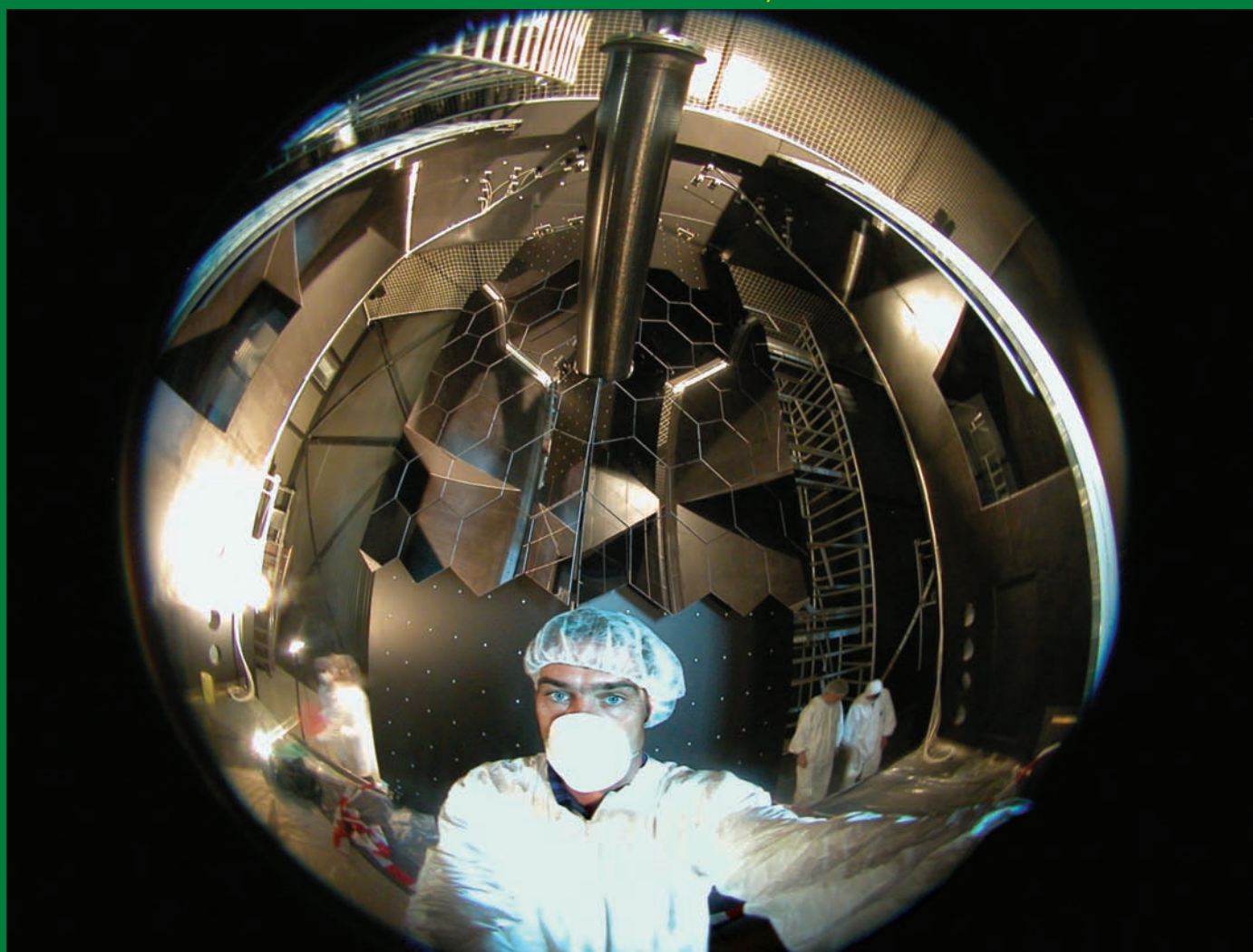


INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

# CERN COURIER

VOLUME 47 NUMBER 6 JULY/AUGUST 2007



## LHCb prepares for RICH physics

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**IOP Publishing**



**Cover:** Ring imaging Cherenkov (RICH) detectors will play an important role in the LHCb experiment at CERN (p30). This photograph, taken from the front of the detector, shows hexagonal elements of the spherical mirrors of RICH2, with reflections of the flat mirrors and the photon-detector enclosures. It also shows Michael Hoch, who took the photograph.



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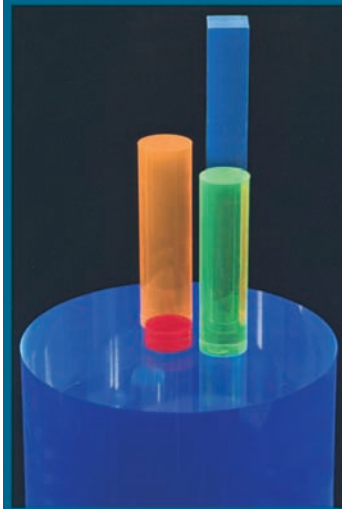
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## LHC NEWS

# CERN announces new date for LHC start-up...

Speaking at the 142nd session of the CERN Council on 22 June, CERN's director-general, Robert Aymar, announced that the LHC will start up in May 2008, taking the first steps towards studying physics at a new high-energy frontier. A low-energy run originally scheduled for 2007 has been dropped as the result of a number of minor delays accumulated over the final months of LHC installation and commissioning, including the failure in March of a pressure test in an inner-triplet magnet assembly.

The first cool-down of an eighth of the machine (sector 7-8) to the operating temperature of 1.9 K began earlier this year (*CERN Courier* May 2007 p5). While this took longer than scheduled, it provided important lessons, allowing the LHC's operations team to iron out teething troubles and gain experience that will be applied to the other seven sectors. Now tests on powering up sector 7-8 are underway, and the cool-down of sector 4-5 has begun. At the same time, physicists and engineers are making modifications to the inner-triplet magnet assemblies (*CERN Courier* June 2007 p5).



A welder at work on LHC sector 1-2. This is the last sector to be interconnected.

The new schedule foresees successive cooling and powering of each of the LHC's sectors in turn this year. Hardware commissioning will continue throughout the winter, allowing the LHC to be ready for high-energy running by the time CERN's accelerators are switched on in the spring. Beams will be first injected at low energy

and low intensity to give the operations team experience in driving the new machine, before the intensity and energy are slowly increased.

Installation of the large and equally innovative apparatus for experiments at this new and unique facility will continue at the same time, to be completed on a schedule consistent with that of the accelerator.

# ...and Council approves additional resources

In another major development, Council approved a programme of additional activities together with the associated budget resources. This decision follows the definition of the European Strategy for Particle Physics adopted by Council last year (*CERN Courier* September 2006 p29). It makes it possible to start implementing the strategy as presented by CERN management last autumn. The approved resources

amount to an extra SwFr240 million for 2008–2011. The host states, France and Switzerland, have committed to providing half of these additional funds.

The extra resources are essential to ensure full exploitation of the discovery potential of the LHC and to prepare CERN's future. The programme consists of four priority themes: an increase in the resources dedicated to the experiments and to reliable operation of

the LHC at its nominal luminosity; renovation of the injector complex; a minimum R&D programme on detector components and focusing magnets in preparation for an increase in the LHC luminosity and for enhancement of the qualifying programme for the Compact Linear Collider study; and activities of scientific importance for which contributions from other European organizations will be essential.

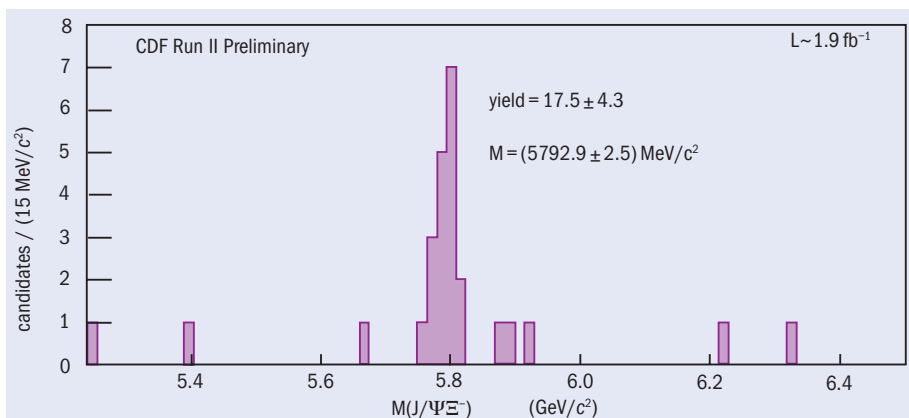
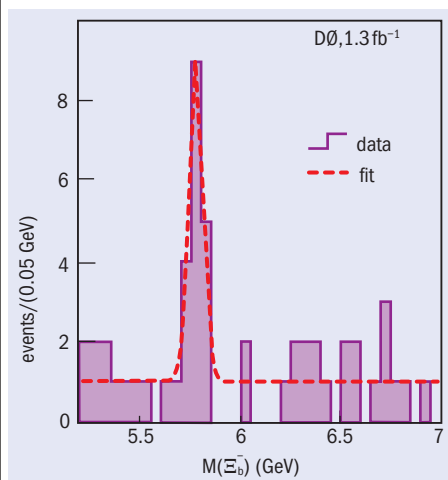
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FERMILAB

# DØ and CDF find same new baryon



Invariant mass distributions for  $\Xi_b^-$  candidate events found in the DØ (left) and CDF (right) experiments at Fermilab. The two experiments yield consistent values for the  $\Xi_b^-$  mass.

After several years of independently gathering and analyzing data at Fermilab's Tevatron, the DØ and CDF collaborations have reported the observation of the same new baryon within days of each other.

The DØ collaboration announced the first direct observation of the strange b baryon,  $\Xi_b^-$ , in a paper submitted to *Physical Review Letters* on 12 June. Then, at a packed Fermilab seminar on 15 June, no sooner had Eduard De La Cruz Burelo reported on DØ's discovery than Dmitry Litvintsev from the CDF collaboration rose to present independent evidence for the very same particle. Consisting of three quarks – d, s and b – the  $\Xi_b^-$  is the first observed particle to be formed of quarks from all three generations.

The ALEPH and DELPHI experiments at LEP had previously found indirect evidence for the  $\Xi_b^-$  in the form of an excess of events with a  $\Xi^-$  and a lepton of the same sign. Now the two experiments at the Tevatron have been able to reconstruct fully the specific decay,  $\Xi_b^- \rightarrow J/\Psi \Xi^-$ , where the products decay in their turn:  $J/\Psi \rightarrow \mu^+ \mu^-$ ,  $\Xi^- \rightarrow \Lambda^0 \pi^-$  and

$\Lambda^0 \rightarrow p \pi^-$ . While the  $\Lambda$  and  $\Xi^-$  have decay lengths of a few centimetres, the  $\Xi_b^-$  travels only a millimetre or so before it decays.

The analysis basically consists of searching for events with muon pairs that correspond to a  $J/\Psi$  together with a proton and two pions of the same sign. One pion and the proton must have a mass equivalent to the  $\Lambda$  and come from a vertex that is an appropriate distance from the origin of the second pion. The  $\Lambda$  and this pion should then have a mass equivalent to a  $\Xi^-$  and a common vertex corresponding to the  $\Xi^-$ 's decay point. The next step is to match the origins of the  $\Xi^-$  candidates with those of the  $J/\Psi$ s to reconstruct the decay of the  $\Xi_b^-$ .

In an analysis of  $1.3 \text{ fb}^{-1}$  of data collected during 2002–2006, the DØ collaboration found 19 candidate events for  $\Xi_b^-$  while the CDF collaboration found 17 candidates in  $1.9 \text{ fb}^{-1}$ . Both experiments measured the mass of the new particle, with consistent results. In their submitted paper, DØ gives the measured mass as  $5.774 \pm 0.011$  (stat.)  $\pm 0.015$  (syst.)  $\text{GeV}/c^2$ , and quotes

a significance of  $5.5\sigma$  for the observed signal. At the seminar, CDF presented a preliminary mass value of  $5.7929 \pm 0.0024$  (stat.)  $\pm 0.0017$  (syst.)  $\text{GeV}/c^2$ , with a significance of  $7.8\sigma$ . DØ has also measured the ratio of the cross-section multiplied by the branching ratio of their observed  $\Xi_b^-$  events relative to that for the well-known  $\Lambda_b$  baryons. The measured ratio is  $0.28 \pm 0.13$ .

The discovery of the  $\Xi_b^-$  is the latest in a chain of discoveries made by CDF and DØ over the past few years. Last October, the CDF collaboration reported the observation of  $\Sigma_b$  particles, related to the  $\Xi_b$  (*CERN Courier* December 2006 p9). As the Tevatron delivers more and more data, the possibilities increase for the observation of even rarer processes.

### Further reading

DØ collaboration V Abazov *et al.* 2007 <http://arxiv.org/abs/0706.1690>.  
CDF collaboration [http://www.cdf.fnal.gov/physics/new/bottom/070607\\_blessed-cascadeB/](http://www.cdf.fnal.gov/physics/new/bottom/070607_blessed-cascadeB/).

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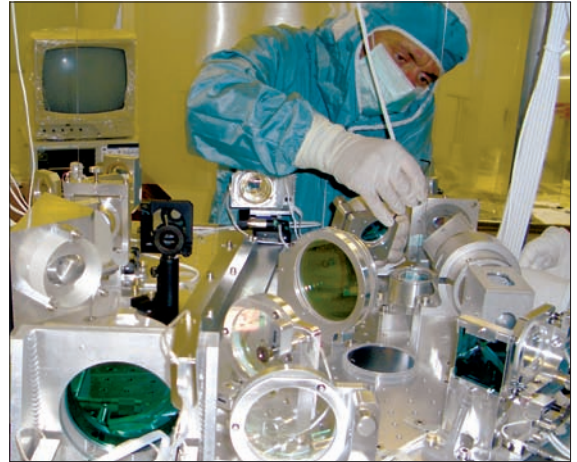
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## GRAVITATIONAL WAVES

# VIRGO opens up new astronomy



A view of the two arms of the Virgo interferometer. (Photos courtesy INFN.)



Setting up the injection bench for laser input.

On 18 May, the Virgo laser interferometer for the detection of gravitational waves started its first science run at the European Gravitational Observatory, Pisa, marking a step forward towards a new astronomy. If Virgo and its counterparts, LIGO in the US and GEO600 in Germany, succeed in detecting gravitational waves, they will reveal new information about the universe.

Until now, astronomy has been based on photons – electromagnetic waves – originating from the accelerated motion of electric charges, as in a burning star. Gravitational waves originate instead in matter's most intrinsic characteristic, its mass. A direct consequence of general relativity, gravitational waves are perturbations of the gravitational fields that are produced by the accelerated motion of masses, as in star collisions. According to general relativity, gravitational fields distort space-time and the passage of gravitational waves produces ripples, like on the surface of a pond. A light beam travelling through this perturbed space-time should be subject to tiny oscillations in the time it takes to

bounce between two widely spaced mirrors.

Laser interferometers, such as Virgo, are ideal instruments to detect these phenomena. They can compare with enormous accuracy the times that light takes to go back and forth along two perpendicular arms, 3–4 km long. Minuscule changes in these times caused by gravitational waves will appear as microscopic changes in the interference fringes.

Having reached a sensitivity close to the design value, and comparable to that of the LIGO interferometers, Virgo has now begun scientific operation. The data collected will complement data from other detectors, and improve the overall statistical significance.

In an important step that greatly increases the value of the data collected in Europe and the US, Virgo and the LIGO Science Collaboration have agreed to share their data. The constitution of a worldwide network of detectors, the data for which are analysed coherently, has several basic advantages. The coincidence between weak signals sensed in widely separated locations allows the rejection of spurious

events from local noise. The arrival-time difference of a gravitational-wave signal of various detectors enables reconstruction by triangulation of the position of the source in the sky and measuring the wave-front at several points allows the determination of all of the parameters characterizing gravitational waves.

With the instruments close to their design sensitivities, researchers could detect gravitational waves in the coming four months of common data-taking, although the “discovery” probability is estimated to be only about 1%, even for binary neutron-star coalescence – one of the better known sources. To increase this probability, the researchers have set up a coordinated, two-stage improvement campaign. This will bring the overall detection probability into the range of one event a year for 2009–2010, and a few tens of events a year for 2013–2014. If attained, it will mark the birth of gravitational-wave astronomy.

- Virgo is funded on an equal basis by the Centre National de la Recherche Scientifique and the Istituto Nazionale di Fisica Nucleare.

Les physiciens des particules du monde entier sont invités à apporter leurs contributions aux *CERN Courier*, en français ou en anglais. Les articles retenus seront publiés dans la langue d'origine. Si vous souhaitez proposer un article, faites part de vos suggestions à la rédaction à l'adresse [cern.courier@cern.ch](mailto:cern.courier@cern.ch).

*CERN Courier* welcomes contributions from the international particle-physics community. These can be written in English or French, and will be published in the same language. If you have a suggestion for an article, please send your proposal to the editor at [cern.courier@cern.ch](mailto:cern.courier@cern.ch).

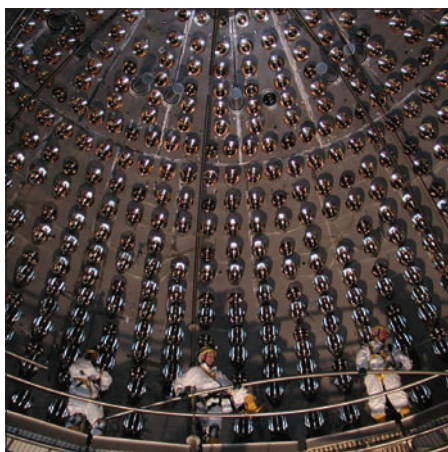
## NEUTRINOS

# Borexino begins data taking at Gran Sasso

The Borexino detector is now fully operational at the Laboratori Nazionali del Gran Sasso. This milestone comes after several years of technical developments that have led to the lowest background levels ever achieved, followed by construction and commissioning. In addition, problems at the underground laboratory and with local authorities – owing mainly to environmental concerns – caused four years of delay.

Borexino's main goal is the measurement of the monoenergetic (862 keV) neutrinos from the decay of  ${}^7\text{Be}$  formed in a branch of the proton–proton (pp) fusion chain in the Sun (*CERN Courier* October 1998 p12). Previous experiments indicate a severe suppression of these neutrinos, which are important in understanding solar neutrinos and neutrino oscillations.

The experiment will detect neutrino–electron scattering in real time in its central volume of 300 tonnes of ultrapure



At work inside Borexino's steel sphere lined with phototubes. (Courtesy INFN.)

liquid scintillator (100 tonnes of fiducial mass). This is shielded by 1000 tonnes of ultrapure quenched pseudocumene (1-2-4 trimethylbenzene) and 2400 tonnes

of purified water. A stainless-steel sphere contains the pseudocumene and also supports 2200 photomultipliers to detect the light produced by neutrino interactions, while 200 phototubes facing into the shielding water provide a veto for muons.

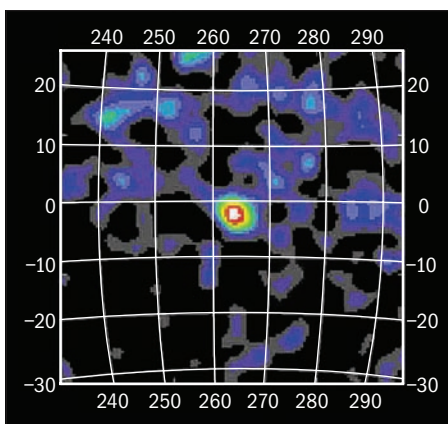
Borexino will cast light on the low mixing-angle solution for neutrino oscillation, which is still to be confirmed at low energies, and should provide information on the electron–neutrino survival probability in the transition region (0.7–4.0 MeV) between vacuum and matter oscillations. With its very low threshold – well below 1 MeV – the experiment also has the potential to explore other solar neutrino signals for the first time, and to test the astrophysical model of the Sun at the level of a few per cent. In addition, Gran Sasso provides the ideal location for the study of geoneutrinos, thanks to the low level of backgrounds from nuclear reactors.

## ASTRONOMY

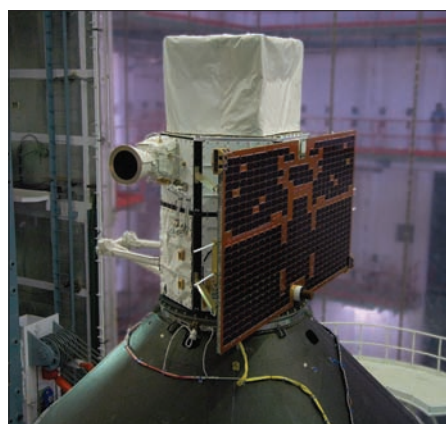
## AGILE takes its place in orbit

On 23 April, the Indian Polar Satellite Launch Vehicle (PSLV) launched the Italian astronomical satellite, AGILE, into orbit from the Sriharikota base in Chennai-Madras. AGILE (Astrorivelatore Gamma a Immagini Leggero) is a 350 kg satellite dedicated to high-energy astrophysics. Its main goal is the simultaneous detection of hard X-ray and gamma-ray cosmic radiation in the energy bands 15–60 keV and 30 MeV–50 GeV, with optimal imaging and timing.

Ten days after launch, on 4 May, the instruments on board the satellite – the tracker, the mini-calorimeter, and the X-ray detector – were switched on and the first data transmitted back to Earth. All proved to work well, and commissioning proceeded according to schedule until the end of June. The tracker, the main scientific instrument on AGILE, is based on state-of-the-art, reliable technology of solid-state silicon detectors developed by INFN laboratories.



Left: A preliminary map (galactic co-ordinates) of photons with energy above 100 MeV of the Vela Pulsar region. The observation took about half a day (7 orbits) on 29–30 May. The image represents only the central part of the field of view of the AGILE gamma-ray imager and background rejection is based on an instrument configuration that is not yet optimized. Right: The AGILE satellite integrated on the fourth stage of the PSLV rocket on 15 April. (Courtesy AGILE and ASI Science Data Centre.)



The AGILE Mission is funded and managed by the Italian Space Agency (ASI), with co-participation from the Italian Institute of Astrophysics, the Italian Institute of Nuclear Physics, and several universities and research centres – including the National Research Council, the National

Agency for New Technologies, Energy and the Environment, and the Consorzio Interuniversitario per la Fisica Spaziale. The industrial contractors involved are Carlo Gavazzi Space, Oerlikon-Contraves, Alcatel-Alenia Space Italia-LABEN, Telespazio, Galileo Avionica, Intecs and Mipot.



## RESEARCH FUNDING

# German particle physics gets funding boost

Physicists in Germany will soon be able to strengthen their role in the international quest to understand the fundamental laws of nature. On 15 May, the Senate of the Helmholtz Association of German Research Centres announced that it will grant €25 m in funding over the next five years to support the Helmholtz Alliance, Physics at the Terascale, in a proposal led by the DESY research centre. In this alliance, DESY – together with Forschungszentrum Karlsruhe, 17 universities and the Max Planck Institute for Physics in Munich – will bring together existing competencies in Germany in the study of elementary particles and forces.

At the same time, the Helmholtz Alliance will provide the basis to drive technological advancement in a much more focused way. This new initiative comes at a time when German particle physicists are making large contributions to international collaborations at particle accelerators, such as the LHC at CERN, and a future International Linear Collider.


Alliance funds will finance more than 50 new positions for scientists, engineers and technicians during the initial five-year period. Junior scientists, in particular, will be given the opportunity to lead research groups with options for tenure positions. This is intended to open up attractive new perspectives for a future career in particle physics. Joint junior positions at all partner institutes, coordinated recruitment and teaching substitutes for researchers who are abroad will together provide a framework where it is possible for scientists to work away from their home institutes at large-scale international research centres without interfering with teaching provision.

The new network will enhance collaboration between universities and research institutes in data-analysis fields and the development of new technologies. Particular support will be given to the design of new IT structures, as well as detector and accelerator technologies that are of central importance for the sustainable development of particle physics in the future.

As a member of the alliance, DESY

will offer its facilities for testing and development of detector and accelerator technology, and 10 Helmholtz Alliance

positions will be opened at the laboratory. An analysis centre for LHC data will also be established at DESY.



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## Diamonds offer solution for quantum computers

Quantum computing relies on the ability to store and manipulate qubits (superpositions of 1 and 0), but this is not easy to do without losing coherence. Now, Mikhail Lukin and colleagues from Harvard University, Stuttgart University and Texas A&M University have made a huge breakthrough. Using optical and microwave manipulation of electron and nuclear spins associated with a nitrogen vacancy in diamonds, they have succeeded in creating a controllable quantum register.

Using the spins to store qubits and transfer them without loss of coherence even at room temperature, the team got them to interact coherently, having made use of the coupling

between the nitrogen-vacancy spin system and the nuclear spins of nearby carbon-13 nuclei, which naturally make up 1.1% of a diamond. Their observations indicate that when advanced nuclear magnetic resonance techniques are used, controlled manipulation of a few coupled nuclear spin qubits is possible with coherence times that can approach seconds. These registers could be used as a basis for scalable, optically coupled quantum information systems.

### Further reading

MV Gurudev Dutt *et al.* 2007 *Science* **316** 1312.

## Meditation improves attention

Many of the claimed benefits of meditation are often fairly subjective, but recent research shows a clear and measurable effect on attention. Richard Davidson and colleagues at the University of Wisconsin-Madison and Leiden University asked 17 volunteers to spend three months studying Vipassana meditation, which is supposed to help reduce distractions and enhance awareness through mental training.

Participants were asked, before and after their intensive meditation, to try to spot one or two numbers among a series

of letters flashed on a screen, with the two numbers coming as little as half a second apart. The results showed a boost in correct recognition of the second number, which increased from 60% of the time to as much as 90% (with an average of 80%). This seems to indicate that the brain can be trained to make use of its resources in more efficient ways.

### Further reading

HA Slagter *et al.* 2007 *PLoS Biology* **5** e138; doi:10.1371/journal.pbio.0050138.

## Lunar laser ranging does it better

The Gravity Probe B (GP-B) satellite was launched by NASA in 2004 to test, among other things, the effect predicted by general relativity that the Earth would drag inertial frames with it as it rotates. TW Murphy Jr of the University of California and colleagues have argued that as the frame-dragging effect is a consequence of gravitomagnetism it has already been confirmed by lunar laser ranging measurements in the Earth-Moon system to a higher accuracy than GP-B will provide. That said, the data from the sophisticated gyroscope system on GP-B

are still interesting since they will provide a very direct measurement. GP-B will also test a related general relativistic effect, the "geodetic effect", which is an additional gravitation-induced precession.

### Further reading:

TW Murphy Jr *et al.* 2007 *Phys. Rev. Lett.* **98** 071102.

SM Kopeikin 2007 *Phys. Rev. Lett.* **98** 229001.

TW Murphy Jr *et al.* 2007 *Phys. Rev. Lett.* **98** 229002.

## Muons see inside an active volcano

If you want to look at what lies inside a volcano, it turns out that cosmic rays may be just what you need. Hiroyuki Tanaka and colleagues from the University of Tokyo and Nagoya University have managed to use cosmic-ray muons to create a "radiograph" near the top of Mt Asama, one of the largest and most active volcanoes in Japan. They succeeded in measuring the internal structure of a newer crater region known as Mt Kama-yama, through the bulk of an older volcanic rim, Mt Maekake-yama.

Tanaka and colleagues used emulsion chambers with some shielding to help prevent exposure to the effects of lower-energy natural radioactivity. The approach is novel, a big advantage of emulsion chambers being that they need no electric power and are light enough to carry up a mountain. The technique has clear potential for monitoring active volcanoes from points that are not too close for comfort.

### Further reading

H KM Tanaka *et al.* 2007 *Nucl. Instrum. Methods Phys. Res. A* **575** 489.

## Cold fusion appears again

Cold fusion is one of those topics that just keeps coming back, most recently as reported in an article in *Naturwissenschaften*. Frank Gordon of the US Navy's Space and Naval Warfare Systems Center in San Diego and colleagues have reported new evidence for low-energy fusion in a palladium-deuterium film deposited on nickel. Not only do they get significant rises in temperature, but they find what seem to be nuclear tracks in CR-39, the etch-track detector familiar to particle physicists! Is there something interesting going on? Time and more experiments should eventually find out.

### Further reading

S Szpak, PA Mosier-Boss and FE Gordon, 2007 *Naturwissenschaften* **94** 511.

## Hubble detects ring of dark matter

Astronomers using the Hubble Space Telescope have discovered a ghostly ring of dark matter that formed during a titanic collision between two massive galaxy clusters. Because ordinary matter in the cluster shows no evidence of such a ring, this discovery is among the strongest evidence yet for non-baryonic dark matter.

Clusters of galaxies are the largest gravitationally bound structures in the universe. They typically contain hundreds or thousands of galaxies, forming at the knots of the filamentary sponge-like distribution of matter on very large scales. Numerical simulations show how the accretion of matter from the filaments to the knots make galaxy clusters grow in size. This one-dimensional accretion (along a filament) results in frequent, near head-on collisions among clusters or groups of galaxies, whereas interactions between individual galaxies usually occur only when there is significant rotation.

The galaxy cluster Cl 0024+17 – some  $5 \times 10^9$  light-years away ( $z=0.4$ ) – is supposed to have experienced exactly such a head-on collision 1 or 2 thousand million years ago. The first evidence of this was obtained in 2002 by Oliver Czoske, from the University of Bonn, and collaborators. By studying the velocity distribution of the galaxies in the cluster, they found two distinct groups with opposite velocity, suggesting that there are two sub-clusters moving away from each other along the line-of-sight. Their numerical simulations confirm



*This Hubble Space Telescope composite image shows in blue the ring-like dark matter distribution superimposed on the optical view of the galaxy cluster Cl 0024+17. (Courtesy NASA, ESA, MJ Jee and H Ford of Johns Hopkins University.)*

the collision scenario and suggest a sub-cluster mass ratio of 2:1.

