred Λ polarization component along the photon direction is less than unity, the total magnitude of the polarization vector is equal to unity. Since these observations are not required by the kinematics of the reaction (except at extreme forward and backward angles) there must be some underlying dynamical origin.

Both analyses have proposed simple quark-based models to explain the phenomenology, however they differ fundamentally in their description of the spin transfer mechanism. In the electroproduction analysis a simple model has been proposed from data using a 2.567 GeV longitudinally polarized electron beam (Carman et al. 2003 and CERN Courier June 2003 p7). In this case a circularly polarized virtual photon (emitted by the polarized electron) strikes an oppositely polarized u quark inside the proton (figure 2a). The spin of the struck quark flips in direction according to helicity conservation and recoils from its neighbours, stretching a flux-tube of gluonic matter between them. When the stored energy in the flux-tube is sufficient, the tube is "broken" by the production of a strange quark–antiquark pair (the hadronization process).

In this simple model, the observed direction of the Λ polarization can be explained if it is assumed that the quark pair is produced with two spins in opposite directions – anti-aligned – with the spin of the $\bar{s}$ quark aligned opposite to the final u quark spin. The resulting Λ spin, which is essentially the same as the s quark spin, is predominantly in the direction of the spin of the incident virtual photon. The spin anti-alignment of the $s\bar{s}$ pair is unexpected, because according to the popular $^3P_0$ model, the quark–antiquark pair should be produced with vacuum quantum numbers ($J=0$, $S=1$, $L=1$, i.e. $J^\pi=0^+$), which means that their spins should be aligned two-thirds of the time (Barnes 2002). This could imply that this model for hadronization may not be as widely applicable as previously thought.

The new photoproduction analysis, with data using a circularly polarized real photon beam in the 0.5–2.5 GeV range, introduces a different model that can also explain the Λ polarization data. In this hypothesis, shown in figure 2b, the strange quark–antiquark pair is created in a $^3S_1$ configuration ($J=1$, $S=1$, $L=0$, i.e. $J^\pi=1^-$). Here, following the principle of vector-meson dominance, the real photon fluctuates into a virtual ϕ meson that carries the polarization of the incident photon. Therefore, the quark spins are in the direction of the spin of the photon before the hadronization interaction.

The s quark of the pair merges with the unpolarized di-quark within the target proton to form the Λ baryon. The $\bar{s}$ quark merges with the remnant u quark of the proton to form a spinless K^+ meson.

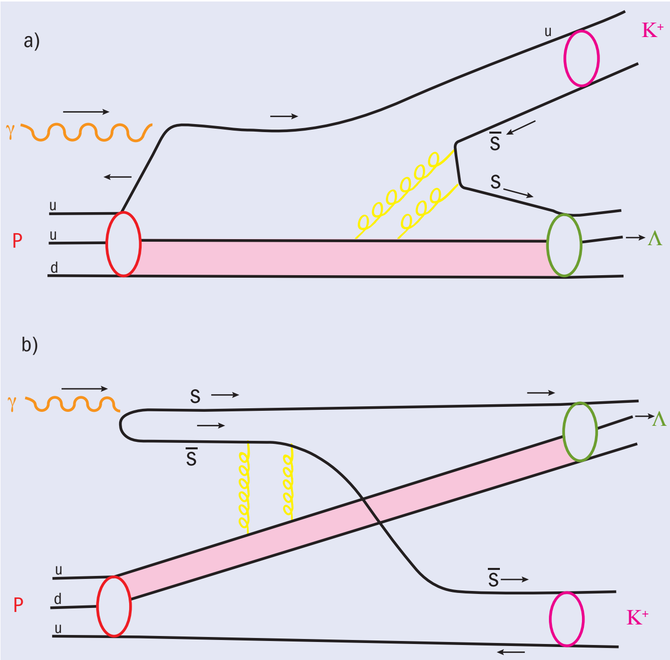


Fig. 2. (a) A model of the reaction where a circularly polarized virtual photon strikes an oppositely polarized up quark inside the proton. The spin of this quark flips and the quark recoils from its neighbours. A strange-antistrange quark pair is created from a $J^\pi = 0^-$ two-gluon exchange (in lowest order) to produce the final state K^+ and Λ hyperon. (b) A model of the reaction where an $s\bar{s}$ quark pair is produced from a circularly polarized real photon that hadronizes such that the s quark in the Λ retains its full polarization after being "precessed" by a spin–orbit interaction, while the $\bar{s}$ quark ends up in the spinless kaon. In both pictures the shaded band represents a spinless ud di-quark system.

In this model, the strong force, which rearranges the s and $\bar{s}$ quarks into the Λ and K^+, respectively, can precess the spin of the s quark away from the beam direction, but the s quark, and therefore the Λ, remains 100% polarized. This provides a natural explanation for the observed unit magnitude of the Λ polarization vector seen for the first time in the measurements by CLAS.

The model interpretations presented from the two viewpoints do not necessarily contradict each other. Both assume that the mechanism of spin transfer to the Λ hyperon involves a spectator $J^\pi = 0^+$ di-quark system. The difference is in the role of the third quark. Neither model specifies a dynamical mechanism for the process, namely the detailed mechanism for quark-pair creation in the first case or for quark spin precession in the second. If we take the gluonic degrees of freedom into consideration, the model proposed in the electroproduction paper (Carman *et al.* 2003) can be realized in terms of a possible mechanism in which a colourless $J^\pi = 0^-$ two-gluon subsystem is emitted from the spectator di-quark system and produces the $s\bar{s}$ pair (figure 2a). This is in conflict with the $^3P_0$ model, which requires a $J^\pi = 0^+$ exchange. To the same order of gluon coupling, the model interpretation proposed by the photoproduction analysis (Schumacher 2007) is the quark-exchange mechanism, which is again mediated by a two-gluon current. The amplitudes corresponding to these models may both be present in the production, in principle, and contribute at different levels depending on the reaction kinematics.

Extending these studies to the $K^{*+}\Lambda$ exclusive final state should be revealing. In the electroproduction model, the spin of the u quark is unchanged when switching from a pseudoscalar K^+ to a vector K^{*+}. If the $s\bar{s}$ quark pair is produced with anti-aligned spins, the spin direction of the Λ should flip. On the other hand, in the photoproduction model the u quark in the kaon is only a spectator. Changing its spin direction – changing the K^+ to a K^{*+} – should not change the Λ spin direction. Thus, there are ways to disentangle the relative contributions and to understand better the reaction mechanism and dynamics underlying the associated strangeness-production reaction. Analyses at CLAS are underway to extract the polarization transfer to the hyperon in the $K^{*+}\Lambda$ final state.

Beyond the studies of hyperon production, understanding the dynamics in a process of this sort can shed light on quark–gluon dynamics in a domain thought to be dominated by traditional meson and baryon degrees of freedom. These issues are relevant for a better understanding of strong interactions and hadroproduction in general, owing to the non-perturbative nature of QCD at these energies. We eagerly await further experimental studies and new theoretical efforts to understand which multi-gluonic degrees of freedom dominate in quark pair creation and their role in strangeness production, as well as the appropriate mechanism(s) for the dynamics of spin transfer in hyperon production.

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Résumé

Des hypérons polarisés éprouvent la dynamique du spin du quark

Deux nouvelles mesures dues au Laboratoire Jefferson remettent en cause les idées actuelles sur la dynamique du spin du quark à la suite d'études sur le transfert du spin dû au rebond du faisceau lors de réactions de photoproduction et d'électroproduction dans les états finals du $K^+\Lambda$. Des analyses émanant de deux expériences menées dans le Hall B à l'aide du spectromètre CLAS ont fourni des résultats détaillés sur le transfert du spin du photon incident polarisé (réel ou virtuel) à l'hypéron Λ dans l'état final. Les deux analyses ont proposé des modèles simples basés sur des quarks pour expliquer la phénoménologie, mais elles diffèrent fondamentalement dans leur description du mécanisme de transfert du spin et dressent des tableaux tout différents de la dynamique du spin du quark.

Daniel S Carman, **TS Harry Lee**, **Mac Mestayer**, *Jefferson Lab and* **Reinhard Schumacher**, *Carnegie Mellon University*

ILL celebrates 40 years i

This year is the 40th anniversary of the Institut Laue-Langevin in Grenoble, w

The Institut Laue-Langevin was founded on 19 January 1967 with the signing of an agreement between the governments of the French Republic and the Federal Republic of Germany. In recognition of this dual nationality it was named jointly after the two physicists Max von Laue of Germany and the Frenchman Paul Langevin. The aim was to create an intense source of neutrons devoted entirely to civil fundamental research. The facility was given the status of "service institute" and was the first of its kind in the world. It was to be the world's leading facility in neutron science and technology, offering the scientific community a combination of unrivalled performance levels and unique scientific instrumentation in the form of a very large cold neutron source equipped with 10 neutron guides – each capable of providing three or four instruments with a very high-intensity neutron flux.

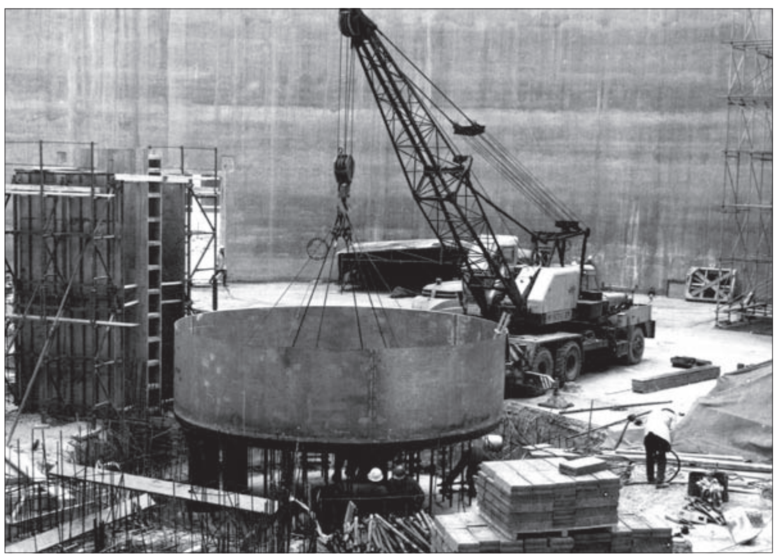
The construction of the institute and its high-flux reactor in Grenoble represented an overall investment of 335 M French francs (1967 prices, equivalent to about €370 M today) and was jointly undertaken by France and Germany. The reactor went critical in August 1971 and reached its full power of 57 MW in December that same year. Since then, the high-flux reactor has successfully maintained its position as the most powerful neutron source for scientific research in the world.

The UK joined the two founding countries in 1973, becoming the institute's third full associate member. Over the following years, the level of international co-operation has gradually been extended, with a succession of "scientific membership" agreements with Spain (1987), Switzerland (1988), Austria (1990), Russia (1996), Italy (1997), the Czech Republic (1999), Sweden and Hungary (2005), and Belgium and Poland (2006).

The ILL is operated jointly by France, Germany and the UK, and has an annual budget of around €74 M. It currently employs around 450 staff, including 70 scientists, about 20 PhD students, over 200 technicians, 60 reactor operations and safety specialists, and around 50 administrative staff; the breakdown by nationality is 65% French, 12% German and 12% British.

The ILL is a unique research tool for the international scientific community, giving scientists access to a constantly upgraded suite of high-performance instruments arranged around a powerful neutron source. More than 1500 European scientists come to the institute each year and conduct an average of 750 experiments. Once their experiment proposal has been accepted by the Scientific Council, scientists are invited to the institute for an average period of one week.

The fields of research are primarily focused on fundamental science and are extremely varied, including condensed matter physics, chemistry, biology, nuclear and particle physics and materials science. Thanks to the combination of an intense neutron flux



The ILL buildings today (top) with the cylindrical reactor hall just visible to t the reactor hall in April 1970 (bottom left); and the large neutron guide ha

in the service of science

which runs the world's most powerful neutron source for scientific research.

the right.; construction of the reactor vessel within the concrete wall of all in 1974 (bottom right). (Courtesy ILL and Artechnique.)

and the availability of a wide range of energies (from 10^{-7} eV to 10^{5} eV), researchers can examine a whole range of subjects. The samples that are studied can weigh anything from a tenth of a milligram to several tonnes. Most of the experiments use neutrons as a probe to study various physical or biological systems, while others examine the properties of the neutrons themselves. It is here that there is the most overlap with the physics of elementary particles and where low-energy physics can help to tackle and solve problems usually associated with high-energy physics experiments, as the following selected highlights indicate.

Neutron basics

The neutron is unstable and decays into a proton together with an electron and an anti-neutrino. Its lifetime, τ_n, is one of the key quantities in primordial nucleosynthesis. It determines how many neutrons were available about three minutes after the Big Bang, when the universe had sufficiently cooled down for light nuclei to form from protons and neutrons. It therefore has a strong influence on the abundance of the primordial chemical elements (essentially ^{1}H, ^{4}He, ^{2}H, ^{3}He and ^{7}Li).

Twenty years ago, in an experiment at ILL, Walter Mampe and colleagues achieved a new level of precision in measuring τ_n by storing ultracold neutrons in a fluid-walled bottle and counting the number of neutrons remaining in the bottle for various storage times. The experiment used a hydrogen-free oil to coat the walls in order to minimize the loss of neutrons in reflections at the walls. The final result of $\tau_n = 887.6 \pm 3$ s was the first to reach a precision well below 1% (Mampe *et al.* 1989). This value has found a number of applications, in particular making it possible to derive the number N of light neutrino types from a comparison of the observed element abundances with the predicted ones. The argument depends on the relationship between N and the expansion-rate of the universe during nucleosynthesis: the more light neutrinos that contribute to the energy density, the faster the expansion, leading to different element abundances. The result from ILL led in turn to a value of $N = 2.6 \pm 0.3$ which made a fourth light neutrino generation extremely unlikely (Schramm and Kawano 1989). The stringent direct test that N is indeed equal to 3 came soon after with a precision measurement of the width of the Z boson at the LEP collider at CERN.

The neutron lifetime also feeds into the Standard Model of particle physics through the ratio of the weak vector and axial-vector coupling constants of the nucleon. Together with the Fermi coupling constant determined in muon decay, it can be used to determine the matrix element V_{ud} of the Cabibbo–Kobayashi–Maskawa matrix. This in turn, provides a possibility for testing the Standard Model at the low-energy frontier and is one of the continuing motivations to ▷

The storage bottle inside the four-fold mu-metal shielding of the instrument used in the high-precision measurement of the neutron's electric dipole moment at ILL. (ILL/Artechnique.)

Installation of the new reactor vessel in February 1994 (ILL).

improve still further the measurements of the neutron lifetime and of decay asymmetries in experiments at the ILL and elsewhere.

Another key property of the neutron for particle physics is the hypothetical electric-dipole moment (EDM), which has a high potential importance for physics beyond the Standard Model. The existence of an EDM in the neutron would violate time-reversal, T, and hence – through the CPT theorem – CP symmetry. The Standard Model predicts an immeasurably small neutron EDM, but most theories that attempt to incorporate stronger CP violation beyond the CKM mechanism predict values that are many orders of magnitude larger. An accurate measurement of the EDM provides strong constraints on such theories. A positive signal would constitute a major breakthrough in particle physics.

In 2006, a collaboration between the University of Sussex, the Rutherford Appleton Laboratory and the ILL announced a new tighter limit on the neutron's EDM (*CERN Courier* April 2006 p6). Based on measurements using ultracold neutrons produced at the ILL, the upper limit on the absolute value was improved to 2.9×10^{-26} e cm (Baker *et al.* 2006). The experiment stored neutrons in a trap permeated by uniform electric and magnetic fields and measured the ratios of neutron-to-mercury-atom precession frequencies; shifts in this ratio proportional to the applied electric field may in principle be interpreted as EDM signals.

