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CERN COURIER

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

Advisory board James Gillies, Rolf Landua and Maximilian Metzger

Laboratory correspondents:
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Art director Andrew Giaquinto
Senior production editor Jonathan Cailes
Production editors Lizi Brown, Jesse Karjalainen
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Advertising
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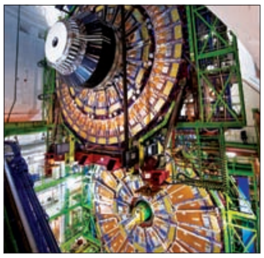
Barry Barish likes a challenge p15

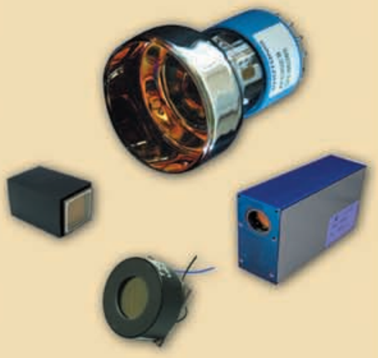


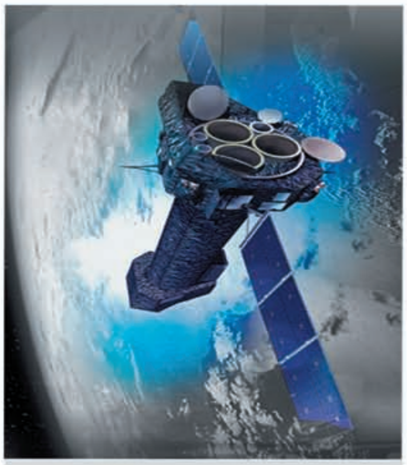
CMS goes underground p27

Can you see yourself here? p35

Features

Cover: With an area of more than 200 m^2 of silicon, the CMS Tracker contains some 9.3 million microstrips and 66 million pixels, assembled into nine different units (p22). This photo shows Valeria Radicci at work on just one of them, the microstrip inner barrel. (Courtesy Stuart Brown/STFC.)





LHC EXPERIMENTS

ALICE and CMS line up the final big pieces underground

With the completion of two major installation projects, nearly all the infrastructure for the ALICE experiment is now in place in the cavern at Point 2 on the LHC ring, near St. Genis-Pouilly in France. Further round the ring, at Point 5 near Cessy, the final large piece has descended into the cavern for the CMS detector, which is the first of its kind to have been constructed above ground before being lowered piece by piece into the cavern below.

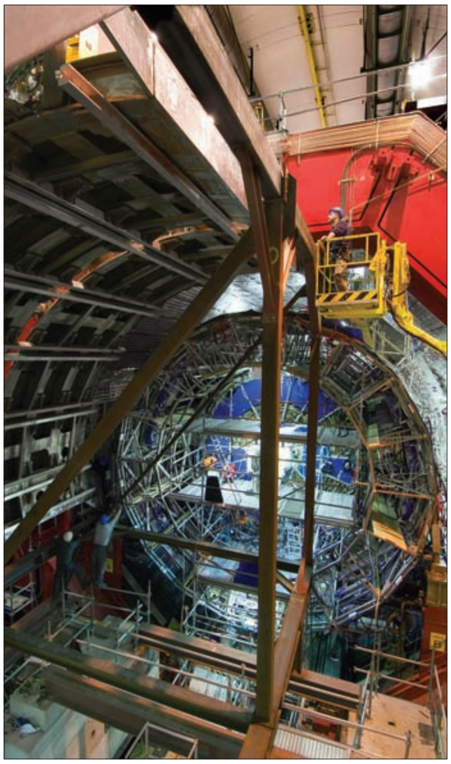
In the ALICE cavern, the electromagnetic calorimeter support structure and "mini" space frame – the device for connecting service networks to the inside of the detector – went into position at the end of 2007. At 7 m high and with a weight of 30 tonnes, the calorimeter support structure consists of two austenitic stainless steel "half-shells", welded and bolted together to give the structure its specially-designed curved form. Once the calorimeter is in place, the support will have to bear nearly three times its own weight.

Lowering the structure and positioning it within the ALICE detector constituted major technical challenges for the ALICE installation team, who made numerous preparatory tests, and had to dismantle two walkways to free up the passage into the cavern. They then inserted the structure inside the detector, sliding it in between the face of the magnet and the metal space-frame that bears detector systems in the centre of ALICE. At one point there was a clearance of only a couple of centimetres between the moving structure and the magnet.


ALICE's "mini" space frame, which carries all the supply cables for services.

Two weeks later, the final big piece of the jigsaw went into place – the "mini" space frame, which resembles a giant socket outlet and weighs 14 tonnes. The device is almost 10 m long and carries all the supply cables for the services required for detector operation (gas, water, electricity, signals). Sitting straight across from the magnet, it connects the inner detector with the outside world.

Around the LHC ring at Point 5, the CMS Collaboration has celebrated the descent of the 15th and final large element of the detector into the experiment's cavern (p28). Weighing 1430 tonnes and asymmetrical in shape, the end cap designated YE+1 is the largest of the three pieces that form one end of the detector. After the lowering operation, the piece was temporarily stowed as far as possible from the central components to leave room to cable the central tracker (p22) and install the beam pipe.


The electromagnetic support structure for ALICE (left) slides into the narrow gap between the magnet (red) and the space frame that holds other detector elements. (Photos courtesy Mona Schweizer for CERN.)

Once these components are all in place CMS will be almost ready. All that will remain will be to seal all the components of the detector, and perform the final tests with cosmic rays and the magnet fully powered to 4 T.

● For a video of the final lowering operation for CMS, see http://cdsweb.cern.ch/record/1083427.

Sommaire

SPIN PHYSICS

The team at SPIN@COSY looks inside a spin resonance

The SPIN@COSY polarized-beam team has found striking new results while studying the spin-manipulation of polarized deuterons at the Cooler Synchrotron (COSY) at the Forschungszentrum in Jülich. The team – from Michigan, COSY, Bonn, the Japan Proton Accelerator Research Complex (J-PARC), Indiana and Groningen, led by Michigan's Alan Krisch – used a new RF-solenoid magnet to manipulate the spins of stored 1.85 GeV/c deuterons (spin-1 bosons).

Maria Leonova, a graduate student at Michigan, and Alexander Schnase, an electrical engineer at J-PARC, designed the new RF-solenoid, which was built by Dieter Prasuhn and his accelerator team at COSY. It used the same sophisticated RF high-voltage supply as its predecessor, an RF-dipole (*CERN Courier* December 2004 p5). However, the RF solenoid produces a longitudinal RF magnetic field rather than a radial field.

The goal of the experiment was to test precisely a new analytic matrix formalism developed by Alexander Chao of SLAC, a theoretical member of the SPIN@COSY team (Chao 2005). The Chao formalism is the first generalization of the famed Froissart–Stora formula, which allows the calculation of the beam polarization after passing through a spin resonance (Froissart and Stora 1960). This formula is valid only if the initial beam polarization is measured long before crossing the spin resonance and the final beam polarization long after crossing it. As polarized beam hardware and the understanding of spin dynamics improved, however, polarized beam enthusiasts became eager to learn what happens very near or even inside a spin resonance.

Vasily Morozov at Michigan used the Chao formalism to calculate in detail what might happen in a new type of experiment, where a 1 MHz RF-magnet's frequency is swept by a fixed range of 400 Hz, while its end-frequency f_{end} steps through many different values near and inside an RF spin resonance (figure 2). The Chao–Morozov calculations predicted that, if the magnet's resonance strength ε was not high enough to flip the spin fully, then there would be large oscillations in the final polarization. These oscillations seem so sensitive to ε and other parameters, such as the beam's momentum spread, Δp/p, and the resonance's central frequency f_r, that the oscillations might provide a new way to measure such parameters precisely.

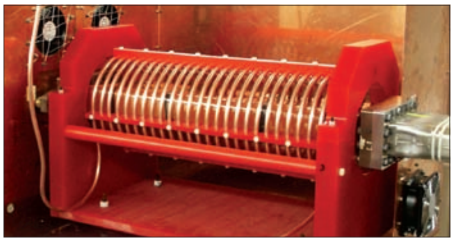


Fig. 1. The water-cooled RF-solenoid with a longitudinal RF magnetic-field integral of 1.95 Tmm peak to peak. (Courtesy Hans Stockhorst/Forschungszentrum, Jülich.)