In 2004, when Myungkook Jee from the John Hopkins University started to study the dark-matter distribution in Cl 0024+17, he was not aware that this was such a peculiar cluster of galaxies. He was at first annoyed when he saw the ring-like distribution because he had never seen such a pattern in other clusters, and thought it was an artefact. It is indeed

tricky to derive the dark-matter distribution in a cluster from the distortion it causes on the shape of background galaxies, but the analysis of this weak gravitational lensing now seems to be well under control, with the release of the first 3D map of the dark matter distribution (*CERN Courier* January/February 2007 p11).

The ring-like structure, which measures 2.6 million light-years across, is reminiscent of the famous Cartwheel Galaxy (*CERN Courier* March 2006 p12) shaped by a frontal collision with another galaxy. A similar scenario – but on the scale of galaxy clusters – is most likely at the origin of the dark-matter ring found by Jee and colleagues.

To validate this scenario, they performed a collisionless N-body simulation of the head-on interaction between two spherical dark-matter halos. The simulation shows how the cluster collision triggers a radially expanding shell of dark matter around each cluster core. These shells superimpose in projection on the sky to form the ring-like pattern.

The unique spatial distribution of this ring, compared with both the galaxies and the hot X-ray emitting gas in the cluster, is strong evidence for the existence of dark matter. It confirms a similar result found in the Bullet Cluster (*CERN Courier* October 2006 p9) and makes it difficult for any theory trying to reproduce the effect of dark matter by modified Newtonian dynamics (MOND).

### Further reading

MJ Jee *et al.* 2007 *Astroph. Journal* **661** 728.

### Picture of the month



This multiwavelength view of the nearby galaxy Messier 81 was obtained by combining observations in infrared, visible and ultraviolet light. This beautiful spiral galaxy is almost visible with the naked eye in the Great Bear (*Ursa Major*) constellation, which includes the seven stars forming the Big Dipper. The infrared view by the Spitzer Space Telescope and the ultraviolet image by the GALEX satellite were superimposed on the image from the Hubble Space Telescope. The infrared light (shown red in the image) reveals hot dust in the spiral arms heated by the intense ultraviolet radiation (shown in blue) emitted by young, massive stars. (Hubble data courtesy NASA, ESA and A Zezas of the Harvard-Smithsonian Center for Astrophysics; GALEX data courtesy NASA, JPL-Caltech, GALEX Team J Huchra *et al.* of the Harvard-Smithsonian Center for Astrophysics; Spitzer data courtesy NASA/JPL-Caltech/S Willner of the Harvard-Smithsonian Center for Astrophysics.)

# CERN COURIER ARCHIVE: 1964

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

**CERN**

## A busy summer season at the PS

On 29 July, the intensity of the circulating beam in the CERN proton synchrotron (PS) reached, for the first time,  $10^{12}$  (a million million) protons per pulse. Adopting the next prefix in the series (kilo-, mega-, giga-, etc), engineers at the PS are now talking of the intensity in terms of the “teraproton”. This intensity is a hundred times greater than the design figure.

### A bubble chamber...

In the second half of June, the British National Hydrogen Bubble Chamber successfully came into operation in the East bubble-chamber building of the CERN PS. Before the end of the first week, which had been allotted only for tests, several thousand photographs [of positive pion interactions] were accumulated for physicists in Durham and Turin, and the chamber's first scheduled experiment began the week after.

This new liquid-hydrogen bubble chamber is the largest so far operated in Europe. Although usually known as the 150 cm chamber, the British chamber in fact has a length of 60 inches, equivalent to 152.4 cm (that is, at room temperature, about 0.6 cm less at the operating temperature of  $-246^{\circ}\text{C}$ ). The chamber was built by the collaborative efforts of three British universities (Birmingham, Liverpool and London), the Rutherford High Energy Laboratory and the Department of Scientific and Industrial Research, at a cost of about £1 million (SwFr12 million).

In the first two weeks of full operation for physics experiments (25 June – 5 July), 100 000 pictures were obtained showing interactions of negative kaons of momentum 5.08 GeV/c [the  $\text{o}_2$  beam]. This experiment (T49) was for the “K collaboration” linking physicists in Birmingham, Glasgow, London (Imperial College) and Oxford Universities as well as groups at the Rutherford High Energy Laboratory and the Max-Planck Institute in Munich. In the third week (9–14 July), a further 40 000 pictures with  $\text{K}^-$  at 5.08 GeV/c were obtained and the beam line was then re-adjusted to give positive



Part of the equipment enclosure for the missing-mass spectrometer experiment in the South experimental hall of the proton synchrotron at CERN. In the foreground, the paper-tape punch and electronic typewriter can be seen, which are operated from the Mercury computer in the Data Handling laboratories; to their left is an automatic graph plotter also operated by the computer. The long flexible tube [top] provides ventilation in the area of the hydrogen target and the target can be watched by means of the television receiver that can be seen on the table behind the blackboard.

kaons at 5 GeV/c for the T55 experiment, in which groups at Cambridge (UK) and Brussels (Belgium), as well as at CERN, are collaborating. After a 10 hour rest to allow some emulsion and nuclear chemistry exposures in the  $\text{o}_2$  beam, the run ended (15–19 July) with another 66 000 pictures for the T49 experiment, this time using negative kaons at 6 GeV/c.

### ...and an online computer

The “missing-mass spectrometer” has been designed to carry out a systematic investigation of the unstable mesons (or meson “resonances”). This apparatus, which, incidentally, is of particular interest from the point of view of the development of experimental techniques at CERN, uses a hydrogen target, together with a collection of sonic spark chambers and scintillation counters to detect the incoming and outgoing particles. The electrical signals from the detection system are registered by electronic scalers, which translate them into numbers ready for recording (in an electrically coded form) on magnetic tape. The numerical data are also transmitted over a cable, 1.2 km long, to the “Mercury” computer, which carries out various calculations and transmits the results back to the physicists at the PS. This allows a constant check to be kept on the functioning of the apparatus and, more particularly, on the results being

obtained. The progress of the experiment is in fact determined by the kind of results that it gives. This is the first time that an experiment has been carried out at the PS “online” to a computer.

● Compiled from “Last Month at CERN” pp86-88 and pp102–104.

## COMPILER'S NOTE

With the advent of electronic counters and online computers, particle physics during the 1960s and 1970s was being liberated from dependence on photography. In their heyday, bubble chambers were enabling several momentous breakthroughs, despite some physicists suggesting that they would soon become obsolete. In February 1964, for example, one of the most famous bubble chamber pictures of all was taken with the 80 inch hydrogen bubble chamber at Brookhaven. It showed an  $\Omega^-$ , the “missing link” in the ordering of subatomic particles into the “eightfold way” or SU(3) symmetry, which clinched the argument for the existence of quarks. Almost a decade later, in 1973, the large heavy-liquid bubble chamber Gargamelle, at CERN's PS, revealed the first example of a neutral-current process, providing pivotal evidence for the unification of the electromagnetic and weak forces.

# Keeping antihydrogen: the ALPHA trap

Antimatter is difficult to make, let alone store. **Jeffrey Hangst** describes how ALPHA, an experiment attempting to trap antihydrogen at CERN, overcomes some of the difficulties and he questions the reality of ever making more than the tiniest amounts of antimatter.

Suppose, as the villain of a story, you absolutely needed to transport a macroscopic amount of antimatter, for whatever sinister purpose. How would you go about it and could you smuggle it, for example, into the Vatican catacombs? The truth is that we will probably never have a macroscopic amount of antimatter for such a scenario to ever become reality.

According to the preface to the popular novel *Angels and Demons* (2000), author Dan Brown was apparently inspired by the imminent commissioning of CERN's "antimatter factory", the Antiproton Decelerator (AD). The real-life AD has now been fully operational for about five years, and the experiments there have produced some notable physics results. One of the big stories along the way was the synthesis in 2002 of antihydrogen atoms by the ATHENA and ATRAP collaborations (*CERN Courier* November 2002 p5 and December 2002 p5, respectively).

This feat was an important step towards one of the ultimate goals of everyday antimatter science: precision comparisons of the spectra of hydrogen and antihydrogen. According to the CPT theorem, these spectra should be identical. To get an idea of what precision means in this context, take a look at the website of 2005 Nobel Laureate Theodor Hänsch, which has the following cryptic headline:  $f(1S-2S) = 2\,466\,061\,102\,474\,851(34)$  Hz. This may look like a cryptic puzzle appearing in Brown's fiction, but it simply means that the frequency of one of the  $n=1$  to  $n=2$  transitions in hydrogen has been measured with an absolute precision of about 1 part in  $10^{14}$ . This is impressive, but where do we stand with antihydrogen?

## Storing antihydrogen

Both ATHENA and ATRAP produced antihydrogen by mixing antiprotons and positrons in electromagnetic "bottles" called Penning traps (figure 1). Penning traps feature strong solenoidal magnetic fields and longitudinal electrostatic wells that confine charged particles. The antiprotons come from CERN's AD, and the positrons come from the radioactive isotope  $^{22}\text{Na}$ . The whole process involves cleverly slowing, trapping, and cooling both species of particles (Amoretti *et al.* 2002 and Gabrielse *et al.* 2002). But here's the rub: when the charged antiproton and positron com-



Fig. 1. ALPHA's Penning trap for catching antiprotons from CERN's AD. The stack of gold-plated electrodes is placed in a cryostat inside a superconducting solenoid magnet generating a field of up to 3 T. (Courtesy N Madsen/Swansea.)

bine, the neutral antihydrogen is no longer confined by the fields of the Penning trap, and the precious anti-atom is lost. The ATHENA experiment demonstrated antihydrogen production because it could detect the annihilation of the anti-atoms when they escaped the Penning trap volume and annihilated on the walls.

To study antihydrogen using laser spectroscopy, anti-atoms need to be sustained for longer. In the 1s–2s transition mentioned above, the excited state (2s) has a lifetime of about a seventh of a second; while in ATHENA, an anti-atom would annihilate on the walls of the Penning trap within a few microseconds of its creation. Thus, the next-generation antihydrogen experiments include the provision for trapping the neutral anti-atoms that are produced in a mixture of charged constituents.

The Antihydrogen Laser Physics Apparatus (ALPHA) collaboration has recently commissioned a new device designed to trap the neutral anti-atoms. ALPHA takes the place of ATHENA at the ▷

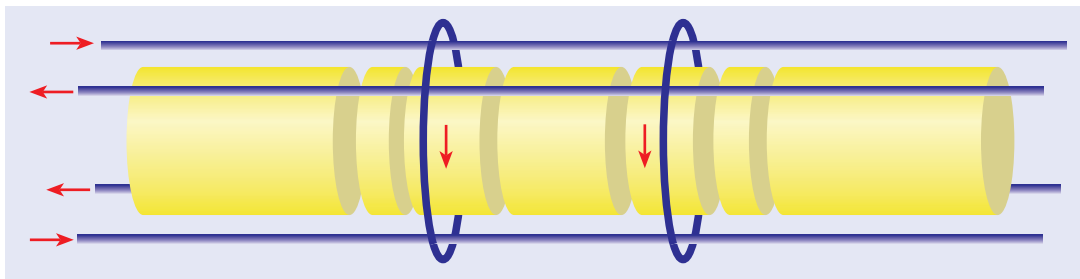


Fig. 2. Depiction of a Ioffe-Pritchard trap, surrounding the electrodes of a Penning trap for charged particles. The arrows show the direction of current flow in the magnetic coils.

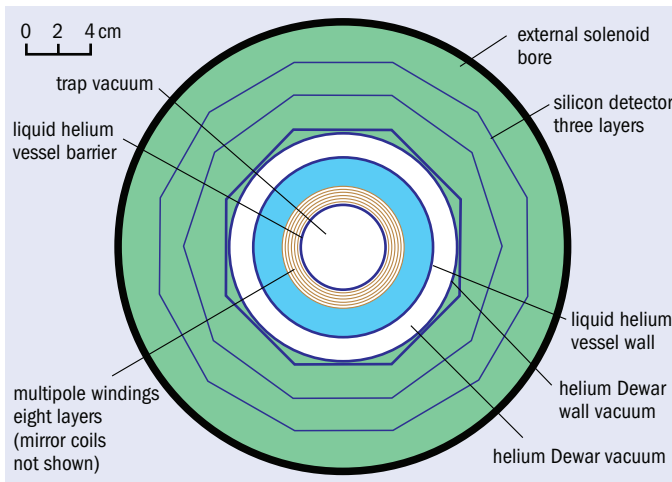


Fig. 3. Schematic cross-section of the ALPHA device.

AD and features five of the original groups from ATHENA (Aarhus, Swansea, Tokyo, RIKEN and Rio de Janeiro) plus new contributors from Canada (TRIUMF, Calgary, UBC and Simon Fraser), the US (Berkeley and Auburn), the UK (Liverpool) and Israel (Nuclear Research Center, Negev).

Neutral atoms – or anti-atoms – can be trapped because they have a magnetic moment, which can interact with an external magnetic field. If we build a field configuration that has a minimum magnetic field strength, from which the field grows in all directions, some quantum states of the atom will be attracted to the field minimum. This is how hydrogen atoms are trapped for studies in Bose-Einstein condensation (BEC). The usual geometry is known as an Ioffe-Pritchard trap (figure 2). A quadrupole winding and two solenoidal “mirror coils” produce the field to provide transverse and longitudinal confinement, respectively. Figure 2 also shows the electrodes that provide the axial confinement in the Penning trap for the charged antiprotons and positrons. The idea is that the antihydrogen produced in the Penning trap is “born” trapped within the Ioffe-Pritchard trap – if its kinetic energy does not exceed the depth of the trapping potential.

This is a big “if”. A ground-state hydrogen atom has a magnetic moment that gives us a trap depth of only about 0.7 K for a magnetic well depth of 1 T. The superconducting magnetic traps that we can build and squeeze into our experiments will give 1–2 T of well-depth for neutral atoms. All antihydrogen experiments to date occur in devices cooled by liquid helium at 4.2 K, but there are strong indications that the antihydrogen produced by direct mixing of antiprotons and positrons is warmer than this, with temperatures of at least hundreds of kelvin. ATRAP has devised a laser-assisted method of producing antihydrogen that may give

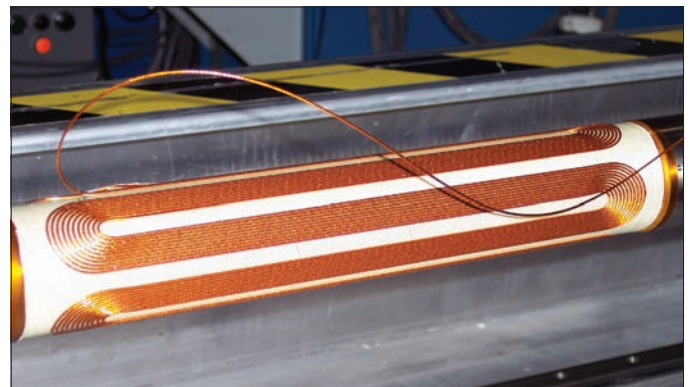


Fig. 4. The ALPHA octupole being wound at Brookhaven. The superconducting cable is fixed to an adhesive substrate using ultrasonic energy. The magnet has eight layers, similar to the one shown here. (Courtesy J Escallier/BNL.)

colder atoms, but their temperature has not yet been measured. (Note that the highly excited antihydrogen atoms produced in both experiments can have significantly larger magnetic moments, thus experiencing higher trapping potentials. The trick, then, is to keep them around while they decay to the ground state.) Both groups are investigating new ways to produce colder anti-atoms, and the 2007 run at the AD (June–October) promises to be revealing.

### Designer magnets

A second important issue facing both collaborations is the effect on the charged particles of adding the highly asymmetric Ioffe-Pritchard field to the Penning trap. Penning traps depend on the rotational symmetry of the solenoidal field for their stability. As ALPHA collaborator Joel Fajans of Berkeley initially pointed out, the addition of transverse magnetic fields to a Penning trap can be a recipe for disaster, leading either to immediate particle loss, or to a slower, but equally fatal, loss due to diffusion. Fajans’ solution, adopted by the ALPHA collaboration, is to use a higher-order magnetic multi-pole field for the transverse confinement. A higher-order field can, in principle, provide the same well-depth as a quadrupole while generating significantly less field at the axis of the trap, where the charged particles are confined.

To construct such a magnet, the ALPHA collaboration surveyed the experts in fabrication of superconducting magnets for accelerator applications. It turns out that the Superconducting Magnet Division at the Brookhaven National Laboratory (BNL) had previously developed a technique that is almost tailor-made to our needs. The key here is to use the proper materials in the construction of the magnet. To detect antiproton annihilations, ALPHA incorporates a three-layer silicon vertex detector similar to those

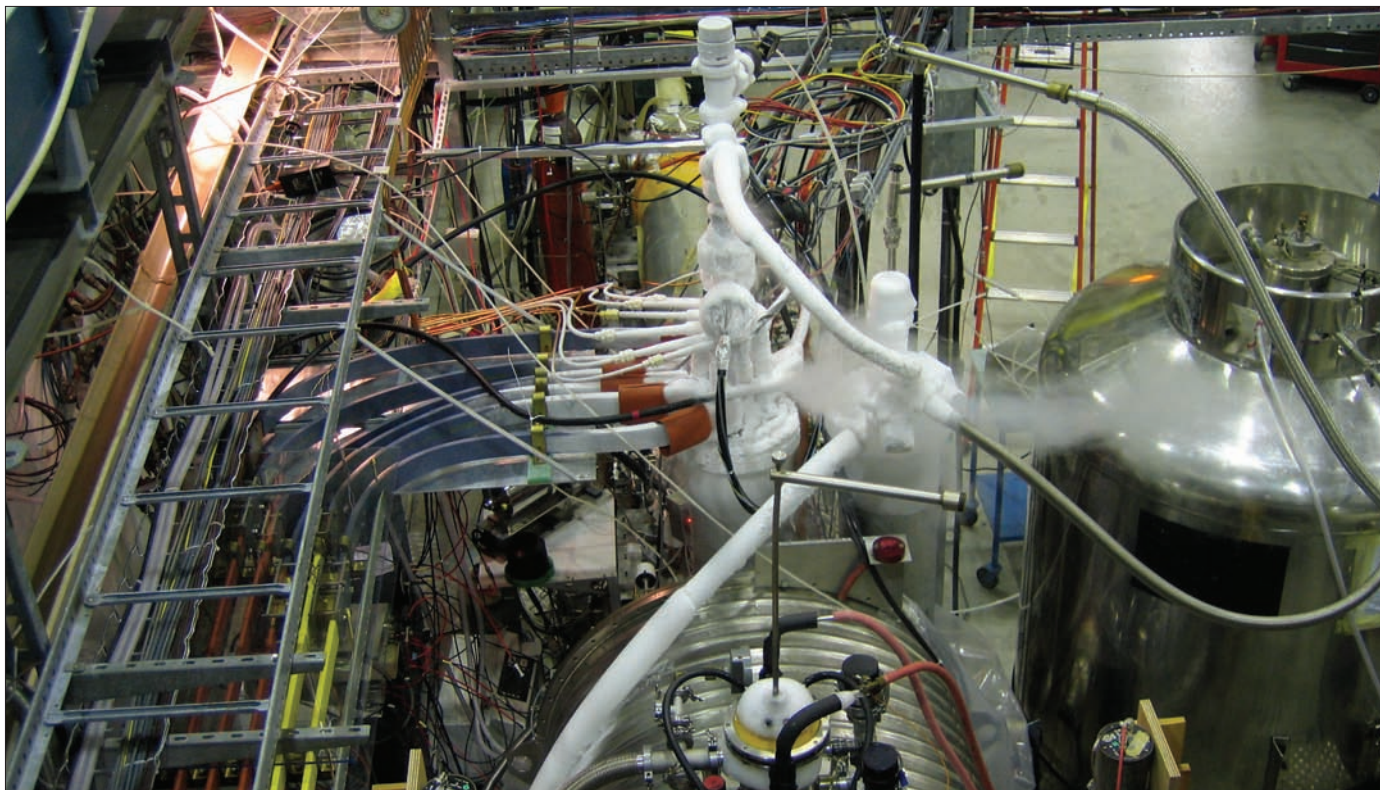


Fig. 5. The working ALPHA device. The corrugated pipe is the superconducting solenoid for the Penning traps. (Courtesy N Madsen.)

used in high-energy experiments (figure 3). However, the annihilation products (pions) must travel through the magnets of the atom trap before reaching the silicon. Therefore, it is highly desirable to minimize the amount of material used in the magnet construction to minimize multiple scattering between the vertex and the detector. So bulky stainless-steel collars for containing the magnetic forces, as used in the Tevatron or the LHC, cannot be used.

The Brookhaven process uses composite materials to constrain the superconducting cable that forms the basis of the magnet. Using a specially developed 3D winding machine, the team at BNL was able to wind an eight-layer octupole and the mirror coils directly onto the outside of the ALPHA vacuum chamber (figure 4). The mechanical strength is provided by pre-tensioned glass fibres in an epoxy substrate. Only the superconducting cable is metal.

The new ALPHA device (figure 5) was designed and constructed during the AD shutdown of November 2004 to July 2006 and commissioned during the physics run at the AD in July–November 2006. The Brookhaven magnets performed beautifully, demonstrating that charged antiprotons and positrons can be stored in the full octupole field for times far exceeding those necessary to synthesize antihydrogen. We even made the first preliminary attempt to produce and trap antihydrogen in the full field configuration; but we have yet to observe evidence for trapping.

Meanwhile, the ATRAP collaboration worked hard to commission a new quadrupole trap for antihydrogen and succeeded in storing clouds of antiprotons and electrons in their new device. The 2007 physics run at the AD promises to be an exciting one for antihydrogen physics. Both ALPHA and ATRAP should have operational devices that are capable – in theory – of trapping neutral antimatter for the first time.

### Back to Dan Brown

So let's look at what is possible in experiments with antimatter today, leaving the speculation to aficionados of sci-fi and NASA. If you wanted to take antimatter to the offices of your national funding agency, you might consider taking some antiprotons, since most of the mass-energy of an antihydrogen atom is in the nucleus. This might be tempting, since our charged-particle traps are certainly deeper than those for neutral matter or antimatter. ATRAP and ALPHA initially capture antiprotons in traps with depths of a few kilo-electron-volts, corresponding to tens of millions of kelvin. But, density is an issue. A good charged-particle trap for cold positrons has a particle density of about  $10^9 \text{ cm}^{-3}$ . Antiproton density is much smaller, but we'll be optimistic and use this number. So to transport a milligram of antiprotons – of the order of  $10^{21}$  particles – you would need a trap volume of  $10^{12} \text{ cm}^3$ , or  $10^6 \text{ m}^3$ . That means a cube 100 m wide, which will not fit in your luggage. Incidentally, a milligram of antimatter, annihilating on matter, would yield an energy equivalent to about 50 tonnes of TNT.

So, what about transporting some neutral antimatter? Neutral atom traps certainly have higher densities. The first BEC result for hydrogen at MIT reported a density in the order of  $10^{15} \text{ cm}^{-3}$  for about  $10^9$  atoms in the condensate. This is better, but still far less than a milligram, even if you can get the atoms from a gas bottle. The size of the trap is now down to  $10^5 \text{ cm}^3$ , which is more manageable. Note, however, that the BEC transition in this experiment was at  $50 \mu\text{K}$  – far below the 4.2 K that we hope to achieve with antihydrogen. Unfortunately, to get really cold and dense atomic hydrogen requires using evaporative cooling – throwing hot atoms away to cool the remaining ones in the trap. This implies damaging your lab before you send the surviving, trapped antiatoms to ▷

# Cryogenic Valves



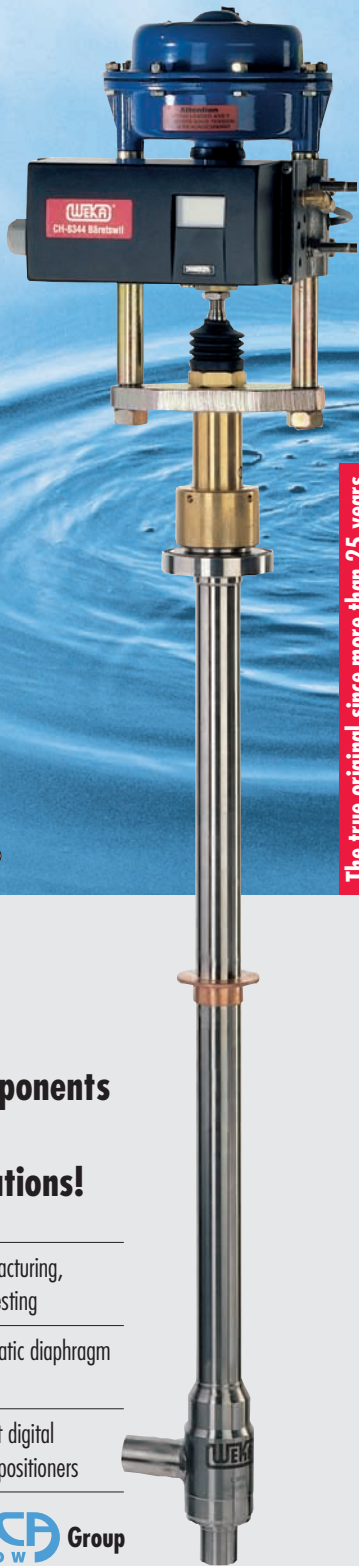
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## ANTIMATTER

their final, cataclysmic fate. And don't forget that the total history of antiproton production here on Earth amounts to perhaps a few tens of nanograms in the past 25 years or so. Unfortunately, the antiproton production cross-section is unlikely to change.

How many anti-atoms can we trap? The Japanese-led ASACUSA experiment, using an extra stage of deceleration after the AD, can trap around a million of the 30 million decelerated antiprotons that the AD delivers every 100 s or so (*CERN Courier* March 2005 p8). Suppose we could make all of these into antihydrogen (in comparison, ATHENA achieved about 15%). The trapping efficiency for neutral anti-hydrogen is anybody's guess at this point – we would be grateful for 1%. This is why the very notion of having a dense cloud of interacting antihydrogen atoms will bring a weary smile to the face of anyone working in the AD zone. Using the above figures, it would take us  $10^{19}$  s – about 300 billion years – to accumulate just one milligram. One might also question if anyone could engineer a device reliable enough to safely contain an explosive quantity of anti-matter – not in my lab, thanks.

Back down to the sober reality here at CERN, we would be happy just to demonstrate trapping of antihydrogen in principle. This means initially trapping just a few anti-atoms – not making a BEC or antihydrogen ice. The future of our emerging field seems to depend on this, although ASACUSA is developing a plan to do spectroscopy on antihydrogen in flight. Time will tell which approach proves more promising. Two things are certain: the real technology of antimatter production and trapping lags far behind Dan Brown's imagination; and the Vatican is safe from us.

### Further reading

More on the ALPHA experiment at <http://alpha.web.cern.ch/alpha>.  
M Amoretti *et al.* (ATHENA collaboration) 2002 *Nature* **419** 456.  
G Andresen *et al.* (ALPHA collaboration) 2007 *Phys. Rev. Lett.* **98** 023402.

W Bertsche *et al.* (ALPHA collaboration) 2006 *Nucl. Instr. Meth. Phys. Res. A* **566** 746.

M Charlton and JS Hangst 2005 *Physics World* October 2005 p22.  
G Gabrielse *et al.* (ATRAP collaboration) 2002 *Phys. Rev. Lett.* **89** 233401.

### Résumé

*Conserver l'antihydrogène: le piège ALPHA*

*Il est déjà difficile de fabriquer de l'antimatière; la stocker est encore plus difficile. Les expériences ATHENA et ATRAP menées au CERN fabriquaient de l'antihydrogène en mélangeant des antiprotons et des positrons dans un «piège» électromagnétique, mais une fois constitué l'antihydrogène neutre pouvait s'échapper. La nouvelle expérience ALPHA, menée au Décélérateur d'antiprotons au CERN, va piéger l'antihydrogène en utilisant la méthode Ioffé-Pritchard. L'un des éléments-clés est un aimant supraconducteur innovant où sont utilisés des matériaux composites au lieu d'acier pour contenir les forces magnétiques. L'article évoque également la possibilité de fabriquer un jour plus que des quantités infinitésimales d'antimatière.*

**Jeffrey Hangst**, University of Aarhus, Denmark, ALPHA spokesperson and former ATHENA physics coordinator.



# Carbon ions pack a punch

During a recent CERN workshop on hadron therapy, renowned oncologist Hirohiko Tsujii talked to **Carolyn Lee** about the success of hadron therapy in fighting cancers.

Hirohiko Tsujii is director of the Research Center for Charged Particle Therapy, at the National Institute of Radiological Sciences (NIRS), in Chiba, Japan. He is known internationally for his work on treating cancer with carbon ions and is the first doctor to have treated patients using hadron therapy in a clinical environment. Japan is the first country to have a heavy-ion accelerator for medical purposes, built as part of a national 10-year strategy for cancer control. Since the Heavy Ion Medical Accelerator in Chiba (HIMAC) opened in 1994, the facility has provided treatment for more than 3000 patients with various cancers and has resulted in a significant increase in the number of survivors after treatment. Recently, the Committee of Senior Officials for Scientific and Technical Research (COST) and the European Network for Research in Light-Ion Hadron Therapy (ENLIGHT) invited Tsujii as guest of honour at the COST-ENLIGHT workshop on hadron therapy, held at CERN on 3–4 May.