E really does equal mc^2

Particle physics makes daily use of the relationship between mass and energy, expressed in Albert Einstein's famous equation. An experiment at the ILL in 2005 combined with one at the Massachusetts Institute of Technology (MIT), made the most precise direct-test of the equation to date, with researchers at ILL measur-

Laue and Langevin

The signing ceremony for the creation of the Institut Laue-Langevin. Left: G Stoltenberg, the German Minister for Research and Technology; Right A Peyrefitte, the French Research Minister. (Courtesy ILL.)

The German physicist Max von Laue (1879–1960) received the Nobel Prize in Physics in 1914, in Stockholm, for demonstrating the diffraction of X-rays by crystals. This discovery revealed the wave nature of X-rays by enabling the first measurements of wavelength and showing the organization of atoms in a crystal. It is at the origin of all analysis methodology based on diffraction using X-rays, synchrotron light, electrons or neutrons.

Paul Langevin (1879–1946) was an eminent physicist from the pioneering French team of atomic researchers, which included Pierre and Marie Curie. A specialist in magnetism, ultrasonics and relativity, he also dedicated 40 years of his life to his responsibilities as director of Paris's Ecole de Physique et de Chimie. His study of the moderation of rapid neutrons, i.e. how they are slowed by collisions with atoms, was invaluable for the design of the first research reactors.

ing energy, E, while the team at MIT measured the related mass, m. The test was based on the fact that when a nucleus captures a neutron, the resulting isotope with mass number A+1 is lighter than the sum of the masses of the original nucleus with mass number A and the free neutron. The energy equivalent to this mass difference is emitted as gamma-rays, the wavelength of which can accurately be measured by Bragg diffraction from perfect crystals.

The team at MIT used a novel experimental technique to measure the masses of pairs of isotopes by comparing the cyclotron frequencies of the two different ions confined together in a Penning trap. They performed two separate experiments, one with ^{28}Si and ^{29}Si, the other with ^{32}S and ^{33}S, leading to mass differences with a relative uncertainty of about 7×10^{-8} in both cases. At the ILL, a team from the National Institute of Standards and Technology measured the energies of the gamma-rays emitted after neutron capture by both ^{28}Si and ^{32}S using the world's highest-resolution double crystal gamma-ray spectrometer, GAMS4. The combination of the high neutron flux available at the ILL reactor and the energy accuracy of the GAMS4 instrument allowed the team to determine the gamma-ray energies with a precision of better than 5 parts in 10 000 000. By combining the mass differences measured in America and the energy measurements in Europe, it was possible to test Einstein's equation, with a result of $1-\gamma mc^2/E = (-1.4 \pm 4.7) \times 10^{-7}$ – which is 55 times more accurate than the previous best measurements (Rainville *et al.* 2005).

These three examples give only a tiny glimpse into one aspect of the science that is undertaken at the ILL each year, illustrating the possibilities for testing theories in particle physics and cosmology. The institute looks forward to the next 40 years of fruitful investigations and important results in these fields as well as across many other areas of science.

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Résumé

L'ILL fête 40 ans au service de la science

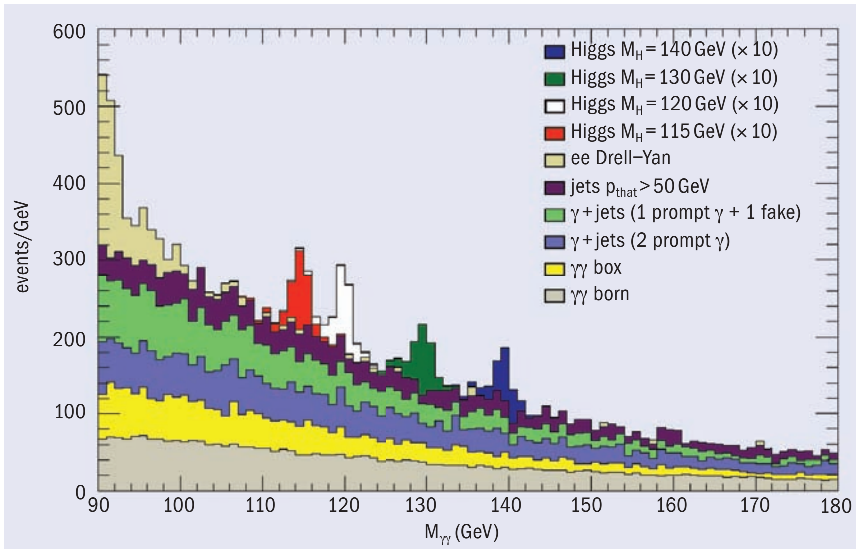
Cette année est celle du quarantième anniversaire de l'Institut Laue-Langevin, qui exploite la plus intense des sources de neutrons destinées à la recherche scientifique. Géré à titre principal par l'Allemagne, la France et le Royaume-Uni, l'ILL fournit un outil de recherche unique à la communauté scientifique et met à sa disposition une série d'équipements de haute performance qui ne cessent d'être perfectionnés. Chaque année, plus de 1500 scientifiques européens se rendent à l'ILL pour y participer à quelque 750 expériences. Les domaines de recherche, extrêmement variés, relèvent essentiellement de la science fondamentale et comprennent la physique de la matière condensée, la chimie, la biologie, la science des matériaux et la physique nucléaire et des particules. Cet article donne quelques exemples des recherches menées dans ce dernier domaine.

Françoise Vauquois, *ILL, and* **Christine Sutton**, *CERN.*

PHYSTAT-LHC combines statistics and discovery

The latest in a series of workshops on statistical topics in particle physics looked at the best techniques to support claims of discoveries among the wealth of data that is expected to emerge from the LHC next year. **Louis Lyons** and **Albert De Roeck** report.

Workshop organizer, Louis Lyons (second from left), visits the ATLAS experiment together with statisticians (left to right) Jim Berger, Nancy Reid, Jogesh Babu and Paul Baines. (Courtesy Jogesh Babu.)



A plot from a Monte Carlo simulation for the CMS experiment, showing possible Higgs signals at four different masses, each scaled up by a factor of 10 to make them more visible. It corresponds to 1 fb^{-1} of integrated luminosity.

With the Large Hadron Collider (LHC) due to start running next year, the PHYSTAT-LHC workshop on Statistical Issues for LHC Physics provided a timely opportunity to discuss the statistical techniques to be used in the various LHC analyses. The meeting, held at CERN on 27–29 June, attracted more than 200 participants, almost entirely from the LHC experiments.

The PHYSTAT series of meetings began at CERN in January 2000 and has addressed various statistical topics that arise in the analysis of particle-physics experiments. The meetings at CERN and Fermilab in 2000 were devoted to the subject of upper limits, which are relevant when an experiment fails to observe an effect and the team attempts to quantify the maximum size the effect could have been, given that no signal was observed. By contrast, with exciting results expected at the LHC, the recent meeting at CERN focused on statistical problems associated with quantifying claims of discoveries.

The invited statisticians, though few in number, were all-important participants – a tradition started at the SLAC meeting in 2003. Sir David Cox of Oxford, Jim Berger of Duke University and the Statistical and Applied Mathematical Sciences Institute, and Nancy Reid of Toronto University all spoke at the meeting, and Radford Neal, also from Toronto, gave his talk remotely. All of these experts are veterans of previous PHYSTAT meetings and are familiar with the language of particle physics. The meeting was also an opportunity for statisticians to visit the ATLAS detector and understand better why particle physicists are so keen to extract the maximum possible information from their data – we devote much time and effort to building and running our detectors and accelerators.

The presence of statisticians greatly enhanced the meeting, not only because their talks were relevant, but also because they were available for informal discussions and patiently explained statistical techniques. They gently pointed out that some of the “discoveries” of statistical procedures by particle physicists were merely

Bayesians vs frequentists

Bayesianism and frequentism are two very different fundamental approaches to statistics. Neither is particularly recent. Rev Thomas Bayes' work was published posthumously in 1763, while Jerzy Neyman's frequentist confidence intervals first appeared in 1937.

The differences between the two approaches are so marked that they even use different definitions of probability. For a frequentist, it is the ratio of successful outcomes in a very large number of repeated trials under essentially identical conditions, for example throwing a dice and seeing how often the number 5 is uppermost. Thus frequentists cannot ascribe a probability to a one-off event ("Will the first astronaut to Mars return to Earth alive?") or to a physical variable ("Is the mass of the top quark below 175 GeV?"). By contrast, Bayesians use their degree of belief as a measure of probability and can use it for a broader variety of situations. The numerical value ascribed to the Bayesian probability of some particular event ("What is the probability that it will rain in Geneva tomorrow?") can vary from person to person, depending on each one's particular knowledge.

Given a particular data set, Bayesians make statements about the probability of parameter values, or of theories being true, by using Bayes' theorem. This requires the use of a "prior" that quantifies what is known about the quantity of interest, before the data are obtained. Frequentists, on the other hand, will only make statements about parameter values or theories for which the observed data are a likely outcome of the experiment. Baysians and frequentists can sometimes be vociferously critical of each other's methods, but many physicists are prepared to take a more pragmatic approach in what they use.

"re-inventions of the wheel" and that some of our wheels resemble "triangles", instead of the already familiar "circular" ones.

The meeting commenced with Cox's keynote address, The Previous 50 Years of Statistics: What Might Be Relevant For Particle Physics. In particular, he discussed multiple testing and the false discovery rate – particularly relevant in general-purpose searches, where there are many possibilities for a statistical fluctuation to be confused with a discovery of some exciting new physics. Cox reminded the audience that it is more important to ask the correct question than to perform a complicated analysis, and that when combining data, first to check that they are not inconsistent.

One approach to searching for signs of new physics is to look for deviations from the Standard Model. This is usually quantified by calculating the p-value, which gives the probability – assuming the Standard Model is true – of finding data at least as discrepant as that observed. Thus a small p-value implies an inconsistency between the data and the Standard Model prediction. This approach is useful in looking for any sort of discrepancy. The alternative is to compare the predictions of the Standard Model with some specific alternative, such as a particular version of supersymmetry. This is a more powerful way of looking for this particular form of new physics, but is likely to be insensitive to other possibilities.

Luc Demortier of Rockefeller University gave an introduction to the subject of p-values, and went on to discuss ways of incorporating systematic uncertainties in their calculation. He also mentioned that, in fitting a mass spectrum to a background-only hypothesis and to a background plus a 3-parameter peak, it is a common misconception that in the absence of any signal, the difference in χ^2 of the two fits behaves as a χ^2 with 3 degrees of freedom. The talk by Kyle Cranmer of Brookhaven National Laboratory dealt with the practical issues of looking for discoveries at the LHC. He too described various methods of incorporating systematics to see whether a claim of 5σ statistical significance really does correspond to such a low probability. The contributed talk by Jordan Tucker from University of California, Los Angeles, (UCLA) also explored this.

While the LHC is being completed, the CDF and DØ experiments are taking data and analysing it at the Fermilab collider, which currently provides the highest accelerator energies. Fermilab's Wade Fisher summarized the experience gained from searches for new phenomena. Later, speakers from the major LHC experiments discussed their "statistical wish-lists" – topics on which they would like advice from statistics experts. Jouri Belikov of CERN spoke for the ALICE experiment, Yuehong Xie of Edinburgh University for LHCb and Eilam Gross of the Weizmann Institute for ATLAS and CMS. It was particularly pleasing to see the co-operation between the big general-purpose experiments ATLAS and CMS on this and other statistical issues. The Statistics Committees of both work in co-operation and both experiments will use the statistical tools that are being developed (see below). Furthermore, it will be desirable to avoid the situation where experiments make claims of different significance for their potential discoveries, not because their data are substantially different, but simply because they are not using comparable statistical techniques. Perhaps PHYSTAT can claim a little of the credit for encouraging this collaboration.

When making predictions for the expected rate at which any particle will be produced at the LHC, it is crucial to know the way that the momentum of a fast-moving proton is shared among its constituent quarks and gluons (known collectively as partons). This is because the fundamental interaction in which new particles are produced is between partons in the colliding protons. This information is quantified in the parton distribution functions (PDFs), which are determined from a host of particle-physics data. Robert Thorne of University College London, who has been active in determining PDFs, explained the uncertainties associated with these distributions and the effect that they have on the predictions. He stressed that other effects, such as higher-order corrections, also resulted in uncertainties in the predicted rates.

Statisticians have invested much effort on "experimental design". A typical example might be how to plan a series of tests investigating the various factors that might affect the efficiency of some production process; the aim would be to determine which factors are the most critical and to find their optimal settings. One application for particle physicists is to decide how to set the values of parameters associated with systematic effects in Monte Carlo simulations; the aim here is to achieve the best accuracy of the estimate of systematic effects with a minimum of computing. Since a vast amount of computing time is used for these calculations, the potential savings could be very useful. The talks by statisticians Reid and Neal, and by physicist Jim Linnemann of Michigan State University, addressed this important topic. Plans are underway to set up a working group to look into this further, with the aim of producing recommendations on this issue.

Two very different approaches to statistics are provided by the Bayesian and frequentist approaches (see box). Berger gave a summary of the way in which the Bayesian method could be helpful. One particular case that he discussed was model selection, where Bayesianism provides an easy recipe for using data to choose between two or more competing theories.

With the required software for statistical analyses becoming increasingly complicated, Wouter Verkerke from NIKHEF gave an overview of what is currently available. A more specific talk by Lorenzo Moneta of CERN described the statistical tools within the widely used ROOT package developed by CERN's René Brun and his team. An important topic in almost any analysis in particle physics is the use of multivariate techniques for separating the wanted signal from undesirable background. There is a vast array of techniques for doing this, ranging from simple cuts via various forms of discriminant analysis to neural networks, support vector machines and so on. Two largely complementary packages are the Toolkit for Multivariate Data Analysis and StatPatternRecognition. These implement a variety of methods that facilitate comparison of performance, and were described by Frederik Tegenfeldt of Iowa State University and Ilya Narsky of California Institute of Technology, respectively. It was reassuring to see such a range of software available for general use by all experiments.

Although the theme of the meeting was the exciting discovery possibilities at the LHC, Joel Heinrich of University of Pennsylvania returned to the theme of upper limits. At the 2006 meeting in Banff, Heinrich had set up what became known as the "Banff challenge". This consisted of providing data with which anyone could try out their favourite method for setting limits. The problem included some systematic effects, such as background uncertainties, which were constrained by subsidiary measurements. Several groups took up the challenge and provided their upper limit values to Heinrich. He then extracted performance figures for the various methods. It seemed that the "profile likelihood" did well. A talk by Paul Baines of Harvard University described the "matching prior" Bayesian approach.

Unlike the talks that sometimes conclude meetings, the summary talk by Bob Cousins of UCLA was really a review of the talks presented at the workshop. He had put an enormous amount of work into reading through all of the available presentations and then giving his own comments on them, usefully putting the talks of this workshop in the context of those presented at earlier PHYSTAT meetings.

Overall, the quality of the invited talks at PHYSTAT-LHC was impressive. Speakers went to great lengths to make their talks readily intelligible: physicists concentrated on identifying statistical issues that need clarification; statisticians presented ideas that can lead to improved analysis. There was also plenty of vigorous discussion between sessions, leading to the feeling that meetings such as these really do lead to an enhanced understanding of statistical issues by the particle-physics community. Gross coined the word "phystatistician" for particle physicists who could explain the difference between the probability of A, given that B had occurred, compared with the probability of B, given that A had occurred. When the LHC starts up in 2008, it will be time to put all of this into practice. The International Committee for PHYSTAT concluded that the workshop was successful enough that it was worth considering a further meeting at CERN in summer 2009, when real LHC data should be available.

Further reading

For additional information on the PHYSTAT-LHC meeting, including transparencies of all of the invited and contributed talks, see http://phystat-lhc.web.cern.ch/phystat-lhc/index.html.

The PHYSTAT-LHC Proceedings will appear as a Yellow Report later this year.

The website for the Banff meeting is www.birs.ca/birspages.php?task=3Ddisplayevent&event_id=3D06w5054.