The data from the new experiment showed striking oscillations that agree very well with these calculations (figure 3). The experiment's data also verified the polarization's extreme sensitivity to the resonance's strength, ε, the resonance's frequency spread, $\delta f_{\Delta p}$, (owing to the beam's momentum spread, Δp/p), and the resonance's central frequency f_r. Moreover, the data clearly demonstrate that the oscillations' size increased rapidly as the beam's momentum spread decreased (Morozov *et al.* 2007 and 2008).

These new experimental results also confirm the validity of the Chao matrix formalism. It may now be used to understand better the behaviour of the 100–250 GeV polarized protons stored in RHIC at Brookhaven and, perhaps in the future, polarized antiprotons in the Facility for Antiproton and Ion Research at GSI (p32), or polarized protons stored in J-PARC or even in the LHC at CERN.

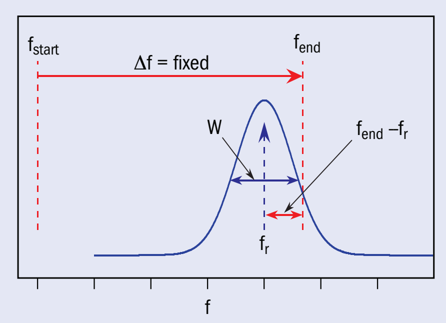


Fig. 2. The end-frequency f_{end} of the 400 Hz sweep (shown in red) is moved in steps through the RF-generated spin resonance (shown in blue).

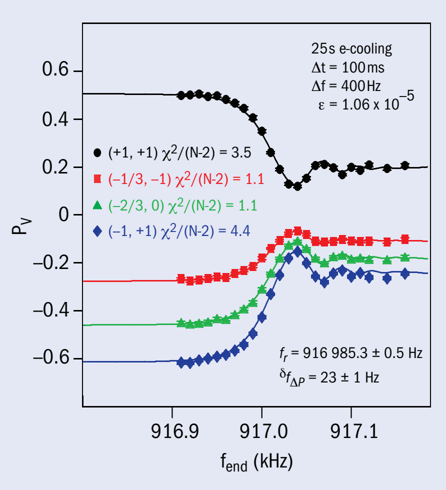


Fig. 3. Vertical vector polarization (P_V) of 1.85 GeV/c stored deuterons plotted against the end-frequency of the 400 Hz sweep; this fit and other fits give precise measured values of ε (± 0.5%), $\delta f_{\Delta p}$ (± 1 Hz), and f_r (± 0.00005%).

Further reading

A W Chao 2005 *Phys. Rev. ST Accel. Beams* **8** 104001.

M Froissart and R Stora 1960 *Nucl. Instrum. Methods* **7** 297.

V S Morozov *et al.* 2007 *Phys. Rev. ST Accel. Beams* **10** 104001.

V S Morozov *et al.* 2008 *Phys. Rev. Letts.* **100** 054801.

KEK

Superstrings reveal the interior structure of a black hole

The Hitachi SR11000 model K1 supercomputer calculated the interior structure of a black hole. It provides a peak performance of 2.15 teraflops peak. (Courtesy KEK.)

A research group at KEK has succeeded in calculating the state inside a black hole using computer simulations based on superstring theory. The calculations confirmed for the first time that the temperature dependence of the energy inside a black hole agrees with the power-law behaviour expected from calculations based on Stephen Hawking's theory of black-hole radiation. The result demonstrates that the behaviour of elementary particles as a collection of strings in superstring theory can explain thermodynamical properties of black holes.

In 1974, Stephen Hawking at Cambridge showed theoretically that black holes are not entirely black. A black hole in fact emits light and particles from its surface, so that it shrinks little by little. Since then, physicists have suspected that black holes should have a certain interior structure, but they have been unable to describe the state inside a black hole using general relativity, as the curvature of space–time becomes so large towards the centre of the hole that quantum effects make the theory no longer applicable. Superstring theory, however, offers the possibility of bringing together general relativity and quantum mechanics in a consistent manner, so many theoretical physicists have been investigating whether this theory can describe the interior of a black hole.

Jun Nishimura and colleagues at KEK established a method that efficiently treats the oscillation of elementary strings depending on their frequency. They used the Hitachi SR11000 model K1 supercomputer installed at KEK in March 2006 to calculate the thermodynamical behaviour of the collection of strings inside a black hole. The results showed that as the temperature decreased, the simulation reproduced behaviour of a black hole as predicted by Hawking's theory (figure 1).

This demonstrates that the mysterious thermodynamical properties of black holes can be explained by a collection of strings fluctuating inside. The result also indicates that superstring theory will develop further to play an important role in solving problems such as the evaporation of black holes and the state of the early universe.

Further reading

K N Anagnostopoulos *et al.* 2008 *Phys. Rev. Lett.* **100** 021601.

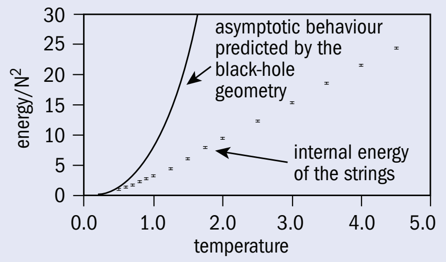


Fig. 1. Plot of the energy of the collection of strings against the temperature. The solid line represents the behaviour of the black hole predicted by Hawking's theory. The results agree in the lower temperature regime, where the calculation based on general relativity becomes valid.

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.

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.

FUNDING

Particle physics in the UK is facing a severe funding crisis

When the UK announced its science budget for 2008–2011 on 11 December, it looked like good news. An additional £1200 m was to be spent on science, and at the end of the period the budget would be 19% higher than at the start – an increase of more than 11% after inflation. The Science and Technology Facilities Council (STFC), which is responsible for the CERN budget as well as for UK particle and nuclear physics, astronomy, space science, the Rutherford Appleton and Daresbury Laboratories, ESA, ESO, ILL, ESRF and much else, received an extra £185 m, representing an increase of 13.6% (6% after inflation).

Aerial view of the Rutherford Appleton Laboratory, which is being hit hard by the funding crisis in the UK. The Diamond light source is visible beyond. (Courtesy STFC.)

However, the headlines hid a darker truth. Once the accounting was done correctly, this increase to STFC translated into a deficit of £80 m. Later the same week, Richard Wade, the UK delegate to the CERN Council, was obliged to make the following statement "whilst we strongly support CERN and the consolidation programme, under the circumstances I cannot vote in favour of the increased budget at this meeting".

The problem arises because much of the increase is directed to issues such as capital depreciation of STFC facilities and maintenance in the UK's universities. Of the £185 m, nearly half (£82 m) is in so-called "non-cash", which is a balance-sheet adjustment to take account, for example, of the cost of capital and depreciation; this is not available for spending on the research programme. Most of the rest goes straight to the universities as a supplement to research grants to pay much of the "full economic cost" of research. What remains is the "flat cash" to pay for the science that STFC does, and this is eaten away as inflation bites.

To make matters worse, STFC has inherited liabilities of about £40 m from previous decisions by ministers to run the Synchrotron Radiation Source (SRS) at Daresbury for a while in parallel with the new Diamond third-generation synchrotron source. The SRS now has to be decommissioned, and there was an unexpected VAT bill from the Treasury on the operation of the new facility by Diamond Light Source Ltd. There are also increased costs for running Diamond and the second target stations for the ISIS spallation neutron source, which have been known about for some four years, but which were not yet fully funded. As a result, STFC has an £80 m hole in its budget, just to continue with what it does now.

The decisions STFC has made to accommodate the hole are severe: withdrawal from major international programmes, job losses estimated to lie in the hundreds (including probably some compulsory redundancies) and cut-backs across exploitation grants for almost all projects. As a result the UK is withdrawing from important international commitments – the Gemini telescopes, the International Linear Collider and ground-based solar-terrestrial physics. Other programmes are also likely to be affected.

There is widespread anger and dismay in the UK, as these decisions were taken with no proper peer review and no consultation with the community. Concerns are shared not only by the particle physicists and astronomers directly affected by the cuts. The Royal Society, the Institute of Physics and the Royal Astronomical Society have all expressed concern, as have university vice-chancellors.