Tsujii has three decades of experience in developing hadron therapy as a novel treatment for cancer. The deposited radiation dose for charged hadrons (protons and heavier ions) rises to a peak near the end of the particle's range. The aim with hadron therapy is to use this effect to irradiate tumours, while sparing healthy tissue better than with X-rays (*CERN Courier* December 2006 p17). "Before working at NIRS, I was involved with proton-beam therapy at Tsukuba University," he says. Tsujii also worked on research for pion treatment in the US, where the use of pions in cancer therapy was pioneered at Los Alamos in co-operation with New Mexico University. "The biological effect was not as high as expected and it was also claimed that pions could produce a very nice distribution in the human body," he explains. "However, compared with hadron therapy, such as with protons or carbon ions, the distribution was not that good. Eventually it was decided to stop the study that used pions."

Japan is a major pioneer of hadron therapy. Each year, 650 000 people in the country are diagnosed with cancer and the number is expected to increase to 840 000 by 2020. Deep-seated tumours are the most challenging type of cancer and Tsujii has developed a special interest in treating them. Tumours found in the lungs, cervix, head and neck, liver, prostate, or bone and soft tissue, for



*Hirohiko Tsujii, the first oncologist to treat patients with hadron therapy, presented the results from his clinical studies at the COST-ENLIGHT workshop at CERN in May.*

example, are often treated with hadron therapy as they can be difficult to operate on and conventional radiotherapy is not always as effective.

"The reason we at NIRS decided to use carbon ions rather than protons is that it is the most balanced particle. It has the property of providing a constant treatment to the tumour and also has a higher biological effect on the tumour," explains Tsujii. This means that the carbon-ion beam can be more focused on the tumour, resulting in the greatest cell damage to the tumour with less injury to the surrounding healthy tissue. "Of course, as the mass of the particle increases there is a higher relative biological effectiveness (RBE). But the ratio of RBE between the peak to plateau [before the peak] gets worse when using a particle with a higher mass. Therefore, when considering the biological effect,

the carbon ion is the most balanced."

After treating more than 3000 patients, Tsujii feels that it has been a good decision to use carbon ions in cancer treatment. "There was a lot of discussion in deciding what particle would be best. We decided to choose carbon ions and, for the time being, I am satisfied with this decision." It took several years before coming to the optimum level of treatment with carbon ions. The local control for almost all types of tumours is 80–90%, and after choosing the optimal level of treatment the local control is expected to be more than 90%.

"Another point that I want to focus on is the use of 'hypofractionated' radiotherapy," says Tsujii. A patient treated with photons – X-ray treatment – will, on average, require about 30–40 fractions (doses) over 6–7 weeks. With carbon ions, the treatment can be given in a single day (just one dose or fraction) for stage I lung cancer while cervical and prostate cancer or other large tumours require only 16–20 fractions against around 40 fractions using conventional treatment. "It is important to note that there is a minimal toxicity to healthy cells. At the beginning we had some severe toxicity, but we analysed the treatment and techniques, and completely overcame the problem we had when we initially started the studies."

As chair of the Particle Therapy Co-operative Group, an international group that coordinates all hadron therapy (such as ▷

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## INTERVIEW

protons and carbon ions), Tsujii sees the future development of carbon-ion therapy as the more popular choice for oncologists. Even the name of this group suggests the changes taking place. Once the Society for Proton Beam Therapy, the name now reflects increased development in high-energy radiation with carbon ions.

"I believe that many parts of radiotherapy will be replaced by carbon therapy – it is just simpler in terms of smaller fractions to apply to the patient, compared with photons. It is a rather complicated procedure with carbon ions, but as each part of the procedure is established, once it is decided, the necessary technique is fixed. This means that we can apply the more reliable technique to the patient's treatment," says Tsujii.

For small tumours, the results with carbon ions or photons may be similar, such as in early-stage lung cancer, where the tumour is smaller than 3 cm in diameter. If the tumour is larger, then carbon ions prove to be the better treatment. "We are especially interested in the treatment of tumours in the pelvis or spinal area, which are often difficult to treat with surgery, and we have focused on treating bone and soft-tissue sarcoma – large tumours of 10–15 cm diameter – and we are very satisfied with the improved local control and longer survival rates," says Tsujii.

Tsujii has not seen a single case of radiation-induced cancer among the patients treated since starting the carbon-ion treatment for cancer 13 years ago. There is a possibility of some cancer being induced by carbon-ion irradiation, but the distribution close to the target area is much better than in traditional treatment. However, the risks of developing radiation-induced cancer are probably similar for both treatments.

The cost of building these kinds of facilities is something that many governments are considering, including Germany and Italy (*CERN Courier* December 2006 p17). Japan has started a new carbon-ion therapy facility and two proton therapy facilities at a cost of around €100 m, while in Germany and Italy, new facilities with dual capabilities for using carbon ions and protons are expected to open in 2008, at a cost of €90 m each. Tsujii's pioneering work seems certain to be expanded to other parts of the world.

### Further reading

For further information about the COST-ENLIGHT workshop see <http://enlight.web.cern.ch/enlight/Cost-enlightMay07.htm>.

### Résumé

*Les ions carbone contre le cancer*

*Hirohiko Tsujii, directeur de l'Institut national des sciences radiologiques de Chiba (Japon), est connu au niveau international pour ses travaux sur le traitement du cancer par les ions carbone. Il a été le premier à traiter des patients par hadrothérapie dans un environnement clinique, et le Japon est le premier pays à avoir construit un accélérateur d'ions lourds à des fins thérapeutiques. Le centre en question a traité plus de 3000 patients. Hirohiko Tsujii a été récemment l'hôte d'honneur de l'atelier COST-ENLIGHT sur l'hadrothérapie tenu au CERN. Dans cet entretien, il parle à Carolyn Lee des succès obtenus par l'hadrothérapie dans la lutte contre le cancer.*

**Carolyn Lee**, CERN.

# VERITAS telescopes celebrate first light

The latest in a series of VHE gamma-ray telescopes has come on line in Arizona. It will study gamma-ray sources ranging from supermassive black holes to dark matter.



The four VERITAS telescopes at the Whipple Observatory. (Courtesy Steve Criswell, Smithsonian Astrophysical Observatory.)

For three days in late April, collaboration members gathered with invited guests and the general public to celebrate the completion of the Very Energetic Radiation Imaging Telescope Array System (VERITAS). Located near Mount Hopkins in southern Arizona, the new array joins HESS in Namibia, MAGIC in the Canary Islands and CANGAROO-III in Australia in the exploration of the gamma-ray skies at energies from 100 GeV to beyond 10 TeV. The First Light Fiesta included a one-day scientific symposium, a well-attended public lecture, public tours of the new detector and a formal inauguration ceremony followed by an outdoor banquet.

## Cherenkov astronomy

VERITAS is the latest stage in the evolution of very-high-energy (VHE) gamma-ray astronomy, a field where many aspects are closer to particle physics than to traditional astronomy. The basic idea is to use the Earth's atmosphere as the "front end" of the detector, much like a calorimeter in a collider experiment. At high energies, gamma rays initiate extensive air showers in the upper atmosphere, and relativistic particles in these showers radiate Cherenkov photons that penetrate to ground level. An imaging detector located anywhere in the light pool can use the size and pattern of hits in its camera to reconstruct the energy and direction of the shower and, by extension, the primary particle that spawned it. This is the principle of the imaging atmospheric

Cherenkov telescope (IACT). The effective area of the detector is the size of the light pool, which is of the order of 100 000 m<sup>2</sup>.

The main background comes from charged cosmic rays, energetic protons and light nuclei, which typically outnumber gamma rays by a factor of more than 1000. These can be rejected by using differences in the morphology of gamma-initiated and hadron-initiated showers that are manifest in the image at the camera's focal plane. Indeed, it is the cosmic-ray rejection power afforded by multiple views of the shower that has motivated the construction of the modern arrays of IACTs.

The basic technique traces back to the early 1950s, when pioneering measurements were made using instruments built with war-surplus searchlight mirrors. Following a long learning curve, the Whipple collaboration announced the detection of the first VHE source, the Crab Nebula, in 1989. The detector used a 10 m mirror and a pixellated camera, allowing the use of imaging to improve the signal-to-noise ratio. The Crab Nebula, a strong and steady source with a spectrum extending to beyond 50 TeV, has since become the "standard candle" in the field.

During the 1990s, more imaging Cherenkov detectors were built as interest in high-energy gamma-ray astronomy intensified around the world. This was partly because the Compton Gamma-Ray Observatory had been placed in orbit and was discovering dozens of sources at giga-electron-volt energies. Notable ▷



One of the four VERITAS 12m telescopes near Mount Hopkins in Arizona, showing the camera box, tessellated mirror and counterweights. (Courtesy David Hanna, McGill University.)

among the second-generation detectors was HEGRA, an array of five small telescopes constructed on La Palma in the Canary Islands, which demonstrated the power of “stereo” observations.

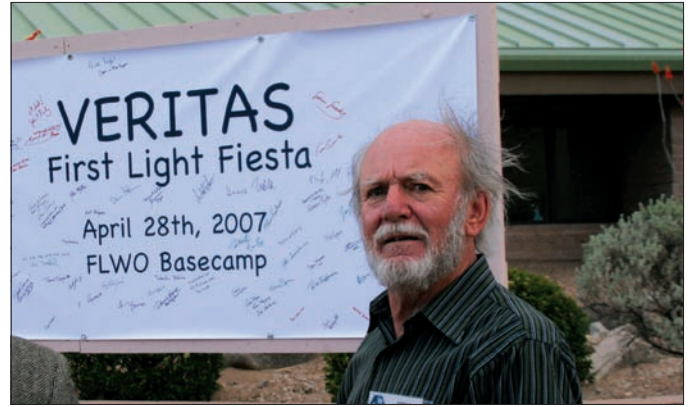
Towards the end of the decade, plans began for a third generation of detectors, exploiting the advantages of arrays from large reflectors viewed by fine-grained cameras. The VERITAS collaboration, with members from institutes in the US, Canada, Ireland and the UK, combined the original Whipple group with new collaborators from gamma-ray, cosmic-ray and particle-physics research. Together, they proposed a detector for southern Arizona, built a prototype at the Whipple Base Camp in the summer of 2003 and obtained funding for a four-telescope array later that year.

The final array consists of four IACTs, each of which uses a 12-m-diameter mirror to focus light onto a camera comprising 499 close-packed 29 mm photomultiplier tubes (PMTs). Each mirror is tessellated, with 350 identical hexagonal facets mounted on a steel frame. PMT pulses are digitized by custom-built 500 MS/s flash analogue-to-digital converters and readout is initiated by a three-level trigger, which starts with discriminators on each channel, proceeds to pattern recognition in each camera and finally makes an array-based decision.

### First and future light

Although the First Light ceremony was held in April, VERITAS has been making observations in a variety of configurations since 2003, as each telescope has been commissioned. The first stereo observations were made in 2006 when the second telescope was completed and came in time to detect the blazar Mrk 421 in an active state. More importantly, VERITAS detected a similar source, Mrk 501, during a quiescent phase with a flux of only 0.8 gammas per minute. Such a measurement had not been possible with only one VERITAS telescope. During the 2006–2007 observing season, with two and then three telescopes, VERITAS has measured phase-dependent variable VHE flux from the microquasar candidate LSI+61303, and has detected VHE gamma rays from the giant radiogalaxy M87, as well as the distant active galaxy 1ES 1218+30.4. Analysis of these and other topics are well in hand for the summer conferences, and the collaboration presented its preliminary findings at the First Light symposium.

The fourth telescope was completed in early 2007 and the array



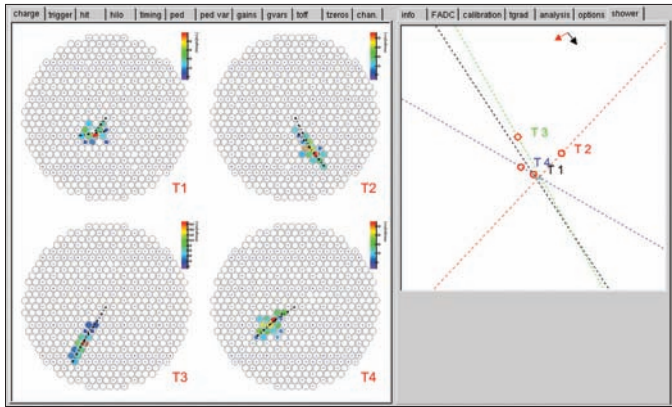
Trevor Weekes, one of the pioneers of very-high-energy astronomy and founder of the VERITAS collaboration. (Courtesy Ken Gibbs, Smithsonian Astrophysical Observatory.)

is now the most sensitive gamma-ray telescope in the northern hemisphere. It is able to make a  $5\sigma$  detection of a source with a flux level a tenth that of the Crab Nebula in under an hour (the original Whipple detection of the Crab Nebula required more than 50 hours). In the energy range from 100 GeV to 30 TeV, VERITAS's effective area is greater than 30 000 m<sup>2</sup> and its energy resolution is 10–20%. Single-event angular resolution is better than 0.14°, and sources with reasonable flux will be located to better than 100 arc-seconds. The 3.5° field of view, with off-axis acceptance above 65% out to 1° from the centre, will allow sky surveys as well as the mapping of extended sources.

In contrast to collider experiments, where data on different physics topics are accumulated simultaneously with different triggers, telescopes are pointed instruments and a scheduling committee decides where they point. For the first two years of observations, VERITAS will spend half of the available hours on four Key Science Projects (KSPs). The remaining time will be given over to observations proposed by groups within the collaboration.

One KSP is a survey of part of the Milky Way visible from the northern hemisphere, which will search for new sources with fluxes greater than about 5% of the Crab Nebula. Another KSP is an indirect search for dark matter. WIMPs could cluster in gravitational wells such as nearby dwarf galaxies or globular clusters and then annihilate, producing a continuum of gamma rays that may be strong enough to be seen by VERITAS. Although less direct than a search for supersymmetric particles at an accelerator, the gamma-ray technique targets a larger range of candidate masses.

Another KSP concerns galactic sources such as pulsar-wind nebulae and supernova remnants (SNRs), while yet another deals with extragalactic sources known as active galactic nuclei (AGNs). SNRs are interesting because they could possibly be the source of most galactic cosmic rays. With the new-generation detectors, their morphologies can be resolved and this will aid in the understanding of particle acceleration models. Gamma rays from AGNs are thought to originate in their relativistic plasma jets, which are powered by accretion of host-galaxy material by a supermassive black hole. These sources are notoriously time-variable, so the plan is to conduct multi-wavelength campaigns using contemporaneous X-ray, optical and radio observations to uncover the physics processes at work in these high-energy objects.



Online display of a shower measured by VERITAS. Left: the camera images from each telescope. Right: the impact point of the shower core (intersection of dashed lines), along with the telescope positions. (Courtesy Gernot Maier, McGill University.)

All observations will be pre-empted when a gamma-ray burst (GRB) occurs in a visible part of the sky and VERITAS turns its attention to it. The telescope is connected to a network that relays GRB detections from spacecraft and the array can slew to any part of the sky at a rate of 1°/s.

Later this year the Gamma-ray Large Area Space Telescope (GLAST) should join the hunt for high-energy gamma rays from a vantage point in orbit around the Earth. With its wide field of view

and sensitivity in energy from 20 MeV to more than 100 GeV, it will provide complementary data and increase the scientific reach of the new ground-based observatories. After many years of design, construction and commissioning, the VERITAS collaboration anticipates a rewarding future.

**Further reading**

For more about VERITAS see <http://veritas.sao.arizona.edu>.

**Résumé**

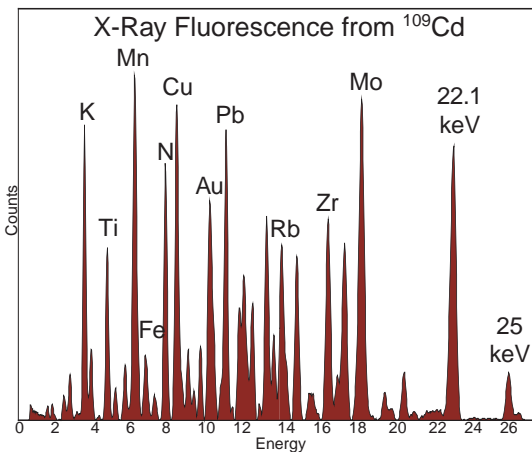
*Inauguration de VERITAS*

*Le dernier en date des télescopes à rayons gamma de très haute énergie est entré en service. Situé dans le sud de l'Arizona, VERITAS est constitué de quatre télescopes détectant le rayonnement Tchérenkov créé lorsque des rayons gamma de très haute énergie donnent naissance à des gerbes de rayons cosmiques dans l'atmosphère. Explorant les ciels de rayons gamma à des énergies allant de 100 GeV à plus de 10 TeV, VERITAS étudiera des sources de rayons gamma allant des trous noirs supermassifs à la matière noire. L'inauguration de l'installation a eu lieu en avril, mais VERITAS réalise en fait des observations depuis 2003 avec la mise en service des différents télescopes.*

David Hanna, McGill University.

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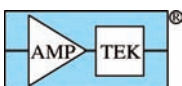
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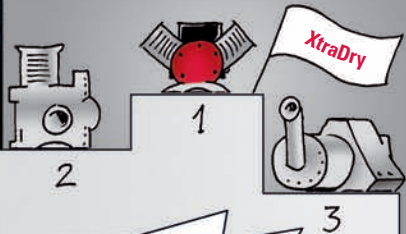
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vacuum dreams!

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# DIS 2007: physics at HERA and beyond

The latest workshop on deep-inelastic scattering looked at the high-precision studies being made during the last days of HERA at DESY and considered the challenges for the future.

Exceptionally beautiful weather, Munich's Holiday Inn hotel and the Gasteig, a modern cultural centre, combined to provide a pleasant and stimulating atmosphere for DIS 2007, the 15th International Workshop on Deep-Inelastic Scattering (DIS) and Related Subjects. Held on 16–20 April, the workshop united more than 300 physicists from around the world, including an encouraging number of students. The programme contained reviews of progress in DIS and QCD, as well as presentations of the latest results from HERA, the Tevatron, Jefferson Lab, RHIC and fixed-target experiments. It also covered related theoretical topics and future experimental opportunities.

With two full days of plenary sessions and six streams of parallel sessions on the other three days, the meeting followed the traditional style of DIS workshops. The parallel sessions covered structure functions and low- $x$  physics, electroweak measurements and physics beyond the Standard Model, heavy flavours, hadronic final states, diffraction and spin physics. A special session that looked to the future of DIS was particularly topical in view of the shutdown at DESY of HERA, the world's only electron–proton collider, at the end of June.

Yuri Dokshitzer, of the University of Paris VI and VII, opened the scientific programme with a review of recent developments in perturbative QCD (pQCD). He explained his motto “1-loop drill, 2-loop thrill, 3-loop chill” and expressed the hope that higher-order corrections can be calculated with the help of  $N=4$  super-Yang–Mills quantum field theory.

## Latest results

Appetizing glimpses of the many new results from the two collider experiments at HERA featured in talks by Christinel Diaconu from the Centre for Particle Physics in Marseille, and by Massimo Corradi of INFN Bologna, for the H1 and ZEUS experiments, respectively. Both experiments have accumulated a total of  $0.5 \text{ fb}^{-1}$  at a proton beam energy of 920 GeV, and analyses of the entire data sample are in full swing. The first H1 and ZEUS combined analysis of  $xF_3$  was a clear highlight of the conference (figure 1). This is the structure function that is dominated by photon– $Z$  interference and is sensitive to the valence quarks at low Bjorken- $x$ .

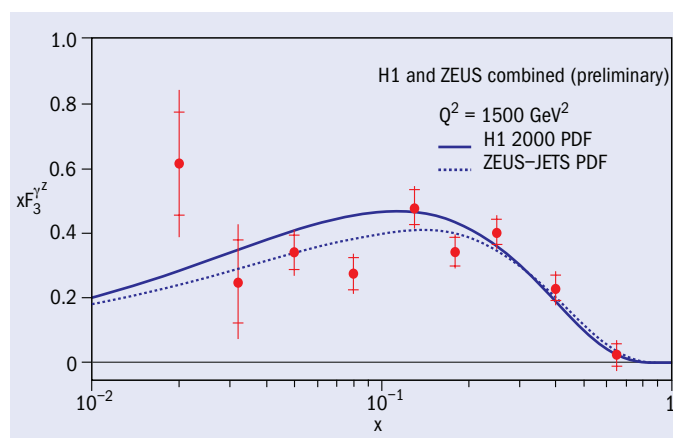


Fig. 1. Plots showing the measurement of the structure function  $xF_3$  from HERA, combining data from both H1 and ZEUS.

Further highlighted results included new data on neutral-current and charged-current inclusive scattering, jets and heavy-flavour production. These data will serve as input for the next generation of more precise fits for parton distribution functions (PDFs) for the proton – essential for studying physics at the LHC at CERN.

Since mid-March the proton beam energy at HERA has been lowered to 460 GeV to enable, in conjunction with the high-energy data at 920 GeV, a model-free determination of the longitudinal structure function  $F_L$ . This measurement is essential for a direct extraction of the gluon distribution within the proton and as a consistency check of DIS theory. Beyond the Standard Model, H1 continues to see, with the full statistics at high energy, the production of isolated leptons at a level of  $3\sigma$  above the expectation. In contrast, ZEUS sees no deviation from the Standard Model.

With the Tevatron proton–antiproton collider at Fermilab performing well, Giorgio Chiarelli of INFN Pisa was able to show a sample of beautiful new results from the CDF and  $D\bar{0}$  experiments. For this conference, he presented data corresponding to up to  $2 \text{ fb}^{-1}$ , covering neutral B-meson oscillations, electroweak physics, jets, searches and results on the production of the top quark, with a new world average for its mass of  $170.9 \pm 1.8 \text{ GeV}/c^2$ . This new  $\triangleright$



Flags of Bavaria (far left), the city of Munich (centre) and Germany (far right) fly together with banners for DIS 2007, outside Munich's Gasteig, where the plenary sessions took place. (Photos courtesy Daniel Kollar/MPI Munich.)

new (low) value is interesting since, together with the mass of the W particle, it favours the minimal supersymmetric model.

William Zajc from Columbia University addressed current understanding of particle production in heavy-ion collisions, as studied at RHIC at Brookhaven National Laboratory (BNL). He highlighted several interesting experimental observations, such as “away-side” jet suppression, that cannot be described within current models, but which may be interpreted as a signal for the production of a nearly perfect, highly viscous quark–gluon fluid.

Turning to spin physics, Jörg Pretz from the University of Bonn gave an overview with emphasis on the nucleon spin puzzle. He presented recent data on helicity distributions for quarks ( $\Delta q$ ) and gluons ( $\Delta G$ ), from the HERMES experiment at DESY and COMPASS at CERN, respectively, as well as direct measurements of  $\Delta G$  from RHIC. He also showed the first combined results on transversity using data from both HERMES and COMPASS as well as from the BELLE experiment at KEK. In a related overview of the rich programme at Jefferson Lab, Zein-Eddine Mezani of Temple University in Philadelphia covered measurements of unpolarized and polarized structure functions and transversity, as well as deeply virtual Compton scattering and generalized parton distributions.

### Theoretical input

Andreas Vogt of Liverpool University spoke about progress and challenges in determining and understanding the PDFs of the proton in next-to-leading order (NLO) and next-to-NLO. An important improvement in the extraction of PDFs, implemented by the Coordinated Theoretical–Experimental Project on QCD (CTEQ), is the inclusion of the effects of charm-mass suppression in DIS, which results in an increase in the PDFs for the u and d quark. A dramatic consequence is an increase by about 8% of the W/Z cross-sections expected at the LHC. Rates of W/Z events are foreseen to serve as precision “luminosity meters” for the LHC data-taking.

Gustav Kramer of Hamburg University discussed recent developments in heavy-flavour production and explained the various heavy-flavour schemes used for pQCD calculations. He stressed the importance of interpolating schemes with variable-flavour



Participants listen to the after-dinner speech in the dramatic setting of the Luftfahrtthalle at Munich's Deutsches Museum.

number and massive heavy quarks (like the general-mass variable-flavour-number scheme) and showed successful comparisons of calculations with data from HERA and the Tevatron.

To allow comparison with experiment, pQCD calculations usually need to be implemented in Monte Carlo generators. Zoltan Nagy from CERN covered this important subject and critically reviewed the various approximations of current implementations of parton showers and their matching to leading order or NLO matrix elements. Nagy expressed concern that current Monte Carlo tools might fail at the LHC and he argued for the development of a new shower concept that allows the shower to be matched to Born and NLO matrix elements.

Raju Venugopalan from BNL covered small-x physics and the expected non-linear effects beyond the conventional Dokshitzer–Gribov–Lipatov–Altarelli–Parisi evolution. He discussed the question of saturation in the context of various models (e.g. colour glass condensate) and data from HERA and RHIC. He also pointed to excellent opportunities at a possible future electron–ion collider (EIC) or even at a “super-HERA” collider such as a large hadron–electron collider (LHeC).

Peter Weisz and Johanna Erdmenger, both from MPI Munich, discussed non-perturbative aspects of QCD. Weisz presented recent algorithmic advances and various results in lattice QCD, indicating progress in the simulation of dynamical quarks beyond the quenched approximation. Erdmenger looked at new approaches that connect string theory and QCD by establishing a connection between a strong coupling (non-perturbative) theory, such as  $N=4$  SYM (“QCD”), and a “dual” weak coupling theory, such as supergravity. Such a relation – the anti-de Sitter/conformal field theory correspondence – can provide new tools to address problems within QCD.

The seven threads of parallel sessions contained a total of 260 talks. Despite the wonderful weather, the sessions had very good attendance, with many lively and fruitful discussions. The spontaneous formation of two additional topical sessions was very much in the spirit of the workshop. One of these was on  $\alpha_s$  measurements from HERA and LEP, and one was on the complications involved



when dealing with a variable number of quark flavours in QCD fits. On the last day the convenors, usually a theorist and an experimentalist for each working group, summarized the parallel sessions.

### Life after HERA

Concluding a special session on the future of DIS, Joel Feltesse of DAPNIA gave a detailed and critical view of future opportunities in DIS. In his opinion DIS will not stop with the end of data-taking at HERA. There is Jefferson Lab with its upgrade to 12 GeV and new machines, such as the EICs at Jefferson Lab and BNL, are on the horizon. An LHeC at CERN would offer an attractive physics programme, particularly if the LHC provides an additional physics case for it. The workshop itself concluded with a talk from Graham Ross from Oxford University. He discussed open questions beyond the Standard Model, which provide motivation for the next round of high-energy physics experiments at the LHC.

For the coming years, much careful analysis remains to be done with the data from HERA to achieve the best possible precision. This is expected to yield valuable information for the understanding of QCD and of the data to be produced at the LHC. HERA's final legacy will be an important asset to high-energy physics. Although the LHC will, we hope, find the Higgs boson and "explain" the mass of gauge bosons, quarks and leptons, it remains the case that the mass of hadronic matter – about 99% of the mass of the visible universe – is entirely dominated by effects due to the strong interaction between gluons and quarks. Deep-inelastic

scattering is the tool to study these interactions. It remains to be seen how much progress will be achieved in the future without new data from an electron–hadron collider.

### Further reading

For the full programme and slides from the presentations see [www.mppmu.mpg.de/dis2007/](http://www.mppmu.mpg.de/dis2007/). Proceedings will be available online via open access this autumn.

### Résumé

*DIS 2007: la physique de HERA et au-delà*

*Le dernier atelier en date d'une longue série sur la diffusion profondément inélastique s'est tenu à Munich en avril. Au programme, des rapports sur les progrès faits dans le domaine de la diffusion profondément inélastique et de la chromodynamique quantique, ainsi que des exposés sur les derniers résultats de HERA, de Tevatron, du Laboratoire Jefferson, du RHIC et des expériences avec cibles fixes. Ont été abordés également divers sujets théoriques et futures expériences possibles dans ce domaine. Une séance spéciale, consacrée à l'avenir de la discipline, était tout particulièrement d'actualité, dans la perspective de la fermeture à la fin du mois de juin de HERA, l'unique collisionneur électron–proton au monde.*

**Günter Grindhammer and Christian Kiesling, MPI Munich.**

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# Heavy-ion workshop looks to the future

At a meeting in central Finland in March, physicists warmed up for the challenges of jet physics in heavy-ion collisions at the LHC.



Workshop participants close to the bridge leading to the physics department at the University of Jyväskylä. (Courtesy Jan Rak.)

When the LHC starts up, heavy-ion physics will enter an era where high transverse-momentum ( $p_T$ ) processes contribute significantly to the nucleus–nucleus cross-section. The LHC will produce very hard, strongly interacting probes – the attenuation of which can be used to study the properties of the quark–gluon plasma (QGP) – at sufficiently high rates to make detailed measurements. At the LHC, high rates are for the first time expected at energies at which jets can be fully reconstructed against the high background from the underlying nucleus–nucleus event.

To prepare for the new high  $p_T$  and jet analysis challenges, the physics department at the University of Jyväskylä, Finland, organized the five-day Workshop on High  $p_T$  Heavy-Ion Physics at the LHC. More than 60 participants attended the workshop, ranging from senior experts in heavy-ion physics to doctoral students. It brought together physicists from operating facilities – mainly RHIC at the Brookhaven National Laboratory (BNL) – as well as from future LHC experiments (ALICE, ATLAS and CMS), and included

valuable contributions from theorists. Jyväskylä in early spring, coupled with reindeer-meat dinners and animated student lectures in the evening, created a superb atmosphere for many discussions of physics, even outside of the official programme.