Earlier meetings can be traced back from the Oxford PHYSTAT '05 website at www.physics.ox.ac.uk/phystat05/reading.htm.

Résumé

PHYSTAT-LHC: des statistiques et des découvertes

La dernière session d'une série d'ateliers sur des sujets statistiques de physique des particules a porté sur les meilleures techniques pour étayer les découvertes présumées parmi la foison de données qui émergeront du Grand collisionneur de hadrons (LHC). Le démarrage de la machine étant prévu pour l'année prochaine, l'atelier PHYSTAT-LHC sur les questions statistiques pour la physique du LHC venait à point nommé pour étudier les techniques statistiques à utiliser dans les diverses analyses pour le LHC. La réunion, tenue au CERN du 27 au 29 juin, a attiré plus de 200 personnes, participant presque toutes aux expériences LHC. Comme à l'accoutumée, les statisticiens ont apporté d'importantes contributions et ont émis des idées qui promettent de se traduire par une amélioration des analyses.

Albert De Roeck, *CERN, and* **Louis Lyons**, *Oxford.*

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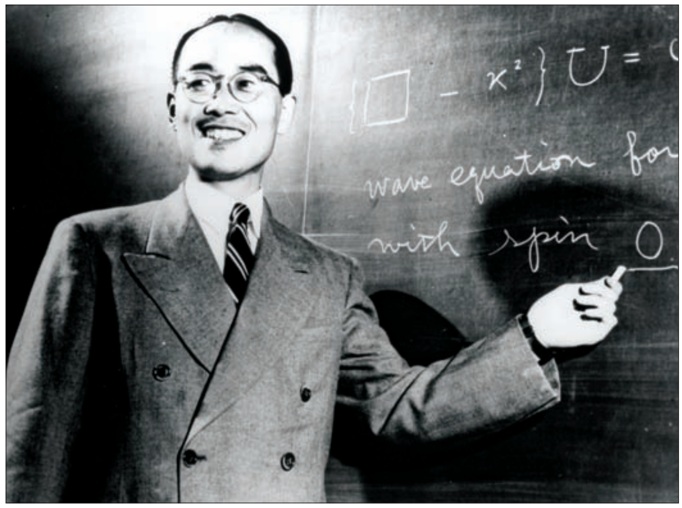
Yukawa's gold mine

In a plenary lecture at the opening session of the symposium to celebrate the centenary of Hideki Yukawa, **Antonino Zichichi** reviewed the unexpected discoveries that came from Yukawa's prediction of a new particle – the pion – and looked at what we can learn from exploration of the new QCD physics: the quark–gluon-coloured world.

This year is the centenary of the birth of Hideki Yukawa who, in 1935, proposed the existence of the particle now known as the π meson, or pion. To celebrate, the International Nuclear Physics Conference took place in Japan on 3–8 June – 30 years after the previous one in 1977 – with an opening ceremony honoured by the presence of the Emperor and Empress. In his speech, the Emperor noted that Yukawa – the first Nobel Laureate in Japanese science – is an icon not only for young Japanese scientists but for everybody in Japan. Yukawa's particle led to a gold mine in physics linked to the pion's production, decay and intrinsic structure. This gold mine continues to be explored today. The present frontier is the quark–gluon-coloured-world (QGCW), whose properties could open new horizons in understanding nature's logic.



Hideki Yukawa, Japan's first Nobel Laureate and eminent scientist, in 1949. (Courtesy AIP Emilio Segrè Visual Archives.)

Production

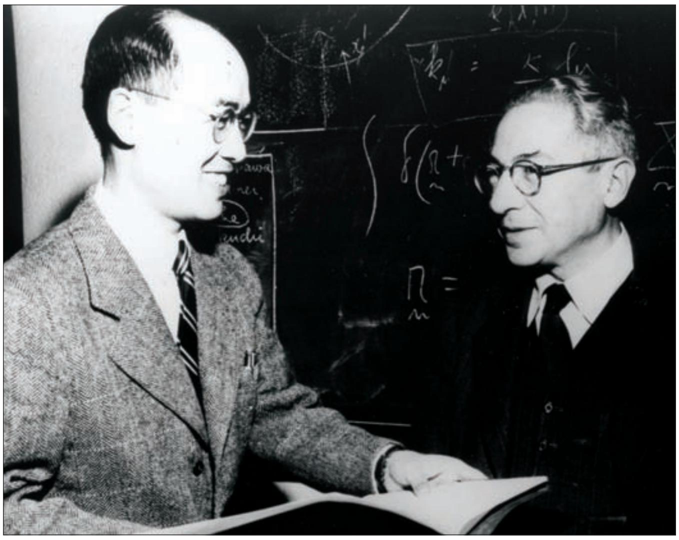
In his 1935 paper, Yukawa proposed searching for a particle with a mass between the light electron and the heavy nucleon (proton or neutron). He deduced this intermediate value – the origin of the name "mesotron", later abbreviated to meson – from the range of the nuclear forces (Yukawa 1935). The search for cosmic-ray particles with masses between those of the electron and the nucleon became a hot topic during the 1930s thanks to this work.

On 30 March 1937, Seth Neddermeyer and Carl Anderson reported the first experimental evidence, in cosmic radiation, for the existence of positively and negatively charged particles heavier and with more penetrating power than electrons, but much less massive than protons (Neddermeyer and Anderson 1937). Then, at the meeting of the American Physical Society on 29 April, J C Street and E C Stevenson presented the results of an experiment that gave, for the first time, a mass value of 130 electron masses (m_e) with 25% uncertainty (Street and Stevenson 1937). Four months later, on 28 August, Y Nishina, M Takeuchi and T Ichimiya submitted to *Physical Review* their experimental evidence for a positively charged particle with mass between 180 m_e and 260 m_e (Nishina *et al.* 1937).

The following year, on 16 June, Neddermeyer and Anderson reported the observation of a positively charged particle with a mass of about 240 m_e (Neddermeyer and Anderson 1938), and on 31 January 1939, Nishina and colleagues presented the discovery of a negative particle with mass $(170 \pm 9)\,m_e$ (Nishina *et al.* 1939). In this paper, the authors improved the mass measurement of their previous particle (with positive charge) and concluded that the result obtained, $m = (180 \pm 20)\,m_e$, was in good agreement with the value for the negative particle. Yukawa's meson theory of the strong nuclear forces thus appeared to have excellent experimental confirmation. His idea sparked an enormous interest in the properties of cosmic rays in this "intermediate" range; it was here that a gold mine was to be found.

In Italy, a group of young physicists – Marcello Conversi, Ettore Pancini and Oreste Piccioni – decided to study how the negative mesotrons were captured by nuclear matter. Using a strong magnetic field to separate clearly the negative from the positive rays, they discovered that the negative mesotrons were not strongly coupled to nuclear matter (Conversi *et al.* 1947). Enrico Fermi, Edward Teller and Victor Weisskopf pointed out that the decay time of these negative particles in matter was 12 powers of 10 longer than the time needed for Yukawa's particle to be captured by a nucleus via the nuclear forces (Fermi *et al.* 1947). They introduced the symbol μ, for mesotron, to specify the nature of the negative cosmic-ray particle being investigated.

In addition to Conversi, Pancini, Piccioni and Fermi, another Italian, Giuseppe Occhialini, was instrumental in understanding the gold mine that Yukawa had opened. This further step required ▷



Hideki Yukawa (left) with Isidor Isaac Rabi at Columbia University. (Courtesy AIP Emilio Segrè Visual Archives.)

the technology of photographic emulsion, in which Occhialini was the world expert. With Cesare Lattes, Hugh Muirhead and Cecil Powell, Occhialini discovered that the negative μ mesons were the decay products of another mesotron, the "primary" one – the origin of the symbol π (Lattes *et al.* 1947). This is in fact the particle produced by the nuclear forces, as Yukawa had proposed, and its discovery finally provided the nuclear "glue". However this was not the end of the gold mine.

The decay-chain

The discovery by Lattes, Muirhead, Occhialini and Powell allowed the observation of the complete decay-chain $\pi \rightarrow \mu \rightarrow e$, and this became the basis for understanding the real nature of the cosmicray particles observed during 1937–1939, which Conversi, Pancini and Piccioni had proved to have no nuclear coupling with matter. The gold mine not only contained the π meson but also the μ meson. This opened a completely unexpected new field, the world of particles known as leptons, the first member being the electron. The second member, the muon (μ), is no longer called a meson, but is now correctly called a lepton. The muon has the same electromagnetic properties as the electron, but a mass 200 times heavier and no nuclear charge. This incredible property prompted Isidor Rabi to make the famous statement "Who ordered that?" as reported by T D Lee (Barnabei *et al.* 1998).

In the 1960s, it became clear that there would not be so many muons were it not for the π meson. Indeed, if another meson like the π existed in the "heavy" mass region, a third lepton – heavier than the muon – would not have been so easily produced in the decays of the heavy meson because this meson would decay strongly into many π mesons. The remarkable π–μ case was unique. So, the absence of a third lepton in the many final states produced in high-energy interactions at proton accelerators at CERN and other laboratories, was not to be considered a fundamental absence, but a consequence of the fact that a third lepton could only be produced via electromagnetic processes, as for example via time-like photons in $\bar{p}p$ or e^+e^- annihilation. The uniqueness of the π–μ case therefore sparked the idea of searching for a third lepton in the appropriate production processes (Barnabei *et al.* 1998).

Once again, this was still not the end of the gold mine, as understanding the decay of Yukawa's particle led to the field of weak forces. The discovery of the leptonic world opened the problem of the universal Fermi interactions, which became a central focus of the physics community in the late 1940s. T D Lee, M Rosenbluth and C N Yang proposed the existence of an intermediate boson, called W as it was the quantum of the weak forces. This particle later proved to be the source of the breaking of parity (P) and charge conjugation (C) symmetries in weak interactions.

In addition, George Rochester and Clifford Butler in Patrick Blackett's laboratory in Manchester discovered another meson - later dubbed "strange" - in 1947, the same year of the π meson discovery. This meson, called θ, decayed into two pions. It took nearly 10 years to find out that the θ and another meson called τ, with equal mass and lifetime but decaying into three pions, were not two different mesons but two different decay modes of the same particle, the K meson. Lee and Yang solved the famous θ–τ puzzle in 1956, when they proved that no experimental evidence existed to establish the validity of P and C invariance in weak interactions; the experimental evidence came immediately after.

The violation of P and C generated the problem of PC conservation, and therefore that of time-reversal (T) invariance (through the PCT theorem). This invariance law was proposed by Lev Landau, while Lee, Reinhard Oehme and Yang remarked on the lack of experimental evidence for it. Proof that they were on the right experimental track came in 1964, when James Christenson, James Cronin, Val Fitch and René Turlay discovered that the meson called K^0_2 also decayed into two Yukawa mesons. Rabi's famous statement became "Who ordered all that?" – "all" being the rich contents of the Yukawa gold mine.

A final comment on the "decay seam" of the gold mine concerns the decay of the neutral Yukawa meson, $\pi^0 \rightarrow \gamma\gamma$. This generated the ABJ anomaly, the celebrated chiral anomaly named after Steven L Adler, John Bell, and Roman Jackiw, which had remarkable consequences in the area of non-Abelian forces. One of these is the "anomaly-free condition", an important ingredient in theoretical model building, which explains why the number of quarks in the fundamental fermions must equal the number of leptons. This allowed the theoretical prediction of the heaviest quark – the top-quark, t – in addition to the b quark in the third family of elementary fermions.

Intrinsic structure

The Yukawa particle is made of a pair of the lightest, nearly-massless, elementary fermions: the up and down quarks. This allows us to understand why chirality-invariance – a global symmetry property – should exist in strong interactions. It is the spontaneous breaking of this global symmetry that generates the Nambu–Goldstone boson. The intrinsic structure of the Yukawa particle needs the existence of a non-Abelian fundamental force – the QCD force – acting between the constituents of the π meson (quarks and gluons) and originating in a gauge principle. Thanks to this principle, the QCD quantum is a vector and does not destroy chirality-invariance.

To understand the non-zero mass of the Yukawa meson, another feature of the non-Abelian force of QCD had to exist: instantons. Thanks to instantons, chirality-invariance can also be broken in a non-spontaneous way. If this were not the case, the π could not be as "heavy" as it is; it would have to be nearly massless. So, can a pseudoscalar meson exist with a mass as large as that of the nucleon? The answer is "yes": its name is η' and it represents the final point in the gold mine started with the π meson. Its mass is not intermediate, but is nearly the same as the nucleon mass.

The η' is a pseudoscalar meson, like the π, and was originally called X^0. Very few believed that it could be a pseudoscalar because its mass and width were too big and there was no sign of its 2γ decay mode. This missing decay mode initially prevented the X^0 from being considered the ninth singlet member of the pseudoscalar SU(3) uds flavour multiplet of Murray Gell-Mann and Yuval Ne'eman. However, the eventual discovery of the 2γ decay mode strongly supported the pseudoscalar nature of the X^0, and once this was established, its gluon content became theoretically predicted through the QCD istantons.

If the η' has an important gluon component, we should expect to see a typical QCD non-perturbative effect: leading production in gluon-induced jets. This is exactly the effect that has been observed in the production of the η' mesons in gluon-induced jets, while it is not present in η production (figure 1).

The interesting point here is that it appears that the η' is the lowest pseudoscalar state having the most important contribution from the quanta of the QCD force. The η' is thus the particle most directly linked with the original idea of Yukawa, who was advocating the existence of a quantum of the nuclear force field; the η' is the Yukawa particle of the QCD era. Seventy two years after Yukawa's original idea we have found that his meson, the π, has given rise to a fantastic development in our thinking, the last step being the η' meson.

The quark–gluon-coloured world

There is still a further lesson from Yukawa's gold mine: the impressive series of totally unexpected discoveries. Let me quote just three of them, starting with the experimental evidence for a cosmic-ray particle that was believed to be Yukawa's meson, which turned out to be a lepton: the muon. Then, the decay-chain $\pi \rightarrow \mu \rightarrow e$ was found to break the symmetry laws of parity and charge conjugation. Third, the intrinsic structure of the Yukawa particle was found to be governed by a new fundamental force of nature, the strong force described by QCD.

This is perfectly consistent with the great steps in physics: all totally unexpected. Such totally unexpected events, which historians call Sarajevo-type-effects, characterize "complexity". A detailed analysis shows that the experimentally observable quantities that characterize complexity in a given field exist in physics; the Yukawa gold mine is a proof. This means that complexity exists at the fundamental level, and that totally unexpected effects should show up in physics – effects that are impossible to predict on the basis of present knowledge. Where these effects are most likely to be, no one knows. All we are sure of is that new experimental facilities are needed, like those that are already under construction around the world.

With the advent of the LHC at CERN, it will be possible to study the properties of the quark–gluon coloured world (QGCW). This is

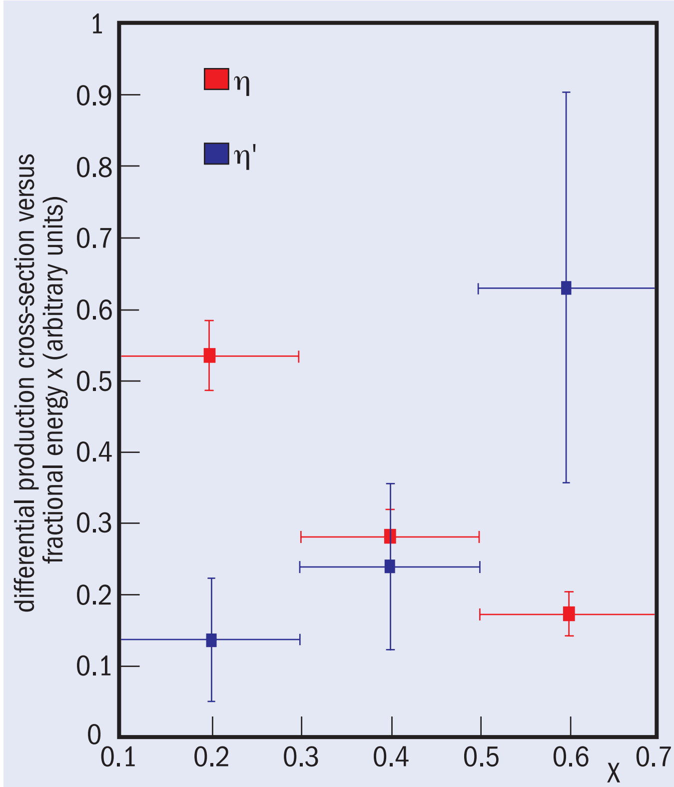


Fig. 1. Distributions of Feynman x for η and η' production, showing the η' leading effect (L Cifarelli et al. *1998.*

totally different from our world made of QCD vacuum with colourless baryons and mesons because the QGCW contains all the states allowed by the $SU(3)_c$ colour group. To investigate this world, Yukawa would tell us to search for specific effects arising from the fact that the colourless condition is avoided. Since the colourless condition is not needed, the number of possible states in the QGCW is far greater than the number of colourless baryons and mesons that have been built so far in all our laboratories.