Members of parliament (MPs) are also concerned. Many have received letters pointing out the damage that the cuts will do to the country's international reputation, and to the image of physics and astronomy in the eyes of those considering what to study at university – there had been fragile signs of a recovery in the number of UK students wishing to study physics. There have been debates and questions in parliament ,and a committee of MPs is now looking into the matter. More than 15 000 people, including Stephen Hawking, Peter Higgs, Sir Patrick Moore and Nobel laureates Sir Paul Nurse, and Sir Harry Kroto, have signed a petition calling on the Prime Minister to reverse the decision to cut vital UK contributions to particle physics and astronomy.

The question remains of who is to blame? The perplexed UK community does not really know; it could just be a huge mistake. However the real issue now is whether the UK Government will do anything to solve the problem. The community sincerely hopes so.

● For more information, including the full statement by Richard Wade, reproduced with permission of the president of CERN council, see www.hep.ucl.ac.uk/~markl/pp/.

NEUTRINOS

Construction of IceCube project at the South Pole reaches the halfway point

The teams installing the IceCube experiment at the South Pole have completed a highly successful austral summer season, during which they installed 18 detector strings – 4 more than in the baseline plan. This marks the halfway point in the construction of the neutrino telescope, which will detect extraterrestrial neutrinos with energies of above 1 TeV (*CERN Courier* May 2006 p24).

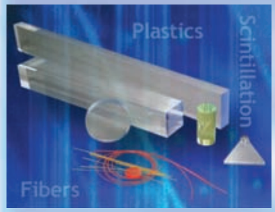
Not only has the team exceeded the 2007/08 baseline plan, they also finished the deployment ahead of schedule. This means that there is plenty of time to prepare the site for next year's season, and suggests that construction of the detector will be complete in three more seasons, as currently planned. Meanwhile, the detector will reach an exposure of a km^2-year within two years – a long anticipated milestone of neutrino astronomy.

IceCube now consists of 40 strings, each instrumented with 60 digital optical modules (DOMs). The drilling and deployment teams were able to make holes 2500 km deep in the Antarctic ice and lower the detector strings at the rate of about one every 50 hours. IceCube now has a volume of half a cubic kilometre.

The last members of the IceCube construction team were due to leave on 15 February, after which the IceCube winter team would take over the job of incorporating the new DOMs into the data acquisition system. The researchers are evaluating each DOM to determine that it survived the deployment and "freeze-in" process. There are now 2400 DOMs in the ice at the South Pole, and in February, 99% of the DOMs that had been powered were working.

In addition to deploying the strings, this season the teams also installed a further 28 tanks for the IceTop array, a surface array to detect high-energy cosmic rays and to provide a veto for air showers that interfere with neutrino detection within IceCube.

● IceCube is an international effort involving 28 institutions and is funded by the US National Science Foundation, with significant contributions from Germany, Sweden, Belgium, Japan, New Zealand, the Netherlands and Switzerland.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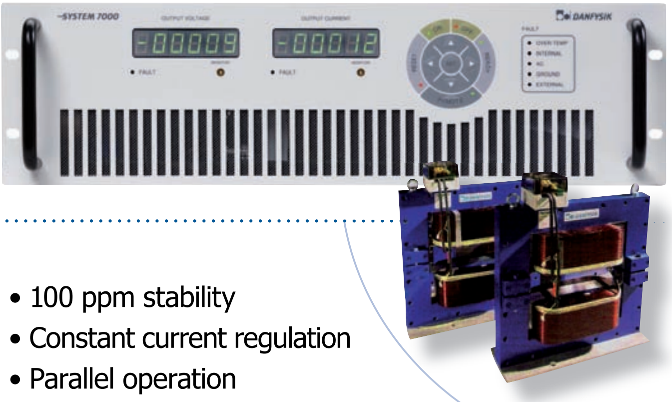
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SCIENCEWATCH

Compiled by Steve Reucroft and John Swain, Northeastern University

Magic carpet nears reality

Is it possible to create a carpet that would wiggle in such a manner as to fly, who knows, perhaps even carrying a passenger? This may seem the stuff of fairy tales and cartoons, but it is now the target of some serious research. Mederic Argentina of the University of Nice, Lakshminarayanan Mahadevan of Harvard University, Massachusetts, and Jan Skotheim of the Rockefeller University, New York, worked out the dynamics of a flexible foil immersed in a fluid and moving near a horizontal surface.

The team finds regions of parameter space where it could be possible to make a "flying carpet", with suitable ripples of the foil providing both lift and forward thrust. Engineering applications are not likely, but small devices might well work. Adam Feinberg and colleagues at Harvard University have previously reported polymer sheets covered with rat muscle cells that can so-called "swim" in response to electrical signals.

Further reading

M Argentina *et al.* 2007 *Phys. Rev. Lett.* **99** 224503.

Adam W Feinberg *et al.* 2007 *Science* **317** 1366.

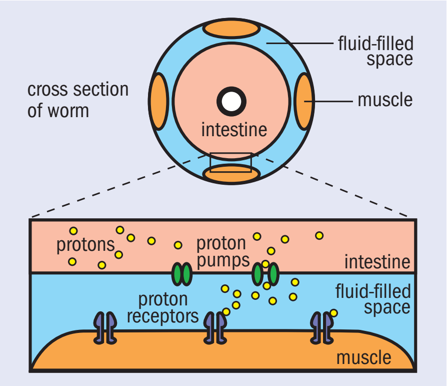
Protons trigger gut reaction in worms

As CERN gets ready to collide protons at the highest energies yet attained on Earth, biologists are finding interesting roles for low-energy protons. Erik Jorgensen of the University of Utah in Salt Lake City and colleagues have found that H^+ ions – in other words, protons – released by the intestines of groundworms, act as triggers for the muscles in the gut that are responsible for defecation.

Such triggers are usually neurotransmitters, and given that interfering with proton receptors in the brain can cause cognitive defects, the idea is now out that protons may actually be the world's smallest neurotransmitters – in addition, of course, to holding the key to what happens at centre-of-mass energies of 14 TeV.

Further reading

Asim A Beg *et al.* 2008 *Cell* **132** 149.



The cross section of a worm, including the muscles that surround the intestine to help the worm defecate. A closer look (bottom) reveals how protons act like neurotransmitters. The protons are pumped out of the intestine and then bind to receptors on the surrounding muscle. (Courtesy Glen Ernstrom, University of Utah.)

A new take on the Casimir effect?

The Casimir effect is well known nowadays in physics: zero-point fluctuations in the electromagnetic field between two conducting plates give rise to an attractive force between them. Less well known, however, is that Michael Fisher and Pierre de Gennes predicted an analogue for condensed matter systems.

C Hertlein of the University of Stuttgart and colleagues have now observed this effect between two surfaces that were immersed in a binary liquid mixture close to criticality. Unlike the usual Casimir effect, this new one has a strong dependence on temperature, which could have applications in nanotechnology – where it is relatively easy to control this bulk parameter.

Further reading

M E Fisher and P G de Gennes 1978 *C. R. Acad. Sci. Paris B* **287** 207. C Hertlein *et al.* 2008 *Nature* **451** 172.

Researchers grow a new rat's heart from cultured cells

Growing complex organs from cultured cells is notoriously difficult, with successes limited to rather simple things such as bladders. Now, Doris Taylor and colleagues at the University of Minnesota, Minneapolis, have made an amazing breakthrough. They took a rat's heart and chemically removed the cells to leave behind a "scaffolding" of connective tissue, devoid of anything that would trigger an immune response, but preserving the basic shape of the heart.

Eight days later, this structure, seeded with cells for blood vessels and heart muscles and jolted with electricity to get it beating, had grown into a working heart – albeit with much reduced efficiency. If this line of research continues successfully, this discovery could lead to an efficient new way to grow all kinds of organs.

Further reading

Harald C Ott *et al.* 2008 *Nature Medicine* DOI: 10.1038/nm1684.

Lithium 'clocks' make the best test of time dilation

Some of the best tests of special relativity involve precision measurements of effects that are nowhere near as "relativistic" as those involved in high-energy physics. Using lithium ions as clocks moving at just 3% and 6.4% of the speed of light, Sascha Reinhardt of the Max Planck Institute für Kernphysik in Heidelberg and colleagues have made the most precise tests yet of the time-dilation effect. With an accuracy of 2×10^{-10}, their results place new limits on possible preferred cosmological reference frames and other theories involving Lorentz invariance violation.