Mike Tannenbaum of BNL gave an opening colloquium which looked back to the 1970s. He listed old results that raised the same questions that are the focus of today's discussions. Many recent questions in high- $p_T$  physics can be traced back to the 1970s at CERN, with proton–proton (pp) collisions at the ISR, which were followed in the early 1980s by proton–antiproton collisions at the SPS. This was when jet physics was born and the first methods of jet analysis were developed. It was reassuring to learn that many CERN results remain valid and that recent thinking is really based on those early understandings. On the other hand, many ideas still remain in a premature state. Only the high-luminosity experiments at RHIC and the LHC are – or will be – able to investigate certain phenomena and measure their effects ▷

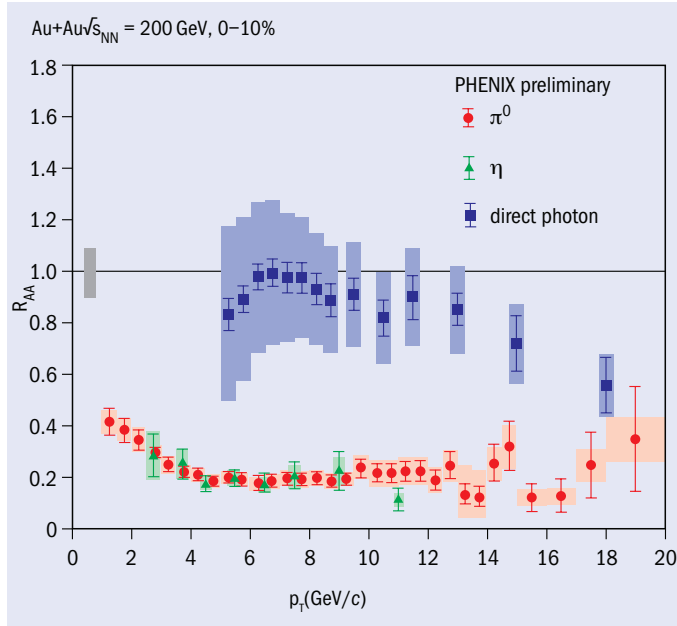


Fig. 1. One of the striking effects observed at RHIC: strong suppression of high- $p_T$  pions ( $\pi$ ) and etas ( $\eta$ ) in gold-gold collisions [PHENIX 2006 Phys. Rev. Lett. **96** 202301] and no or moderate suppression of direct photons.

more precisely. These pp data are therefore very important, not merely because they serve as a baseline for understanding results in heavy-ion collisions.

### Striking gold at RHIC

Several presentations at the workshop reviewed results from RHIC on single-particle spectra and two-particle correlations at high  $p_T$ . Striking effects have been observed in central gold-gold collisions. Among the most prominent are the suppression of high- $p_T$  particles and the suppression of back-to-back correlations. These results show that the jet structure is strongly modified in dense matter consistent with perturbative QCD calculations of partonic energy loss via induced gluon radiation.

The first photon data have shown no nuclear effects up to 10–12 GeV/c, in line with the general expectation that photons (with no colour charge) have no final-state interaction with the deconfined matter that is produced. However, the recent measurement by the PHENIX experiment indicates unexpected suppression, by a factor of two, of photon production in the region above 15 GeV/c – this is almost as large as in the case of light mesons (figure 1). This surprising observation ignited great excitement at the workshop, leading to further discussion of what the possible consequences for LHC physics might be. Any detailed study, however, should await the release of the final data.

Data on heavy flavours from RHIC experiments have also provided puzzles. The measured suppression of heavy-flavour  $p_T$  spectra, which is close to that of light flavours, cannot be explained by radiative energy loss alone and requires a contribution from elastic scattering. Further issues can be addressed by analysis of dijet topology or by the use of two- or multi-particle correlation techniques. Several experimental and theoretical presentations given at the meeting examined the possibility of using multi-

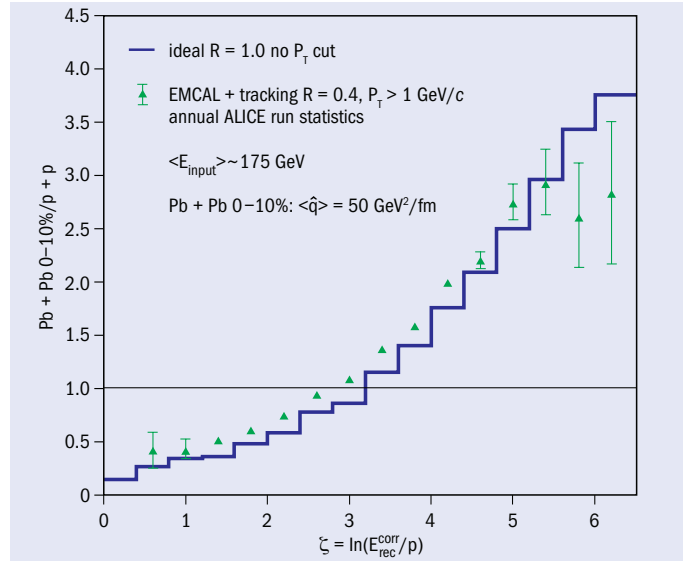


Fig. 2. At the LHC jet structure modifications can be observed with reconstructed jets. Shown here is the expected ratio of fragmentation functions measured in central Pb-Pb and pp. Radiative energy loss leads to a reduction of particles carrying a high momentum fraction and an increase of low-momentum particles from gluon radiation.

particle correlation and photon-hadron correlations to study the partonic  $p_T$  distributions, fragmentation functions, jet shape and other parton properties sensitive to the details of parton interactions with excited nuclear matter.

Another series of talks investigated the features of the parton coalescence process, which is supported by a large amount of experimental data on particle spectra and asymmetrical flow production. On the other hand, jet-orientated analysis of different data (for example,  $\Omega^-$ -charged hadron correlations) does not show the behaviour expected from quark coalescence. Therefore, further work is needed to understand this puzzling situation before the new experiments begin at the LHC.

### Towards the LHC

Among the four large LHC experiments, ALICE is the one that is optimized for heavy-ion physics. The CMS and ATLAS collaborations have also established a heavy-ion programme, which will certainly strengthen the field. The workshop heard about the capabilities of the three experiments for jet reconstruction and analysis of jet structure. The large background from the underlying event is a challenge for all experiments, requiring the development of new techniques for background subtraction. The strength of the ATLAS and CMS experiments is their full calorimetric coverage, and therefore large measured jet rates, which will allow them to measure jets in central lead-lead collisions up to 350 GeV and to perform  $Z^0$ -jet correlation studies. ALICE will use the combination of its central tracking system and an electromagnetic calorimeter to measure jets. The smaller acceptance of the detector will limit the energy range to about 200 GeV. The strength of ALICE lies in its low- $p_T$  and particle identification capabilities. These allow ALICE to measure fragmentation functions down to small momentum fractions and to determine the particle composition of jets (figure 2).

A consistent theoretical approach to describe jet measurements in heavy-ion collisions can only be obtained through detailed Monte Carlo studies of jet production and in-medium modifications. They are needed to optimize the data analysis and to discriminate between different models. Some new event-generators adopted for the challenges of LHC physics (PyQuench, HydJet, HIJING-2) were also discussed during the meeting.

The workshop also examined the recent interest in understanding strongly interacting particles using conjectures from string and higher-dimensional physics. Stan Brodsky of SLAC gave a summary of his understanding of the many QCD effects that appear in kinematical regions not testable by perturbative QCD, where anti-de Sitter space/conformal field-theory models could come into consideration. In the duality picture, due to Juan Maldacena, the intensively interacting quark and gluon fields produced in heavy-ion collisions can be treated as a projection into the higher dimensional black-hole horizon. The equation of motion on the black-hole horizon could become analytically solvable in contrast to the vastly complicated numerical (lattice) approach in non-perturbative QCD theory. The new experiments at LHC energies may shed more light on the role of extra dimensions in curved space and could initiate a revolution in the description of strongly interacting matter.

• The next workshop on this topic will be in Budapest in March 2008 and will offer the opportunity to display the latest theoretical results before the LHC is running with pp collisions at 14 TeV.

### Further reading

For more information see [www.jyu.fi/science/laitokset/fysiikka/en/research/conferences/lhc07](http://www.jyu.fi/science/laitokset/fysiikka/en/research/conferences/lhc07).

The proceedings will be published in the PoS at SISSA.

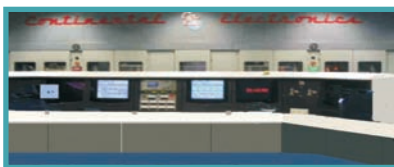
### Résumé

*Atelier sur les ions lourds*

*Les physiciens se sont penchés sur les difficiles questions de la physique des jets dans les collisions d'ions lourds au LHC, à l'occasion d'une réunion tenue en Finlande centrale en mars. Plus de 60 participants étaient présents à cet atelier de cinq jours, qui a rassemblé des physiciens de différents horizons, travaillant pour la plupart sur le RHIC, au Laboratoire national de Brookhaven, ou sur les futures expériences du LHC, sans oublier les contributions de nombreux théoriciens. Parmi les sujets abordés, les effets intéressants déjà découverts dans les collisions or-or au RHIC ou encore le rôle des dimensions supplémentaires dans la description de la matière à interaction forte.*

**Kari J Eskola**, University of Jyväskylä and Helsinki Institute of Physics, **Péter Lévai**, Theoretical Physics Department, MTA KFKI RMKI, Budapest, **Andreas Morsch**, CERN, **Jan Rak**, University of Jyväskylä and Helsinki Institute of Physics, and **Vesa Ruuskanen**, University of Jyväskylä.

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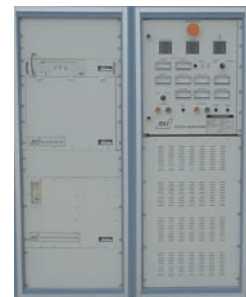
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# LHCb prepares for a RICH

In searching for new physics hidden in the behaviour of charm and beauty quarks, the LHCb exper

When the LHC starts up at CERN, it will provide proton collisions at higher energies than any previous accelerator and at high collision rates. While these conditions should reveal new high-energy phenomena, such as the Higgs mechanism and supersymmetry, they will at the same time open a different window onto new physics through the study of rare processes among existing particles in the Standard Model. This is the territory that the Large Hadron Collider beauty (LHCb) experiment will explore.

By undertaking precision studies of the decays of particles that contain heavy flavours of quarks (charm and beauty), LHCb will stringently test our knowledge of the Standard Model. In addition, these studies will search for new particles beyond the Standard Model through their virtual effects – just as the mass of the top quark was known well before it was directly observed. The results will provide a profound understanding of the physics of flavour and will cast more light on the subtle difference between matter and antimatter that is manifest in CP violation.

The LHCb detector looks very different from the average hadron collider detector – indeed, it looks more like a fixed-target detector (figure 1) – because of its focus on heavy flavour particles. This choice of detector geometry is motivated by the fact that, at high energies, both B(D) and  $B(\bar{D})$  hadrons are produced at predominantly low angles and in the same “forward” cone. The detector geometry is optimized to detect these forward events efficiently.

LHCb's physics programme depends on being able to distinguish between the particle species produced so good particle identification is a fundamental requirement. The LHCb detector contains calorimeters and muon chambers to identify electrons, photons and muons. But to separate pions, kaons and protons in selected decays, a powerful different technique comes into play. This is the ring imaging Cherenkov (RICH) detector, first proposed at CERN in 1977 by Jacques Séguinot and Tom Ypsilantis, who was a member of the LHCb collaboration until his death in 2000 (Séguinot and Ypsilantis 1977; *CERN Courier* October 2000 p48).

The basic idea is that when a charged particle passes through a medium faster than the speed of light in that medium, it will emit Cherenkov radiation (named after the 1958 Nobel prize winner Pavel Cherenkov, who was the first to characterize the radiation rigorously). The effect is like a shock wave of light similar to the sonic boom of an aircraft travelling faster than the speed of sound.

This radiation is emitted at an angle to the direction of motion of the particle, forming a cone of light around the particle's track. The angle of emission,  $\theta$ , depends on the velocity of the particle but not on its mass, with  $\cos\theta = 1/n\beta$ , where  $n$  is the refractive index of the medium and  $\beta$  is the velocity relative to the velocity of light in free space,  $c$ . Combining this velocity information with a measurement of the momentum of the particle (using tracking

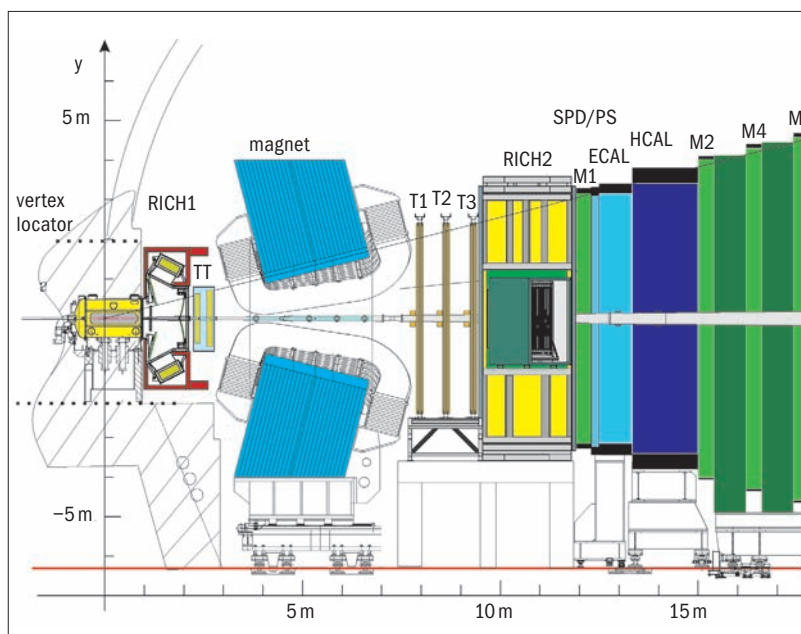


Fig. 1. (Left) The basic layout of LHCb. The interaction point is to the left, and the centre of the detector. Fig.2. (Right) The layout of RICH1 shows how the detector plane. In this way, cones of light about the particle tracks propagate at an early stage to tilt the focusing mirrors slightly and introduce second

detectors and a known magnetic field), yields the mass of the particle and therefore its identity.

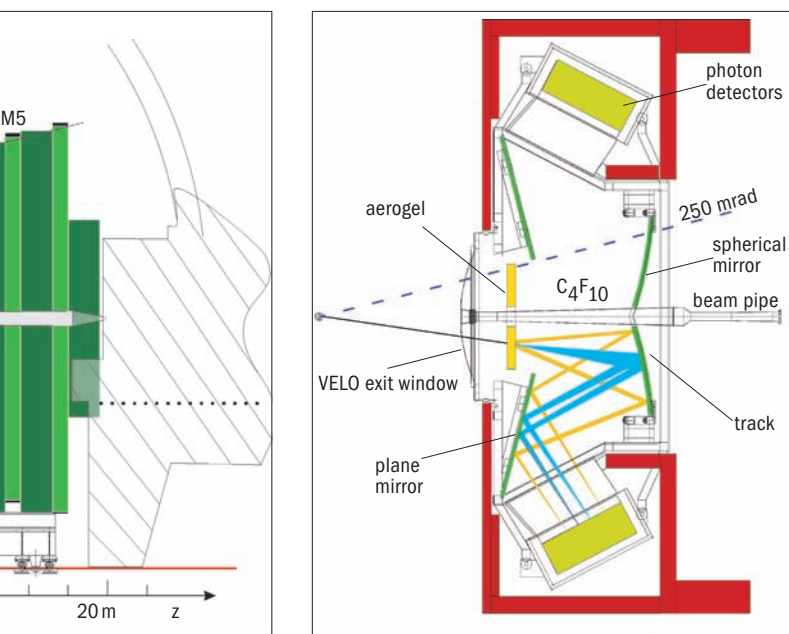
The simplest Cherenkov detectors are threshold devices that only produce a signal if the velocity of a charged particle exceeds the minimum necessary to produce Cherenkov radiation in a particular medium, or “radiator”. Taken together with a momentum measurement, this allows particles that are heavier than a certain mass to be separated from lighter ones. Such detectors have been employed in many experiments since the 1950s, for example in the classic detection of the antiproton at Berkeley – an experiment in which the young Ypsilantis participated (*CERN Courier* November 2005 p27).

## Rings and radiators

The RICH detector is a far more sophisticated development. In a RICH device, the cone of Cherenkov light emitted in the radiator is detected on a position-sensitive photon detector. This allows the reconstruction of a ring or disc, the radius of which depends on the emission angle,  $\theta$ , and hence on the velocity of the particle. In the RICH used by LHCb, the photons are collected by a spherical mirror and focused onto an array of photon detectors at the focal plane (figure 2 shows the principal in LHCb's RICH1 detector). By

# H harvest of rare beauty

Experiment will depend on a powerful technique to identify particles produced in collisions at the LHC.



within the vertex locator (VELO), and the LHC beam pipe passes through the spherical mirrors bring Cherenkov light at different angles to focus at produce rings of different radius at the detector. The designs were changed to use planar mirrors to keep the structure more compact.

focusing the radiation, the photons will form a ring with a radius that depends on the emission angle,  $\theta$ , but not on where the light is emitted along the particle track.

The choice of which radiator to use is crucial, as every medium has a restricted velocity range over which it can usefully identify particles. Too low a velocity, and the particle will produce no light; too high, and the Cherenkov angle for all particle species will saturate to a common value, making identification impossible. It was therefore important for LHCb to choose a medium, or combination of different media, that would be effective over the full momentum range of interest – from around 1 GeV/c, up to and beyond 100 GeV/c. To achieve this coverage, the experiment uses a combination of three radiators – aerogel, perfluoro-n-butane ( $C_4F_{10}$ ) and carbon tetrafluoride ( $CF_4$ ).

Silica aerogel is a colloidal form of quartz solid, but with an extremely low density and a high refractive index (1.01–1.10), which makes it perfect for the lowest-momentum particles (order of a few GeV/c). One of the key design issues for LHCb was the use of aerogel in ring-imaging mode. This was a new idea, inspired by the development of much higher-quality, very-clear aerogel (figure 3). Previously, the material had only been used in threshold counters. To cover the regions of medium and high momentum,

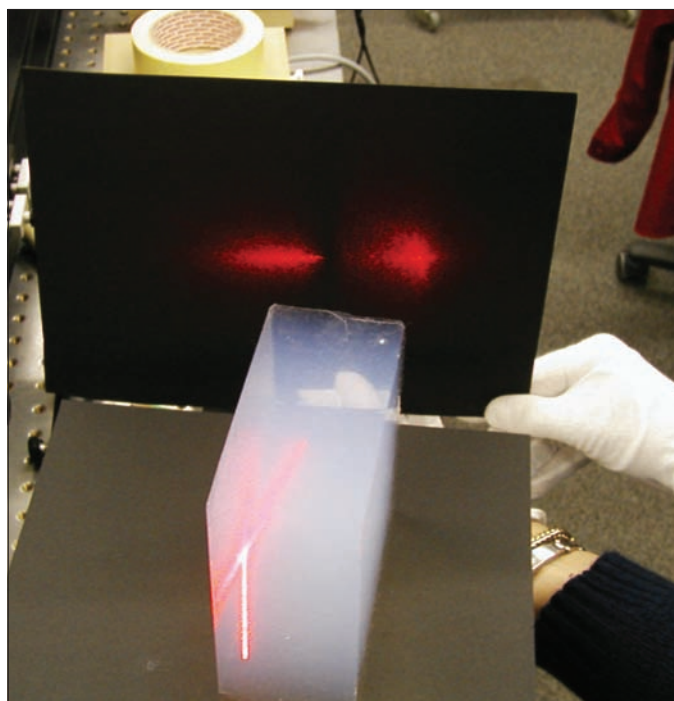


Fig. 3. A laser beam passes through silica aerogel, which has a very low density. (Courtesy INFN/LHCb Milano-Bicocca group.)

LHCb uses a combination of  $C_4F_{10}$  and  $CF_4$  radiators for momenta from around 10 GeV/c to around 65 GeV/c, and from around 15 GeV/c to more than 100 GeV/c, respectively.

The early design of the system had three separate detectors, one for each radiator, but for a variety of reasons it proved more practical to combine the aerogel and  $C_4F_{10}$  radiators into a single device with wide acceptance. This is the RICH1 detector, which is located upstream to detect the low-momentum particles (figure 1). The  $CF_4$  radiator is housed in RICH2, downstream of the tracking system and the LHCb magnet. This has an acceptance that is limited to the low-angle region where there are mostly high-momentum particles.

One challenge in both cases, was to minimize the amount of material within the detector acceptance. Therefore, the designs were changed at an early stage to tilt the focusing mirrors slightly and to introduce secondary flat mirrors that bring the Cherenkov radiation right out of the detector acceptance. This allows for a smaller photon-detector area and a more compact system.

A more radical redesign took place later, as the engineering designs for the various subdetectors became more realistic. It became clear that LHCb had too much material and needed re-designing. The challenge was also to improve the trigger

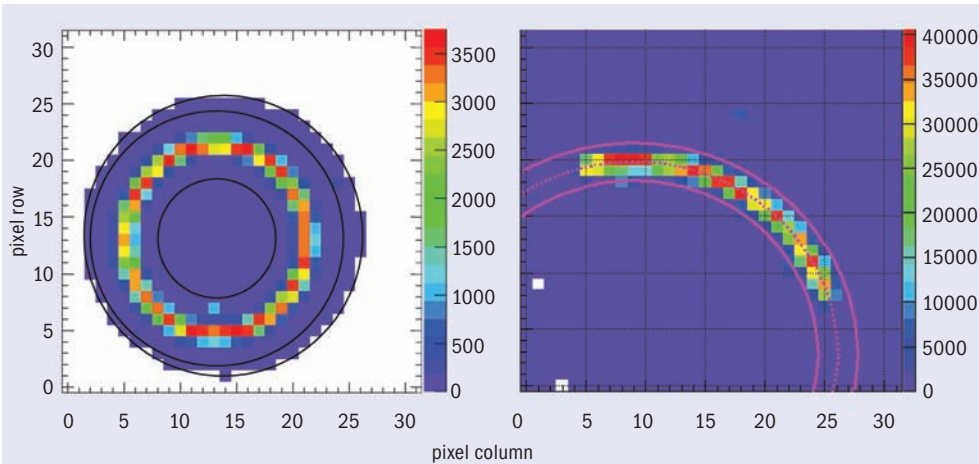


Fig.4. Left: a single HPD detector reveals a complete ring of Cherenkov light from test beam particles in nitrogen gas. Right: the larger Cherenkov angle in a  $C_4F_{10}$  radiator means that a single HPD sees only part of a ring. In both cases, the images show the cumulative effects of several particles following the same path in the test beam.

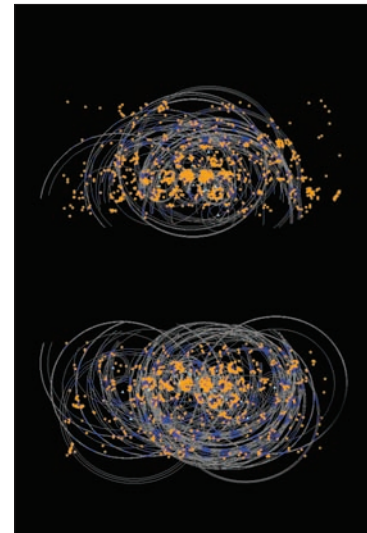


Fig.5. Simulation of rings from LHC events in RICH1.

performance by increasing the precision of the momentum measurement, and this required increasing the magnetic field in the region of the VERtix LOcator (VELO) and the trigger tracker (TT) between RICH1 and the dipole magnet (see figure 1).

While RICH2 remained relatively unaffected, RICH1 underwent a major redesign. To protect the sensitive photon detectors from the greatly increased magnetic field, extremely heavy iron shielding had to be added to the apparatus. Accommodating these shields in the very congested region of LHCb's experimental area near RICH1 was a major challenge.

### Seeing the light

Particles produced in the collisions in LHCb will travel through the mirrors of RICH1 prior to reaching measurement components further downstream. To reduce the amount of scattering, RICH1 uses special lightweight spherical mirrors constructed from a carbon-fibre reinforced polymer (CFRP), rather than glass. There are four of these mirrors, each made from two CFRP sheets moulded into a spherical surface with a radius of 2700 mm and separated by a reinforcing matrix of CFRP cylinders. The overall structure contributes about 1.5% of a radiation length to the material budget of RICH1. As RICH2 is located downstream of the tracking system and magnet, glass could be used for its spherical mirrors, which in this case are composed of hexagonal elements (see cover).

Perhaps surprisingly, the "flat" secondary mirrors in the RICH detectors are not truly flat. Producing completely flat, but thin, mirrors is a difficult technological challenge because it is hard to maintain their rigidity over a long period of time. Instead, giving the mirrors a small amount of curvature (a radius of curvature greater than 600 m in RICH1 and around 80 m in RICH2), increases their structural integrity. The small distortions that this curvature introduces to the images of the Cherenkov ring can be corrected with software during data analysis, and therefore do not degrade the final performance of the system.

Both RICH detectors use hybrid photon detectors (HPDs) to measure the positions of the emitted Cherenkov photons. The HPD is a vacuum photon detector in which a photoelectron, released

when an incident photon converts within a photocathode, is accelerated by a high voltage of typically 10–20 kV onto a reverse-biased silicon detector. The tube focuses the photoelectron electrostatically – with a demagnification factor of around five – onto a small silicon detector array.

The LHCb collaboration has developed a novel dedicated pixel-HPD for the RICH detectors, working in close co-operation with industry. Here, the silicon detector is segmented into 1024 "super" pixels, each  $500\ \mu\text{m} \times 500\ \mu\text{m}$  in area and arranged as a matrix of 32 rows and 32 columns. When a photoelectron loses energy in silicon, it creates electron-hole pairs at an average yield of one for every 3.6 eV of deposited energy. The nominal operating voltage of LHCb's HPDs is –20 kV, corresponding to around 5000 electron-hole pairs released in the silicon. Careful design of read-out electronics and interconnects to the silicon detector results in a high efficiency for detecting single photoelectrons. The experiment requires 484 tubes in total – 196 for RICH1 and 288 for RICH2 – to cover the four detection surfaces.

### Testing times

To verify the quality of the HPDs and the associated components in the low-level data acquisition (DAQ), the LHCb collaboration has conducted a series of RICH test-beam exercises, most recently during September 2006 in the North Area at CERN's Prévessin site. In the test beam, the apparatus consisted of a gas vessel filled with either nitrogen ( $N_2$ ) or  $C_4F_{10}$  as the radiator medium, together with a housing for the photo-detectors that was separated from the gas enclosure by a transparent quartz window. The test beam from the SPS consisted mainly of pions, with small contributions from electrons, kaons and protons, and had a 25 ns bunch-structure; the same as will be provided by the LHC.

Columns of 16 HPDs observed the Cherenkov radiation emitted by the particles as they traversed the gas enclosure. The ring of Cherenkov light illuminated either one HPD, when using  $N_2$  as radiator, or up to four neighbouring HPDs with the  $C_4F_{10}$  radiator (figure 4). The resulting data were recorded using final versions of the DAQ electronics and pre-production releases of the LHCb



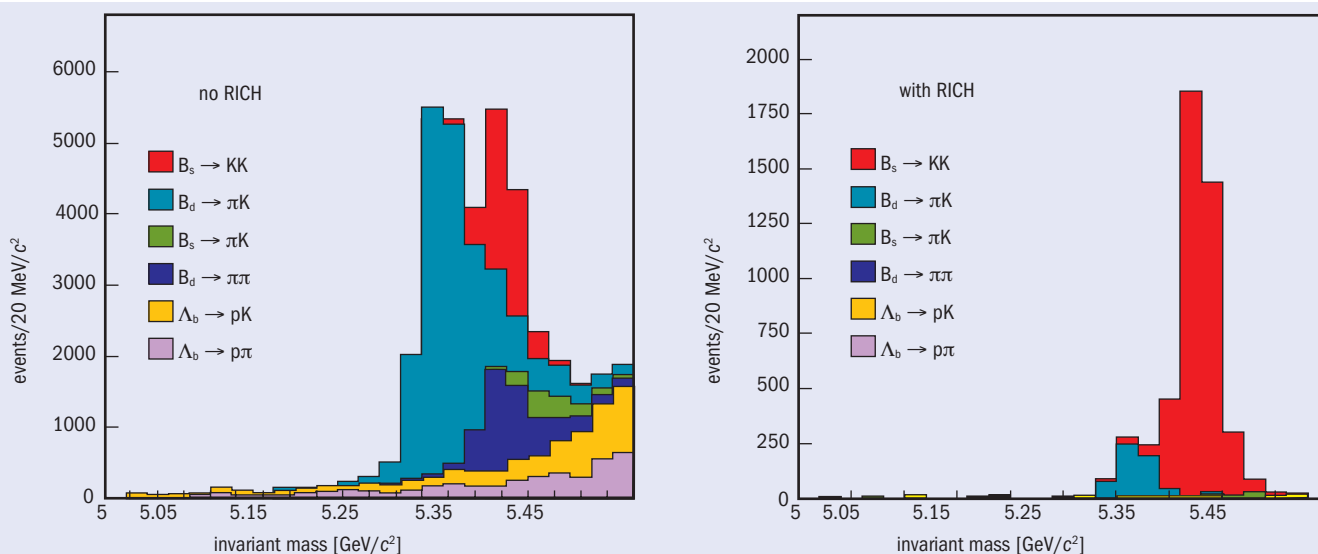


Fig. 6. Plots from simulations indicate the power of the LHCb RICH in picking out a particular process – here, the decay  $B_s \rightarrow KK$ .

online software environment. An early version of the LHCb online-monitoring kept a check on the status of the test set-up and the quality of recorded data.

The analysis of the recorded test-beam data using the full LHCb reconstruction and analysis software involved a significant effort, but the results made it worthwhile. The tests verified the design specifications of the HPDs in a “real life” environment, with the measurement of properties such as the photoelectron yield and the resolution of the Cherenkov angle reconstructed from the data. Using the official LHCb software framework for the analyses also allowed the quality of the software to be verified with real data, so the team could spot any issues not seen in earlier simulation studies. The evaluation of the beam-tests indicates so far that all the hardware and software components involved in the tests match – or exceed – expectations, successfully passing an important milestone on the way to the start-up of the LHCb experiment.