So, a first question is: what are the consequences for the properties of the QGCW? A second question concerns light quarks versus heavy quarks. Are the coloured quark masses in the QGCW the same as the values we derive from the fact that baryons and mesons need to be colourless? It could be that all six quark flavours are associated with nearly "massless" states, similar to those of the u and d quarks. In other words, the reason why the top quark appears to be so heavy (around 200 GeV) could be the result of some, so far unknown, condition related to the fact that the final state must be QCD-colourless. We know that confinement produces masses of the order of a giga-electron-volt. Therefore, according to our present understanding, the QCD colourless condition cannot explain the heavy quark mass. However, since the origin of the quark masses is still not known, it cannot be excluded that in a QCD coloured world, the six quarks are all nearly massless and that the colourless condition is "flavour" dependent. If this was the case, QCD would not be "flavour-blind" and this would be the reason why the masses we measure are heavier than the effective coloured quark masses. In this case, all possible states generated by the "heavy" quarks would be produced in the QGCW at a much lower temperature than ▷

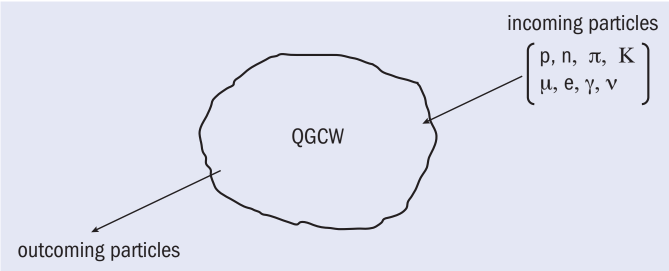


Figure 2: A simplified diagram to illustrate how to study the quark-gluon coloured world QGCW – the special set of detectors is not shown. The QGCW is produced in a collision between heavy ions ($^{208}Pb^{82+}$) at maximum energy.

is needed in our world made of baryons and mesons, i.e. QCD colourless states. Here again, we should try to see if new effects could be detected due to the existence, at relatively low temperatures in QGCW physics, of all flavours, including those that might exist in addition to the six so far detected.

A third question concerns effects on the thermodynamic properties of the QGCW. Are these properties going to be along the "extensivity" or "non-extensivity" conditions? With the enormous number of QCD open-colour-states allowed in the QGCW, many different phase transitions could take place and a vast variety of complex systems should show up. The properties of this "new world" should open unprecedented horizons in understanding the ways of nature's logic.

A fourth, related problem would be to derive the equivalent Stefan–Boltzmann radiation law for the QGCW. In classical thermodynamics, the relation between energy density at emission, U, and the temperature of the source, T, is $U = sT^4$ – where s is a constant. In the QGCW, the correspondence should be $U = p_T$ and T = the average energy in the centre-of-momentum system, where p_T is the transverse momentum. In the QGCW, the production of "heavy" flavours could be studied as functions of p_T and E. The expectation is that $p_T = cE^4$, where c is a constant, and any deviation would be extremely important. The study of the properties of the QGCW should produce the correct mathematical structure to describe the QGCW. The same mathematical formalism should allow us to go from QGCW to the physics of baryons and mesons and from there to a more restricted component, namely nuclear physics, where all properties of the nuclei should finally find a complete description.

The last lesson from Yukawa

With the advent of the LHC, the development of a new technology should be able to implement collisions between different particle states (p, n, π, K, μ, e, γ, ν) and the QGCW in order to study the properties of this new world. Figure 2 gives an example of how to study the QGCW, using beams of known particles. A special set of detectors measures the properties of the outgoing particles. The QGCW is produced in a collision between heavy ions ($^{208}Pb^{82+}$) at the maximum energy available, i.e. 1150 TeV and a design luminosity of 10^{27} cm^{-2} s^{-1}. For this to be achieved, CERN needs to upgrade the ion injector chain comprising Linac3, the Low Energy Ion Ring (LEIR), the PS and the SPS. Once the lead–lead collisions are available, the problem will be to synchronize the "proton" beam with the QGCW produced. This problem is being studied at the present time. The detector technology is also under intense R&D since the synchronization needed is at a very high level of precision.

Totally unexpected effects should show up if nature follows complexity at the fundamental level. However, as with Yukawa's gold mine that was first opened 72 years ago, new discoveries will only be made if the experimental technology is at the forefront of our knowledge. Cloud-chambers, photographic emulsions, high-power magnetic fields and powerful particle accelerators and associated detectors were needed for the all the unexpected discoveries linked to Yukawa's particle. This means that we must be prepared with the most advanced technology for the discovery of totally unexpected events. This is Yukawa's last lesson for us.

● This article is based on a plenary lecture given at the opening session of the Symposium for the Centennial Celebration of Hideki Yukawa at the International Nuclear Physics Conference in Tokyo, 3–8 June 2007. For the full article with complete references see www.ccsem.infn.it/ref/yukawa.html.

Further reading

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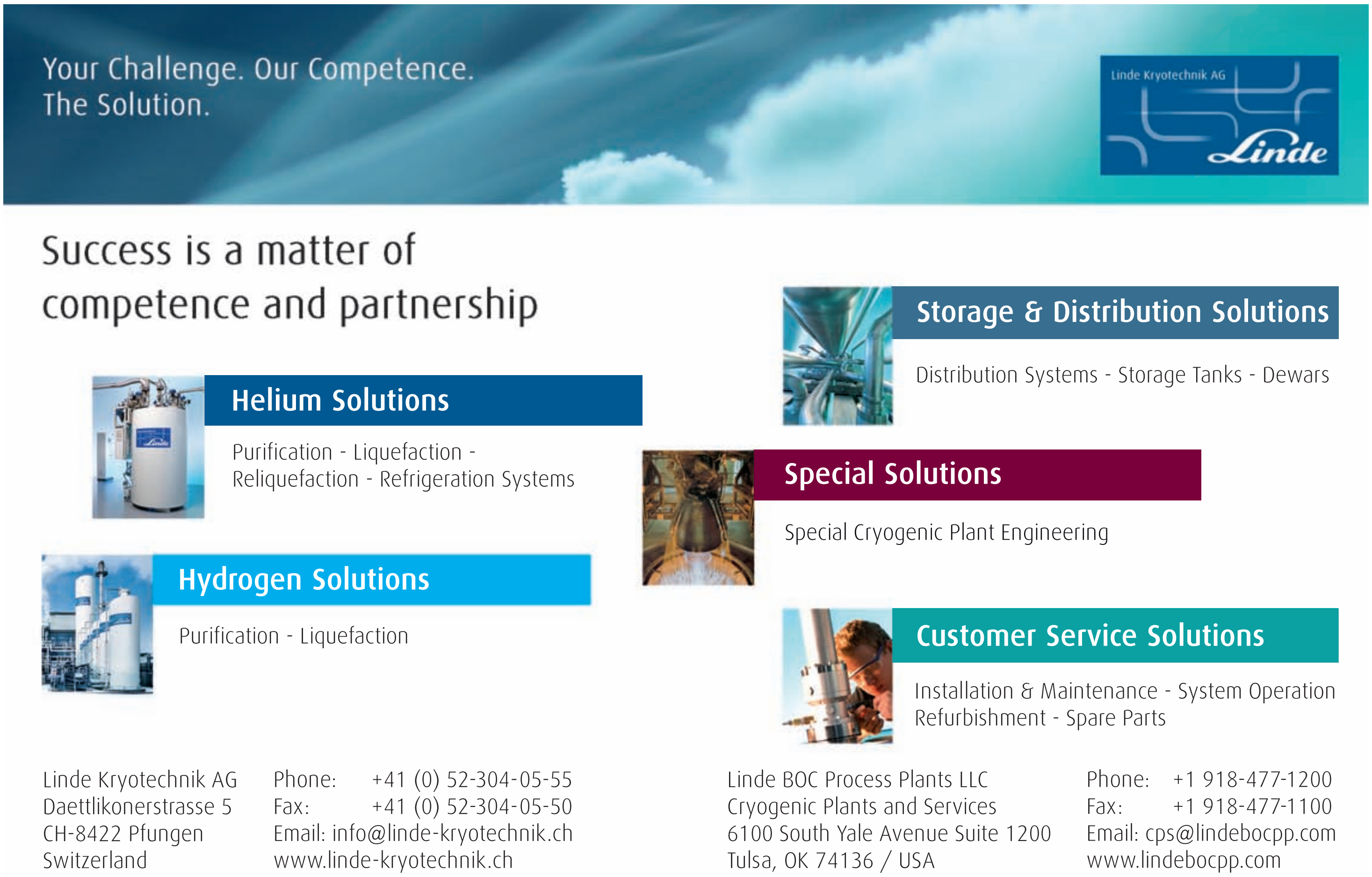
Résumé

La mine d'or de Yukawa

Cette année marque le centenaire de la naissance de Hideki Yukawa, qui a proposé en 1935 l'existence d'une particule qu'on appelle aujourd'hui le méson π, ou pion. Dans une conférence présentée au symposium organisé en l'honneur du centenaire de Hideki Yukawa, au Japon, Antonino Zichichi a passé en revue beaucoup des découvertes inattendues auxquelles a donné lieu la prédiction du pion par Yukawa. Il a expliqué comment la particule de Yukawa s'est muée en une mine d'or pour la physique en se penchant sur la production et la désintégration du pion, ainsi que sur sa structure intrinsèque. L'exploration de cette mine d'or se poursuit aujourd'hui, la frontière actuelle étant le monde coloré des quarks et des gluons, dont les propriétés pourraient ouvrir de nouveaux horizons pour comprendre la logique de la Nature.

Antonino Zichichi, *INFN/University of Bologna and CERN.*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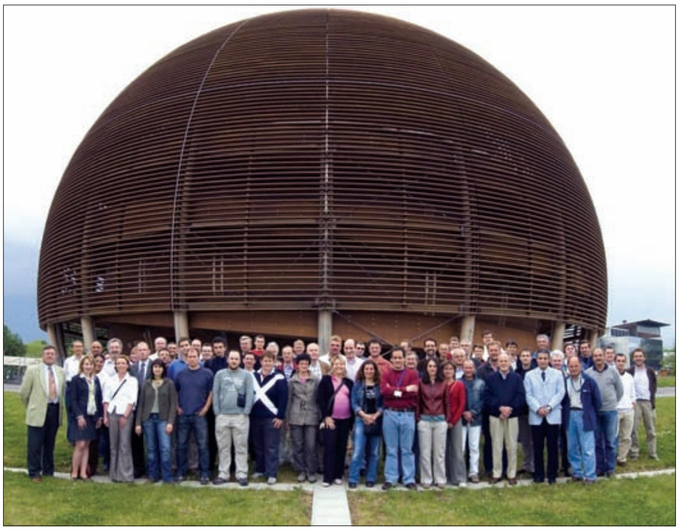
SYMPOSIUM

CERN inaugurates LHC cyrogenics



Members of the CERN cryogenic groups in front of the Globe of Science and Innovation, where the symposium took place. (Globe conception T Buchi, Charpente Concept and H Dessimoz, Group H.)

Inauguration and ribbon-cutting ceremony of LHC cryogenics by CERN officials: from left, Giorgio Passardi, leader of cryogenics for experiments group; Philippe Lebrun, head of the accelerator technology department; Giorgio Brianti, founder of the LHC project; Lyn Evans, LHC project leader and Laurent Tavian, leader of the cryogenics for accelerators group.

The beginning of June saw the start of a new phase at the LHC project, with the inauguration of LHC cryogenics. This was marked with a symposium in the Globe of Science and Innovation attended by 178 representatives of the research institutes involved and industrial partners. It also coincided with the stable low-temperature operation of the cryogenic plant for sector 7–8, the first sector to be cooled down (*CERN Courier* May 2007 p5).

The LHC and its large particle detectors make intensive use of superconducting magnets and cryogenics. The LHC helium cryogenic system is the largest and most complex ever built, with more than 160 kW equivalent at 4.5 K and 20 kW at 1.8 K (*CERN Courier* May 2004 p5). Cryogenic systems are important for both the ATLAS and CMS detectors, which use different technologies, with helium and argon required for their superconducting magnet systems and for the ATLAS calorimeter (*CERN Courier* December 2005 p28).

The system for the LHC involves many industrial-scale devices, where reliability is of paramount importance. The LHC's energy of 7 TeV requires a strong magnetic field, which is provided by niobium-titanium coils operating at 1.9 K. Besides enhancing the performance of the niobium-titanium superconductor, this temperature regime makes use of the excellent heat-transfer properties of helium in its superfluid state. The design for the LHC cryogenics had to incorporate both newly ordered and reused refrigeration plant from LEP operating at 4.5 K – together with a second stage operating at 1.9 K – in a system that could be replicated around the LHC.

The main elements for both the accelerator and the detectors are now operational. The large superconducting magnets and liquid argon calorimeters for the ATLAS and CMS experiments have been cooled and tested, and all superconducting magnets for the accelerator have been procured from industry, cold tested at CERN and installed in the ring. The first 3.3 km sector of the machine – one-eighth of the circumference – has been cooled down and tested, permitting the full-scale validation of basic design choices. In particular, thanks to the superfluid helium cooling system, the magnet temperature could be controlled to within 0.1 K over the sector length. The results were recently reported at the CEC 2007 conference in Chattanooga, Tennessee. Although the commissioning work is far from finished, the cyrogenics groups at CERN felt that after 10 years of construction it was now a good time to celebrate, organizing the Symposium for the Inauguration of LHC Cryogenics that took place on 31 May-1 June at CERN's Globe of Science and Innovation. After an inaugural address by CERN's director-general, Robert Aymar, the programme included 21 presentations of the different aspects of the system, an industrial exhibition by seven companies, and visits to technical sites above and below ground.

The symposium brought together specialists from industry, participating institutes and CERN, all involved in the design and construction of the LHC cryogenic system. Some 20 general and scientific journalists also attended. The event culminated with the formal inauguration and ribbon-cutting by the LHC project leader Lyn Evans and a final buffet. The event was co-sponsored by Air Liquide DTA (France), ISQ (Portugal) and Linde Kryotechnik AG (Switzerland).

● The programme for the symposium can be found at http://indico.cern.ch/internalPage.py?pageId=3&confId=9046.

COLLABORATION

Chile strengthens relations with CERN...

The President of Chile, Michelle Bachelet, paid a visit to CERN during her three-day tour of Switzerland at the beginning of June. The visit was also the occasion for the signing of a co-operation agreement between CERN and Chile's Comisión Nacional de Investigación Científica y Tecnológica (CONICyT), represented by the commission's president, Vivian Heyl.

During the visit, Michelle Bachelet and her delegation were greeted by CERN's director-general, Robert Aymar, and shown the ATLAS experiment and the LHC. Bachelet also took time to meet the Chilean community working at CERN, comprising several physicists in the Theory Group and the ATLAS experiment.