Further reading

Sascha Reinhardt *et al.* 2007 *Nature Physics* vol 3 **12** 863.

ASTROWATCH

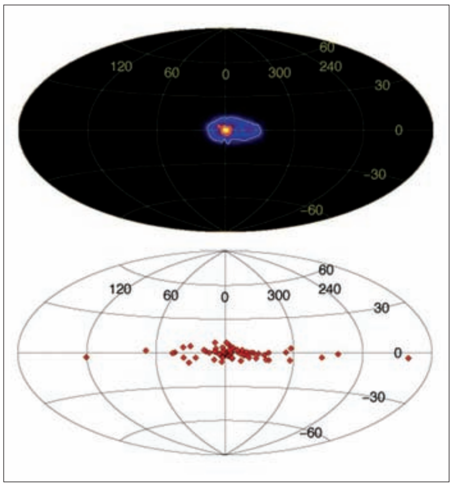
Compiled by Marc Türler, INTEGRAL Science Data Centre and Observatory of Geneva University

Positrons prefer one side of the galaxy

A new study of the gamma-ray emission of positron annihilation in the Milky Way reveals an asymmetric distribution in the galactic disc. The only sources known to have a similar asymmetry are low-mass X-ray binaries that emit energetic X-rays. This suggests that they are the main producers of positrons in the disc of our galaxy.

After five years in orbit, the imaging spectrometer SPI of the European Space Agency's INTEGRAL satellite has accumulated a great deal of data from the central region of the galaxy, revealing with increasing detail the spatial distribution of an emission-line at 511 keV. This line is emitted by the annihilation of electrons with positrons, which produces a pair of gamma-ray photons each with an energy of 511 keV, equivalent to the rest-mass of the electron. Previous studies have shown that the 511 keV emission is roughly circular around the galactic centre, with an extension consistent with the bulge of the Milky Way. This simple and smooth distribution raised the idea that the positrons could come from the annihilation of lightweight dark-matter particles (*CERN Courier* November 2004 p13). A subsequent study, however, showed that the allowed range of masses for these elusive particles is very limited (*CERN Courier* December 2006 p14).

The new map of positron annihilation obtained by Georg Weidenspointner from the Centre d'Etude Spatiale des Rayonnements in Toulouse, France, and colleagues is consistent with previous results, but shows an additional asymmetric galactic-disc component. Surprisingly, the emission on one side of the galaxy is 1.8 times stronger than on the other side, with a significance of 3.8σ. The effect becomes even bigger – by a factor of 2.2 – if account is taken of the fact that about 30% of the observed emission can be ascribed to positrons from the decay of radioactive aluminium (^{26}Al), which is observed to be roughly symmetric in this region of the galaxy (*CERN Courier* January/February 2006 p10). The difference of about 10% in observing time on both sides of the galaxy cannot lead to the asymmetry, nor can it be ascribed to instrumental background variations or to the presence of the galactic stellar bar, which is oriented in a way that would yield an opposite asymmetry.



All-sky map of the distribution of annihilating positrons (top) and of energetic low-mass X-ray binaries (bottom). The galactic centre is in the middle and both images show an asymmetry in the galactic disc towards the right side. (Courtesy ESA/Integral/MPE/G Weidenspointner et al.*)*

The peculiar distribution of positrons in the galaxy is an important clue to understanding their origin. The only other known population of galactic sources having an asymmetry matching the 511 keV observations is that of low-mass X-ray binaries detected at photon energies above 20 keV. These systems, which are composed of a low-mass star – like the Sun – and a neutron star or a black hole, have already been proposed as good candidates for the production of positrons through photon-photon interactions in the disc of plasma surrounding the compact object.

Assuming X-ray binaries produce the 511 keV emission in the galactic disc, Weidenspointner and collaborators estimate that these sources would also produce half of the observed emission in the galactic bulge. Type Ia supernovae and the supermassive black hole at the galactic centre (*CERN Courier* April 2007 p10) could account for the remainder of the emission, without the need to invoke the more exotic scenario of dark matter annihilation.

Further reading

G Weidenspointner *et al*. 2008 *Nature* **451** 159.

Picture of the month

What is it? Tinker Bell, Peter Pan's fairy? A cosmic bird, a dragonfly or an angel? Whatever your preference, this is an amazing view of three interacting galaxies at a distance of 650 million light-years. The image is a combination of near-infrared observations with the NACO instrument mounted on the Very Large Telescope (VLT) of the European Southern Observatory (ESO) and of optical images from the Hubble Space Telescope.

Hidden behind this graceful view is a rare and dramatic collision of three galaxies of roughly similar sizes. The "head" of the creature is violently forming stars at a rate of nearly 200 solar masses per year and is flying by the other galaxies at a speed of 400 km/s. (Courtesy ESO.)

CERN COURIER ARCHIVE: 1965

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

CERN

Sifting high-energy particles

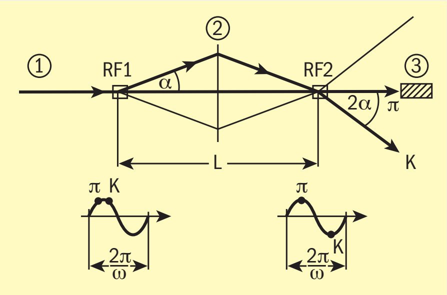
At 5.30 a.m. on 25 January 1965 the first photograph was taken showing tracks and interactions of 10 GeV/*c* negative kaons in the 152 cm British bubble chamber at CERN. The kaons, from a target in the 28 GeV proton synchrotron, were separated from a much greater number of other particles in passing along the o_2 beam line equipped with radiofrequency (RF) separators. The kaon momentum was nearly twice that obtained using electrostatic separators in this beam line.

Separated beams

When the primary accelerated-proton beam of the synchrotron strikes a target, a shower of secondary particles is produced – pions, kaons, antiprotons, neutrons etc. These are collected into a beam, and when interactions of only one kind of particle at a specific momentum are to be investigated, the beam line equipment has to separate the wanted particles from the others. With rare particles such as kaons, considerable ingenuity is required to select wanted particles while eliminating several hundred times as many unwanted ones. Momentum selection of charged particles, provided by bending and focusing magnets, is not enough and selection of particle mass has also to be made using a particle separator.

Electrostatic separators

The simplest particle separator is a strong electrostatic field, created by applying a high voltage between two parallel metal plates. A charged particle travelling between the plates is deflected by an amount that depends on its velocity, so particles with the same momentum but different mass – and thus different velocities – are deflected by different amounts. Heavier particles have a smaller velocity for a given momentum, but as the desired energy increases the difference in velocities becomes smaller – because of the relativity effect – and finally it is no longer possible to achieve any worthwhile separation.



Radiofrequency separators

As early as 1956, W K H Panofsky of Stanford University suggested using radiofrequency electromagnetic fields to distinguish particles at high velocities; V I Veksler (USSR) made similar suggestions in 1958. Prof. Panofsky put forward more specific ideas at CERN in 1959; these were taken up and developed with the final result now seen.

The new separator is basically a sensitive timing device; only particles covering a particular distance at the correct velocity go through, while the others are intercepted. All particles entering the separator must have the same momentum and this initial selection is done in the first part of the beam line. Referring to the figure, the beam (1) then passes through the first radiofrequency cavity, RF1, a 3 metre length of waveguide that guides a travelling electromagnetic wave. Incoming particles travel through the cavity at the same speed as the wave and thus experience a steady electromagnetic field, which deflects them in a vertical plane through an angle that depends on the time of arrival of the particle with respect to the wave amplitude; in the example, a pion (π) and a kaon (K) both arrive at the peak of the wave and receive the deflection α.

A magnetic lens system (2) focuses all of the particles from the first cavity into a second one 50 metres downstream, RF2, that guides an identical wave. Owing to the slight difference in velocity between pions and kaons of the same momentum, pions arrive first. The system is adjusted so that a pion meets exactly the same part of the wave as before whereas a kaon arrives when the wave has reached its peak in the opposite sense. The pion is thus deflected again through an angle α proceeding along the axis of the system, while the kaon is turned through an angle α in the opposite direction, emerging at an angle 2α to the axis.