The full LHCb detector has been extensively modelled in a detailed simulation, based on the Geant4 software package, taking into account all important aspects of the geometry and materials together with a full description of the optics of the RICH detectors. This has provided a platform for the development of sophisticated analysis software to reconstruct the events and provide excellent particle identification. Figure 5 shows an example of the complex event environment that LHCb will face in collisions at the LHC. To disentangle the event, the analysis performs a combined likelihood-fit to all known tracks in the event. By considering all tracks and radiators in a single fit, the algorithm naturally accounts for the most predominant background to a given ring, namely the neighbouring rings.

Figure 6 illustrates just how powerful this technique is. Here, using the detailed Geant4 simulations, the mass peak for the decay  $B_s \rightarrow KK$  is shown, together with the background contributions from other two-body decays. Without the kaon identification capabilities provided by the RICH detectors, the  $B_s$  signal is swamped by background. Such efficient hadron identification will be a crucial component in the successful analysis of LHCb data.

Currently, the RICH group is fully focused on the commissioning of the RICH detectors at the experimental area at Point 8 on the LHC ring. The RICH2 detector is completely installed and the HPDs and readout systems are being commissioned. The magnetic shielding and radiator enclosure for RICH1 is in place and installation of all HPDs and optics will be completed later this year. Commissioning of the detector control and safety systems, together with the readout DAQ systems is also progressing at full speed. Everything is on track to have the system fully functional and ready for action for first data in 2008.

#### Further reading

For further information about LHCb and its particle identification techniques see the latest conference presentations at <http://lhcb-doc.web.cern.ch/lhcb-doc/presentations/conferencetalks/2007.htm>.

J Séguinot and T Ypsilantis 1977 NIM **142** 377.

#### Résumé

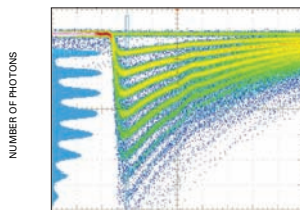
*LHCb: à la recherche de la beauté cachée*

*Dans sa recherche d'une nouvelle physique cachée dans le comportement des quarks charmés et beauté, l'expérience LHCb devra être en mesure de distinguer entre les types de particules produites. Une bonne identification des particules est donc fondamentale. Pour séparer les pions, les kaons et les protons dans certaines désintégrations, l'expérience utilisera le détecteur RICH (détecteur de rayonnement Tchénkov à focalisation annulaire). Avec la construction de deux détecteurs RICH, la collaboration LHCb a dû résoudre des problèmes difficiles en faisant appel à des solutions innovantes. À présent, les détecteurs sont installés au Point 8 du LHC et la mise en service est en cours: le système devrait être pleinement opérationnel pour les premières données en 2008.*

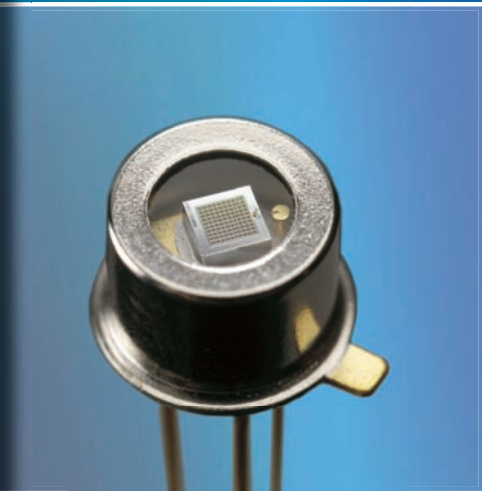
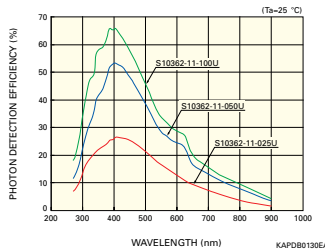
**Chris Jones and Ulrich Kerzel**, Cambridge University, on behalf of the LHCb Collaboration.

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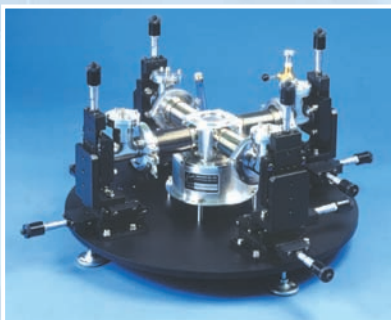
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# FACES AND PLACES

## FACILITIES

# Germany launches XFEL project

On 5 June, the German federal minister of education and research, Annette Schavan, officially launched the European X-ray laser project XFEL. With funding negotiations between the 12 interested countries well advanced, the Europe-wide call for tenders for the underground constructions has now begun, and ground-breaking is expected to take place in early 2008.

The construction costs for the 3.4 km long X-ray laser facility, which will extend between the DESY laboratory in Hamburg and the neighbouring town of Schenefeld in Schleswig-Holstein, will amount to €986 million (as of 2005). An early phase will realize an €850 million initial version, which will comprise all of the tunnels and buildings required for the complete facility, but only three out of five beamlines and six out of 10 experimental stations. The 12 international partners (Denmark, France, Greece, Hungary, Italy, the People's Republic of China, Poland, Russia, Spain, Sweden, Switzerland and the UK) will cover at least 25% of the costs of this initial version. The German share of at most 75% will be born by the federal government and the two



*Left to right: During the XFEL launch ceremony German research minister Annette Schavan, Hamburg mayor Ole von Beust, and the minister-president of Schleswig-Holstein Peter Harry Carstensen consider how to build a complete cavity from reproductions of a one-cell niobium resonator. (Courtesy DESY.)*

host states of the facility, Hamburg and Schleswig-Holstein.

In a communiqué signed during the launch ceremony, the representatives of the partner countries declared their intention to start the construction of the XFEL as quickly as possible in view of the international

competition situation. They also stated their intention to sign a convention on the foundation of an XFEL Limited Liability Company responsible for constructing and operating the European X-ray laser by the end of 2007. Commissioning of the initial version of the facility should begin in 2013, with the international partners aiming to upgrade it as soon as possible, even before that date, to the complete 10-station facility.

The European XFEL is an international joint project with a strong connection to DESY. The facility will comprise a 2.1 km long linear accelerator – based on the superconducting accelerator technology developed by the TESLA Technology Collaboration – and several undulators in which the electron beam will generate high-intensity, ultra-short pulses of X-ray laser radiation with wavelengths of 6–0.085 nm. These will open up new perspectives for research in fields such as materials science, plasma physics, structural biology, geological research and chemistry, which could also pave the way for new applications, for example in biomedicine and pharmacy.

● For more information see [www.xfel.net](http://www.xfel.net).

## AWARDS

# CERN spin-offs are big winners at the Salon des Inventions

Nine companies whose inventions make use of technologies developed at CERN received awards at the 35th Salon des Inventions, held in Geneva on 18–22 April. This year's event, at which CERN was guest of honour, brought 775 exhibitors from 45 countries, with 1000 exhibits.

PXL Industries received a gold medal and the Prix OSEO and Innovation France for developing the CERN-patented system of testing the airtightness of seals used in a vacuum or under high pressure. A gold medal and the Prix du Ministère Français Chargé de la Recherche went to RAYTEST France in recognition of the ClearPET small animal PET system, developed in the Crystal Clear Collaboration (*CERN Courier* July/August 2005 p27)



*CERN's stand at the Salon des Inventions, which was held in Geneva in April this year.*

Gold medals also went to Geodesie Industrielle for their alignment system, developed at CERN for precision alignment

of beam-line elements; Ijspeert Innovative Technologies for its CERN-patented diaphragm system, which can be used to centre unusual shapes inside tubes; MAAT Gknowledge for MammoGrid, a Grid-based mammogram analysis system that will be implemented in the Extremadura region of Spain; PANalytical for their PIXCEL detector, which uses Medipix2, a spin-off from a CERN technology developed to track individual photons; and SpinX for its microfluidics system, which allows complex biological experiments to be performed in nanolitre volumes on a larger scale than ever before (see *CERN Courier* May 2005 p54).

TTA Techtra received a silver medal for the Micro-Chemical-Vias prototypes designed and built in collaboration with CERN.

## Underground neutrino physics wins Markov Prize



The Markov Prize ceremony with, from left to right, Evgeny Alexeev, Georgy Zatsepin, Olga Ryazhskaya, Oscar Saavedra and Victor Matveev, director of INR. (Courtesy INR.)

The Institute for Nuclear Research (INR) of the Russian Academy of Sciences in Moscow has awarded the 2007 Markov Prize to Evgeny Alexeev and Olga Ryazhskaya of INR, and Oscar Saavedra (Turin University, Italy) for developing experimental facilities and methods that resulted in the detection of neutrino signals from the supernova SN1987A, as well as for outstanding contributions to the development of underground neutrino physics.

The three researchers received their Markov Prize diplomas at the 5th Markov Readings in Moscow on 10–11 May, held

to commemorate the legacy of Russian scientist Moisey Alexandrovich Markov (1908–1994). Markov founded a number of areas of investigation in elementary-particle physics, gravitation and cosmology, and in particular, in the creation of large-volume underwater and ice neutrino facilities.

The readings were organized by INR, the Lebedev Physical Institute, the Petersburg Institute For Nuclear Physics of the Russian Academy of Sciences and JINR Dubna, where Markov worked for many years. They were dedicated to Markov's birthday, which is celebrated on 13 May.

## IPA honours Vinod Sahni in Mumbai

Vinod Chandra Sahni, director of the Raja Ramanna Centre for Advanced Technology and director of the Physics Group of Bhabha Atomic Research Centre, has won the MM Chugani Memorial Award of the Indian Physics Association (IPA) for 2004. Ashok Misra, president of the Indian National Academy of sciences presented the award for excellence in applied physics at a ceremony on 24 May at the Tata Institute of Fundamental Research, Mumbai.

In 2005 Shani was instrumental in commissioning Indus-2, the Indian synchrotron radiation source for research in experimental physics. During the process of setting up Indus-2, the country's biggest particle accelerator, he ensured that much of the technology was developed indigenously. He has also steered the Indian participation in the construction of the LHC at CERN.



Vinod Sahni, right, receives his IPA award from Ashok Misra, left. (Courtesy IPA.)

## Quark and neutrino studies win 2007 DESY thesis prizes

Markus Ackermann from DESY in Zeuthen and Lars Finke from Hamburg University have won this year's PhD Thesis Prize of the Association of the Friends and Sponsors of DESY in recognition of their research.

Finke earned his doctorate in the H1 collaboration with a thesis on the production of charm and beauty quarks at DESY's electron-proton collider, HERA. Thanks to the high-precision vertex detector at H1, he used for the first time all high-energy particles from



Markus Ackermann (left) and Lars Finke, who received the 2007 DESY thesis prize for their work on high-energy neutrinos and charm and beauty quarks, respectively. (Courtesy Ackermann/Finke.)

the collisions for his measurements. This allowed him to verify the predictions of QCD with unprecedented precision. Ackermann wrote his thesis at Humboldt University Berlin as a member of the AMANDA collaboration. In

his search for cosmic point-sources of high-energy neutrinos using the AMANDA neutrino telescope at the South Pole, he deduced the lowest upper limits worldwide for neutrino fluxes from such sources.

## CERN engineer becomes SC Industry Person of the Year

Amalia Ballarino, CERN's project leader for the high-temperature superconducting (HTS) current leads for the LHC, has received the award of Superconductor Industry Person of the Year for 2006. The leading industry newsletter, *Superconductor Week*, presents this prestigious international award for achievement in the development and commercialization of superconductors.

Ballarino has worked on HTS materials since she arrived at CERN in 1997. The HTS current leads are used in the LHC to transfer current from the room-temperature power converters to the superconducting magnets operating at liquid helium temperature. The LHC is equipped with more than a thousand leads, which represent the world's first real large-scale commercial application of HTS material. The high-temperature superconducting material used in the LHC leads is a compound of bismuth (Bi-2223), which at the LHC operates at temperatures between 50K and 4.2K.

As project leader, Ballarino has been responsible for the whole process, from



*Amalia Ballarino, CERN's HTS project leader.*

the initial HTS testing and selection to the engineering design and collaboration with industry and laboratories around the world for the manufacturing and testing of the final series production.

## Veneziano receives Oskar Klein Medal

Every year the organizing committee of the Oskar Klein Memorial Lectures invites a distinguished researcher to give a memorial lecture and to receive a medal in memory of the Swedish theorist Oskar Klein. This year the honour went to Gabriele Veneziano from CERN, who gave the 2007 Oskar Klein Memorial Lecture in Stockholm on 19 June, with the title String theory, gravity, and cosmology. Veneziano is well known for work that dates back to his PhD studies in the early 1970s. This looked for the solution to problems in the strong interactions but later transformed itself into the basic equation of string theory.



*Gabriele Veneziano, right, receives congratulations from his PhD supervisor, Hector Rubinstein. (Courtesy Per Osland.)*

## DESY's Albrecht Wagner receives honorary degree

Albrecht Wagner, chair of the DESY directorate, has received the degree of *Doctor honoris causa* of Paris-Sud University. Anita Bersellini, president of the university, presented the award during a ceremony on the UNESCO premises on 12 June. The honorary degree recognizes Wagner's work in the field of particle physics. In his laudation, Guy Wormser, director of the Laboratoire de l'Accélérateur Linéaire, noted the great pleasure with which Wagner's French colleagues welcomed his distinction with the doctorate, recognizing "his excellent scientific contributions to particle physics and his international leading role".



*Albrecht Wagner, who gained an honorary doctorate from Paris-Sud University.*

## Queen Elizabeth II bestows honour on Tim Berners-Lee

Queen Elizabeth II, UK head of state, has appointed Sir Tim Berners-Lee, inventor of the web and director of the World Wide Web Consortium, to be a member of the Order of Merit. The Order of Merit, founded in 1902 by King Edward VII, is a special mark of honour conferred by the sovereign on individuals of exceptional distinction in the arts, learning, sciences and other areas. Appointments to the Order are the sovereign's personal gift and ministerial advice is not required. Twenty-four individuals plus foreign recipients may hold the honour at one time. Other current members include the mathematician Sir Michael Atiyah and physicist Sir Roger Penrose.

## Padua welcomes a new honorary citizen

In a ceremony at the Palazzo della Ragione in Padua on 23 May Steven Weinberg, professor at the physics and astronomy departments of the University of Texas at Austin, was made an honorary citizen of Padua. The citation read “Padua, City of Galileo Galilei, acknowledges an exceptional contribution to the study and public understanding of theoretical physics and



studies of the fundamental forces of nature that have contributed to the evolution of scientific thought.” While in Padua, Weinberg gave a lecture entitled *The Mystery of the Dark Energy* to about 800 high-school students, and also presented a technical talk on *Perspectives on Inflation* to members of the astronomy and physics departments of the University of Padua.

### ANNIVERSARIES

## Thirring reaches his 80th birthday

Walter Thirring, who was head of the Theory Division and a director at CERN from 1968 to 1971, celebrated his 80th birthday on 29 April. Professor at the University of Vienna from 1959 until he became emeritus in 1997, he also founded in 1993 the Erwin Schrödinger Institute in Vienna. He is well known for his work in quantum field theory, and in particular the Thirring model for a self-interacting Dirac field. On 15 May, the faculty of physics at the University of Vienna held a well-attended “Thirring Fest” in his honour. Among those celebrating with Walter in Vienna was his one-time student, Julius Wess of the University of Munich, who has become well known as one of the co-inventors of supersymmetry.



Walter Thirring, left, with his former student, Julius Wess. (Courtesy André Martin.)

## Vladimir Kadyshevsky celebrates his 70th in style

A seminar and celebration took place on 11 May at the Joint Institute for Nuclear Research (JINR) in honour of Vladimir Kadyshevsky, who was 70 on 5 May. Kadyshevsky has been with JINR since 1962, rising to be director of the JINR Laboratory of Theoretical Physics from 1987 to 1992, and director of JINR from 1992 to 2005. During those years of economic instability in Russia he and his colleagues managed not only to keep the institute safe and sound but even to strengthen its position.

Throughout his research career, Kadyshevsky has maintained an interest in key problems of elementary-particle physics, ranging from studies of lepton-hadron symmetries in weak processes prior to the development of the Standard Model, to a recent new approach to describing strong and electroweak interactions beyond the Standard Model. His name is associated with the relativistic formulation of quantum field theory in the quantized space-time that satisfies unitarity and generalized causality conditions. In particular he developed a 3D integral equation for the relativistic scattering amplitude, known as Kadyshevsky’s equation.

Kadyshevsky has also actively participated in international collaborations. In 1977–78 he headed the group of Soviet physicists working at Fermilab and in 1983–85 was leader of JINR’s programme for the DELPHI experiment at CERN’s LEP collider. He has paid much



Kadyshevsky, who turned 70 in May.

attention to the development of scientific trends at JINR, bringing about international co-operation of JINR physicists with scientists all over the world. He continues to contribute much to the development of basic research as JINR’s Scientific Leader.

An ardent promoter of higher education, Kadyshevsky has been in the Physics Faculty of Moscow State University since 1970, and is currently head of elementary-particle physics. It was his initiative to open an international university in Dubna in 1994 and he has been its president since then.

## OBITUARIES

## Maurice Jacob 1933–2007

Maurice Jacob, for many years a theorist at CERN, passed away suddenly on 2 May, after a heart attack, following a long struggle with illness. With his death, CERN has lost one of its leading figures, the French physics community has lost one of its pillars, the European particle-physics community has lost one of its most dedicated servants, and his many friends have lost one of their staunchest supports.

Originally from Lyon in France, Maurice started his physics studies in 1953 at the École Normale Supérieure in Paris. He began his research career at Saclay and, while still a PhD student, he continued brilliantly during a stay at Brookhaven. It was there in 1959 that Maurice, together with Giancarlo Wick, developed the helicity amplitude formalism that is the basis of many modern theoretical calculations. Maurice obtained his PhD in 1961 and, after a stay at Caltech, returned to Saclay. A second American foray was to SLAC, where he and Sam Berman made the crucial observation that the point-like structures (partons) seen in deep-inelastic scattering implied the existence of high-transverse-momentum processes in proton–proton collisions, as the ISR at CERN subsequently discovered.

In 1967 Maurice joined CERN, where he remained, apart from influential visits to Yale, Fermilab and elsewhere, until his retirement in 1998. He became one of the most respected international experts on the phenomenology of strong interactions, including diffraction, scaling, high-transverse-momentum processes and the formation of quark–gluon plasma. In particular, he pioneered the studies of inclusive hadron-production processes, including scaling and its violations. Also, working with Ron Horgan, he made detailed predictions for the production of jets at CERN's proton–antiproton collider. The UA2 and UA1 experiments subsequently discovered these. He was also interested in electron–positron colliders, making pioneering calculations, together with Tai Wu, of radiation in high-energy collisions.

Maurice was one of the scientific pillars of CERN, working closely with experimental



colleagues in predicting and interpreting results from successive CERN colliders. He was indefatigable in organizing regular meetings on ISR physics, bringing together theorists and experimentalists to debate the meaning of new results and propose new measurements. He was one of the strongest advocates of Carlo Rubbia's proposal for a proton–antiproton collider at CERN, and was influential in preparing and advertising its physics. In 1978 he organized the Les Houches workshop that brought the LEP project to the attention of the wider European particle-physics community. He also organized the ECFA workshop at Lausanne in 1984 that made the first exploration of the possible physics of the LHC. It is a tragedy that Maurice has not lived to enjoy data from the LHC.

From 1982 to 1988, Maurice led the CERN Theoretical Physics Division, and was greatly involved in managing the laboratory. He was always scrupulous in his responsibilities, and conscientious to a fault. Colleagues from this time will always remember his human understanding and his dedication to ensuring that they could progress in their research without being troubled by the administrative burden that he shouldered so unobtrusively. His cameo performances in the Theory Division Christmas party play were always greatly appreciated, particularly the year when he appeared as a blue-faced Schtroumpf.

In parallel with his activities and responsibilities at CERN, Maurice also found the time and the energy to play prominent roles in the French Physical Society, of which he was president in 1985, the European Physical Society, of which he was president from 1991 to 1993, and in scientific publishing. He was for many years an enthusiastic supporter of European physics

journals, particularly those of North-Holland, now Elsevier. He was in particular an energetic and supremely fair editor of *Physics Letters B*, and founding editor of *Physics Reports*. He also provided valued editorial advice to *Physics Today*, *CERN Courier* (for which he was a prolific photographer) and the World Scientific Publishing Company. Maurice was also a prolific speaker and writer about particle physics, capable of engaging and inspiring the general public.

During the 1990s, Maurice selflessly placed his intimate knowledge of the European physics scene at the service of CERN by assisting then director-general Chris Llewellyn Smith as his advisor for relations with the member states. During a difficult period while approval and funding for the LHC were being secured, he travelled energetically, consulted widely and served the particle-physics community assiduously as an invaluable contact between the organization and its many stakeholders. He was also appreciated greatly as a scientific advisor to ESA.

After retirement, Maurice returned to relative tranquility in the Theory Division. Unfortunately, he was struck by a chronic and debilitating illness that made it hard for him to enjoy to the full his richly deserved retirement. Nevertheless, he maintained his equanimity and curiosity, and his active interest in physics and CERN matters in general.

During his energetic career, Maurice received many honours, including the Silver Medal of the French CNRS in 1967. He was elected a foreign member of the Swedish Academy, a corresponding member of the French Academy of Sciences, a member of the Academia Scientiae, and an honorary member of the Physics and Natural History Society of Geneva. He was also appointed a chevalier of the French Légion d'Honneur.

Maurice's many friends around the world valued immensely his sincere kindness, his lucidity, his energy, his self-effacing nature and his inexhaustible willingness to help, advise and assist them. We will miss him sorely. Our thoughts at this time are with his wife Lise, whom he met in the early 1950s soon after he began his studies in Paris, as well as their children and their families.

## Hugh Muirhead 1925–2007

Hugh Muirhead, who died at the age of 81 on 19 January, was the last surviving member of the Bristol group that made the historic discovery of the pion in 1947. Cecil Powell's group, which also comprised Cesare Lattes and Giuseppe Occhialini, found two events in nuclear emulsions exposed at high altitude that showed unequivocally that the pion was the true Yukawa meson, and that it decayed into a muon and a neutrino. It was for this landmark discovery and for the development of the nuclear emulsion technique that Powell later received the Nobel Prize.

After obtaining his PhD from Bristol, Hugh moved first to the University of Glasgow and in 1957 to Liverpool University, where he stayed until his retirement. The move to Liverpool coincided with the discovery at Columbia University of parity violation in nuclear beta decay and in muon decay. Using muons from the 400 MeV cyclotron, Hugh and his team of young research students demonstrated that parity was also violated in muon capture. This completed the third leg of the Puppi triangle, the first step towards establishing



the universality of weak interactions (*CERN Courier* June 2007 p33). It was at this time that Hugh wrote his book *The Physics of Elementary Particles* (Pergamon 1965), an outstanding pedagogical contribution to the phenomenology of particle physics, which astonished many theorists when they realized that its author was a “mere” experimentalist.

In the mid-1960s Hugh joined the Liverpool Film Analysis group. He became a world expert on the study of antiproton physics using the bubble-chamber technique and made a number of significant contributions in this field.

Hugh was no stranger to CERN. In the

early 1980s, and nearing the end of his career, he joined the UA1 collaboration, led by Carlo Rubbia and Alan Astbury, to study high-energy proton–antiproton collisions in the SPS. This applied Simon van der Meer's brilliant invention of stochastic cooling to collect antiprotons in sufficient numbers and under suitable conditions for the production of the long-predicted  $W^{\pm}$  and  $Z^0$  bosons. Hugh's professional life thus began and ended with key roles in two of the great discoveries of 20th-century physics, both of which resulted in Nobel prizes.

Hugh was always grateful that he had been able to spend his entire working life pursuing the passion for physics that was first awakened by his part in cosmic-ray experiments in mountain observatories, and he maintained a keen interest in developments in the field long after his retirement. He is survived by his wife Jean and their three children. With his passing, a chapter has closed in modern physics. *Colleagues, former students and friends, Owen Lock, Mike Houlden, Alan Kemp, John Eades and Alan Astbury.*

## József Zimányi 1931–2006

József Zimányi, the high-energy nuclear physicist who first established relativistic heavy-ion research in Hungary, died on 26 September 2006. His passing is a great loss for Hungarian and European science, especially for the heavy-ion community.

Jozsó (as he was known to his friends) was born in Budapest in 1931. He caught the physics bug at an early age: at 16 he constructed a small model of Europe's first Moon radar experiment in Zoltán Bay. After graduating with a PhD in physics from the Eötvös Loránd University, he moved to the Central Research Institute for Physics in Budapest – an institute he remained faithful to for more than 50 years.

He first worked on nuclear spectroscopy experiments, where his speciality was measuring  $\gamma$ – $\gamma$  angular correlations in nuclear decays. After 15 years of successful work in this area, his interest shifted to



the new field of heavy-ion collisions. In 1969 he visited the Niels Bohr Institute in Copenhagen where discussions were taking place about the potential of colliding heavy ions at high energies. He joined the enthusiastic group of “heavy-ion physicists”

and was frequently invited to participate in their common research work in Copenhagen.

In parallel, Jozsó began to build bases in Budapest. He became head of the Theoretical Physics Department in 1973, which, through his tireless efforts, he gradually transformed into one of the leading theoretical centres for heavy-ion physics. In the mid-1970s, he began publishing theoretical papers. His first, a widely appreciated theoretical work, discussed hydrodynamical aspects of heavy-ion collisions and became famous as the Bondorf–Garpman–Zimányi model. To follow non-equilibrium processes, he also developed the Montvay–Zimányi hadrochemical model. When experimental results from the BEVALAC at Berkeley ignited widespread interest, he investigated properties of pionic Bose–Einstein condensation. He later made an excursion



into biophysics, investigating pattern recognition with neural networks.

At every stage, Jozsó's exciting work and enthusiastic personality attracted many talented students, who he advised and nurtured with great care. He used his many international connections to expose them to foreign academic cultures and new ideas. This was the secret behind his successful establishment of the Budapest school. Jozsó used to say, "A successful model must be simple and effective, just like a shaving blade."

Jozsó strongly supported Hungarian participation in CERN's extended heavy-ion research programme in the 1990s. He masterminded Hungary's membership of CERN in 1992, which opened up new opportunities for Hungarian physicists; he himself became a member of the NA49 Collaboration. He represented Hungary on the CERN Council and was a member of the Hungarian CERN committee from 1992 to 2004. Jozsó provided his full support for Hungarian activities in the

ALICE experiment at the LHC and for the founding of the Budapest LHC Grid station at the Research Institute for Particle and Nuclear Physics (RMKI). In addition, he supported the activity of the Hungarian PHENIX group, which since 2001 has participated in ultrarelativistic heavy-ion experiments at RHIC in Brookhaven. Jozsó also played an active role in re-organizing the Hungarian scientific grant system with his extensive experience with foreign funding agencies. He and his colleagues created a peer-review system similar to that of the National Science Foundation in the US. The Hungarian system, OTKA, has worked successfully for the past 15 years.

Despite all of these administrative duties, Jozsó never lost his active touch with physics. These same years saw the birth of the Zimányi–Moszkowski model for an improved mean-field theoretical description of nuclear matter; of the SPACER model for full-scale pion interferometry investigations; and of the ALCOR coalescence model to explain hadronic production ratios at

CERN's SPS, which garnered even greater success when experimental results from RHIC lent strong support to the existence of a quark coalescence mechanism for hadron production at intermediate transverse momenta. Jozsó became a member of the Hungarian Academy of Sciences in 1990 and the European Academy of Arts, Sciences and Humanities elected him to membership in 1997. In 1992 he received the Officer Cross of the Order of Merit of the Hungarian Republic, and the Széchenyi Prize was bestowed upon him by the President of Hungary in 2000. Jozsó was working until his last days with the same extraordinary activity and driving force that has been an inspiration to his students and close colleagues throughout his life. His students, friends and followers feel a great loss; they will keep his heritage alive in Budapest and around the world.

● A workshop was held in Zimányi's memory in July 2007, see [www.kfki.hu/~zj75/](http://www.kfki.hu/~zj75/).  
*Ulrich Heinz, Ohio State University, and Péter Lévai, RMKI Budapest.*

## NEW PRODUCTS

**Agilent Technologies** has introduced its first digitizer from the Acqiris product line. The Acqiris DP1400 high-speed digitizer features a compact design and highly integrated technology for extremely low power consumption, as well as a simultaneous multibuffer acquisition and readout (SAR) mode to improve measurement throughput. For more information about the Acqiris product line see [www.acqiris.com](http://www.acqiris.com).

**Bolidt** now offers the Bolidtop E.10 floor system – the first synthetic floor system that does not cause a static charge. This system, which prevents the exchange of electrons between shoes and the floor, offers a practical solution, for example near sensitive electronic equipment. For more details see <http://elo.bolidt.com> or contact Margriet van Gemert, tel +31 78 684 5485 or e-mail [marcom@bolidt.nl](mailto:marcom@bolidt.nl).

The **ETL group** has announced a new multi-range pressure standard for a wide variety of high-accuracy pressure measurements for calibration, testing and transfer standard applications. Designated the 785, it incorporates one or two Digiquartz absolute

or gauge pressure transducers used exclusively as reference standards. Multi-ranging allows each Digiquartz transducer to replace three separate transducers. Communication to a host computer is via RS-232 or IEEE-488. For further information contact Derek Noble, tel +44 17 844 72130 or e-mail [sales@explorocean.com](mailto:sales@explorocean.com).