The co-operation agreement between CERN and CONICyT provides a framework for the long-term participation of students and scientific and technical staff from Chile's universities and research institutes in CERN's experimental programme. At the same time, Pedro Pablo Rosso, rector of the Pontificia Universidad Católica, and José Rodriguez, rector of the Universidad Técnica Federico Santa María, also signed agreements with ATLAS spokesman Peter Jenni relating to co-operation between the experiment and their two universities.

The President of Chile, Michelle Bachelet (right), in the ATLAS cavern with (from left to right) Peter Jenni, ATLAS spokesman, Vivian Heyl, CONICyT president, and Robert Aymar, CERN's director-general.

Robert Aymar signing the co-operation agreement between CERN and Chile's Comisión Nacional de Investigación Científica y Tecnológica (CONICyT).

...and Mexican research council signs MOU

José Antonio de la Peña, the deputy-director for science of the main Mexican funding agency Consejo Nacional de Ciencia y Tecnología (CONACyT), came to CERN on 14–15 May. His visit included the LHC experiments and the CLIC facility, and it concluded with his signing a memorandum of understanding together with Robert Aymar, CERN's director-general, for Mexican contribution to the ALICE experiment.

A major part of the visit centred on discussions between de la Peña and leaders of the ALICE collaboration. The bulk of Mexican effort at CERN is concentrated on the ALICE experiment at the LHC, with about 35 people (half of them students) in two detector projects, the V0 (a forward detector) and the cosmic-ray trigger array ACORDE. De la Peña underlined his satisfaction with the ACORDE detector, which has been conceived, completely designed and produced by the groups from Cinvestav, BUAP (Puebla) and ICN-UNAM, under the project leader Arturo Fernández from BUAP. He also expressed the wish to extend the collaboration of CONACyT to other areas at CERN, mainly in connection with the training of Mexican undergraduate and postdoctorate researchers.

José Antonio de la Peña (right) signs the MOU between CONACyT and CERN.

AWARDS

EPS honours quark mixing with 2007 prize

The European Physical Society High Energy and Particle Physics Prize for 2007 has been awarded to Makoto Kobayashi of KEK and Toshihide Maskawa of the University of Tokyo for "the proposal of a successful mechanism for CP violation in the Standard Model, predicting the existence of a third family of quarks". Experimental evidence for CP violation first emerged in 1964 (p12) but it was not until 1973 that Kobayashi and Maskawa pointed to a possible solution to the unexpected phenomenon. They noted that mixing between different quarks (as first proposed by Nicola Cabibbo in 1963) could explain the CP violation so far observed – but only if there were six types of quark, rather than the three known at the time. This bold suggestion was subsequently verified with the discovery in experiments of three new types of quark and by the recent observations by the Belle and BaBar experiments of CP violation in the decays of B mesons at precisely the level predicted by the theory of Kobayashi and Maskawa. Kobayashi received the prize on behalf of the two physicists on 23 July at the EPS conference on High Energy Particle Physics in Manchester. The award ceremony also saw the presentation of further EPS prizes.

For physics that is intimately connected with the third generation of quarks required by Kobayashi and Maskawa, the 2007 EPS Young Physicist Prize was awarded to Ivan Furić of the University of Chicago, Guillelmo Gómez-Ceballos of the Massachusetts Institute of Technology and Stephanie Menzemer of Ruprecht-Karls-Universität Heidelberg. They were rewarded for "their outstanding contributions displaying individual creativity and collaborative effort to the complex analysis that provided the first measurement of the frequency of B_s oscillations".

Makoto Kobayashi (right) receives the 2007 EPS HEPP award, on behalf of himself and his colleague Toshihide Maskawa, from David Wark, Chair of the EPS HEPP Board. (Courtesy Per Osland.)

The 2007 Gribov Medal for outstanding work by a young physicist in theoretical particle physics and/or field theory was awarded to Niklas Beisert of the MPI für Gravitationsphysik for his "contributions to the exploration of integrability properties of a 4D quantum field theory, N = 4 supersymmetric Yang-Mills theory".

The 2007 EPS Outreach Prize was awarded to CERN's Richard Jacobsson and Charles Timmermans of NIKHEF and Radboud University for their "outstanding contributions in promoting high-energy physics to the public and in high schools in Europe". Jacobsson has been involved in outreach at CERN for many years, most recently with the LHCb experiment for the LHC. Timmermans is the principal initiator of the HISPARC project through which Dutch high-schools are participating in the study of cosmic rays (*CERN Courier* July/August 2004 p12). In addition, the Outreach Prize Selection Committee made special mention of Anne Gaud McKee, who lost her life in a walking accident in 2006. She created the company Miméscope and, in particular, the spectacle *The DELPHI Oracle,* performed at CERN at the closure of LEP in 2000 and later in Lausanne, Paris, London and Edinburgh (*CERN Courier* June 2000 p31.).

INDUSTRY

ATLAS rewards two pixel suppliers

The Fraunhofer Institut für Zuverlässigkeit und Mikrointegration (IZM) in Berlin and the company SELEX Sistemi Integrati have received supplier awards from the ATLAS collaboration, presented in a ceremony held on 13 June. The prizes were for the manufacture of modules for the ATLAS pixel detector. SELEX supplied 1500 of the modules for the tracker, while IZM produced a further 1300. The modules, each made up of 46 080 channels, form the active part of the ATLAS pixel detector. IZM and SELEX received the awards for the excellent quality of their work – the average number of faulty channels per module was less than 2×10^{-3}. They also stayed within budget and on schedule. The two suppliers demonstrated great flexibility in designing modules based on electronic components and sensors that were imposed by the experiment.

ATLAS spokesperson Peter Jenni (right) presented the ATLAS supplier awards to Herbert Reichl, IZM director, and Simonetta Di Gioia from SELEX.

In responding to the challenge, IZM and SELEX used two different methods. SELEX used a process involving indium deposits followed by thermocompression, while IZM opted for the electrolytic deposition of Pb/Sn. Both techniques allowed the strict characteristics required by ATLAS to be met. SELEX worked in close collaboration with the Genoa and Milan INFN groups, while IZM collaborated with the University of Bonn.

APPOINTMENTS

SLAC announces new heads for particle and particle astrophysics

Steven Kahn, the current deputy-director of the Kavli Institute for Particle Astrophysics and Cosmology (KIPAC), has been named the next director of particle and particle astrophysics (PPA) at SLAC. David MacFarlane, currently the assistant director for elementary particle physics, will take on the role of deputy-director of particle and particle astrophysics.

As director of PPA, Kahn will oversee SLAC's B-Factory programme (the PEP-II accelerator and the associated detector, BaBar), the work at KIPAC sponsored by the US Department of Energy, the SLAC-based teams working on the ATLAS experiment at the LHC at CERN and also the International Linear Collider effort, advanced accelerator research and the non-accelerator particle physics programmes.

He will replace Persis Drell, who has served as director of PPA since 2002, on 1 August. Drell will stay on as deputy director of the laboratory until the end of the year. In addition to serving as deputy director of PPA, Kahn retains the joint faculty appointment at SLAC and in Stanford's physics department that he has held since moving to Stanford four years ago. Prior to that, Kahn served as chair of the physics department at Columbia University, where he oversaw both astrophysics and particle physics research. He has also served on the Fermilab Physics Advisory Committee for the past four years and was an influential member of the committee that wrote the High Energy Physics Advisory Panel's *Quantum Universe* report. While he will step down from his current role at KIPAC to take the new position, he will continue working as deputy-director of the Large Synoptic Survey Telescope project.

David MacFarlane (left) and Steve Kahn take on new roles at SLAC. (Courtesy SLAC.)

David MacFarlane served as spokesperson for the BaBar collaboration from 2004 until 2006, and he joined SLAC's faculty in the autumn of 2005 from the University of California at San Diego.

LETTERS

Thirring's achievements

The short article above the picture of Walter Thirring and Julius Wess on p38 of the July/August 2007 edition of *CERN Courier* mentions the Thirring model, but this is only one of Thirring's many achievements. Besides contributions to gravity and general relativity – following in the line of his father, Hans Thirring – he made pioneering contributions to dispersion relations and the quark model, and he obtained many beautiful results in the field of rigorous quantum mechanics. In particular, with Elliott Lieb, he gave a beautiful proof of the "stability of matter", i.e. the fact that, if you ignore gravity, an assembly of N atoms has a binding energy and a volume proportional to N. He is also a pianist, an organist and a composer of chamber music.

Andre Martin, CERN.

The Greek origin of zero

In his review of *The Human Touch* by Michael Frayn (*CERN Courier* July/August 2007 p54) Gordon Fraser said: "The concept of zero, attributed to the Greeks, was imported from the Orient (the Arabic zifr is commemorated in our 'cipher')." However, readers of *CERN Courier* should be informed that the concept of zero is correctly attributable to the Greeks. By trying to understand what there is between zero and one, Zeno (500 BC) discovered his famous formula, the modern formulation of which is:

$$1 = \sum_{n=1}^{\infty} (½)^n$$

The Arabic zifr came many centuries later.

Antonino Zichichi, INFN/University of Bologna/CERN.

CO-OPERATION

The members of ERF sign charter document of formal association

At a recent meeting at DESY in Hamburg, the founding members of the European Association of National Research Facilities (ERF) signed a charter document to constitute the association formally.

The ERF is an initiative by 11 European laboratories to promote the co-operation between individual nationally funded large-scale research facilities in Europe. Among its associates are European laboratories that provide large facilities with neutrons, lasers, synchrotron light, ions and particles with open access to international scientific communities. Its present chair is Albrecht Wagner, chairman of the DESY directorate. The association now has 14 nationally funded European laboratories as members, which together serve more than 13 000 users worldwide and cover a wide research spectrum, from archaeology to life sciences, including an estimated 20% directly or indirectly connected with industry.

The aim of the ERF is to provide a forum to coordinate the development of leading national facilities for European research and to develop mechanisms and best practices for international access to large-scale research facilities. It will act as a source of scientific and technical expertise for national and European policy making and represent a large constituency of large-scale research facilities speaking with one voice to decision makers. With the help of topic-oriented joint initiatives and consortia, the ERF will make resources for large-scale research facilities available by co-operation.

● The founder members of ERF are Societé Civile Synchrotron Soleil, France; Gesellschaft für Schwerionenforschung mbH, Germany; Elettra-Societa Sincrotrone, Italy; DESY; MAX-Lab, Sweden; Grand Accelerateur National d'Ions Lourds, France; Paul Scherrer Institut, Switzerland; FOM Rijnhuizen, the Netherlands; Max-Born Institut, Germany; Hahn-Meitner Institut, Germany; and Science and Technology Facilities Council, UK.

● http://www.europeanresearchfacilities.eu.

Albrecht Wagner (DESY and Chair of ERF) signing the ERF charter document. From left to right: A Kleyn (FOM Rijnhuizen), R Eichler (PSI), D Raoux (Soleil), K G Jeffery (STFC), C Rizzuto (Elettra), W Sandner (MBI/Laserlab-Europe) and M Steiner (HMI).

NEW PRODUCTS

DeMaCo has gained three renewed certificates this year. Along with ISO 9001, it was awarded the ISO 3834-2 certification for welding quality assurance. The company has also obtained the PED Module H and H1 certificates, which indicate the independence to design and produce pressure equipment without a TPI. For more information, see www.demaco.nl/vacuum.

Interface Concept and **ACT/Technico** have unveiled a new high-performance COTS graphics PMC, the IC-GRA-PMCa. As an advanced graphics board, the IC-GRA-PMCa features a 128 MB DDR memory at 266 Mbps, two video output channels with resolutions of up to 1280 × 1024 pixels at 60 Hz and multiple interfaces (DVI, VGA, RGsB, STANAG). Two video inputs support an SVGA capture resolution. For further details, tel +1 800 445 6194, +1 215 956 1200 or +33 298 573 030; e-mail sales@acttechnico.com or info@interfaceconcept.com, or see www.acttechnico.com.

AMS Technologies has announced the availability of new current-sense resistors from Caddock Electronics, Inc. The Model SR20 is now available in resistance values as low as 0.005 ohm (5 milliohm) for continuous currents up of to 20 A. It features Kelvin (four-wire leads) for accurate 1% performance. The compact footprint uses little board space, but operates cool for outstanding stability. For details, tel +49 89 89 577 514; email caddock@ams.de or see www.ams.de.

Andor Technology has launched two new spectrographs, the Shamrock SR-500 and SR-750. Features include direct and responsive control of the spectrograph and camera through Andor Solis software, allowing the user to control wavelength and calibration, grating selection, shutter control and filter selection, and a facility to join spectra together. For details, tel +44 28 9023 7126 or see www.andor.com.

MINISTERIAL VISITS

On 11 June, the Austrian minister of science and research, **Johannes Hahn** (left), visited CERN. After touring the CMS experiment with **Felicitas Pauss**, deputy president for the collaboration committee of CMS, Hahn visited the computing centre, met with CERN's director-general, **Robert Aymar**, and later met Austrian students based at CERN.

The following day, on 12 June, it was the turn of **Claus Hjort Frederiksen** (left), the Danish employment minister, to come to CERN. He was given a tour of the ALICE cavern by **Jens Jorgen Gaardhoje** from the Niels Bohr Institute and a member of the ALICE collaboration, and also visited the ATLAS experiment.

Poland's minister for science and higher education, **Michal Sewerynski** (centre), followed suit on 12 July. His tour of CERN included the CMS experiment, together with the spokesperson, **Jim Virdee** (left), and CERN's chief scientific officer, **Jos Engelen**. His visit finished with a presentation of Polish companies involved with CERN. The minister also had time to meet Polish personnel at CERN.

A day later, on 13 July, **Ján Mikolaj** (second from left), deputy prime minister and minister of education of the Slovak Republic, came to CERN. His visit included a tour of the ALICE experiment, here with deputy spokesperson Paolo Giubellino (yellow hard hat), ATLAS and the computer centre. He was also shown the CLIC facilities and took time to meet the Slovak personnel working at CERN.

Anton Anton (far right), president of the National Authority for Scientific Research in Romania, came to CERN on 19 April. His visit included tours of the ATLAS and ALICE experiments and the LHC tunnel. Here he talks with members of CERN's Romanian community.

Lithuanian prime minister **Gediminas Kirkilas** (far left) came to CERN on 2 July. His visit included a guided tour of the ATLAS cavern, accompanied by CERN's director-general, **Robert Aymar** (second from left) and an inspection of the LHC tunnel.

OBITUARIES

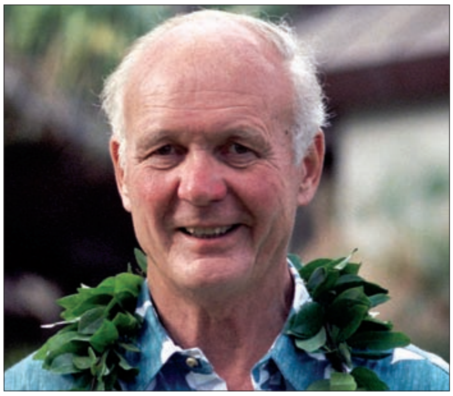
Vincent Z Peterson 1921–2007

Vincent Z Peterson died peacefully in Berkeley, California, on 17 May 2007. He was 85. He was professor of high-energy physics, first at Caltech and later at the University of Hawaii, where he founded – and then headed – the high-energy physics group until his retirement in 1992.

Vince was born and raised in Galesburg, Illinois, and went to Pomona College, majoring in physics. During the Second World War, he was assigned to special projects in antisubmarine detection in the US Navy. After the war, he attended the University of California, Berkeley, where he received his PhD in physics with W K H Panofsky, before joining Caltech, where he remained for 12 years.

In 1962, he was hired by the University of Hawaii to set up a programme in high-energy physics. Hawaii had become the 50th state of the US in 1959 and had decided that its university should become a major research institution. Vince was able to get a sizeable grant from the Atomic Energy Commission and brought in Bob Cence and Vic Stenger in 1963 to form the core experimental group. He developed a close collaboration with the Moyer–Helmholtz group at the Lawrence Radiation Laboratory in Berkeley, while his own group began assembling the apparatus needed for bubble chamber analysis in Hawaii. Vince had a great feeling for what was important in the field and made sure that the Hawaii group was always involved in forefront experiments, particularly through close collaborations with Berkeley, Fermilab and several large university groups.