No matter when a particle arrives at the first cavity, if it is a pion it will finally emerge along the axis of the system and if it is a kaon it will be deflected. Emerging pions therefore form a narrow beam which can be absorbed in a beam stopper (3) while kaons form a fan of angle 4α, from which they can be collected into a beam by a suitable lens system. It may seem strange to arrange for pions to follow the axis since it is the kaons that are desired, but the real problem is to eliminate the maximum number of unwanted particles (which outnumber the others by several hundred times) and these can be guided more surely into the stopper when they are kept near the axis of the system.

- Compiled from the article pp35–37 (based on information supplied by the late Bryan Montague, *CERN Courier* January/February 2005 p49).

COMPILER'S NOTE

In particle colliders, beam–beam collisions produce interactions deep inside the detectors and only after each collision can the task of identifying wanted events begin. In the LHC, proton beam bunches will cross each other on average 30 million times per second in the detectors and high luminosity could produce up to 20 events per bunch crossing. The data-acquisition systems are aiming to record a couple of hundred potentially interesting events per second, which means sifting one in several million candidates. This may make the one-in-several-hundred sifting achieved by the RF separators in 1965 seem modest, but that was all that was needed and the method employed was elegance itself.

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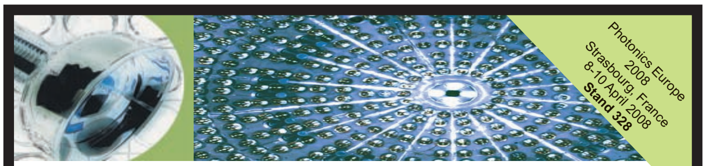

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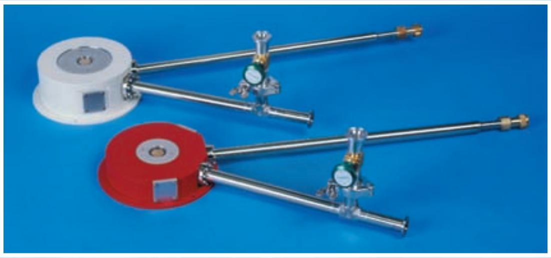

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Barry Barish and the GDE: mission achievable

The head of the Global Design Effort for a future International Linear Collider talks about challenges past, present and future.

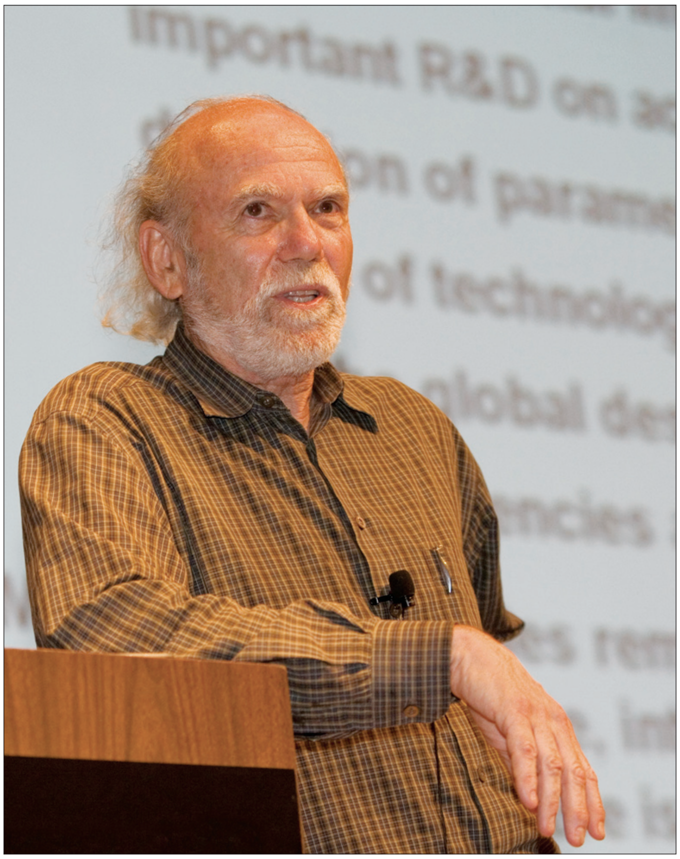
Barry Barish likes a challenge. He admits to a complete tendency to go for the difficult in his research – in his view, life is an adventure. Some might say that his most recent challenge would fit well with a certain famous TV series: "Your mission, should you choose to accept it... is to produce a design for the International Linear Collider that includes a detailed design concept, performance assessments, reliable international costing, an industrialization plan, and siting analysis, as well as detector concepts and scope."

Barish did indeed accept the challenge in March 2005, when he became director of the Global Design Effort (GDE) for a proposed International Linear Collider (ILC). He started in a directorate of one – himself – at the head of a "virtual" laboratory of hundreds of physicists and engineers around the globe. To run the "lab" he has set up a small executive committee, which includes three regional directors (for the Americas, Asia and Europe), three project managers and two leading accelerator experts. There are also boards for R&D, change control and design cost.

Barish operates from his base at Caltech, where he has been since 1962 and ultimately became Linde Professor of Physics (now emeritus). His taste for research challenges became evident in the 1970s, when he was co-spokesperson with Frank Sciulli (also at Caltech) of the "narrow band" neutrino experiment at Fermilab that studied weak neutral currents and the quark substructure of the nucleon. He later became US spokesperson of the collaboration behind the Monopole, Astrophysics and Cosmic Ray Observatory, which operated from 1989 to 2000 in the Gran Sasso National Laboratory (LNGS). The experiment did not find monopoles, but it set the most stringent upper limits so far on their existence (*CERN Courier* May 2003 p21).

In 1991 he also began to lead the design of the GEM detector for the Superconducting Super Collider project, together with Bill Willis of Columbia University. In October 1993, however, the US congress infamously shut down the project and Barish found himself in search of a new challenge. He did not have to look far, as Caltech was already involved in the Laser Interferometer Gravitational-wave Observatory (LIGO), conceived to search for effects even more difficult to detect than neutrinos. The project was already approved and just beginning to receive funding. Barish became principal investigator in 1994 and director of the LIGO Laboratory in 1997.

Here was an incredibly challenging project, Barish explains, that was "making the audacious attempt to measure an effect of 1 in 10^{21}". It has indeed achieved this precision, but has not yet detected gravitational waves (*CERN Courier* December 2007 p17). "Now it's down to nature," says Barish, who found the work on LIGO very satisfying. "There is no way I would have left it except for an exciting new challenge – and the ILC is certainly challenging." He says that it was hard to move on, "but I felt I could make a difference". Moreover, he adds: "The likelihood is that the ILC will be important for particle physics."



Barish became director of the Global Design Effort for the International Linear Collider in 2005. (Courtesy Fermilab Visual Media Services.)

At 72 years old, Barish does not expect to participate in the ILC – the earliest it could start up would be in the 2020s. "The plan is short term. The question was whether I could pull together a worldwide team to conceive of a design that will do the job," he says. With no background in accelerator physics, Barish may not seem the obvious choice for the task. However, he points out that "coming in from the outside, not being buried in the forest, can be very useful". In addition he believes that he is a good student, and ▷

that a good student can be a good leader: "If you do your homework, if the people you work with respect you, then it's possible."

An important factor in building the team behind the GDE is that there is not as much history of collaboration in accelerator physics as there is in experimental particle physics. Barish points out that many of the members of the accelerator community have met only at conferences. There has never been real collaboration on accelerator design, so the GDE is a learning process in more than one sense. There are also interesting sociological issues, as the GDE has no physical central location, and meetings usually take place via video and tele-conferencing. Barish likens his job as director to "conducting the disparate instruments in an orchestra".

In February 2007, the GDE reached a major milestone with the release of the Reference Design Report (RDR) for a 31 km long electron–positron linear collider, with a peak luminosity of about $2 \times 10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$, at a top centre-of-mass energy of 500 GeV, and the possibility of upgrading to 1 TeV (*CERN Courier* April 2007 p4). The report contains no detailed engineering; it might state, for example, that a magnet is needed for a certain task, but it does not describe how to build it. The report also contains a preliminary cost estimate, of some $6700 million plus 13 000 person-years of effort.

The final goal will be to produce a strong engineering design, and to optimize costing to form a serious proposal. An appealing deadline is the 2010 ICHEP meeting in Paris. By then there should be results from the LHC that could justify the project. "The main job," says Barish "is to design a good machine and move once it's justified."