**Hamamatsu Photonics** has announced the new S10200 TDI (time delay integration) sensor, featuring the latest high-speed, high-sensitivity, back-thinned CCD image sensors. These have an option for 1024, 2048 or 4096 pixel length by 128 pixel height, 90% peak quantum efficiency to visible light, with high UV and near IR sensitivity. They also offer data readout at 30 MHz per pixel. Hamamatsu Photonics has also introduced the new multi-pixel photon counter (MPPC), the S10362-11 series. The device uses a Geiger-mode avalanche photodiode structure for ultra-low-level light detection. The MPPC is easily connected to an external circuit for simple operation and is supplied in a compact 5 mm package. For more information, e-mail [europe@hamamatsu.com](mailto:europe@hamamatsu.com) or see [www.sales.hamamatsu.com](http://www.sales.hamamatsu.com).

## LETTERS

### Sunset in Antarctica

Thank you for the nice update on the deployment of the IceCube detector on p39 of the April issue of *CERN Courier*. I have, however, a very small comment about the caption for the picture. If the photo was taken on 18 January, it cannot show a "sunset". The sun may be low on the horizon, but it actually sets only once a year in Antarctica, on 23 March.  
*Cécile Roucelle, LBNL.*

## MEETING

The **3rd International High-Energy Physics Conference** (HEPMAD07) is on 10–15 September at Antananarivo, Madagascar. It will cover a wide range, from high-energy physics through nuclear and environmental physics to astrophysics. It aims to blend a standard conference with an introductory school in each subject and to give an opportunity to promote theoretical physics in developing countries. Deadline for registration is 10 August. For more details see [www.lpta.univ-montp2.fr/users/qcd/hep.html](http://www.lpta.univ-montp2.fr/users/qcd/hep.html) or contact Stephan Narison, e-mail [narison@lpta.univ-montp2.fr](mailto:narison@lpta.univ-montp2.fr).

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ELETTRA is a laboratory exploiting a third generation synchrotron light source operated by Sincrotrone Trieste S.C.p.A. as a user facility and is developing a fourth generation source (FERMI@ELETTRA). The extremely high quality machine and beam lines have set new performance records and have produced results of great scientific interest.

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A new fourth generation light source, FERMI, is being designed and constructed along side ELETTRA. FERMI is a single pass Free Electron Laser (FEL) utilizing harmonic generation techniques for the production of photon beams, whose quality is state-of-the-art.

For more information, see <http://www.elettra.trieste.it/FERMI/>

We are seeking the following candidates:

#### Ref. A/07/02 Postdoc Scientist for the Laser Lab.

The successful candidate will join the ongoing R&D work on the Laser Systems for the FERMI FEL project, and in particular the use of fibre lasers and amplifiers for seeding the regenerative amplifier systems. The candidate is expected to carry on studies in both theoretical and practical issues related to optimization of the system performance.

#### Ref. A/06/21 Experienced Accelerator Physicist for FERMI

The candidate will be a member of the accelerator physics group and will be involved in the design and implementation of the beam transfer line of the FERMI project especially taking care of the beam collimation, beam dump, undulator optics and other related issue.

#### Ref. A/06/20 Experienced Accelerator Physicist for ELETTRA

The candidate will be involved in the projects of the accelerator physics group especially concerning linear and non-linear optics and participate in accelerator physics shifts.

#### Ref. A/06/16 Physicist for the Accelerator Magnets

The Physicist will develop the magnetic design and supervise the construction and measurement of the various magnets (dipoles, quadrupoles, steerers, chicanes, phase-shifters, etc) requested for the FERMI project.

#### Ref. A/05/14 Accelerator Physicist For Accelerator Physics Group

The candidate will be engaged in setting the conditions of the accelerators to obtain the best beam quality, analysis of the machine characteristics to improve its performance, development of accelerator physics software and participation in shifts for accelerator physics experiment as well as get involved with the electron beam dynamics calculations of the FERMI project.

For any further details please see our web site:

<http://www.elettra.trieste.it/Jobs/>

We thank all applicants in advance.

## Deutsches Elektronen-Synchrotron Laser Development



**DESY is one of the leading accelerator centres worldwide engaged in exploring the structure of matter. The main research areas range from elementary particle physics and various synchrotron radiation applications to the construction and use of X-ray lasers.**

The Free-Electron-Laser FLASH is a unique light source producing laser-like pulsed femtosecond coherent radiation in the VUV and soft X-ray wavelength range. Several optical lasers ensure the operation of FLASH. For the operation and development of the photoinjector laser system, the laser system for time-resolved experiments and for a new femtosecond synchronization system we are looking for two

### Laser Physicists (m/f)

We expect you to hold a Ph.D. in physics with emphasis on laser physics. You worked with mode-locked solid state laser systems or femtosecond laser systems and you have experience with the synchronisation of radio frequency and laser systems. With your ability to manage complex tasks you will work, in close cooperation with our highly motivated team of scientists and engineers, on the further development of our laser systems for accelerator operation and for pump-probe experiments. If you are interested in this position, you may contact Dr. S. Schreiber (+49 40/8998-4360) or Dr. S. Düsterer (+49 40/8998-1625). Please send your complete application papers quoting the reference code to our personnel department.

The position is limited to 3 years.

Salary and benefits are commensurate with those of public service organisations in Germany. DESY is an equal opportunity, affirmative action employer and encourages applications from women. DESY has a kindergarten on site.

#### Deutsches Elektronen-Synchrotron DESY

Member of the Helmholtz Association

Code: 78/2007 · Notkestraße 85 · D-22603 Hamburg · Germany

Phone: +49 40/8998-3392 · [www.desy.de](http://www.desy.de)

E-Mail: [personal.abteilung@desy.de](mailto:personal.abteilung@desy.de)

**Deadline for applications: August 15, 2007**

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IOP Publishing

## National Synchrotron Light Source II

Brookhaven National Laboratory invites applications from scientists, engineers, and professionals with leading expertise who are interested in playing a significant role in the design and construction of the new world-leading, ultra-low emittance, third generation synchrotron, the National Synchrotron Light Source II (NSLS-II).

NSLS-II will be highly optimized to deliver ultra-high brightness and flux and exceptional beam stability. It will also provide advanced insertion devices, optics, detectors, robotics, and an initial suite of scientific instruments. Together, these will enable the study of material properties and functions with unprecedented high spatial and energy resolution as well as ultra-high sensitivity.

The NSLS-II project will design, build, and install the accelerator hardware, experimental apparatus, civil construction, and central facilities required to produce this new synchrotron light source.

Recruitment efforts are currently underway in the following areas:

- Design and Engineering
- Accelerator Physics
- Beamlines and Instrumentation
- X-Ray Optics
- Conventional Facilities
- Project Controls

Interested applicants for scientific, engineering, and professional positions are encouraged to submit a resume to [peterespo@bnl.gov](mailto:peterespo@bnl.gov). For further information about BNL, NSLS-II, or specific job openings, please visit <http://www.bnl.gov/nsls2/>.

*BNL, a multiprogram research facility managed by Brookhaven Science Associates for the U.S. Department of Energy, is an equal opportunity employer committed to building and maintaining a diverse work force.*



[www.bnl.gov](http://www.bnl.gov)



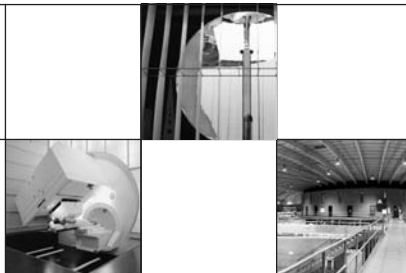
## TRIUMF ACCELERATOR DIVISION HEAD

TRIUMF, Canada's National Laboratory for Particle and Nuclear Physics, is one of the leading accelerator centres worldwide exploring the structure of matter with a variety of accelerated particle beams. The Laboratory's main research areas are comprised of subatomic physics and significant programs in material science with muSR, Beta-NMR, and the life sciences. TRIUMF also operates ISAC, the world's most intense ISOL facility for the production of high intensity radioactive beams, with several new experimental programs being commissioned in the next few years

At present, we have an immediate opening for an experienced individual who will be appointed as Head of the Accelerator Division and member of the senior management team. As Division Head, this individual will assume overall responsibility for all accelerator activities at TRIUMF, including those available to national and international users, and will provide leadership and direction to the staff within this division. In addition, the successful candidate will have the opportunity to develop and lead new accelerator and beam initiatives consistent with TRIUMF's scientific programs. As a member of the Management team, he/she will participate in strategic meetings aimed at defining the science goals and development strategies for the laboratory.

For complete details of this challenging career position, please visit our web site at: <http://www.triumf.info/public/> and click on "Employment Opportunities" and select Competition No. 139. You will find further details, as well as the qualification requirements and full application instructions. TRIUMF is an equal opportunity employer, and we regret that only those applicants being considered for the position will be contacted for an interview. Thank you for your interest in TRIUMF.

PAUL SCHERRER INSTITUT



The Paul Scherrer Institute is a centre for multi-disciplinary research and one of the world's leading user laboratories. With about 1200 employees it belongs as an autonomous institution to the Swiss ETH domain and concentrates its activities on solid-state research and materials sciences, elementary particle physics, energy and environmental research as well as biology and medicine.

As user laboratory PSI operates a system of cyclotrons with the highest average proton beam power worldwide. This complex is the backbone of a multidisciplinary research centre making use of intense secondary beams from the pion production targets and from the spallation neutron source SINQ. To contribute to the further development of the proton facilities, specifically the high energy beam transport system and secondary beamlines, we are looking for an

# Accelerator Physicist

### Your tasks

You will take responsibility for the operation and maintenance of beam transport systems in the PSI proton accelerator complex. Primarily this concerns the transport channel which guides the 590 MeV, 1 MW proton beam from the exit of the Ring Cyclotron to the SINQ spallation target. Your work includes beam optical calculations and the conceptual layout of the various technical interlock systems which are implemented to avoid damage of beamline components or the target by the high power beam. The beamline contains two meson production targets generating intense pion and muon beams for several secondary beamlines, dedicated to various research applications. Your responsibility includes the maintenance and development of these secondary beamlines as well as the support of the users. An ongoing activity involves design and construction of a transport channel guiding a pulsed proton beam to a new source for ultra-cold neutrons (UCN).

### Your profile

You hold a PhD degree in physics or equivalent, with preferably good knowledge of the physical, technical and operational aspects of accelerators. Experiences in beam optics design as well as basic knowledge in magnet design and vacuum systems are advantageous. The successful candidate also has excellent communication skills in German and/or English and exhibits extraordinary team spirit. We offer an exciting environment where leading edge accelerator science and technology is performed in various areas. As a world-class institute, we expect corresponding performance from you. The responsibility given to you will be in accordance with your experience.

### We are looking forward to your application.

For further information please contact Dr Mike Seidel, head of the Accelerator Division ABE, phone +41 56 310 3378, e-mail: [mike.seidel@psi.ch](mailto:mike.seidel@psi.ch).

Please send your application to: Paul Scherrer Institut, Human Resources, Mr. Thomas Erb, ref. code 8580, 5232 Villigen PSI, Switzerland.

Further job opportunities: [www.psi.ch](http://www.psi.ch)



## POST-DOCTORAL FELLOWSHIPS FOR NON ITALIAN CITIZENS

IN THE FOLLOWING RESEARCH AREAS  
**THEORETICAL PHYSICS (N. 10)**  
**EXPERIMENTAL PHYSICS (N. 20)**

The INFN Fellowship Programme 2007/2008 offers 30 (thirty) positions for non Italian citizens for research activity in theoretical or experimental physics.

Fellowships are intended for young post-graduates who are under 35 years of age by October 20, 2007. Each fellowship, initially, is granted for one year and then, may be extended for a second year.

The annual gross salary is EURO 28.000,00.

Round trip travel expenses from home country to the INFN Section or Laboratory will be reimbursed, also lunch tickets will be provided for working days.

Candidates should submit their application form, a statement of their research interests and enclose three reference letters.

Candidates should choose at least two of the following INFN sites, indicating their order of preference.

• INFN Laboratories:

Laboratori Nazionali di Legnaro (Padova), Laboratori Nazionali del Gran Sasso (L'Aquila), Laboratori Nazionali del Sud (Catania), Laboratori Nazionali di Frascati (Roma);

• INFN Sections in the universities of:

Torino, Milano, Milano Bicocca, Padova, Genova, Bologna, Pisa, Napoli, Catania, Trieste, Firenze, Bari, Pavia, Cagliari, Ferrara, Lecce, Perugia, Roma "La Sapienza", Roma "Tor Vergata", "Roma Tre".

The research programs, must be focused on the research fields of the Section or Laboratory selected (<http://www.infn.it>).

Applications must be sent to the INFN no later than October 20, 2007.

Candidates will be informed by May 2008 about the decisions taken by the INFN selection committee.

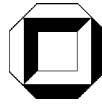
Fellowships must start from September to December 2008. Requests for starting earlier accepted.

Information, requests for application forms, and applications should be addressed to Istituto Nazionale di Fisica Nucleare, Direzione Affari del Personale, Ufficio Borse di Studio - Casella Postale 56 - 00044 Frascati (Roma) Italia.

**ISTITUTO NAZIONALE DI FISICA NUCLEARE**

IL PRESIDENTE

(Prof. Roberto Petronzio)



Universität Karlsruhe (TH)

Research University · founded 1825



The University of Karlsruhe (TH) and the Forschungszentrum Karlsruhe are joining forces to form the Karlsruhe Institute of Technology (KIT) and are planning to integrate their research activities both structurally and strategically. Within the framework of this award-winning concept for the future, funded by the German Excellence Initiative, we seek applications for the joint position of

### Professor (W3) for Theoretical Astroparticle Physics

at the Forschungszentrum Karlsruhe and at the Department of Physics.

We are looking for an expert in the area of theoretical astroparticle physics. Candidates with broad scientific competence and innovative research spanning the areas of astrophysics, elementary particle physics or cosmology will be considered.

The position offers excellent opportunities for collaboration within the Department of Physics, with other departments of the University and with the Forschungszentrum Karlsruhe in the framework of KIT. This includes the „Centre for Elementary Particle and Astro-Particle Physics“ (CETA), the Transregional Collaborative Research Centers SFB/TR9 „Computational Particle Physics“ and SFB/TR 27 „Neutrinos and Beyond“ and the Research Training Group GRK 742 „High Energy Physics and Particle Astrophysics“. Close collaboration within the Helmholtz-Programme Astroparticle Physics and contributions to its further development are expected.

Teaching duties include education of physics students as well as of students majoring in other natural sciences or engineering.

The University of Karlsruhe (TH) aims to increase the number of female professors and especially welcomes applications from women.

Handicapped persons with equal qualifications will be preferred.

In the case of a first appointment to a professorship, this position will be tenure track according to the regulations of the State of Baden-Württemberg. Exceptions from this rule are possible.

Applications with the usual credentials as well as information on the five most important publications and a statement about past and planned research and teaching activities should be sent before **October 1<sup>st</sup>, 2007** to **Dekan der Fakultät für Physik, Universität Karlsruhe (TH), 76128 Karlsruhe, Germany.**

### Faculty Position in High Energy Theory at The Ohio State University

The Department of Physics in the College of Mathematical and Physical Sciences at The Ohio State University invites applications for an anticipated faculty appointment effective Fall Quarter of 2008, contingent upon funding. Highly qualified candidates at the junior level in the targeted area of Theoretical High Energy Physics, with a focus on theory and phenomenology relevant to physics at the Large Hadron Collider, will be considered. Applicants should have a Ph.D. and an outstanding research record. A commitment to excellence in teaching at both the undergraduate and graduate levels is essential. Rank will be commensurate with qualifications and experience.

The Department's current areas of research are Theoretical and Experimental High-Energy Physics, Theoretical Astrophysics and Cosmology, and Experimental Particle Astrophysics, as well as Theoretical and Experimental Nuclear Physics, Atomic, Molecular and Optical Physics, Biophysics, Condensed Matter Physics, and Physics Education Research.

The Department currently has 60 faculty and approximately 40 postdoctoral researchers, 160 graduate students and 275 undergraduate majors. This entire growing research operation is located in the new Physics Research Building, containing state-of-the-art office, meeting, and laboratory space.

All applications should be submitted electronically at  
<http://www.physics.ohio-state.edu/jobs/facultyapp/>  
<<http://www.physics.ohio-state.edu/jobapp/>>

Candidates should submit a letter of application, a complete curriculum vitae including a list of publications, a brief description of research plans, and a teaching statement. They should also arrange for at least four letters of recommendation to be sent to:

**Faculty Searches**  
**The Department of Physics, The Ohio State University,**  
**191 West Woodruff Ave., Columbus, OH 43210**

Applications will be considered on an ongoing basis. Job application assistance is available for dual career situations.

To build a diverse workforce, Ohio State encourages applications from women, minorities, veterans, and individuals with disabilities. Flexible work options are available. EEO/AA Employer.

### Research Associate Develop Superconducting RF for Future and Far-Future Accelerators CLASSE, Cornell University

Cornell Laboratory for Accelerator Sciences and Education (CLASSE) has an opening for a Research Associate to work on a broad range of topics involving RF superconductivity for particle accelerators. Our activities cover research on cavities for the International Linear Collider (ILC), Energy Recovery Linac (ERL) as well as basic SRF issues related to high gradients, high Q and new materials for advanced accelerator application. We have state of the art facilities in cavity fabrication, preparation, tests and basic research including a variety of surface analytic instruments. Research Associates generally participate in several of the above activities.

This is a 3-year appointment with expectation for renewal, subject to mutual satisfaction and availability of funds. A PhD in Physics or Engineering is required with related experience in one or more of the following areas: low temperature physics, materials, microwaves, high vacuum, high temperature, and surface analysis.

As an Ivy League university, Cornell provides an intellectually stimulating research environment with opportunities to work with undergraduate and graduate students. We also have strong collaborations with Fermilab, DESY, JLab and ANL.

Please send a cover letter, including curriculum vitae and a publications list to Dr. H. Padamsee, Newman Laboratory, Cornell University, Ithaca, NY 14853, and arrange for three letters of recommendation to be sent. E-mail correspondence may be directed to [search@lepp.cornell.edu](mailto:search@lepp.cornell.edu). Cornell University is an equal opportunity, affirmative action educator and employer.

**Search Committee Chair, Newman Laboratory,  
Cornell University, Ithaca, NY 14853.**

Applications should include a curriculum vitae, a publication list, a statement of research interests, and a short summary of teaching and research experience.

Electronic mail inquiries may be addressed to  
**Search@LEPP.Cornell.edu**

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





## SENIOR RESEARCH SCIENTIST POSITION

The Abdus Salam International Centre for Theoretical Physics (ICTP), is a world-class institution focused on research in basic sciences with responsibility for the promotion, dissemination and support of science, especially in developing countries. It operates under the aegis of UNESCO and IAEA.

### P-4 post

- Physics at Large Hadron Collider (LHC) and Future High energy accelerators

The successful candidate is expected to carry out an independent and competitive programme of research in the forefront of his/her field. He/she should create and lead a research team composed of post-doctoral fellows and visitors. He/she should act as a liaison between the High Energy section and CERN as well as other major accelerator centres around the world. The successful candidate is also expected to lecture in the High Energy Diploma Programme; coordinate and supervise the organization of schools and conferences as well as run the visiting programme in the area of Physics at LHC and Future High Energy Accelerators.

### All candidates must possess:

- Ph.D. or equivalent doctoral level in physics, with speciality in High Energy Physics
- At least 8 years of research experience at a competitive international level after completion of Ph.D. The candidate must have an established record of accomplishment in a broad area of research and be engaged in independent research at the frontiers of his/her field.
- Excellent knowledge of written and spoken English
- A positive attitude towards the international and multicultural characteristics of the assignment

The annual remuneration, based on UNESCO P-4 level, starts at about \$98,069 if there are no dependants and \$105,312 if there are dependants, and is exempt from income tax. There is an attractive benefits package which includes 30 days of annual vacation, home travel, education grant for dependent children, pension plan and medical insurance.

Information and on line application forms are available at ICTP's intranet site at <http://portal.ictp.it/vacancy>. Deadline for receipt of applications: 30 September 2007.

## Technische Universität Berlin



The Technical University Berlin, Faculty II, Institute for Optics and Atomic Physics and the Deutsches Elektronen-Synchrotron DESY (DESY) want to fill in a joint appointment a professorship (W3) for



### "Accelerator Physics for Novel Light Sources"

Reference number: II-662

Besides taking an adequate share in teaching physics courses at the university the position includes the coordination of accelerator physics research and development at DESY in Zeuthen as a leading scientist.

DESY, a member of the Hermann von Helmholtz-Association, develops, constructs and operates accelerator facilities for research in basic natural science available to researchers worldwide. The research programme spans from particle physics to the physics of condensed matter and to molecular biology. DESY plays a central role in the accelerator construction for the European X-ray Laser XFEL. Some important R&D work for this project and for the existing FEL FLASH is being pursued at Zeuthen.

The Technical University Berlin and DESY are looking for an internationally recognized scientist, who will play a major role in the development of accelerator physics and technology with emphasis on Free Electron Lasers. Close cooperation with BESSY and the Max-Born Institute is aimed for. Further information can be obtained from Dr.U.Gensch ([ulrich.gensch@desy.de](mailto:ulrich.gensch@desy.de)), Dr.R.Brinkmann ([reinhard.brinkmann@desy.de](mailto:reinhard.brinkmann@desy.de)) or Prof.T.Möller ([thomas.moeller@physik.TU-Berlin.de](mailto:thomas.moeller@physik.TU-Berlin.de)).

Conditions for the position are lecturing qualifications or equivalent scientific achievements obtained in industry or research centres as well as educational aptitude. Experience in raising external funds is being expected. Compliance with the requirements of the profession according to § 100 BerlHG are assumed (information will be given on request).

The Technical University is an equal opportunity employer. Women, therefore, are particularly encouraged to apply. Applications of disabled persons will be preferred in cases of equal qualification.

Applications should be sent before Sept 15, 2007 to the president of the Technical University Berlin, **Dekanat der Fak. II, Sekr. MA 5-11, Strasse des 17.Juni 136, 10623 Berlin.**

## The Faculties of Physics of the Ludwigs-Maximilian University, the Technische Universität München and the Cluster of Excellence 'Origin and Structure of the Universe'

invite applications for

### Six W2 Professorships / Junior Research Group Leaders

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 fundamental forces and dynamics driving the expansion of our 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.

Within the framework of the cluster we are seeking candidates for six positions of Junior Research Group (JRG) leaders with special focus on particle-, astroparticle- and astrophysics. These JRG-leaders will also become associate professors (salary scale W2) at the Faculty of Physics of the Ludwigs-Maximilian Universität (LMU) and the Technische Universität München (TUM) for initially 6 or 5 years, respectively. Evaluation for tenure will start after three years.

The successful candidates are expected to create and lead a JRG in one of the following fields:

- Particle Physics with Neutrons (Experiment - TUM)
- Dark Energy (Experiment - LMU)
- Heavy Quark Physics (Experiment - LMU)
- Extra Dimensions (Theory - LMU)
- Theoretical Particle Physics and the Early Universe (Theory - LMU)
- Cosmic Galaxy Evolution and Nucleosynthesis (Theory - LMU)

Besides profiting from scientific infrastructures present on the campus Garching the groups will also be integrated in transregional research activities either ongoing or planned. Active participation in the teaching program for experimental/theoretical physics at the corresponding Faculty of Physics and of the Cluster is required.

Formal requirements for these positions are a Diploma from a University or a University for applied sciences, pedagogical qualifications and specialized skills for scientific research which are documented by a PhD. Other scientific accomplishments, gained possibly also outside academia, are welcome. Applicants should have several years of experience in the corresponding fields of physics (experiment, astronomical observations or theory).

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 and official advertisement of these positions can be found on

<http://universe-cluster.de> (→jobs)

Applicants should complete the corresponding web-forms latest by 31.08.2007.

Dean of the Faculty of Physics  
Department für Physik  
Ludwigs-Maximilian Universität

Dean of the Faculty of Physics  
Physik Department  
Technische Universität München

Excellence Cluster  
'Origin and Structure of the Universe'  
c/o Prof. Dr. Stephan Paul

The GKSS Research Centre is located in Geesthacht near Hamburg, Germany, with a further centre in Teltow near Berlin, and is a member of the Helmholtz Association of German Research Centres. With its approximately 700 employees it undertakes, in collaboration with universities and industry, research and development in the areas of coastal research, materials research, regenerative medicine, and structure research with neutrons and synchrotron radiation.

## ESR Position in Metal Hydride Development

In the framework of the European Marie Curie Research Training Network "COSY: Complex Solid State Reactions for Energy Efficient Hydrogen Storage" (<http://www.cosy-net.eu>) the Institute of Materials Research at the GKSS Research Centre Geesthacht near Hamburg in Germany is offering an ESR (Early Stage Researcher) position for students interested in the development of nanocrystalline light metal hydrides and hydride composites.

COSY consists of 13 European partners from Spain, Italy, France, Great Britain, Switzerland, the Netherlands and Germany. The aim is the characterization and optimization of novel light weight hydride composites. The results are the basis for further optimisation of such materials for mobile hydrogen storage applications, e.g. in tanks for emission-free automobiles.

**Tasks:** The position involves the production of metal hydride composites by high energy milling and their characterization with respect to structure with a strong focus on SANS (at GKSS research reactor FRG-1 and ILL, Gr noble resp.) and SAXS (at DESY in Hamburg and ESRF, Gr noble, resp.) investigations. Further methods include XRD and TEM (in collaboration with project partners). Also the relevant application properties, i.e. hydrogen sorption kinetics and thermodynamics and the influence of additives shall be investigated in order to be able to interpret the results from structural characterization.

The candidates are expected to present the results on project meetings, international conferences, and in scientific publications and to contribute to patent applications.

**Qualifications:** A master degree in materials science, physics, or inorganic chemistry, or related fields is required. Experience in SANS and/or SAXS measurements, theory and evaluation, the thermodynamics of metallic alloys, chemical reactions, and electro-chemistry are highly desirable. Knowledge in powder metallurgy, metal hydrides and/or hydrogen technology would be an additional advantage. Appropriate presentation, communication, and writing skills are expected.

In the context of a personal Career Development Plan a one year exchange with the Institut Polytechnique de Gr noble, France is planned (<http://www.inpg.fr/LTPCM/>). Also extended visits to other partners of the network will be conducted. Furthermore the applicant will have the chance to visit several hydrogen technology related training workshops and personnel education seminars. Opportunity for carrying out a PhD thesis at the Technical University of Hamburg-Harburg is offered.

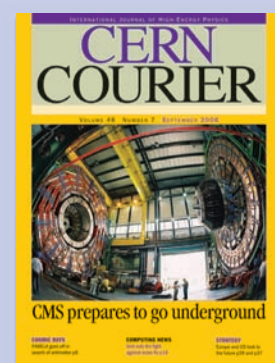
**Restrictions:** Because of EU funding restrictions, the applicant has to be a non-German European citizen and must not have worked for more than 12 months in Germany within the last 3 years. The potential candidate must not have more than 4 years research experience since finishing his master degree. The positions will be paid according to EU rules and include a certain amount of travel allowances.

GKSS and the EU seek to increase the number of women in science. Therefore especially female researchers are strongly encouraged to apply. Physically handicapped persons with equal qualifications will be preferred.

Interested students should send their application using Reference No. **W 11** together with the usual attachments (CV, copies of degrees and other qualifications, research interests, publication list) to the **GKSS-Forschungszentrum Geesthacht GmbH, Personalabteilung, Max-Planck-Str. 1, 21502 Geesthacht, Germany (personal@gkss.de)**. The closing date for applications is two months after publication of this advertisement. Applications will be considered until the position is filled. Further information about the partners of the network can be found at <http://www.cosy-net.eu> or Dr. Klaus Taube (Phone: +49 4152 87-25 41, klaus.taube@gkss.de)

**GKSS • FORSCHUNGSZENTRUM GEESTHACHT  
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**TENURE TRACK FACULTY POSITION IN  
EXPERIMENTAL PARTICLE PHYSICS**

**University of Rochester  
Department of Physics and Astronomy**

The Department of Physics and Astronomy at the University of Rochester invites applications for a tenure-track position in experimental particle physics, with the appointment to begin on January 1, 2008. Appointments at higher levels might be considered based on the applicant's qualifications.

We seek outstanding candidates to either strengthen or complement our current activities in experimental particle physics, which include programs within the CDF, D0, CLEO, MINERvA and CMS (LHC) experiments.

The successful candidate is expected to initiate an independent research program, either within these collaborations, or in experiments not currently pursued by Rochester faculty. Candidates should have outstanding records in research, and strong commitments to excellence in undergraduate and graduate teaching. We will continue to accept applications until the position is filled.

Salary will be competitive, and applications from women and members of underrepresented minority groups are encouraged. Applicants should submit a curriculum vitae, a list of publications, and a description of their proposed research, and should arrange for at least five letters of recommendation to be sent to:

Department of Physics and Astronomy, Attn: Shirley Brignall, University of Rochester, Rochester, New York 14627-0171, USA

Applications may also be submitted by email sent to [shirl@pas.rochester.edu](mailto:shirl@pas.rochester.edu) with the subject line "HEP faculty position."

*The University of Rochester is an equal opportunity/affirmative action employer and encourages applicants from members of minority groups and women. All applications are considered without regard to race, sex, age, religion or national origin.*



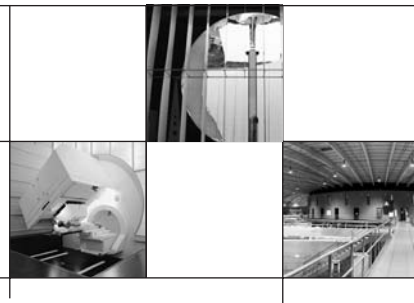
**TRIUMF  
ENGINEERING DIVISION HEAD**

TRIUMF, Canada's National Laboratory for Particle and Nuclear Physics, is one of the leading accelerator centres worldwide exploring the structure of matter with a variety of accelerated particle beams. The laboratory's main on-site research areas include subatomic physics with exotic isotopes, muons, and pions, as well as programs in material science with mu-SR, beta-NMR and life sciences with radioactive isotopes. TRIUMF operates a 500 MeV H- cyclotron, several other accelerators for use with medical isotope production, as well as a new variable-energy cw heavy-ion superconducting (SRF) linear accelerator. TRIUMF is also involved in several subatomic physics research programs at laboratories around the world.