Among various important experiments,



Hawaii was involved in studying CP violation in $K^0 \rightarrow 2\pi^0$ at the Bevatron, transition radiation at SLAC, charmed particle production, weak neutral weak currents and QCD with neutrinos at Fermilab.

Detector development was one of Vince's continuing interests and he maintained close ties with colleagues at high-energy labs. In particular, he encouraged and supported the work of Hawaii group-member Sherwood Parker at Berkeley and SLAC. This included the development of wire chambers for external muon identification, silicon microstrip detectors and pixel detectors.

Vince did not neglect the theoretical side of high-energy physics but arranged for Peter Dobson and San Fu Tuan to come to Hawaii to start a theory group. Starting in 1965, Vince and San Fu organized a series of highly successful topical conferences that took place every other summer until 1985. At one memorable conference in 1973, Don Perkins of Oxford announced the discovery of weak neutral currents at CERN, to the great excitement of the other attendees, including Richard Feynman.

Vince was part of the international committee that organized conferences on neutrino physics and was conference director for the Neutrino '81 meeting in Maui. In the 1980s, the experimental group split into accelerator and non-accelerator physics and the Hawaii DUMAND Center was formed with the purpose of building an undersea muon and neutrino detector off the coast of the Big Island of Hawaii. Vince was the director, with Vic Stenger as associate director and John Learned as technical director. Although the project was eventually cancelled, Hawaii pioneered the field of VHE neutrino astrophysics, which is still under active development today with experiments in the Mediterranean and Antarctica. With Vince's encouragement, Learned and other group members played major roles in the IMB proton-decay experiment in Cleveland and the Super-Kamiokande experiment in Japan. The 1998 paper announcing the first evidence that neutrinos have mass included Learned, Stenger and other group members as co-authors.

Vince and his wife Elisabeth (Tess) always treated the members of the group as family, holding many Sunday barbecues at their house in Kailua close to the beach. They spent sabbatical years in Rome, Oxford and Geneva, always keeping in touch with friends around the world – many of whom visited them in Hawaii. Vince led a long and fulfilling life, and he will be remembered and missed by his family and friends.

Andrea Peterson and Vic Stenger.

Wolfgang Kummer 1935–2007

Wolfgang Kummer, a prominent Austrian theoretical physicist and former president of CERN Council (1985–1987), passed away on 15 July 2007 after a long fight with cancer. He obtained a doctorate in physics in 1960 from the Technical University of Vienna and in 1968 became one of the youngest full professors ever, heading a newly founded second institute for theoretical physics devoted to theoretical high-energy physics.

From early on, Kummer's career was intimately connected with CERN, where he came on a Ford scholarship from October 1961 until March 1962, which Walter Thirring had obtained for him. This brought Kummer into contact with Victor Weisskopf, then director-general of CERN, and Weisskopf invited him to come back as a CERN fellow and his scientific assistant from 1963 to 1964. In 1966, Kummer became the first director of the Institute for High Energy Physics of the Austrian Academy of Sciences, which he led until the end of 1971, parallel to his professorship at the Technical University. Simultaneously, he also became the Austrian delegate to the CERN Council and was soon elected to chair the Finance Committee, overseeing the construction of the ISR. In 1980, Kummer returned to the CERN Council as its vice-president at the point when the SPS was taking shape as a proton-antiproton collider, and the job was more suitably filled by a physicist than a pure diplomat.

Between 1985 and 1987, Kummer was president of CERN Council, a term that was briefly interrupted by the consequences of a terrorist attack at Vienna airport on 26 December 1985, where Kummer was one of the victims, suffering from severe injuries from hand-grenade splinters and shrapnel. After only 11 days in intensive care (and in a rather critical condition), he recovered quickly and immediately resumed his job as Council president. He even attended the annual Schladming Winter School two months after these events, and he skied as ever. Clearly, his regular sporting activities were crucial for his amazingly quick recovery. But Kummer was not only a sportsman in his spare time, he was also a man of culture – in particular a pianist and trained tenor, which in Geneva led to regular chamber music evenings with colleagues such as Volker Soergel and Jack Steinberger.


Wolfgang Kummer (right) with Victor Weisskopf during Weisskopf's 80th birthday celebrations at CERN in 1988.

While Kummer held numerous academic and administrative positions, such as being secretary and then president of the High Energy Board of the European Physical Society from 1995 to 1999, he was especially responsible for building up a theoretical high-energy physics group at the Technical University of Vienna – covering a broad range of research in quantum field theory, string theory and (mainly 2D) quantum gravity. Kummer had contributed foundational work in quantum gauge field theory, in particular by using ghost-free non-covariant gauge fixing. Since the early 1990s, he mainly worked on two-dimensional gravity and he was unceasingly productive much beyond his official retirement in 2003, despite deteriorating health. He remained an active member of the Austrian Academy of Sciences and chairman of the Advisory Board of the Institute for High Energy Physics, Vienna.

Kummer will be missed, both as an eminent physicist and by those who knew him personally as a man of sincere kindness and warmth. We mourn his loss together with his wife Lore, who was always by his side.
W Majerotto, A Rebhan, M Regler, and W Thirring, Vienna.

Carlo Caso 1940–2007

Italian physicist Carlo Caso from Genoa University and INFN passed away on 7 July, after several months of a courageous fight against cancer. He actively participated in the experimental programme at CERN throughout his scientific career, spending some seven years at the laboratory as a fellow and scientific associate.

Carlo's long involvement in particle physics started in the 1960s, with the Genoa group, using CERN's liquid-hydrogen bubble chambers – first the 2000 HBC and later the Big European Bubble Chamber – to study various facets of the production and decay of meson and baryon resonances. He later joined a collaboration using the European Hybrid Spectrometer with a rapid-cycling bubble chamber as vertex detector. Among many achievements, this team was the first to measure – with excellent precision – the lifetime of the charmed D mesons. At the start of the LEP era, Carlo and his group moved to the DELPHI experiment and participated in the construction and running of the High-density Projection Chamber (the barrel electromagnetic calorimeter) and then contributed significantly to measurements of beauty physics and Higgs searches.

After LEP, Carlo's interest turned to the LHC and the ATLAS experiment. He led a group from Genoa engaged in the design and construction of the pixel detector and made significant personal contributions to this effort. He also maintained an active interest in the ATLAS experiment and its collaboration, serving as chairman of the ATLAS Publication Committee. Sadly, Carlo did not survive to enjoy the LHC data.

Alongside his research, Carlo played an important role as a teacher. A full professor of experimental physics in Genoa, he was able to motivate many of his students. He instilled in them a love of physics, and to ask questions and not to be satisfied with a superficial answer. In addition to all other activities, he also found time to serve as chairman of the Physics Department of Genoa University, chairman of the University Council and member of the Physics Advisory Committee of the Italian Ministry of Education. He was a member of several national and international physics societies and was still acting as expert reviewer for the scientific programmes of Europe. For years, he also devoted part of his energy to the Particle Data Group, where he was responsible for the gauge bosons sector.

Our thoughts and sincere sympathy are with his family, including his wife Lella and his daughters Alessandra and Raffaella. We will all miss Carlo sorely.
His friends.

RECRUITMENT

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Interested candidates are encouraged to contact Professor Mike Snow at **snow@iucf.indiana.edu** or **(812)-855-7914**, and to submit a letter of application, current curriculum vitae and arrange for submission of a minimum of six letters of reference to Kathy Hirons at **khirons@indiana.edu** (or by mail to **Professor Mike Snow, Faculty Search, Department of Physics, 727 E. 3rd St., Bloomington, IN, 47405-7105**).

Further information about the IU Physics Department and IUCF can be found at http://www.physics.indiana.edu and http://www.iucf.indiana.edu.

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Prof. Robert Wald, Chair, Department of Physics,
University of Chicago, 5720 S. Ellis Ave, Chicago, IL 60637
E-mail should be sent to Ms. Pat Plitt at p-plitt@uchicago.edu.

Review of applications will start in the fall, 2007, and will continue until the position is filled. To ensure full consideration, applications should be received no later than November 1, 2007.

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THE UNIVERSITY OF CHICAGO

THEORETICAL HIGH ENERGY PHYSICS

The Physics Department and the Enrico Fermi Institute at the University of Chicago invite applications for a tenure-track faculty appointment in Theoretical High Energy Physics. We are encouraging applications from candidates with recognized accomplishments in areas such as: physics of the standard model and beyond; collider physics; and particle cosmology. The successful candidate is expected to establish an independent research program while effectively contributing to the Department's undergraduate and graduate teaching programs.

The appointment is expected to be at the Assistant Professor level. Appointment at the level of Associate Professor or Full Professor is possible for exceptionally well qualified candidates. Applicants should submit a curriculum vitae and a brief research statement, and arrange to have three reference letters sent, to:

EFI Search Coordinator, Enrico Fermi Institute Director's Office,
University of Chicago, 5640 Ellis Ave, Chicago, IL 60637
E-mail should be sent to the EFI Search Coordinator,
efisrch@ulysses.uchicago.edu.

Review of applications will start in the fall, 2007, and will continue until the position is filled. To ensure full consideration, applications should be received no later than November 1, 2007.

The University of Chicago is an equal opportunity, affirmative action employer.

THE UNIVERSITY OF CHICAGO

Massachusetts Institute of Technology

It takes everyone at MIT to be MIT.

Postdoctoral Associate

The Laboratory for Nuclear Science at MIT invites applications for one or more postdoctoral research associate positions with the Hadronic Physics Group. There are currently opportunities to participate in experiments addressing several important physics issues. These opportunities include: the use of parity-violating electron scattering (JLab and Mainz) to measure the weak charge of the proton and as a precision Standard Model test; the use of photo-pion and other reactions (JLab, HIGS) to study chiral symmetry breaking in QCD; an experiment (MIT) to study the neutron-proton radiative capture process at the very low energies relevant to the epoch immediately following the Big Bang, to test theories of the formation of the lightest elements; and a very sensitive search (Oak Ridge) for a non-zero value of the neutron electric dipole moment, which is a crucial test for physics beyond the Standard Model.

A Ph.D. in experimental nuclear or particle physics is required. Please send a curriculum vitae, publication list, and three letters of recommendation to:

Professor Robert P. Redwine
Room 26-453
Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge, MA 02139-4307

You may also email resumes to redwine@mit.edu

MIT is an equal opportunity/affirmative action employer. Applications from women, minorities, veterans, older workers, and individuals with disabilities are strongly encouraged.

http://web.mit.edu

Forschungszentrum Karlsruhe
in der Helmholtz-Gemeinschaft

Universität Karlsruhe (TH)
Research University • founded 1825

KIT
Karlsruhe Institute of Technology

Forschungszentrum Karlsruhe, member of the Helmholtz-Association of German Research Centres is one of the largest national laboratories in Germany with major activities in the research areas Energy and Atmosphere, Nano- and Microtechnology and Structure of Matter. Forschungszentrum Karlsruhe and University of Karlsruhe (TH) are currently merging their activities under the roof of the Karlsruhe Institute of Technology, KIT.

KIT invites applications for the joint positions of

Scientific Head of the Institute for Scientific Computing at the Forschungszentrum Karlsruhe

and

Professor (W3) for Parallel and Distributed High Performance Systems at the University of Karlsruhe (TH)

The Institute for Scientific Computing, IWR, of the Forschungszentrum Karlsruhe operates the central computing centre of the Forschungszentrum to serve the IT-demands of its various research programmes within the Helmholtz-Association of German research centres. IWR also runs the Grid Computing Centre Karlsruhe, GridKa, the central European node in the worldwide computing and data grid of the international elementary particle physics activities and is the driving force for the development of Grid computing in Germany.

In the framework of KIT the computing centres of Forschungszentrum and Universität Karlsruhe are merged to the Steinbuch Centre for Computing, SCC, to become one of the leading German scientific computing centres. The head of the IWR will be member of the directorate of the Steinbuch Centre for Computing. The SCC is linked to all research areas of KIT as a service and research partner and is involved in numerous national and international scientific computig projects. Applicants therefore apart from their scientific expertise should have appropriate application experience.

The scientific profile of the candidate in the field of “Parallel and Distributed High Performance Systems” should cover the following topics:

- grid computing
- development and evaluation of appropriate architectures, protocols and policies for grid computing
- quality management and performance management in distributed environments
- decentralized and self-organising solutions
- integrated service-oriented architectures
- virtualisation concepts

Candidates are expected to have internationally recognized scientific standing, the willingness for interdisciplinary collaboration and the ability to lead a large research and service institute. The holder of the chair will give lectures on the above mentioned topics at the KIT.

We are an equal opportunity employer, but as we wish to increase the proportion of females in higher management we especially encourage qualified women to apply for this position. If applicants are equivalently qualified, handicapped candidates applicants will be selected preferentially.

Applications with CV and publication list should be sent to **Prof. Dr. Reinhard Maschuw, Member of the Executive Board of Forschungszentrum Karlsruhe, P.O. Box 3640, 76021 Karlsruhe, Germany** by **30 September 2007**. Information on the candidate’s previous experience in research and education as well as reprints of five major publications should be enclosed.

Internet: www.fzk.de

The Strategic Helmholtz Alliance “Physics at the Terascale” (http://www.terascale.de) is a research network supported by the Helmholtz Associaction and comprises the research centres DESY and FZ Karlsruhe, 17 German universities, and the Max-Planck Institute for Physics. In the framework of the worldwide endeavour of studying the foundations of matter using accerelators with highest energies, the Alliance will sustainably bundle and advance the expertise and strengths of the participating institutes.

TECHNISCHE UNIVERSITÄT DRESDEN

In the Institute for Nuclear and Particle Physics at the Faculty of Science we have an immediate opening for a tenure track

Helmholtz Junior-Professorship (W1) in Experimental Particle Physics

The successful applicant will lead a ”Young Investigator Group” of the Helmholtz Alliance. He/she will be engaged in data analysis of the ATLAS experiment at the LHC as well as in detector R&D for the ”International Linear Collider”, ILC. Close collaboration is expected with the research groups on experimental and theoretical particle physics and with the electronics lab of the institute. The candidate is expected to participate in general teaching activities of the Department of Physics and especially in teaching of the advanced level courses in "Nuclear and Particle Physics".

We are looking for applicants with a Ph.D. in experimental particle physics, whose excellent achievements as a Post-Doc in an international particle physics collaboration qualify them as a leader of a ”Young Investigator Group”. The group will be funded from the Helmholtz Alliance.

Employment prerequisites are in accordance with the Saxony University rules and regulations (§ 46 Saxony University Statues - new version). Accordingly, the candidate will have completed a university degree, have the educational qualifications, as well as specialized knowledge in research work (normally an excellent doctorate /PhD). Junior Professors will be offered up to a four year contract. This contract, after a positive intermediate evaluation, can be extended for a total of up to 6 years (§ 45 of the Saxony University Statutes - new version). Subject to a successful final evaluation a tenured position of a senior staff scientist will be granted at the institute after the end of the Junior-Professorship. Applications for professorships within Technische Universität Dresden are possible after the successful intermediate evaluation in line with the rules of the Saxony University Statues.

Applications from women are particularly welcome. The same applies to the disabled. Please submit your application together with your CV, your scientific employment record, list of publications, copies of the certificate of your highest academic degree and copies of 5 publications before **October 15, 2007** in electronic form to prodekan@physik.tu-dresden.de (note, that currently no receipt of digitally signed or encrypted documents is possible) and in written form to:

TU Dresden, Dekan der Fakultät Mathematik und Naturwissenschaften, Herrn Prof. Dr. M. Ruck, 01062 Dresden, Germany.