In the meantime there is important R&D to be done. Two key areas concern the high-voltage gradient proposed in the machine – an average of 31.5 MV/m – and the effects of electron clouds. Electrons from the walls of the beam pipe cause the positron beam to blow up, thereby reducing the luminosity, and ultimately the number of events. The clouds decay naturally and cease to be a problem if there is sufficient time between bunches, but this reduces the collision rate. The conservative option to keep the rate high would be to have two positron rings to inject alternate pulses into the linac. However, this has huge cost implications so, as Barish says: "There is huge motivation to solve the problem." One attractive possibility that needs further investigation involves grooving and coating the beam pipe, which could reduce the electron cloud a hundredfold.

However, just before the end of 2007, bad news on funding in both the US and the UK struck a major blow to the plan foreseen at the time that the RDR was released. The UK dealt the first strike, stating that it would "cease investment" in the project, while the US reduced funding for the ILC from $60 million to $15 million as part of a hastily agreed compromise budget for FY2008. Barish recalls the complete surprise of the congressional decision on a budget that President Bush had put forward in February 2007. "We went to bed as normal on Friday (14 December), and woke up on Monday to find the project axed out."

The cuts in the two countries are both quantitatively and qualitatively different. In one sense the UK's decision is more serious, as it appears to be a policy decision taken with no input from the community (p8). Barish says that the main loss here to the GDE is in intellectual leadership. He hopes that continued funding in the UK for general accelerator R&D will mean that the project does not lose people that he says are irreplaceable. In contrast, he expects to see the R&D for the ILC revived in the US budget for FY2009 (starting October 2008), albeit at a level lower than the $60 million originally promised for FY2008. Here the problem is how to cope with the loss of people over the coming months, as there is no funding left to support them in the current budget. Where it hurts most, says Barish, is that the US will not be able to develop the same level of home-grown expertise in the technology required for the ILC, compared with Japan or Europe.

A revival of the ILC in the US budget was a key assumption when Barish and the GDE executive committee met for a relatively rare face-to-face meeting at DESY on 12 January to formulate a new plan. At least the collaboration that Barish has forged is "strong enough to give us the ability to adjust and move on, even with reduced goals". The aim of the new plan that has emerged is to reduce the scope of the R&D work, but maintain the original schedule of completion by 2010 for items with the highest technical risk, while stretching other parts of the programme to 2012.

The work on high-gradients, underway globally, and tests at Cornell University on reducing the electron cloud will remain high priorities for part one of the newly defined Technical Design Phase, to be ready for 2010. Part two, which will focus on the detailed engineering and industrialization, should be ready by 2012.

Looking further ahead, Barish acknowledges that an ILC-like machine could be the end of the line for very high-energy accelerators, but he points out that accelerators for other applications have a promising future. The GDE itself is already providing an important role in teaching accelerator physics to a new generation. "There is no better way to train them than on something that is pushing the state of the art," he says. In fact, he sees training as a limiting factor in breeding new experts – whether young people or "converts" from other areas of physics, as many accelerator physicists now are. One problem that he is aware of is that "accelerator people are not revered – but they should be!".

Despite the recent setbacks with the GDE, Barish remains determined to achieve his mission. "In these ambitious, long-range projects you are going to hit huge bumps in the road, but you have to persevere," he says. What is vital in his view, is that the agenda should remain driven by science, and that this alone should determine if and when the ILC is built on the firm foundations laid by the GDE. Let us hope that those who fund particle physics have the vision to ensure that one day he can say: "Mission accomplished."

Résumé

Barry Barish et le Projet mondial de conception: mission possible

Barry Barish, de Caltech, aime relever les défis. Ses domaines de recherche ont pu aller des expériences sur les neutrinos aux instruments destinés à détecter les ondes gravitationnelles. En mars 2005, il a relevé un défi d'un autre genre en devenant directeur du Projet global de conception pour un futur Collisionneur linéaire international (ILC). Dans cet entretien, il explique ce qu'il pense pouvoir apporter à cette collaboration mondiale. Il évoque également les incidences de la récente réduction des crédits consacrés à l'ILC aux Etats-Unis, et de la décision du Royaume-Uni de se retirer du projet GDE. L'effort se poursuivra, mais avec des objectifs redéfinis axés sur les aspects technologiques.

Christine Sutton, *CERN.*

Quarkonium physics at the dawn of the LHC era

More than a hundred experimentalists and theorists met at DESY in October to discuss the latest advances in quarkonium physics.

The Quarkonium Working Group (QWG) formed in 2002 to further research in all aspects of quarkonium physics and to bridge communication between theory and experiment in the field. The group has since sponsored a series of workshops on quarkonium physics, starting at CERN in November 2002 (*CERN Courier* March 2003 p6 and September 2006 p46). The latest meeting took place at DESY, Hamburg, on 17–20 October 2007. Hot topics included recent advances in the theory of quarkonium production at the Tevatron and the B-factories; quarkonium production and in-medium behaviour in heavy-ion collisions; the new narrow-resonance states discovered by the Belle, BaBar and CLEO experiments; applications of quarkonium physics to the search for physics beyond the Standard Model; and quarkonium experiments in the LHC era.

Quarkonium physics has played an important role in establishing QCD as the accepted theory of strong interactions. It has decisively contributed to the development of the quark model of hadrons and to the understanding of the properties of QCD. It also provides a unique window into the interplay between perturbative and non-perturbative QCD. As such, quarkonium physics remains at the forefront of QCD research and is an important testing ground for state-of-the-art computational tools for QCD, such as effective field theories, factorization theorems, higher-order perturbative calculations and lattice QCD. The insights gained from quarkonium studies build greater confidence in predictions for Standard Model processes and, consequently, in predictions of new physics backgrounds at the LHC. The recent discovery of remarkable new resonance states in the charmonium region of the spectrum – exciting in its own right – provides further opportunities to test the theoretical framework of quarkonium physics.

Participants at the DESY meeting learnt of the first complete next-to-leading-order (NLO) QCD corrections to colour-singlet quarkonium production at the Tevatron (figure 1). Surprisingly, these corrections enhance the colour-singlet production rate by an order of magnitude. Such an unprecedented enhancement could potentially lead to a better understanding of the dominant quarkonium-production mechanisms in hadronic collisions and may eventually explain, along with other puzzles of quarkonium production, the absence of the predicted transverse polarization of $J = 1$ quarkonia at large transverse momenta in the Tevatron measurements. There is also a possible resolution of the apparent

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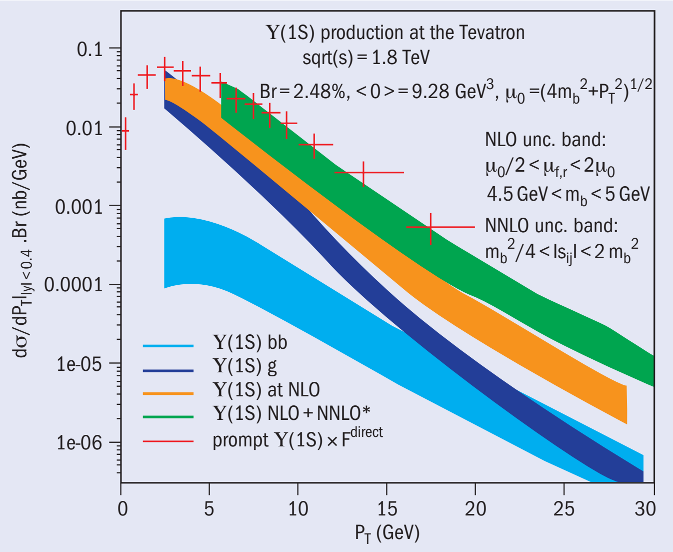


Fig. 1. The Υ(1S) production cross-section at the Tevatron compared with leading-order non-relativistic QCD calculations and including next-to-leading-order colour-singlet corrections. Estimates of the next-to-next-to leading-order contributions are also shown. (Courtesy F Maltoni.)