Supporting our research program, is an Engineering division which provides infrastructure support in terms of engineering, design and fabrication services for on-site projects related to accelerator and beamline developments, experimental detectors, magnets, cryogenics, and buildings and structures, as well as providing similar support for external experiment programs such as SNOLAB and T2K, and for accelerator collaborations such as with JPARC, CERN LHC, and ILC. Planning, plant operations, electrical and HVAC services are also provided by this division.

We currently are seeking an experienced individual who will be appointed as Head of the Engineering Division and member of the senior management team. If you are a physicist with a strong technical background, a solid understanding of engineering principles, experience in accelerator technology, and if you have excellent leadership, management, communication, and interpersonal skills, then we invite you to apply for this excellent career opportunity.

For more information, go to: <http://www.triumf.info/public/> then click on "Employment Opportunities" and select Comp. No. 148. You will find full details, qualification requirements, and application instructions. Thank you for your interest in TRIUMF.



**The Paul Scherrer Institute is a centre for multi-disciplinary research and one of the world's leading user laboratories. With about 1200 employees it belongs as an autonomous institution to the Swiss ETH domain and concentrates its activities on solid-state research and materials sciences, elementary particle physics, energy and environmental research as well as biology and medicine.**

**PSI operates a number of state of the art accelerator facilities for protons and electrons enjoying world-wide recognition. The operation of the facilities at a high level of reliability and the further improvement of their performance requires permanent development and the continuous integration of new technologies.**

**In the Department for Technology, Coordination and Operation, we are looking for a**

# Senior Magnet Engineer (m/f)

## as Head of the PSI Magnet Section

**Your tasks**

Your main task is to lead a small group of engineers, physicists and technicians. The section is responsible for the conception, design and procurement of various types of electromagnets for the PSI beam transport systems and experimental facilities. This includes monitoring the manufacturing process and supervision of the acceptance testing. Your responsibility includes the supervision of magnetic measurements, servicing, repair or modification of new and existing magnets.

**Your profile**

You are a creative graduate engineer or physicist with a good understanding of the technical aspects involved in the design of devices operated under difficult conditions. You already have experience with electromagnets and/or the design of electrical and mechanical components and are familiar with quality control procedures. You are prepared to travel for short trips abroad. You like to work in a team and you have a good working knowledge of the English and German languages.

**We are looking forward to your application.**

For further information please contact Mr. David George, phone. +41 56 310 3588, e-mail: [david.george@psi.ch](mailto:david.george@psi.ch).

Please send your application to: Paul Scherrer Institut, Human Resources, Mr. Thomas Erb, ref. code 8850, 5232 Villigen PSI, Switzerland.

Further job opportunities: [www.psi.ch](http://www.psi.ch)

## Department of Physics

### Research Assistants in Accelerator Science

Salary: £26,536 per annum, inclusive of London Allowance \*

Three STFC/JAI-funded postdoctoral Research Assistant positions are available from July 2007 to June 2010 to work within the John Adams Institute (JAI) for accelerator science at Royal Holloway. This is an opportunity to be part of a rapidly expanding group and to influence our future directions in the field.

Applicants should have a PhD (or be about to submit a thesis) in particle physics, accelerator physics or a related field.

#### **Post 1 - Postdoctoral Research Assistant in Accelerator Physics: Laser-wire (Ref KB/4794)**

This post is for 2 years (with likely renewal for a third year) to work principally on hardware, analysis and machine studies for the laser-wire project, where laser light is used to scan electron beams to determine their transverse size; this project is in association with several international accelerator facilities, including DESY in Hamburg and KEK in Tsukuba where we have running laser-wire experiments.

#### **Post 2 - Postdoctoral Research Assistant in Accelerator Physics: Beam Position Monitors (Ref KB/4791)**

This post is for 3 years, to work on resonant cavity beam position monitor system development and application to dynamics and diagnostics of electron beams. The candidate is expected to play a major role in our ongoing projects at international ILC test facilities, including ATF2 in KEK and at SLAC End Station A.

#### **Post 3 - Postdoctoral Research Assistant in Accelerator Physics: Radiative Physics at CTF3 and ILC simulation (Ref KB/4792)**

This post is for 3 years to work on determining the performance of ILC beam delivery designs using advanced computation and also to build a new experimental programme at CTF3 in CERN in the area of radiative processes from electron beams such as transition, diffraction and synchrotron radiation.

For all posts, there may be some opportunity to teach at undergraduate or postgraduate level. Further details about the posts, the Institute and the work of the Royal Holloway Particle Physics Group can be found on our web site at <http://www.pp.rhul.ac.uk>

Royal Holloway is one of the larger colleges of the University of London, situated on a pleasant campus about 25km west of Central London, close to the town of Windsor and to Heathrow Airport.

Informal enquiries about the posts can be made to Professor Grahame Blair, email: [g.blair@rhul.ac.uk](mailto:g.blair@rhul.ac.uk)

Further details and an application form are available from the Personnel Department, Royal Holloway, University of London, Egham, Surrey TW20 0EX; tel: 01784 414241; fax: 01784 473527; email: [recruitment@rhul.ac.uk](mailto:recruitment@rhul.ac.uk) Please quote the appropriate reference.

The closing date for the receipt of applications is midday, Friday 7th September 2007.

\* Please note that the College is currently undergoing a Job evaluation exercise (HERA) and salaries will therefore be subject to review.

We positively welcome applications from all sections of the community.



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With 30,000 students and 10,000 employees, RWTH Aachen University is one of the leading universities and also the largest employer and training body in the region. Its teaching and research are closely connected to industry and are characterised by an international, innovative and interdisciplinary approach.

## Postdoctoral Position, Physics Data Analysis CMS Experiment

Physikalisches Institut 3A

### Our Profile:

The research program of the institute is experimental particle physics and astroparticle physics at the highest energies. Experiments CMS (Switzerland), D0 (USA), and Pierre-Auger-Observatory (Argentina).

### Your Profile:

1. Experienced in international high energy particle physics experiment,
2. Special qualification in physics data analysis, software and computing,
3. Team oriented style of working.

### Your duties and responsibilities:

Research within the CMS experiment, search for new physics phenomena, especially in relation with top quarks, visualisation and automated reconstruction of particle processes, Grid-computing. Active commitment in teaching.

### Our offer:

The position is to be filled as soon as possible and is for a fixed term until 30.6.2009. Regular working hours are 39.83 hours a week. A PhD is required. Pay scale classification is based upon the relevant labour agreements.

RWTH Aachen University has been rewarded with the "Total-E-Quality-Award" for its efforts with respect to gender equality. Applications from female candidates are explicitly welcome. Female candidates will be given preference in the case of equal suitability, aptitude and professional performance, provided that there is not another, more suitable candidate.

Please refer to § 8 Article 6 of the North Rhine-Westphalian Equal Opportunities Act (Landesgleichstellungsgesetz NW).

RWTH Aachen University has been rewarded with the title "disability-friendly" ("Prädikat behindertenfreundlich") for its efforts with respect to training and employment of severely disabled people. Applications from severely disabled people with appropriate suitability are explicitly welcome. This also applies to people with equal opportunities in accordance with §2 SGB IX (Social Code).

### Your contact person:

For advance information, please contact Mr. Prof. Dr. Martin Erdmann on tel. no. 49-241-8027317 or e-mail [erdmann@physik.rwth-aachen.de](mailto:erdmann@physik.rwth-aachen.de). You can also obtain further information from our websites:

[www.physik.rwth-aachen.de/~erdmann](http://www.physik.rwth-aachen.de/~erdmann)

Please send your application by 30.07.2007 to: Prof. Dr. Martin Erdmann, Physikalisches Institut 3A, Physikzentrum, Otto-Blumenthal-Strasse, D-52056 Aachen Germany.

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**IOP Publishing**



At the **Faculty of Physics** at the Ludwig-Maximilian-University Munich

## Temporary Professorship (W2, tenure track) for Experimental Physics in the field of Heavy Quark Physics

is to be filled for the Winter lecture term 2007/2008.

Recently the Cluster of Excellence *Origin and Structure of the Universe* has been installed on the Garching Campus as part of the Excellence Initiative of the federal government of Germany. The cluster is operated jointly by the physics departments of the two Munich Universities, several Max-Planck Institutes, and the European Southern Observatory (ESO). It aims at a deeper understanding of the fundamental forces and the dynamics which drive the expansion of our universe, the creation of the elements, and the growth of large-scale structures. As part of this effort 10 new research groups will be created to work in key areas of the relevant science.

Within this framework we are seeking candidates for the position of a Research Group (RG) leader who will focus on Experimental Particle Physics and Heavy Quark Physics. Besides profiting from the scientific infrastructure present on the campus Garching, the group will also be invited to join the BMBF Research Centre FSP-101 ("Physics on the TeV scale with ATLAS at LHC") and to use facilities of the Max-Planck-Institute for Physics in Munich. Active participation in the teaching program of the cluster and the university is expected.

The RG-leader will get the status of a temporary professor (tenure track, salary scale W2) in the Faculty of Physics of the Ludwig-Maximilian-University (LMU) München for an initial period of 6 years. Evaluation for promotion to tenure (at salary scale W2) in the Faculty of Physics will start after three years. The professorship represents the subject in its full breadth in research and teaching.

Prerequisites for employment are a university grade, pedagogical suitability, Ph.D. or doctoral degree and additional scientific qualification which can be proven by a habilitation or equivalent achievements or which can result from a junior professorship.

The age of 52 must not be completed at the time of the appointment. In urgent cases exceptions can be permitted. The Ludwig-Maximilian-University aims at raising the proportion of women in research and teaching and therefore explicitly requests female scientists to apply. Seriously handicapped persons with essentially equal aptitude will be given preference.

Application with the usual records (curriculum vitae, certificates, documents, list of publications) should be sent by **15 September 2007** to the **Dean of the Faculty of Physics, Ludwig-Maximilians-Universität München, Schellingstr. 4, 80799 München, Germany.**

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address to [cerncourier@iop.org](mailto:cerncourier@iop.org).**

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### European Synchrotron Radiation Facility

The ESRF is a multinational research institute, employing a staff of about 600, located in Grenoble. The ESRF is financed by 18 countries and carries out fundamental and technological research with synchrotron radiations. The RF Group of the Accelerator Division offers you a position as

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**For further information please consult  
<http://www.esrf.fr/Jobs/Research/PDAS01>**

To apply send a letter and CV, bearing the reference PDAS01 before 15/09/07 to [recruitment@esrf.fr](mailto:recruitment@esrf.fr) or ESRF, Personnel Group, 6 rue Jules Horowitz BP 220, 38043 Grenoble cedex 09



orc.fr

## Max Planck Institute for Gravitational Physics

(Albert Einstein Institute, AEI)



In 2007, the Max Planck Institute for Gravitational Physics (Albert Einstein Institute, AEI) in Hannover, Germany launched a new research division "Observational Relativity and Cosmology" under the direction of Professor Bruce Allen. The Hannover branch of the AEI is a joint undertaking of the LEIBNIZ University Hannover and the MPG. It has approximately 80 scientists and support staff, state-of-the-art electronics and mechanical workshops, optics labs, and other specialized facilities.

The initial focus of the new division will be the search for gravitational waves, as part of the LIGO, VIRGO, and LIGO scientific collaborations. By the end of 2007 the division will have dedicated computing facilities (400TB storage and 2500 CPU cores) optimized for data analysis and Monte Carlo simulations, and core technical staff including programmers and system administrators.

The division is seeking to fill approximately

### ten scientific positions

at the postdoctoral to senior level, including visiting, fixed term (2-5 year) and permanent appointments.

Applications are welcome at any time. They should include a short cover letter and a statement of research interests. Applicants for postdoctoral positions should have three letters of reference sent directly; applicants for other positions should include contact information for at least three references. Materials should be sent electronically to [office-hannover@aei.mpg.de](mailto:office-hannover@aei.mpg.de) with Subject "New hires". Further information about the AEI may be found at <http://www.aei.mpg.de/>.

The Max Planck Society wants to raise the proportion of women in areas where they are under-represented. Women are therefore especially encouraged to apply. The Max Planck Society also wishes to employ more severely challenged persons, whose applications are also encouraged.



MAX-PLANCK-GESELLSCHAFT



UPPSALA  
UNIVERSITET

## Assistant Professor in Experimental Elementary Particle Physics with ATLAS at LHC



The High Energy Physics Collider Group of the Department of Nuclear and Particle Physics at Uppsala University in Sweden is involved in the ATLAS project at CERN's Large Hadron Collider (LHC). The Group has provided 300 of the 2000 SemiConductor Tracker (SCT) modules of the ATLAS central tracking system and is responsible for the build-up and operation of the SCT Detector Control System. The Group is currently pursuing an extensive program of physics simulation studies of the potential to discover the charged Higgs boson with ATLAS. For further information about the Group see <http://www4.tsl.uu.se/~Atlas/index.html> and about the Department <http://www.isv.uu.se>

The Assistant Professorship is a tenure track position that can be held for 4 years and qualifies the holder to subsequently apply competitively for announced Associate Professorships. The task of the appointee is to participate in the operation of the ATLAS detector at CERN, to perform physics analysis of ATLAS data and to supervise the PhD students of the group in these activities. Although there is no obligation to teach courses at the University there will be the opportunity to teach at the undergraduate and postgraduate level. The candidate must have a PhD. Priority will be given to applicants who have completed their PhD within 5 years of the application deadline.

In the selection among the qualified applicants particular importance will be attached to scientific excellence in Elementary Particle Physics. Applicants with a successful record in simulation studies and data analysis of collider-based particle physics experiments will be given first priority.

The salary level is 28 000 SEK/month and upwards depending on qualifications.

A complete version of this advertisement is available at [http://www.personalavd.uu.se/ledigaplats/1344forass\\_eng.html](http://www.personalavd.uu.se/ledigaplats/1344forass_eng.html).

**The application must be written in English and be addressed to the Vice-Chancellor of Uppsala University and have reached the University Registrar, UFV-PA 2007/1344, Box 256, SE-75105 Uppsala, Sweden, fax +46 18 471 2000 by latest 2007-08-15.**

A fax should be followed by a signed original of the application sent within a week of the deadline. The applicant is required to submit two copies of documents and one copy of publications according to instructions found on the web site

<http://www.teknat.uu.se/english/instructions.php>

For further information about the position, please contact Prof. Tord Ekelöf, phone +46 70 4250210, e-mail [Tord.Ekelof@tsl.uu.se](mailto:Tord.Ekelof@tsl.uu.se)

# Jefferson Lab

Thomas Jefferson National Accelerator Facility

## Hall D Staff Scientists (3)

SALARY RANGE: \$50,600 - \$80,000 (SS I) /  
\$63,600 - \$100,600 (SS II)

Thomas Jefferson National Accelerator Facility (Jefferson Lab), located in Newport News, VA, USA, is a world-class scientific laboratory centered around a high-intensity, continuous wave electron beam, which provides a unique capability for nuclear physics research. The lab is managed for the Department of Energy by Jefferson Sciences Associates.

Together with the upgrade of Jefferson Lab beam energy from 6 to 12 GeV, Hall D, a new experimental facility for high-intensity photon beam experiments, will be constructed. Successful candidates will be actively engaged in the research effort and assume a lead role in conceptual planning, proposal development, design, implementation, and operation of the Hall D detector. Following the completion of the facility construction, individuals will assume responsibility for execution of the experimental physics program in Hall D in collaboration with the external user community, and will provide hardware and software support of the Hall D detector and other instrumentation in Hall D. **There will be also the possibility to initiate new research proposals beyond the initial program to search for exotic hybrid mesons with the Hall D detector.**

### MINIMUM QUALIFICATIONS:

A Ph.D. in experimental nuclear, particle, or high-energy astrophysics is required. The successful candidate should either have a high degree of expertise in design, fabrication, assembly and operations of large, complex detectors; or, be a proven expert in hadronic physics analysis; or have extensive experience with large scale detectors or data analysis combined with expertise in either modern high rate data-acquisition and trigger systems or offline software for charged particle tracking and detector simulations. Knowledge of particle identification techniques and calorimetry is also highly desirable.

**For any further questions arising from this advertisement please contact: Dr. E. C. Aschenauer ([elke@jlab.org](mailto:elke@jlab.org))**

**Applicants should email curriculum vitae to: [jobline@jlab.org](mailto:jobline@jlab.org) (noting position title in subject line), and have copies of recent unpublished work, along with three letters of reference sent to: Human Resources Consultant, JSA/Jefferson Lab, 628 Hofstadter Road, Suite 2, Newport News, VA 23606**

**Deadline for applications: August 31, 2007**

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## Lecturer/Reader in Accelerator Physics

Imperial College is ranked in the top ten universities of the world, according to the 2006 Times Higher Education Supplement league tables.

The Imperial College High Energy Physics Group invites applications for a permanent academic appointment in Accelerator Physics at Lecturer or Reader level.

With the Rutherford Appleton Laboratory, the Group is pursuing a R&D programme into a future Neutrino Factory. Major projects are a high power proton driver and the MICE experiment, investigating ionisation cooling. Time will be divided between Imperial College and RAL and will include teaching duties at Imperial College.

The post-holder should have a track record in accelerator physics or, exceptionally, a proven track record in experimental particle physics and a commitment to the development of a capability in accelerator physics. For an appointment at Reader level previous leadership of a project at a major accelerator centre will be expected.

Details of the Imperial High Energy Physics Group can be found at: <http://www.imperial.ac.uk/research/hep> and the ISIS Accelerator Division of RAL at <http://www.isis.rl.ac.uk/>

The starting date will be by negotiation. Salary for an appointment at Lecturer level will be in the range £37,740 to £42,150. Salary at Reader level will be by negotiation commencing at a minimum of £46,560.

Further particulars and an application form are available from: <http://www.imperial.ac.uk/employment/academic/index.htm> or Ms Paula Brown, (email: [paula.brown@imperial.ac.uk](mailto:paula.brown@imperial.ac.uk)). Completed applications should include a curriculum vitae, a list of publications, a statement of research interests and names and addresses of three referees. Applications should be sent to Ms Paula Brown, Blackett Laboratory, Imperial College London SW7 2AZ.

**Closing date for applications 28 August 2007.**

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## DOCTORATE SCHOOL ON PHYSICS, ASTROPHYSICS AND APPLIED PHYSICS

The International Research Doctorate School in "Physics, Astrophysics and Applied Physics", established by the Department of Physics, the Department of Chemistry Biochemistry and Biotechnology for the Medicine, the Institute of Applied Physics, the Institute of General Physiology and Biochemistry of the Milano University and by the Department of Mathematics and Physics of the Catholic University in Brescia, opens 30 PhD positions.

The School awards: 20 fellowships of about 9734.00 Euro per year net (at least one reserved to non EU citizens). Financial support for lodging and travel is granted to non EU citizens and EU citizens non resident in Lombardy. The candidates can apply starting from July 24, 2007. The deadline for the application is **September 20, 2006**.

The Doctorate School offers a three years long international training curriculum, with intensive courses, series of seminars, research stages in high quality, public and private Laboratories for fundamental and applied Physics. The students will be involved in research projects in all mainstream areas in Physics, namely: Condensed Matter, Quantum Optics, Nanotechnologies, Biophysics, Biotechnology, Accelerator and Underground Particle Physics, Nuclear Physics, Astroparticle, Astrophysics, Cosmology, Theoretical Physics, Applied Superconductivity, Electronics, Earth Physics, Environment, Medical and Health Physics.

Information and application form can be found in the following web sites:  
<http://www.unimi.it/ricerca/dottorati/20546.htm>  
[http://www2.fisica.unimi.it/postaur/phys/Concorsi/Concorsi\\_di\\_Ammissione.html](http://www2.fisica.unimi.it/postaur/phys/Concorsi/Concorsi_di_Ammissione.html)

## University of Bern Faculty of Science



Applications are invited for a full  
professorship in  
**Theoretical Physics**

b  
UNIVERSITÄT  
BERN

Opening August 1, 2009 at the Institute for Theoretical Physics, University of Bern, Switzerland. Candidates should have a strong research record in the area of quantum field theory applied to particle physics, in particular, the standard model and the theories that go beyond it. The current research activities at the institute include effective field theories, nonperturbative quantum field theory, and the standard model, in particular, heavy quark physics. The successful candidate is expected to build up a strong research group, to interact with both theoretical and experimental colleagues, to be experienced in attracting external funding, and to actively participate in the teaching and supervision of students.

The University of Bern particularly encourages women to apply for this position.

Applications including a curriculum vitae, a publication list, copies of the most important publications, and a brief outline of past and future research should be sent to Prof. P. Messerli, Dean of the Faculty of Science, University of Bern, Sidlerstrasse 5, CH-3012 Bern, Switzerland, by October 15, 2007.

For further information you may contact Prof. U.-J. Wiese, Institute for Theoretical Physics, University of Bern, Sidlerstrasse 5, CH-3012 Bern, Switzerland.



# 2007 MRS FALL MEETING

[www.mrs.org/fall2007](http://www.mrs.org/fall2007)

## Meeting Chairs:

**Duane Dimos**  
Sandia National Laboratories  
Tel 505-844-6385  
Fax 505-844-1583  
ddimos@sandia.gov

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I. Physikalisches Institut  
Tel 49-551-397601  
Fax 49-551-3912229  
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For additional meeting information,  
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## SYMPOSIA

### CHARACTERIZATION APPROACHES

- A: Combinatorial Methods for High-Throughput Materials Science
- B: Nanoscale Phenomena in Functional Materials by Scanning Probe Microscopy
- C: Quantitative Electron Microscopy for Materials Science
- D: Materials in Transition—Insights from Synchrotron and Neutron Sources
- E: Theory, Modeling, and Numerical Simulation of Multiphysics Materials Behavior

### ELECTRONICS, OPTICS, AND MAGNETICS

- F: Interfaces in Organic and Molecular Electronics III
- G: Large-Area Processing and Patterning for Active Optical and Electronic Devices
- H: Nanostructured Solar Cells
- I: Nanoscale Magnetic Materials and Applications
- J: Spin-Injection and Spin-Transfer Devices
- K: Ferroelectrics, Multiferroics, and Magnetolectrics
- L: Zinc Oxide and Related Materials
- M: Materials and Hyperintegration Challenges in Next-Generation Interconnect Technology
- N: Materials, Integration, and Technology for Monolithic Instruments II
- O: Nuclear Radiation Detection Materials
- P: Diamond Electronics—Fundamentals to Applications II
- Q: Nitrides and Related Bulk Materials

### ENERGY AND ENVIRONMENT

- R: Life Cycle Analysis for New Energy Conversion and Storage Systems
- S: Materials and Technology for Hydrogen Storage
- T: Materials Innovations for Next-Generation Nuclear Energy
- U: Thermoelectric Power Generation
- V: Materials Science of Water Purification

### GENERAL

- W: Forum on Materials Science and Engineering Education for 2020
- X: Frontiers of Materials Research
- Y: Materials Issues in Art and Archaeology VIII

### ENGINEERED MATERIALS

- Z: Bulk Metallic Glasses
- AA: Fundamentals of Nanoindentation and Nanotribology IV
- BB: Magnetic Shape Memory Alloys
- CC: Materials for New Security and Defense Applications
- DD: Microelectromechanical Systems—Materials and Devices
- EE: Phonon Engineering—Theory and Applications
- FF: Synthesis and Surface Engineering of Three-Dimensional Nanostructures

### NANOSYSTEMS

- GG: Excitons and Plasmon Resonances in Nanostructures
- HH: Nanophase and Nanocomposite Materials V
- II: Nanotubes and Related Nanostructures
- JJ: Nanowires—Novel Assembly Concepts and Device Integration
- KK: Nanoscale Pattern Formation

### SOFT MATTER AND BIOSCIENCE

- LL: Bioinspired Polymer Gels and Networks
- MM: Biomolecular and Biologically Inspired Interfaces and Assemblies
- NN: Protein and Peptide Engineering for Therapeutic and Functional Materials
- OO: Solids at the Biological Interface
- PP: Quantum-Dot and Nanoparticle Bioconjugates—Tools for Sensing and Biomedical Imaging
- QQ: Electroactive and Conductive Polymers and Carbon Nanotubes for Biomedical Applications

## MEETING ACTIVITIES

### Symposium Tutorial Program

Available only to meeting registrants, the symposium tutorials will concentrate on new, rapidly breaking areas of research.

### Exhibit

A major exhibit encompassing the full spectrum of equipment, instrumentation, products, software, publications, and services is scheduled for November 27–29 in the Hynes Convention Center. Convenient to the technical session rooms and scheduled to complement the program, the MRS Fall Exhibit offers everything you need all under one roof.

### Publications Desk

A full display of over 935 books will be available at the MRS Publications Desk. Symposium Proceedings from both the 2006 MRS Spring and Fall Meetings will be featured.

### Student Opportunities

Graduate students planning to attend the 2007 MRS Fall Meeting are encouraged to apply for a Symposium Assistant position and/or a Graduate Student Award. Applications will be accessible on the MRS Web site by May 15.

### Career Center

A Career Center for MRS members and meeting attendees will be open Tuesday through Thursday.



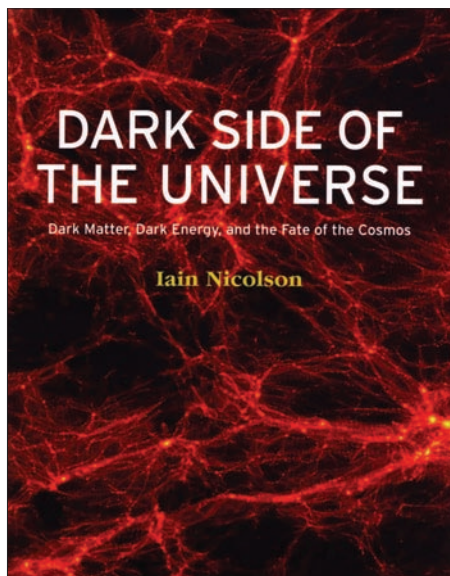
**Canadian Light Source** **Centre canadien de rayonnement synchrotron**



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# BOOKSHELF



**Dark Side of the Universe. Dark Matter, Dark Energy, and the Fate of the Cosmos** by Iain Nicolson, Canopus. Hardback ISBN 0954984633, £19.95.

If you are a particle physicist interested in cosmology, this book is for you. It makes a broad, clear and precise overview of our current understanding of dark matter and dark energy – the invisible actors governing the fate of the universe.

It is a challenge to try to make these apparently obscure concepts familiar to any motivated reader without a scientific background. But the author, Iain Nicolson, has been entirely successful in his enterprise. With a pleasant balance between text and colourful illustrations, he guides the reader through a fascinating, invisible and mysterious world that manifests its presence by shaping galaxies and the universe itself.

The book starts with an introduction to key concepts in astrophysics and the development of classical cosmology. It then describes the observational evidence for dark matter in galaxies and clusters of galaxies, showing that massive extremely dim celestial bodies cannot account for the missing mass. Particle physics is not neglected, with a description of our understanding of ordinary “baryonic” matter and the quest for detecting exotic weakly interacting massive particles (WIMPs). An entire chapter is also devoted to the idea that modified Newtonian dynamics (MOND) could be an alternative to the existence of dark matter. The second half of the book is devoted to cosmological

## Summer Bookshelf

Summer for physicists is the season of conferences as well as (or instead of!) well-earned holidays, perhaps providing more time for reading about topics away from mainstream particle physics. In this Bookshelf, some of our regular contributors review a selection of less technical books for dipping into on the beach or on long plane journeys.

observations and arguments that suggest the existence of dark energy – an even more mysterious ingredient of the universe. The pieces assemble through these chapters to reveal a universe that is flattened out by inflation and that is essentially made of cold dark matter, with dark energy acting as a cosmological constant.

This new cosmology is generally accepted as the standard model and gives the full measure of the dark side of the universe. The visible matter studied by astronomers so far appears to be just the tip of the iceberg (less than 1%) and even baryonic matter studied so far by physicists is only about 5% of the mass–energy content of the universe. The remaining 95% is unknown territory, which the book invites us to explore using all techniques available. This will be the major challenge for physics in the 21st century. *Marc Türlér, INTEGRAL Science Data Centre and Geneva Observatory.*

**Why Beauty is Truth: a History of Symmetry** by Ian Stewart, Basic Books. Hardback ISBN 9780465082360, £15.99.

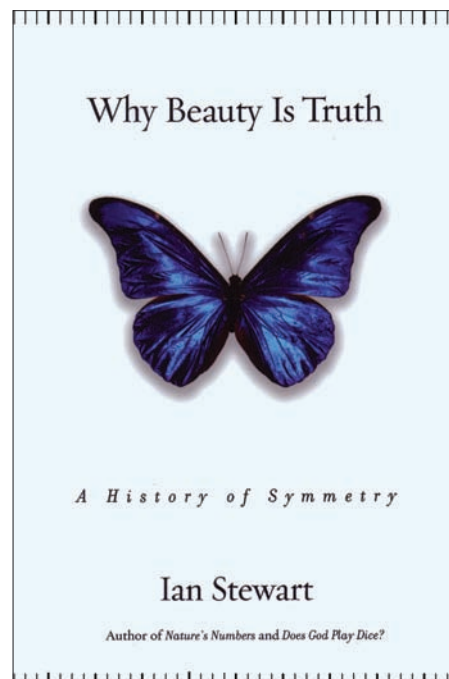
When I was at university studying physics, I used to think that symmetry was one of the most obscure topics that we were asked to digest. Indeed, symmetry is one of those concepts that at first appear clear and straightforward, but become increasingly distant and tricky when you really try to understand all of the implications.