Universität Karlsruhe (TH)
Research University • founded 1825

KIT Karlsruhe Institute of Technology

The **Institute for Theoretical Physics** at the **University of Karlsruhe (TH)** has an opening in **Theoretical Particle Physics** for the

Leader of a Young Investigator Group on Monte Carlo Development

We are looking for a theoretical physicist with expertise in collider physics and the development of parton shower and hadronization Monte Carlo programs who will head a new Young Investigator Group which is being established at the Institute for Theoretical Physics within the Helmholtz Alliance *Physics at the Terascale*. The applicant should have a strong research background with several years of postdoctoral experience in particle physics phenomenology and Monte Carlo development for physics at the Large Hadron Collider.

The position is funded by the Helmholtz Alliance until June 2012 and remunerated according to the TVöD regulations for scientific employees. After this date, the position may become that of a permanent scientific employee at the Institute for Theoretical Physics. The position can be filled January 1, 2008.

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

Interested candidates are requested to submit their CV, description of professional experience and a statement about past and planned research activities before **November 1, 2007**, and should arrange for two letters of recommendation. Applications should be sent to

Frau Renate Weiss
Institut für Theoretische Physik
Universität Karlsruhe (TH)
D-76128 Karlsruhe
Phone: +49 721/608-2081 Fax: +49 721/608-3582
E-Mail: weiss@particle.uni-karlsruhe.de
For further information please contact Prof. D. Zeppenfeld
Phone: +49 721/608-3553
E-Mail: dieter@particle.uni-karlsruhe.de

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

Fakultät für Physik

The Department of Physics of Georg-August-Universität Göttingen

Invites application for a

Helmholtz-Juniorprofessorship (Salary scale W1 BBesO)

of Theoretical Physics, in particular High Energy Particle Physics and Phenomenology

to be filled by January 1, 2008 (temporary appointment into civil service for an initial period of 3 years with a possible extension of another 3 years).

The successful applicant is expected to do research in the fields of

Phenomenology of elementary particles and Physics at the Terascale

The objects of research are to supplement the current and future range of research topics of the group Experimental Particle Physics in the Department of Physics in the field of elementary particle physics at the Terascale (at LHC and ILC) and be closely integrated into the Helmholtz Alliance on “Physics at the Terascale”. The successful candidate is expected to take part in teaching the subject of theoretical physics (Bachelor’s and Master’s courses) as well as the specialization subject of particle physics.

Preconditions for appointments are laid down in § 30 of the Law on Higher Education of Lower Saxony of February 26, 2007 (official law gazette of Lower Saxony, Nds. GVBl 5/2007, p. 69). In case the completion of the doctorate was preceded or followed by employment as an academic assistant or collaborator, the period of the doctorate and the period of employment together should not exceed six years.

Further details can be obtained on request.

We explicitly welcome applications form abroad.

Under certain circumstances part-time employment is possible. Disabled persons with corresponding aptitude for the position will be favoured. The University strives to increase its proportion of female staff and expressly encourages qualified women to apply.

Applications, including a CV, a description of your teaching and research track record, a list of publications and a list or reprints of the five most important publications are requested by **October 15, 2007** and should be sent to

Georg-August-Universität Göttingen
Fakultät für Physik
Der Dekan
Friedrich-Hund-Platz 1
37077 Göttingen

The Faculty of Mathematics and Natural Sciences I of Humboldt University Berlin at the Institute of Physics has an opening for a

Helmholtz Junior-Professorship (W1) for “Phenomenology of Elementary Particle Physics beyond the Standard Model”
starting January 1st , 2008.

The successful applicant will conduct research and teaching in the area of theoretical elementary particle physics. Preferred areas of research are model building and phenomenology beyond the standard model and/or precision calculations of scattering processes with modern techniques.

The candidate is expected to meaningfully complement the existing research activities in theoretical particle physics and to support the accelerator based experimental elementary particle physics at the institute. Her/his activities should be closely integrated into the Helmholtz-Alliance `Physics at the Tera Scale’. Co-operations with DESY, Zeuthen and the Collaborative Research Center 647 `Space-Time-Matter’ are desired. The successful applicant is expected to participate in the general teaching duties of the institute at the undergraduate and graduate level in the subject of theoretical physics.

Applicants have to fulfil the employment requirements for junior-professors according to Berlin University law §102a.

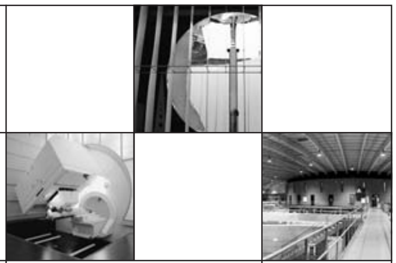
Humboldt University Berlin intends to increase the number of women in research and teaching and particularly encourages female scientists to apply. Applications of scientists from abroad are particularly welcome. In case of equal qualifications handicapped applicants will be favoured.

Please submit your applications including the standard documents along with a short research statement referring to opening number JP007/07 to the

Dean of the Faculty of Mathematics and Natural Sciences I, Prof. Dr. Limberg, Unter den Linden 6, D-10099 Berlin, Germany. Deadline is **October 1, 2007**.
For further information on junior-professorships as well as on the tenure track procedure for a possible W2/W3 professorship appointment see http://forschung.hu-berlin.de/research/young_scientists/juniorprofessuren/

PAUL SCHERRER INSTITUT

PSI



Das Paul Scherrer Institut ist ein multidisziplinäres Forschungszentrum und ein weltweit führendes Benutzerlabor. Mit seinen rund 1200 Mitarbeitenden gehört es als selbstständige Institution zum ETH-Bereich und konzentriert sich auf die Gebiete Festkörperforschung und Materialwissenschaften, Elementarteilchenphysik, Energie- und Umweltforschung sowie Biologie und Medizin.

Am PSI werden mit dem weltweit leistungsstärksten Protonenbeschleuniger hochintensive Mesonen- und Neutronenstrahlen für vielseitige Experimentieranlagen erzeugt. Ein Schwerpunkt der Sektion Targetanlagen und Aktivtechnik ist die Entwicklung, Realisierung und Betreuung der Hochleistungstargets für die Mesonen- und Neutronenproduktion. Für den Ausbau der Anlagen zu höheren Strahlleistungen suchen wir eine/n

Physiker/in

Ihre Aufgaben

Die Tätigkeit umfasst die Konzeption, Systembetreuung und Weiterentwicklung der Targetanlagen für die Mesonenproduktion. Für die technisch-physikalische Auslegung der Targets, Kollimatoren und des Strahlfängers verwenden Sie CAE – Programme für die Simulation der thermomechanischen Struktur und zur Lösung von thermohydraulischen Problemstellungen sowie Monte-Carlo Programme für die Berechnung der Wechselwirkungen der Materialien mit dem Protonenstrahl. Bei Bedarf spezifizieren Sie Versuchsaufbauten zur experimentellen Abklärung wichtiger Betriebsparameter und zur Messung komplexer Materialeigenschaften. Sie besuchen regelmässig internationale Konferenzen und publizieren die Ergebnisse Ihrer Arbeit in Fachzeitschriften. Innerhalb Ihres Fachgebietes haben Sie die Möglichkeit zur Teilnahme an EU-Projekten.

Ihr Profil

Sie sind ein/e praktisch veranlagte/r promovierte/r Physiker/in mit guten Grundlagenkenntnissen in Kernphysik und haben einen starken technischen Background mit Schwerpunkt Thermohydraulik und Strukturmechanik sowie Erfahrung in der Anwendung numerischer Simulationsverfahren, insbesondere der Finite Element Methode (FEM) und der Strömungsmechanik (CFD). Sie haben das Potenzial neue Ideen einzubringen und Zielsetzungen zu definieren. Als teamorientierte und kommunikative Persönlichkeit arbeiten Sie gerne in einer interdisziplinär zusammengesetzten Gruppe. Sie arbeiten selbstständig und verfügen über Eigeninitiative, Hilfsbereitschaft und Praxisorientierung. Gute Englisch- und Deutschkenntnisse sowie die Bereitschaft zum Aufenthalt in kontrollierten Zonen runden Ihr Profil ab.

Wir freuen uns auf den Kontakt mit Ihnen.

Herr Dr. Gerd Heidenreich, Tel. +41 (0)56 310 35 84,
E-Mail: gerd.heidenreich@psi.ch oder Frau Dr. Sabine Teichmann,
Tel. +41 (0)56 310 43 75, E-Mail: sabine.teichmann@psi.ch
beantworten gerne Ihre Fragen.

Ihre schriftliche Bewerbung senden Sie bitte bis 31.10.2007 an:
Paul Scherrer Institut, Personalabteilung, Herr Thomas Erb,
Kennziffer 8590, 5232 Villigen PSI, Schweiz.

Weitere Informationen: www.psi.ch

The **Cluster of Excellence**
'Origin and Structure of the Universe'

Invites applications for

Fellows
Postdoctoral Scientists
Doctoral Students

The Cluster of Excellence 'Origin and Structure of the Universe' has recently been installed at the Campus Garching within the Excellence Initiative of the federal government of Germany. The cluster is operated jointly by the physics departments of the two Munich Universities, the Max-Planck Institutes and ESO. It aims at a deeper understanding of the physics of fundamental forces and their interaction with matter that drives the expansion of the universe, the creation of elements and of large scale structures observed in our universe. For this it will install 10 new research groups working in the key areas of science relevant to this field, and create positions for research fellows, postdoctoral scientists and doctoral students.

The fields of science covered range from cosmology and astrophysics, astro-particle physics to particle- and nuclear physics, pursued theoretically and experimentally.

In the **fellow program** we seek the best scientists in the field of fundamental physics. They will be selected in a competitive scheme across the various fields of research from within the cluster. Selected candidates will be invited to join an existing research group of their choice. Support will be given for the duration of 2 years. Selection panels are held about twice per year.

Postdoctoral researchers will work in specific groups and on well defined projects, outlined in more detail in the specific job description. The position is for initially 3 years.

Doctoral students, selected by a PhD committee will be assigned to a specific project and supervisor. The successful candidates will be enrolled at the University of the supervisor which will also award the doctoral degree in physics The student's progress will be followed by two independent advisors. Funding is for three years.

Besides profiting from scientific infrastructures present on the campus Garching the groups will also be integrated in transregional and international research activities either ongoing or planned. Doctoral students will follow a structured PhD program. Interdisciplinary weekly seminars and journal clubs organized by the cluster as well as the large visiting-scientists program offer excellent opportunities for young researchers to broaden their scientific horizon and start new collaborations.

Active participation in the teaching program for physics at the faculties of physics and of the Cluster is welcome.

The advancement of women in the scientific field is an integral part of the clusters and the university's policy. ***Women, therefore, are especially encouraged to apply***. Persons with disabilities will be given preference over other applicants with equal qualifications.

Details on the different positions can be found on

http://universe-cluster.de (→ jobs)

Applicants should complete the corresponding web-forms.

Excellence Cluster 'Origin and Structure of the Universe'
c/o Prof. Dr. Stephan Paul
Physics Department
Technische Universität München

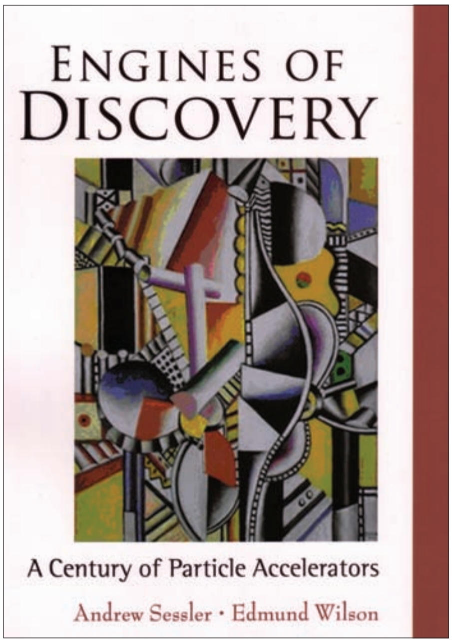
BOOKSHELF

Engines of Discovery: A Century of Particle Accelerators by Andrew Sessler and Edmund Wilson, World Scientific. Paperback ISBN 978-9812700711. £17.

It is said that Galileo always kept 10% of his purse in reserve for his lens grinder so that he could look forward to peering further into the heavens through the next telescope in line. He also actively collaborated with the telescope builder and shared his joy of discovering each new star. Instrument builders and their users have often been the same community and sharing the enterprise together was the norm. Such was also the case with early sub-atomic physicists and chemists in the late 19th and early 20th century, with Ernest Rutherford, John Cockcroft, Ernest Walton, James Chadwick, and so on. The "chasm" began to open in the mid- to late 20th century with the emergence of the culture of large-scale experimental science via teams of specialists in accelerators, detectors, data processors, theoreticians, etc. Today, however, the demands of the next frontier in particle physics are sufficiently daunting that the gap is forced to close again. Witness the emergence of self-organized communities around the world that are working together in moving the field forward.

Engines of Discovery is written by two well-respected practitioners of accelerator science, recognized for their contributions to the field. Andrew Sessler and Edmund Wilson both began their careers at a time when the "chasm" had started to take root and continue in their trade today when it is beginning to heal again – a golden era in the history of development dominated by the use of large particle accelerators.

Sessler received a classical and advanced education from Harvard College and Columbia University in the middle of the last century at a time when the US was a scientific hot-bed, with great pre- and post-war scientists from around the world. Exposed to the greatest minds of the times, Sessler contributed to the very beginnings of the field via his contributions at MURA, the Wisconsin-based Midwestern Universities Research Association. This group pioneered the concept of the fixed field alternating gradient (FFAG) synchrotron – a concept that has been resurrected with a prototype for electrons now being built at the Cockcroft Institute and Daresbury Laboratory in the UK. Sessler then continued to lead the great laboratory in California created by one of the early pioneers, Ernest Lawrence. Sessler brings a substantive and unique perspective that is hard to match through his eminent stature in the community of scientists and humanitarians. He is known for his many contributions to theoretical accelerator physics, including collective beam instabilities, non-linear dynamics, muon colliders and free-electron lasers. Joining him is Edmund Wilson, a veteran from the world-renowned accelerator-based CERN laboratory. Educated at Oxford and having the rare experience of tutelage from and working with John Adams, the architect of many of CERN's accelerators, Wilson brings his decades of research experience in operating accelerators and his formidable skills of inherited pedagogy, composition, literacy and the overall art of story-telling to complete this fascinating saga.



It is indeed a masterly tale of the emergence and growth of a field, told from a unique personal perspective, by two working scientists in the field. Understandably, the book is rich, dense and selective as it starts with the heritage of atomic, nuclear and particle physics and continues through to the end of the 20th century. The field eventually diversified into other basic sciences such as those driven by synchrotron radiation sources, free-electron lasers, laser-plasma interaction, high-field physics, etc – which have spawned much of the innovation and creativity of the latter years. The field has also become immensely global during the past few decades.

The book may appear relatively lean in promoting such diversity of sciences and characters in these recently emerging fields. Such incommensurate expression can be understood in the context of the historical footprint of the authors themselves and is only to be expected for a book of this scope. I would be remiss if I did not point out the brilliance, genius and creativity of the generation of bright emerging international scientists and technologists from Europe, the Americas, Asia and Africa who are transforming the field today. The authors only hint at it in the book via colleagues such as Katsunobu Oide and Chan Joshi, but today one will find many others at institutions around the world.

This is not a book to look at through the lens of a precise historian – or with the obsession of a perfectionist – demanding a complete lexicon, chronology, historical credit, etc. It is above all a book of inspiration. Nevertheless, the book does achieve a natural sense of historical progress and is made even more exciting by the anecdotal and factual bits and pieces put together about some of the players – more so in their order of appearance on the scene, than in any other sense. For every player that is mentioned and adds flair to the book, there are many who are not, including the authors themselves, whose contributions have been substantive.

Above all, this book uplifts one's spirit; one reads it with zest, admiration and awe. The power of sheer dedication, brilliance, creativity, humility and humanity of the whole enterprise expressed in the pages of the book is sure to inspire and motivate generations to come.