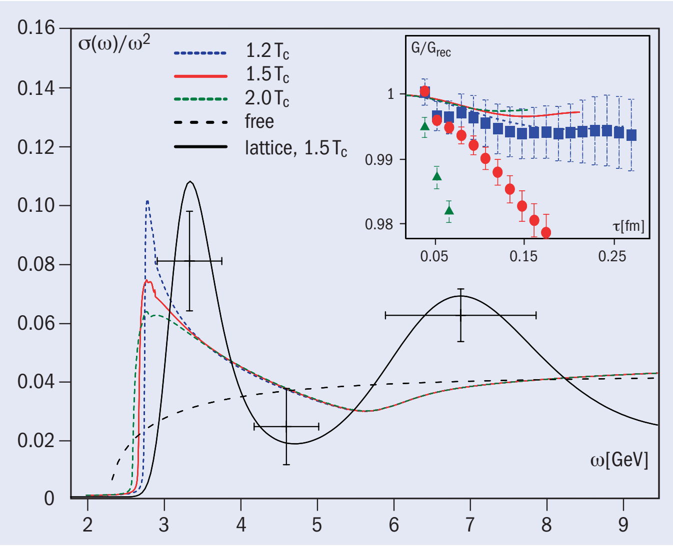


Fig. 2. Different calculations of the η_c spectral function: from lattice QCD extracted from the Euclidean correlator using the maximum entropy method (solid black line); from a finite-temperature potential model (coloured lines); and from propagation of a free heavy quark (black dashed line). Inset: Euclidean correlators from lattice QCD and from the potential model. (Courtesy Á Mócsy.)

Table 1

state	exp	$M+i\Gamma$ (MeV)	J^{PC}	decay modes observed	production modes observed
X(3872)	Belle, CDF, DØ, CLEO, BaBar	$3871.2\pm0.5+\mathrm{I}(<2.3)$	1^{++}	$\pi^+\pi^-J/\psi$, $\pi^+\pi^0J/\psi$ $\gamma J/\psi$	B decays, $p\bar{p}$
	Belle BaBar	$3875.4\pm0.7^{+1.2}_{-2.0}$ $3875.6\pm0.7^{+1.4}_{-1.5}$		$D^0\bar{D}^0\pi^0$	B decays
Z(3930)	Belle	$3929\pm5\pm2+\mathrm{I}(29\pm10\pm2)$	2^{++}	$D^0\bar{D}^0$, D^+D^-	$\gamma\gamma$
Y(3940)	Belle BaBar	$3943\pm11\pm13+\mathrm{I}(87\pm22\pm26)$ $3914.3^{+3.8}_{-3.4}\pm1.6+\mathrm{I}(33^{+12}_{-8}\pm0.60)$	J^{++}	$\omega J/\psi$	B decays
X(3940)	Belle	$3942^{+7}_{-6}\pm6+\mathrm{I}(37^{+26}_{-15}\pm8)$	J^{P+}	$D\bar{D}^*$	e^+e^- (recoil against J/ψ)
Y(4008)	Belle	$4008\pm40^{+72}_{-28}+\mathrm{I}(226\pm44^{+87}_{-79})$	1^{--}	$\pi^+\pi^-J/\psi$	e^+e^- (ISR)
X(4160)	Belle	$4156^{+25}_{-20}\pm15+\mathrm{I}(139^{+111}_{-61}\pm21)$	J^{P+}	$D^*\bar{D}^*$	e^+e^- (recoil against J/ψ)
Y(4260)	BaBar CLEO Belle	$4259\pm8^{+8}_{-6}+\mathrm{I}(88\pm23^{+6}_{-4})$ $4284^{+17}_{-16}\pm4+\mathrm{I}(73^{+39}_{-25}\pm5)$ $4247\pm12^{+17}_{-32}+\mathrm{I}(108\pm19+10)$	1^{--}	$\pi^+\pi^-J/\psi$, $\pi^0\pi^0J/\psi$, K^+K^-J/ψ	e^+e^- (ISR), e^+e^-
Y(4350)	BaBar Belle	$4324\pm24+\mathrm{I}(172\pm33)$ $4361\pm9\pm9+\mathrm{I}(74\pm15\pm10)$	1^{--}	$\pi^+\pi^-\psi(2S)$	e^+e^- (ISR)
Z^+(4430)	Belle	$4433\pm4\pm1+\mathrm{I}(44^{+17}_{-13}{}^{+30}_{-11})$	J^P	$\pi^+\psi(2S)$	B decays
Y(4620)	Belle	$4664\pm11\pm5+\mathrm{I}(48\pm15\pm3)$	1^{--}	$\pi^+\pi^-\psi(2S)$	e^+e^- (ISR)

The new exotic states observed by the Belle, CDF, DØ and BaBar experiments. This table was presented in the talk given by E Eichten.

order-of-magnitude discrepancy between theory and experiment in exclusive double-quarkonium production at the B-factories – a long-standing puzzle in quarkonium physics. New calculations of corrections at NLO in the strong coupling constant, and at NLO and higher in the nonrelativistic expansion, have brought theory and experiment into agreement, albeit with large uncertainties.

With the advent of the LHC, high-energy physics is entering an exciting and crucial period with great potential for discoveries. The LHC experiments will explore a new energy scale and provide stringent tests of many models, theories and scenarios, both within and beyond the Standard Model. The high-energy frontier, where the increased centre-of-mass energy can lead to the observation of new phenomena, complements high-precision experiments at lower energies. The LHC will provide a laboratory for studying quarkonium production mechanisms in matter, both in the collisions of protons and in the high-density environment that is formed in ultrarelativistic heavy-ion collisions.

The LHC's heavy-ion programme is not only of great relevance to quarkonium production, but also for finite-temperature studies. Heavy-ion collisions at the LHC will form a hadronic medium with the highest energy density ever produced in a laboratory. Quarkonium studies play a particularly crucial role here since the quarkonium suppression pattern in heavy-ion collisions should serve as a thermometer for the hadronic medium. During the four days at DESY, speakers revealed important new insights into the behaviour of the quarkonium states in a hot medium, arising both from finite-temperature lattice QCD approaches and temperature-dependent potential models. For the first time, quarkonium spectral-function calculations from potential models appear to be consistent with lattice calculations of the Euclidean correlators (figure 2 p17). However, the interpretation of the experimental data from RHIC is still incomplete. The next RHIC run, with higher statistics d + Au and p + p data, should pin down the effects of cold nuclear matter more precisely before the LHC starts up.

The recent discoveries of narrow-resonance states at the Belle, BaBar and CLEO experiments at KEK, SLAC and Cornell, respectively, are of special interest to the QWG because some of these resonances have been interpreted as quarkonium states (table 1). These states are currently referred to as X, Y and Z. However, as progress is made in understanding their nature, the assignment of more meaningful names for these states becomes increasingly important. The QWG resolved at the DESY meeting to set aside time at the next workshop for a discussion of appropriate names for these states.

Flavour physics has played a crucial role in the development of the Standard Model and should make important contributions to the understanding of physics beyond the Standard Model, even in the minimal-flavour-violation scenario. Since the flavour sector of the Standard Model is not as well understood as the gauge sector, there remain a number of unresolved questions. How many families exist and why? What is the origin of the quark mass? Are there new sources of CP violation? Is there any relationship between the lepton and quark sectors?

Quarkonium physics plays a role in providing further tests of the Standard Model and the potential for discoveries of new physics at the LHC. In particular, radiative decays of Y resonances into leptons could unveil new physics in connection with the existence of a light Higgs particle. Also, invisible decays of heavy quarkonia might exclude or reveal light dark matter (e.g. very light neutralinos). A recent series of CERN workshops also covered these topics (*CERN Courier* September 2007 p29).

The workshop noted the changing experimental landscape of quarkonium physics. While the facilities at SLAC and CLEO are reaching the ends of their lifetimes and the future of Fermilab is unclear, the KEK-B facility and the Beijing Spectrometer experiment will continue to perform superbly in the LHC era. However, dedicated quarkonium facilities to follow up on LHC discoveries will be desirable. Other current and future facilities, while not dedicated to quarkonium studies, will add significantly to our understanding of quarkonia.

The proposed future International Linear Collider is a far-reaching project that would provide deeper insights into the laws of nature in many areas of physics, including quarkonium physics. In the meantime, one of the major goals of the planned luminosity upgrade at RHIC is to improve in-medium quarkonium studies. This upgrade will complement quarkonium in-medium studies at the LHC. The quarkonium production rates at the LHC will be similar to those obtained at the upgraded RHIC since the heavy-ion runs at the LHC, while at higher energy and greater luminosity, will be significantly shorter. Quarkonium studies are also a major component of the antiproton and heavy-ion programmes at GSI, Darmstadt.