In this book, Ian Stewart attempts to shed light on a fundamental question: why, at all, do we need to think of the universe in terms of symmetry? He guides us along an interesting historical path where all the names that you encountered in your studies – from Riemannian manifolds to hamiltonians and Lie groups – transform into real, “normal” people. He takes you to

a Babylonian school and then to a square in Paris where Galois is duelling – and dying – for love. The reading is enjoyable until you arrive at the physical description of our universe. Then, inevitably, it becomes harder to follow the multiple connections between physics and mathematics; again inevitably, the tough mathematical and physical concepts that lie behind our current knowledge of the laws of nature, are only “approached” in the final chapters and not really explored. So, no miracle then.

This is the second book by Stewart that I have reviewed and I was expecting a lighter approach to mathematical things, similar to the one that I had appreciated in *Letters to a young mathematician (CERN Courier July/August 2006 p52)*. It turns out, however, that it is a hard task even for Stewart to explain symmetry in simple terms. I am relieved! Still, I really appreciated it and look forward to his next effort to make accessible the very abstract and distant ideas that science routinely uses.

*Antonella del Rosso, CERN.*



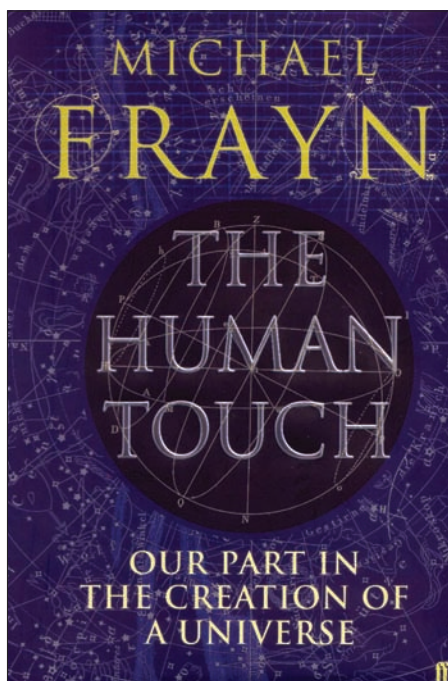
**The Human Touch – Our Part in the Creation of the Universe** by Michael Frayn, Faber and Faber. Hardback ISBN 9780571232178, £20.

British author and dramatist Michael Frayn is extremely bright and so multifariously talented that it must be difficult for him

to know in which direction to channel his prodigious energies. Frayn is best known for his translations of Russian classics, an impressive series of novels (including *Spies*) and some memorable plays – notably the classic comedy *Noises Off*. In 1998, he took a new direction with *Copenhagen*, a highly successful piece of theatre that imagines what happened when quantum pioneers Niels Bohr and Werner Heisenberg – each privy to different sets of nuclear secrets – met during the Second World War.

Remote and inaccessible, quantum science is the Cinderella of modern culture. Frayn, however, showed that – fleshed out with characters – it can make successful theatre. Emboldened by the success of *Copenhagen*, other authors have followed suit, while Frayn has ventured into much deeper scientific waters with his latest book.

In *The Human Touch*, he struggles to disentangle the actual universe from our perception of it. Words and language are what Frayn is good at, and there is some excellent analysis of the syntax in which such a conscious picture is based. On the other hand, he also acknowledges that the description ultimately must become mathematical (quoting Feynman's remark that no amount of intellectual preparation can make deaf ears experience the music of others), but the book has no mathematics. "A non-scientist (like myself) is a fool to



trespass in this great palace of thought," admits Frayn as he meanders on.

The essence is the "unresolvable paradox" of having to reconcile the 14 billion years of the existence of the universe with the fleeting timespan of human consciousness. Frayn's conclusion is that "the world has no form or substance without you and me to provide them; and you and I have no form or substance without the world to provide them in its turn". An example of this: "When scientists talk about objects that exist in space-time... it seems for a moment as if this makes them somehow independent of human experience."

Frayn acknowledges that Jonathan Bennett, his Cambridge philosophy teacher, sees the book's viewpoint as "anthropocentrism run amok". Anthropocentrism flourished when quantum mechanics revealed the bizarre role of the observer in the outcome of things, but became less important as quantum mechanics progressed to the bowels of the human intellectual digestive system.

The extensive footnotes display how Frayn has read far and wide, but not in any scientific depth. When he does tinker with real science, it is clumsy – as when he talks of "the discovery that imaginary numbers were a good model for the paradoxical behaviour of particles in quantum conditions" – and there is a puzzling description of the meaning of negative numbers. It is a rambling book with an index encompassing Democritus, Hitler, Newton, Ralph Waldo Emerson, Noam Chomsky, sexual arousal, Father Christmas, St Matthew, and oboes.

All books have errors. Here, the concept of the "arrow of time" was introduced by Eddington in 1927, not posthumously in 1958; the concept of zero, attributed to the Greeks, was imported from the Orient (the Arabic zifr is commemorated in our "cipher"); our understanding of the development of galaxies is somehow attributed to Victor Weisskopf; and the vital role of symmetry breaking in modern theory is confined to a mention of its role in the weak interactions of radioactive decay. Maybe this was something that Frayn felt he had to get off his chest. Having done so, he should return as quickly as possible to what he excels in: to entertain us and win more awards. *Gordon Fraser, Divonne-les-Bains.*



**BANG! The Complete History of the Universe** by Brian May, Patrick Moore and Chris Lintott, Carlton Books. Hardback ISBN 9781844425525, £20.

For 50 years, Patrick Moore has hosted the BBC's *Sky at Night* television programme. In this book, he has teamed-up with his current co-host, young astrophysicist Chris Lintott, and one-time astronomy PhD student Brian May, who also happens to be the lead guitarist with rock band Queen. The primary audience appears, at first sight, to be the general public. Indeed, most casual readers will be drawn to the hundreds of beautiful images of planets, stars and galaxies that form about half of the 180-odd pages and will be content with the fairly simple accompanying captions.

But with its subtitle *The Complete History of the Universe*, *BANG!* claims to be more than an attractive addition to the average coffee table. Chapters are arranged chronologically, beginning with "Genesis" ( $10^{-43}$  to  $10^{-32}$  seconds A.B. – After Bang!) and progressing through the evolution of stars and planets, to life on Earth and ending some 18.7 billion years later with the "End of the Universe".

However, it appears that one of the chapters has been lost in editing: the time period  $10^{-32}$  seconds to 300 000 years A.B. is missing, which will not win over too many particle physicists. The authors also fail to capture the imagination of the readers in the early chapters because it glosses over some of the basic mysteries of the universe such as the absence of antimatter ("due to reasons we do not yet understand").

The prose is often rather complex, and the beautiful images and simple captions, in fact, do little to help.

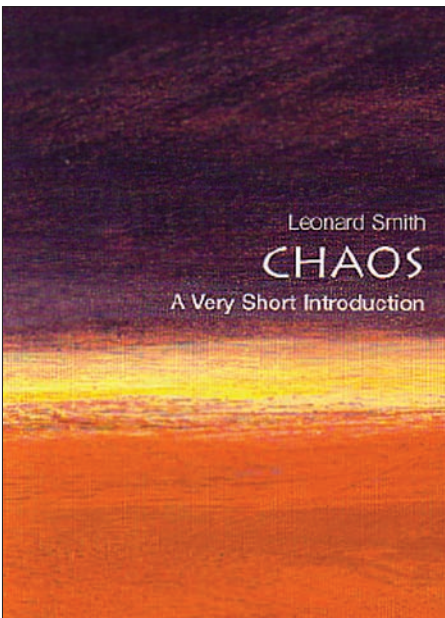
The later chapters are more rewarding. For example, the chapter on star and planet formation includes an excellent description of the development of our solar system and what might have happened if things had been slightly different – such as Jupiter crashing into the Sun and wiping out the intermediate planets. The book ends with a 15-page guide to practical astronomy for beginners – something that I found particularly valuable – and biographies of astronomers/physicists of the past hundred years or so.

Many people will buy this book simply because of the celebrity authors and the pretty pictures, but despite the misgivings mentioned above, *BANG!* has a lot to offer more serious readers.

Dave Barney, CERN.

**Chaos: A Very Short Introduction**

by Leonard Smith, OUP. Paperback ISBN 9780192853783, £6.99.



The mission statement of OUP's Very Short Introductions series says they "are for anyone wanting a stimulating and accessible way in to a new subject". The volume titled *Chaos* deals with the mathematical and physical concepts behind those phenomena where small differences in the present state may have huge consequences in a future state.

I tried hard. Leonard Smith says that the

180-page booklet contains "no equations more complicated than  $X=2$ ". This is perhaps the book's biggest weakness. I would have preferred some formalisms, and definitely a site from which one could download some models to run in simple spreadsheets. That would have helped.

Until I reached page 40, the text was amusing if not always very clear. After that, I think any interested layman with no mathematics background would certainly be lost. I kept going until page 60, at which point I became frustrated: the need to implement and observe working models of the book's examples soon became overwhelming. How many readers will have the skill and patience to write such models? And would that not defeat the idea of the concept of "a very short introduction"?

I do not doubt the author's competence in the field; mine is nil. The book gave me a set of more precise notions about what chaos is and what its governing aspects are; that alone was worth the considerable effort. Moreover, it is well-illustrated throughout and the glossary is good. But the book is an effort to read. Smith himself points out that it is difficult to define "a biology of non-elephants". Chaos comes in all the diversity of non-linear systems, and that makes the task of writing an introduction all but impossible. The result: many of the explanations are "chewy", making it difficult to recommend this little book to friends.

Robert Caillaud, Prévessin, France.

**The problems of physics** by AJ Leggett, OUP. Paperback ISBN 9780199211241, £19.99.

Oxford University Press is now re-issuing some of its most-celebrated classics in the series Oxford Classic Texts. In *The problems of physics*, first published in 1987, Anthony Leggett presents an overview of the frontiers of physics at the time, aimed at the general reader. This includes chapters on cosmology and high-energy physics and also on condensed-matter physics, which is where he writes briefly on superfluidity, the subject of his Nobel prize in 2003. In high-energy physics, he covers the Higgs mechanism and provides, according to a reviewer, "one of the clearest [descriptions] I have come across". Unfortunately, the book is published exactly as it was in 1987, with no attempt to say what has changed in the past 20 years.

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**The Newtonian Legacy** by NJ Evans,  
[www.hep.phys.soton.ac.uk/~evans/NL](http://www.hep.phys.soton.ac.uk/~evans/NL).

There are many free novels available online, but this is probably the only one by a particle theorist. In this e-book, Nick Evans explains modern particle physics for a lay-readership as the background to a murder mystery. WPC Thatcher, a police officer who had previously studied physics, is leading the investigation into the death of a researcher at a physics institute. Her enquiring mind leads her also to ask questions about the Standard Model and beyond.

Reviews on Evans' web page show that his project is succeeding. Meanwhile, for readers of *CERN Courier*, the author has found a lost chapter – "Higgsless Dreams". Read on!

\*\*\*\*\*

WPC Thatcher lay in the darkness, a disconnected consciousness in limbo. Stray worries competed for spare processing time as she tried to sleep, unaware of the room around her or the bed she lay upon. That is until her partner, sprawled next to her, gave out a loud isolated snore breaking the illusion.

Sometimes Mike's grunts would irritate her, but tonight they seemed tolerable or even endearing. Perhaps this was the result of pheromonal warfare between the sexes, she reflected – they had made love earlier.

She was awake after a run to the kitchen to get a warmed bottle of milk for her daughter who had balled for it at 3 a.m. She'd have managed five hours sleep by then – not enough, but sufficient to make a return to oblivion near impossible. She wasn't sure if she'd been awake hours or just minutes since then. Actually she was in that murky state of consciousness where she wasn't entirely sure she wasn't asleep.

The state of their bank balance was clammering for attention. It was near the end of the month and she had meant to check online. She'd worked really hard to ensure a £200 a month pay rise in the previous spring, but it didn't seem to make any difference to the bottom line a week before pay day. She could look in the morning, so why was she worrying about it now?

Think of something else then. Kissing Mike, his weight on top of her. Drowsy pleasure, the first hints of warmth between her thighs... well that wasn't going to get her to sleep!

Try again – work... she was investigating a strange death. A physicist at the local institute, called the Phi, had been found

dead in the grounds – it seemed to be connected to a chemical laboratory he was running at his home. Her degree, which had been in physics, although she could barely dredge up anything specific now, made her the best qualified of the police team to talk to the man's academic colleagues.

The Phi Institute was a centre for the study of theoretical particle physics. The staff seemed to spend their time dreaming up new theories of the most fundamental building blocks of nature – electrons and quarks and so forth, from which all materials are made. They took their ideas and then mathematically calculated the consequences for big experiments that collide particles together at enormous energies. They all seemed to have been waiting for years for an experiment called the Large Hadron Collider to switch on – this machine, in Geneva, Switzerland, will collide protons, creating fireballs with 10 times more energy than ever achieved before. The big hope apparently was to use this energy to create new particles through the famous Einstein  $E=mc^2$  relation, which means mass is just a form of energy.

Now, she wondered, could she remember the thread of this? The main focus was trying to understand the weak nuclear force – a force involved in radioactive decay. The particles of matter have charge under this force, just as electrons carry electric charge. These charges interact through fields that permeate space, communicating the presence of one charge to another and controlling their attraction or repulsion. There are such fields for the weak force just as for electromagnetism.

Somehow those fields are like particles, she remembered. Ah yes! That's quantum theory – the energy in the fields turns out to be divided into lumps. If you interact with the field you might get given a lump of energy or two, but never half a lump. Those lumps of energy behave like particles – the lumps of an electric field are called photons (the same things that make up light, since light is an excitation of electric and magnetic fields).

Now the problem with the weak force lumps (the W bosons was it?) was that they were very massive, unlike photons that are massless.  $E=mc^2$  again tells us they have some intrinsic energy associated with that mass that photons don't have. So you can't just simply adapt electromagnetic theory and get the weak force.

Enter the theorists – they all seem to

believe in this new particle called the Higgs boson. Their explanation was that all of space, even the vacuum between planets, is filled with vast numbers of these new Higgs particles. The Higgs particles have weak force charge so the W bosons keep interacting with them. It's like filling space with treacle; the Higgs particles impede the progress of the W bosons. The energy of that interaction is the W boson mass.

The only problem is that they've never made a Higgs particle. So, concluded the WPC, pleased with herself, that's what they're all looking for.

Is that really the only explanation, she wondered? There must be a theorist who's dreamt up another possibility, surely? Perhaps not? She should look on the internet – maybe she could learn something that would put the Phi staff off story!

Maybe she should really go to sleep? She rolled onto her side. She'd bought a sweater on Sunday – that might have pushed them overdrawn... for goodness sake... It's no good, she concluded, she was going to have to get up and check their bank balance.

Mike didn't move as she shifted to a sitting position and found her slippers. He had earned "midnight-milk-monster" duties for tomorrow she resolved. She padded out of the room across the landing and down the stairs. The first hints of dawn were creeping through the windows and, combined with the light they left on in the hall below, made her path clear.

She paused in the hall to examine her reflection in the large mirror hung on the wall. Her short blonde hair was crushed and askew and she had big black smudges under her eyes. The long, faded, white T-shirt with teddy bears across the front, which was all she was wearing, seemed overly twee. She'd used to look cute in it, hadn't she? Was she looking old or just feeling it? Still, who wants to be a cute policewoman? Some instinctive part of her subconscious still whispered against this rational conclusion.

The computer painted her in a blue glow from the desktop background when she moved the mouse. She summoned up a browser and clicked away to their account summary – it was as bad as she'd feared, though not quite overdrawn. Mike had been in town shopping last Wednesday, judging by the wracked-up debits. Funny, she thought, but he'd probably said and she'd forgotten.

Back to bed? Instead she Googled the



word “higgsless”. There were lots of hits – interesting... she clicked on one at random summoning the abstract of a scientific paper onto the screen. Kaluza Klein... moose... quiver... unitarity... Well, that was pretty unreadable, not to mention bizarre.

Suddenly some part of her brain had caught up with prior events and she found herself frowning. One of those payments from their account had been to Pink Moon – that was a lingerie shop in town. Another had been a chocolate shop. Her heartbeat raced a little and the blood drained from her face. Was Mike cheating on her? She tried to scan back through her life seeking other signs – it was just work and her daughter though. That didn’t seem very reassuring. Don’t panic, you’re being silly – he probably bought them for me, she thought. Not that it was her birthday anytime soon, nor Valentine’s. How about their wedding anniversary? He never remembered that and anyway it was five weeks away. God, she’d been doing so many late nights he could have been anywhere. Maybe she even deserved it then. The word “neglect” came to mind.

Cling to the wedding anniversary idea for a moment – she’d noticed only recently that their every weekend between now and then was booked up with children’s parties, visiting relatives and so forth. And she had made a big fuss about Mike forgetting last year. So she was accusing him of infidelity just because he was more organized than her. She was going to have to find the time to buy him something good now. The panic had ebbed away, well almost.

She clicked on a few more links to distract herself. Finally she got a PowerPoint show that made a little sense. It had been written by some mid-west US professor as part of his research group’s presentation to the Department of Energy for renewed funding. Interestingly, when they needed money these professors appeared to become a lot more comprehensible. She could imagine the panic as they tried desperately to make their talks accessible but not patronizing. Actually, she really could read this one, so the prof. had probably opted for patronizing in his own view!

Apparently the most urgent need for the Higgs was to solve a problem in the theory of scattering two W bosons. Without the Higgs, theory would predict that the probability of two Ws scattering was greater than one (What? If you flip a coin half the

time it will come up heads and half the time it will come up tails but it always adds up to one. Oh, that’s the problem!). If you include the Higgs then all is well.

The same job can be achieved by the inclusion of new heavier copies of the W particles, the presentation continued. It only works for a little bit though, if you give the Ws too much energy you get the same problem again. So then you add in yet more W particles to solve the problem again, and so on indefinitely.

None of this removes the need to explain where the W masses come from though. There seemed to be two ideas – firstly you could eventually resort to a Higgs (or many of them) to generate all these W masses. What you gain from the tower of Ws is that the Higgs mass could be much larger than it would be otherwise, so you might not find it at the LHC.

The second possibility was a bit more bizarre. Apparently you could choose to never end the tower of new Ws – every time you go to a higher energy you just keep finding a new W. If this happened it would mean you’d found an extra dimension of space! Weird.

There was a picture of a spatial direction (not up–down, sideways, or forward and back, but a new direction) which was a tiny circle. If you head off in this new direction you end up back where you started (this seemed to be an acceptable thing to happen, to this professor at least). This direction was going to be so short (smaller round than an atom is across) that in everyday life we’re oblivious to it.

Next there were pictures of the weak force field going round this circle. However it wiggled it always had to come back to the same value after going round the circle.



That means only very special weak force field configurations are allowed. Depending on how much they wiggle they have a certain amount of energy – that energy determines the mass of the associated W particles. You could always add an extra wiggle before you get back to the start so that’s why there is an infinite tower of more and more massive Ws.

Well that was kind of interesting. The mid-west professor had lost patience with his attempts at pedagogy at that point though and the following pages were a mass of equations that meant nothing to the WPC.

The slide’s use as a distraction was over and she was still stressing about Pink Moon. If Mike had bought her a present he’d have to have hidden it somewhere in the house. That wasn’t so easy for him because she did the washing and cleaning so she got to poke her nose most places. Modern equality culture required her to mentally qualify this thought with the point that they had tried an equal sharing of all duties but she’d just not been up to the physicality of cutting the hedge and painting over the stairs. They shared the cooking so the kitchen was out. Likewise the car. Well, she thought, that pretty much leaves the tool cupboard in the garage.

She was just left with the moral dilemma then. If she went to look it would be effectively accusing Mike and spying, wouldn’t it? She could just wait and see what happens on their anniversary. She wasn’t going to be able to think about much else in the meantime though.

She rolled the mouse to show her the final page of the physics presentation. Higgsless models were possible in principle but the extra Ws had to be rather heavy to explain why we hadn’t yet found them, and no completely satisfactory theory yet existed. These physicists always seemed to be waiting to find out the answer. She didn’t have their patience.

The WPC switched off the computer screen and walked out into the kitchen. She unlocked and opened the door into the garage. The fluorescent tube buzzed loudly when she switched it on – she hoped Mike was fast asleep. The car was on the drive so it was easy to reach and open the store cupboard. She realized she wasn’t breathing. Please God.

Garden tools hung neatly from hooks on the back wall of the cupboard. Stacked black plastic flower pots covered the shelf top. A large garden waste bag was on the floor, its top neatly turned over to hide its contents. She reached down to open the bag – her hand was shaking. Inside was a carefully placed Pink Moon bag.

The WPC crept back into bed next to her husband, mentally chastising herself. As she lay down Mike rolled over and blearily asked, “What are you doing? Did you go in the garage?”

“Can’t sleep, just mooching,”

“I thought you’d lost something important.”

“Nothing’s that crucial... except you.” They curled together and fell asleep.

# Searching for physics down below

**Spencer Klein** describes working as a physicist at the South Pole.

The quest for physics can take us in strange directions. In the 1930s, cosmic-ray physicists crossed the globe, measuring the radiation intensity at different latitudes. They have climbed high mountains, flown U-2 former-spy planes and lofted balloons at extreme latitudes – all to further probe the mysterious rays. Neutrino astrophysicists are placing ever-larger detectors in gold, salt and zinc mines. The South Pole, too, is one of the stranger places to study astrophysics.

The Amundsen-Scott South Pole station, a combined scientific station and frontier outpost, is one of the most remote places on Earth. Temperatures range from  $-30\text{ }^{\circ}\text{C}$  in summer to  $-60\text{ }^{\circ}\text{C}$  in winter. Six months of darkness follow six months of light. Everything, from food, fuel, equipment and people, must be flown in on LC-130 Hercules turboprops – aircraft with both wheels (for use on ice runways) and skis (for the packed snow at the pole).

Despite these difficulties, the South Pole has many attractions. Meteorologists, atmospheric scientists and glaciologists have obvious reasons to work there. Microwave and infrared astronomers are attracted by the ultra-dry atmosphere and small daily temperature variations. Neutrino astrophysicists are drawn to the extremely clear, 2800 m-deep ice sheet.

I was privileged to spend three weeks at the station in January/February 2006, to help commission the IceCube neutrino observatory (*CERN Courier* May 2006 p24). It was an amazing and rewarding experience. It all started in Christchurch, New Zealand, where we were issued with an array of extreme cold weather (ECW) gear – a parka, thermal underwear, boots, liners, goggles, etc. The next day, we boarded a US Air Force C-17 aircraft for the five-hour flight to McMurdo Sound, on the coast of Antarctica. This was definitely no commercial flight. The 35 or so passengers sparsely filled the wide-body jet and in-flight service was a lunch bag given out as we boarded. On board, ECW gear was required dress and our luggage was piled in the back.



We landed at Pegasus Field, a set of runway markers on the Ross Ice Shelf, where the terminal building was a mere trailer. McMurdo base resembles an old mining station – a less-than-attractive collection of buildings set amid bare hills, snow and ice. The view was spectacular though, with Mt Erebus visible across the ice shelf.

The next day, 10 of us returned to the Ross Ice Shelf (to Williams Field, the “domestic airport”) to board an LC-130 for the three-hour flight south. We flew over Antarctica’s coastal mountains and central continental plateau, landing at the Amundsen-Scott South Pole station. The station comprised a few large buildings – the almost-finished new station and the dome-covered old station (partly buried in snow) – and a “summer camp” of smaller wood and metal buildings to house the 250-strong summer population. Equipment is piled on long “berms” (ledges), to avoid burial in the drifting snow.

Leaving the aircraft was a shock. Besides the cold (about  $-20\text{ }^{\circ}\text{C}$  when I arrived), the 2835 m altitude complicates walking and breathing, and it is common to experience some initial altitude sickness. Motorized transport was limited, and we often walked the 2 km or so to the IceCube site.

The metal sheathing made the new station seem like a spaceship. Going outside requires “suited up” in an array of ECW gear, rather like putting on a spacesuit. The constant sunlight also took some

adjustment, while other aspects of life at the pole were more congenial. The food – four meals a day – was very good. My room in the new station was small, but comfortable. Less fortunate colleagues ended up in the smaller, canvas-covered wooden buildings.

The physical emptiness of the location led to a certain psychological isolation. Together with being in confined quarters, this made for close working relationships and increased productivity. On the other hand, outside e-mail (available via satellite for eight hours a day) often seemed of limited relevance.

The 2005/6 season was a good one for IceCube. We deployed 480 digital optical modules (DOMs) in eight 2500 m-deep holes in the ice. The holes are drilled using a 5000 gallon/minute stream of  $90\text{ }^{\circ}\text{C}$  water. It wasn’t very “physicist-y” work; IceCube employs drillers with oil-well experience. In fact, the relatively few scientists at the South Pole were outnumbered by heavy equipment operators such as “fuelies” and carpenters; logistics is necessarily king. Only essential work is done at the pole and all non-essential work is done elsewhere.

My own task – commissioning and testing DOMs – was necessary, but relatively mundane. It was satisfying that more than 98% of DOMs survived the enormous pressures and stresses of the re-freezing period. We all helped with other jobs such as pouring 20 kg sacks of Perlite insulation over the IceTop tanks, deploying strings and even cleaning bathrooms. Sadly, I missed the chance to help unearth an electrical junction box buried under 2.5 m of snow.

Several months after leaving, we are now eagerly anticipating the broad range of results on particle, nuclear and astrophysics that IceCube will provide. As a bonus, our measurements of dust layers in the ice – critical for understanding neutrino detection – have shed some light on the weather patterns over the past 200 000 years. It is the science that attracted us to the South Pole, and which will make the entire endeavour worthwhile. *Spencer Klein, LBNL.*

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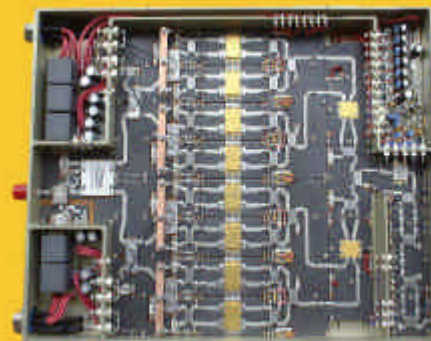


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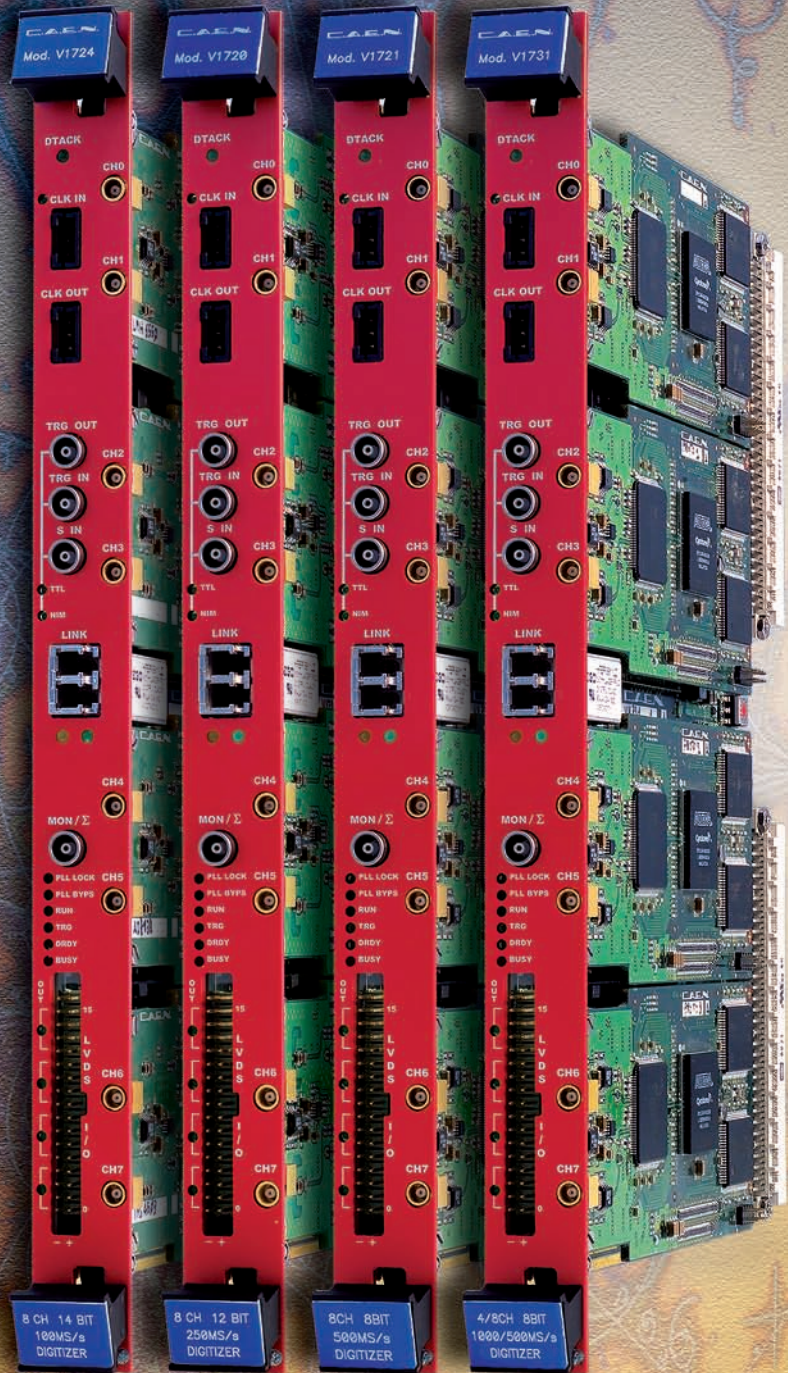
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- VME64X compliant interface
- Optical Link interface
- A2818 PCI controller available for handling up to 8 V1724 daisy chained via Optical Link
- Firmware upgradeable via VME
- Demo software tool for board control and Read-Out



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