Speaking as an individual in the wake of a personal transition from the US to the UK, and taking stock of shifting priorities in the field, I must thank the authors for providing a contextual basis for carrying our work forward with the noble mission of the ultimate quest for the ways of nature and life.

Swapan Chattopadhyay, Sir John Cockcroft Chair of Physics, Universities of Liverpool, Manchester and Lancaster, and director, Cockcroft Institute.

Books received

Exploring the Quantum: Atoms, Cavities, and Photons by Serge Haroche and Jean-Michel Raimond, Oxford University Press. Hardback ISBN 0198509146 £45 ($89.50).

The counter-intuitive aspects of quantum physics have long been illustrated by thought experiments; from Einstein's photon box to Schrödinger's cat. These experiments are now real, with single particles – electrons, atoms or photons – directly unveiling the weird features of the quantum. *Exploring the Quantum* describes a class of thought experiments made real, highlighting measurement processes and decoherence at the quantum-classical boundary. Combining theory and experiments, the book will interest students of quantum physics, teachers seeking illustrations for their lectures, and researchers in quantum optics and quantum information.

Quantum Liquids: Bose Condensation and Cooper Pairing in Condensed-Matter Systems by A J Leggett, Oxford University Press. Hardback ISBN 0198526431 £35 ($64.50).

Starting from first principles, this book introduces the closely related phenomena of Bose condensation and Cooper pairing, in which a very large number of single particles or pairs of particles are forced to behave in exactly the same way, and explores their consequences in condensed-matter systems. The author uses simple concepts and arguments to account for the new phenomena that arise in Bose-condensed and Cooper-paired systems, including superconductivity and superfluidity. The physical systems discussed include liquid He^4, superfluid He^3, the BEC alkali gases, classical and exotic superconductors, and the recently stabilized Fermi alkali gases. The book should suit beginning graduate students in physics or advanced undergraduates.

Introduction to Quantum Information Science by Vlatko Vedral, Oxford University Press. Hardback ISBN 0199215707 £35 ($70).

Based on a series of invited lecture courses at various universities, this book offers a concise and up-to-date introduction to quantum information. In addition to treating quantum communication, entanglement and algorithms in great depth, it also addresses a number of other topics, such as Maxwell's demon, the Bekenstein bound and Caratheodory's treatment of the second law of thermodynamics. All mathematical derivations are based on clear physical pictures, making it ideal as a first introduction to the subject and also to appeal to the specialist.

Lattice Methods for Quantum Chromodynamics by Thomas DeGrand and Carleton DeTar, World Scientific. Hardback ISBN 9812567275 £35 ($64).

This book provides a thorough introduction to the specialized techniques needed to carry out numerical simulations of QCD, namely: a description of lattice discretizations of fermions and gauge fields; methods for doing a simulation; descriptions of common strategies to connect simulation results to predictions of physical quantities; and a discussion of uncertainties in lattice simulations. Moreover, the many connections of lattice QCD to continuum field theory and elementary-particle physics phenomenology are carefully explained. This book is a useful resource for graduate students and researchers interested in the properties of strong interactions.

Path Integrals in Quantum Mechanics, Statistics, Polymer Physics, and Financial Markets, 4th edition by Hagen Kleinert, World Scientific. Hardback ISBN 9812700080 £79 ($138). Paperback ISBN 9812700099 £22 ($38).

This is the fourth, expanded edition of the comprehensive textbook on the theory and applications of path integrals – the first to solve path integrals explicitly for a range of non-trivial quantum-mechanical systems, in particular the hydrogen atom. The book explains the Feynman–Kleinert variational approach and develops it systematically into a variational perturbation theory. It features a variety of systems from the fractional quantum Hall effect to the application of path integrals to financial markets.

Cosmological Relativity: The Special and General Theories for the Structure of the Universe by Moshe Carmeli, World Scientific. Hardback ISBN 9812700757 £26 ($34).

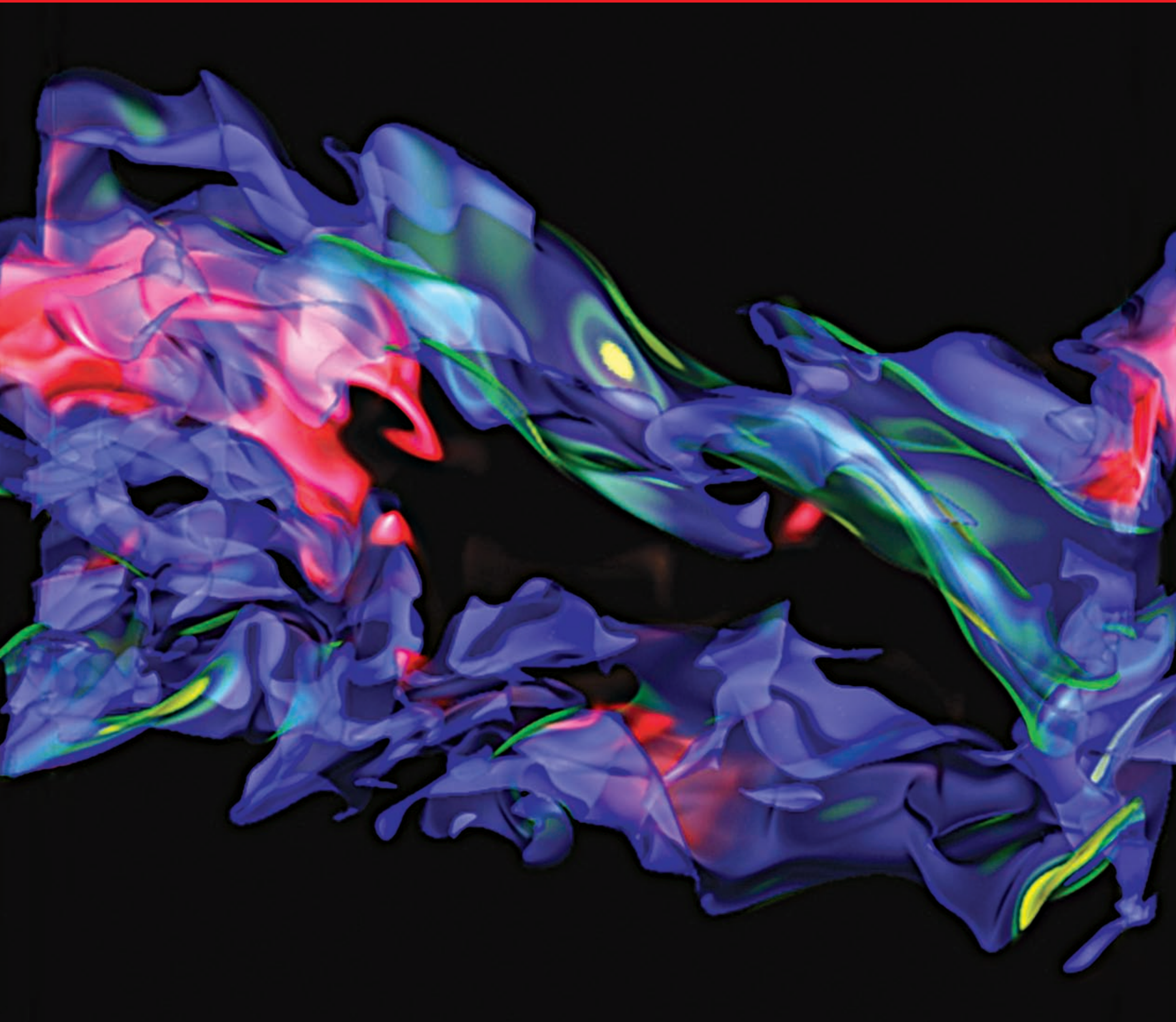
Moshe Carmeli describes the large-scale structure of space, time and velocity as a new cosmological special relativity. He derives a cosmological, Lorentz-like transformation that relates events at different cosmic times and applies it to obtain a new law of addition of cosmic times and derive inflation in the early universe. In the appendices, gravitation is added in the form of a cosmological general relativity theory and a five-dimensional, unified theory of space, time and velocity. Astrophysicists, cosmologists, theoretical physicists and mathematical physicists should all find this book of great interest.

Statistical Mechanics: Algorithms and Computations by Werner Krauth, Oxford University Press. Hardback ISBN 0198515359 £49.95 ($99.67). Paperback ISBN 0198515367 £24.95 ($47.50).

Part of the *Oxford Master Series in Physics*, this book discusses the computational approach in modern statistical physics, adopting simple language and an attractive format with many illustrations, tables and algorithms. Individual chapters focus on subjects as diverse as the hard sphere liquid, classical spin models, single quantum particles and Bose–Einstein condensation, with in-depth discussions of algorithms ranging from basic enumeration methods to modern Monte Carlo techniques. A CD with schematic code, numerical tables and image sequences is included. Like other books in the series, it is aimed at final-year undergraduate and beginning graduate students.

Physics of Strongly Coupled Plasma by Vladimir Fortov, Igor Iakubov and Alexey Khrapak, Oxford University Press. Hardback ISBN 0199299803 £65 ($130).

Strongly coupled plasma has generated much interest recently, as states of matter with high concentration of energy became accessible experimentally. This book is devoted to the physics of such high-density plasma, which has been compressed so strongly that the effects of interparticle interactions and non-ideality govern its behaviour. It presents methods of generation and diagnostics of strongly-coupled plasmas, along with the main theoretical methods and experimental results on thermodynamical, kinetic and optical properties. The book is aimed at physicists, astrophysicists, engineers and material scientists.



End of an era: HERA switches off

Barbara Warmbein witnessed the final moments of beam at the unique machine that was the world's first and only electron–proton collider.

Left: Ferdinand Willeke, who also sent the first proton beam round HERA, pushed the buttons to dump the beams. Right: Volker Soergel, director of DESY during the construction of HERA, with a photo of Bjorn Wiik, who inspired and led the project to build the world's first electron-proton collider, and who sadly died in 1999. (Courtesy DESY.)

When you switch off a major accelerator after 15 years of data taking, you expect that someone will push a big red button. Instead, on 30 June at 11.23 p.m., Ferdinand Willeke – master of DESY's Hadron–Electron Ring Accelerator HERA – pushed two unremarkable grey buttons to dump the protons and positrons. That was the end of HERA, and the 80-strong crowd in the main control room applauded the team for years of successful collisions. Champagne flowed shortly after and the spectators toasted each other with pride, nostalgia and optimism.

Days before, DESY had celebrated its flagship machine in a two-day "HERA Fest" colloquium with international guests and HERA alumni and a party for staff and guests. More than 1800 people gathered in an enormous tent on the DESY site to listen to talks about scientific, technological and sociological achievements around the accelerator. "Exciting times are over – and more are ahead of us," said Rolf-Dieter Heuer, DESY Director for High Energy and Astroparticle Physics. "A new era starts now with the LHC and will hopefully continue with the ILC." "HERA will live on in physics textbooks and as a model for international collaboration," predicted Albrecht Wagner, chair of the DESY Directorate. And Brian Foster, former spokesperson of the ZEUS collaboration, admitted that there was "a certain amount of sadness. The detector worked like a dream and the collaboration formed a very good team".

In HERA, electrons and positrons collided with heavy protons and revealed details of proton structure. Physicists made detailed studies of the properties of the gluons inside the proton and proved the unification of two of nature's fundamental forces. Results from HERA have also helped in planning analyses for the LHC, and data analysis will continue well into the next decade. While the four experiments are being dismantled and in many cases shipped back to the institutes in charge, the accelerator remains in the tunnel, protected against wear, tear and corrosion. HERA is making way for one of DESY's next big projects, PETRA III, a high-brilliance synchrotron radiation source for X-rays. In the end, there was a big red button – on a whiteboard. Researchers had written farewells to their detector and the machine that drove it. Somebody had drawn a button with the caption "Push it".

Barbara Warmbein, DESY.

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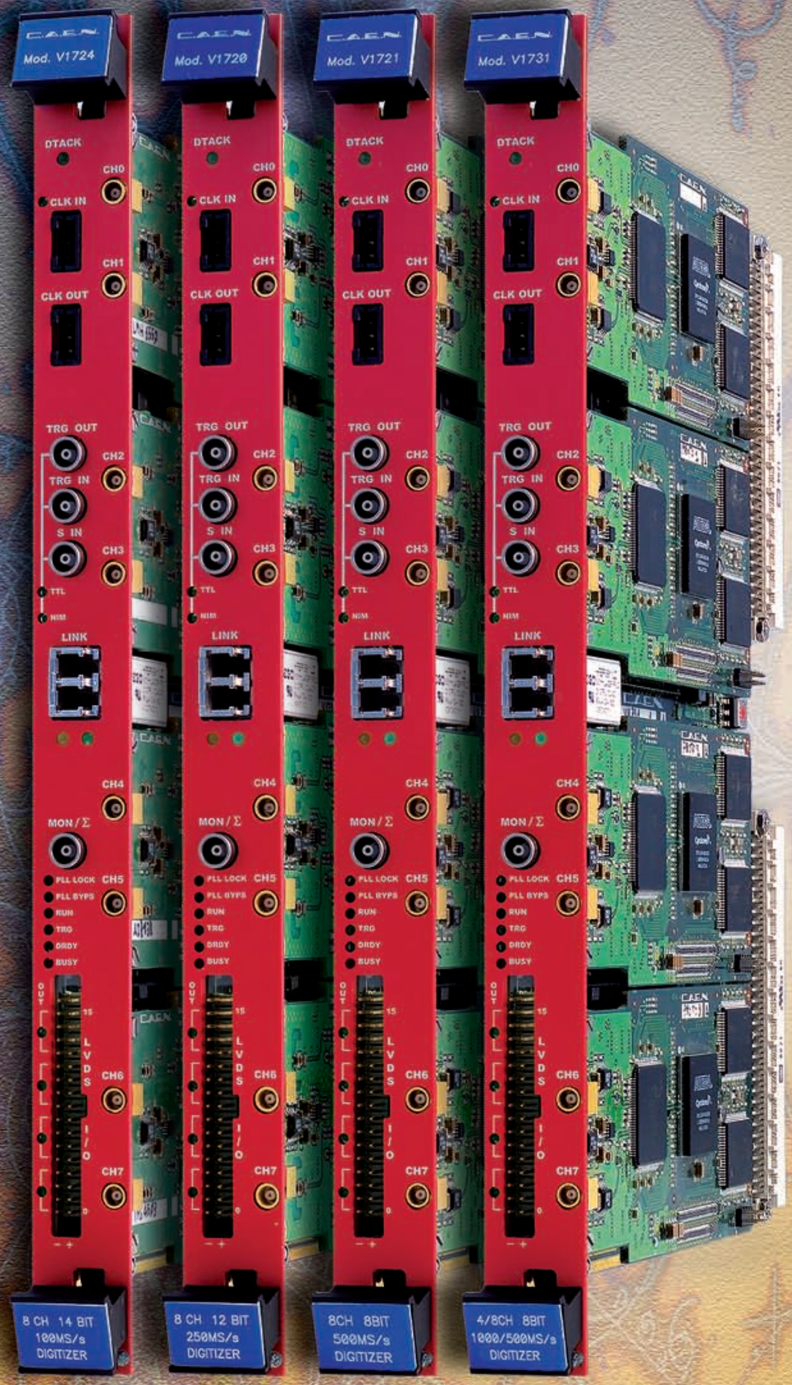

Small details

Great differences

Model	#ch	Res (bit)	Dynamic Range (Vpp)	Sample Rate (MS/s)	Bandwidth (MHz)	Memory (Sample/ch)	Max Recorded time (ms)
V1724	8	14	2.25 - 10	100	DC to 40	512K / 4M	~5 / 42
V1720	8	12	2	250	DC to 125	1.25M / 10M	~5 / 42
V1721	8	8	1	500	DC to 250	2M	~4
V1731	8 - 4	8	1	500 - 1000	DC to 250 - 500	2M - 4M	~4

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