The workshop concluded with a round-table discussion devoted to a dedicated heavy-flavour facility, the general-purpose Super Flavour Factory project. This high-luminosity machine would make high-precision measurements to search for new physics in the flavour sector and would further contribute to strong-interaction physics.

● The QWG and its workshops provide lively forums where experts in quarkonium physics can assess the most recent advances and set out clear, well-defined goals. These goals form a set of action items that are reviewed and updated following each QWG meeting. The action items can be viewed and commented upon from the QWG website at www.qwg.to.infn.it/.

Further reading

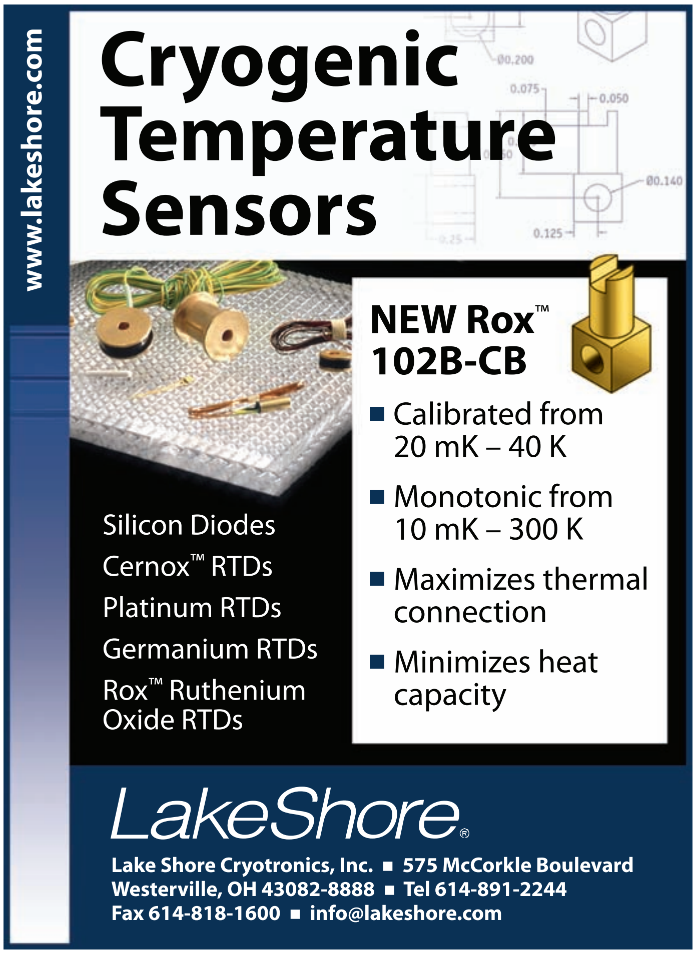
N Brambilla *et al.* CERN 2005 *Yellow Report* arXiv: hep-ph/0412158.

Résumé

La physique du quarkonium à l'aube du LHC

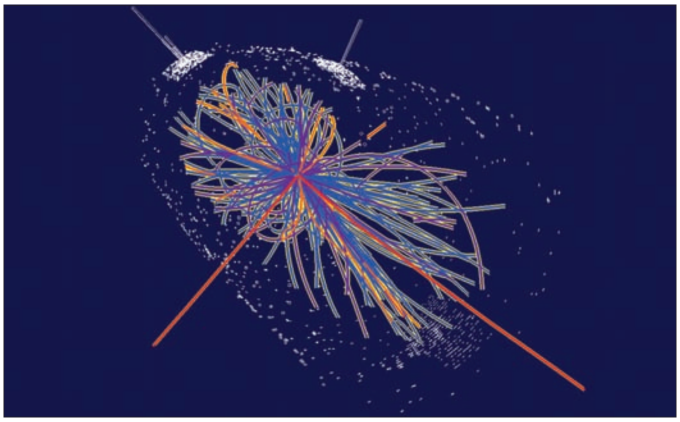
Le groupe de travail sur le quarkonium a été constitué en 2002 pour faire avancer la recherche et promouvoir la communication entre théoriciens et expérimentateurs dans ce domaine. La dernière en date des réunions organisées par ce groupe a eu lieu à DESY, à Hambourg, en octobre 2007. Au programme, des nouvelles de la théorie de la production de quarkoniums au Tevatron et dans les usines à B, la production de quarkoniums et leur comportement dans les collisions d'ions lourds, les nouveaux états à résonance étroite découverts à Belle, BaBar et CLEO, les applications aux recherches sur la physique au-delà du modèle standard, et les expériences sur les quarkoniums à l'ère du LHC.

Geoffrey Bodwin, *ANL*, **Andreas B Meyer**, *DESY*, **Ágnes Mócsy**, *RBRC BNL*, **Miguel Sanchis-Lozano**, *IFIC–Valencia, and* **Ramona Vogt**, *LLNL and UC Davis, for the Quarkonium Working Group.*



New symposium links the vacuum and the universe

A meeting in Austria looked at how vacuum physics at different energy scales continues to help in understanding the universe.



A computer simulation of the detection of a Higgs boson in the CMS experiment at the LHC at CERN. (Courtesy Ianna Osborne/CMS.)

The first Austria–France–Italy (AFI) symposium, From the Vacuum to the Universe, took place on 19–20 October at the University of Innsbruck. Inspired by developments in particle and astrophysics, it explored the physics of the vacuum, its manifestations in the subatomic world and its consequences for the large-scale structure of the universe. Studies of quark confinement; searches for the Higgs boson and other LHC physics; neutrinos; cosmic rays; and astrophysical probes of dark matter – all promise to reveal vital information about the structure of the universe, from the scale of QCD to tera-electron-volts.

The physical world is built from spin-1/2 fermions interacting through the exchange of gauge bosons: massless spin-1 photons and gluons; massive W and Z bosons; and gravitational interactions. The Pauli exclusion principle (PEP), which says that two identical fermions cannot exist in the same quantum state, is responsible for the stability of the physical world and is a pillar of chemistry. Further ingredients are needed to allow the formation of large-scale structures on the galactic scale and to explain the accelerating expansion of the universe. These are the mysterious dark matter and dark energy, respectively. Current observations point to an energy budget of the universe where just 4% is composed of atoms, 23% involves dark matter (possibly made of new elementary particles) and 73% is dark energy (the energy density of the vacuum perceived by gravitational interactions).

The AFI meeting, with a mix of colloquium talks and discussion sessions, deliberated the interplay of this physics and possible synergies between different methods to learn about the physics of the vacuum. It also considered the use of particle physics to understand problems in astrophysics and the large-scale structure of the universe.

The vacuum is associated with various condensates. The QCD scale associated with quark and gluon confinement is around 1 GeV, while the electroweak mass scale associated with the W and Z boson masses is around 100 GeV. These scales are many orders of magnitude less than the Planck-mass scale of around 10^{19} GeV, where gravitational interactions are supposed to be sensitive to quantum effects. The vacuum energy density associated with dark energy is characterized by a scale around 0.002 eV, typical of the range of possible light neutrino masses, and a cosmological constant, which is 54 orders of magnitude less than the value expected from the Higgs condensate and no extra new physics. Finally, the mass scale associated with dark matter remains to be determined. The physics of confinement, the origin of electroweak symmetry breaking, the nature of dark matter and why the dark-energy scale is finite and so much less than the electroweak and QCD scales, are fundamental questions for subatomic physics and its consequences for the macroscopic world.

For fermions, the VIP Collaboration at Frascati and Gran Sasso is performing precise new tests of the PEP for electrons, as Johann Marton of the Austrian Academy of Science described. These experiments look for anomalous 2p → 1s X-ray transitions in copper. Recent results have reduced the probability of a violation of the PEP by two orders of magnitude, with results of tests to a further two orders of magnitude expected shortly. The parameter characterizing possible PEP violation is currently measured to be $\beta^2/2 < 6 \times 10^{-29}$.

The origin of mass is a fundamental problem in QCD and electroweak physics. In QCD the coupling constant that describes the strength of quark–gluon interactions (and gluon–gluon) grows in the infrared. It becomes so large that the quarks and gluons are confined, and in isolation particles carrying the colour quantum number can propagate a maximum distance of only around 1 fm. Reinhard Alkofer of Karl-Franzens University, Graz, explained that recent studies suggest that confinement works differently in the pure gluon theory and in QCD with light quarks. Ghost loops seem to be important. The physical-confinement mechanism is associated with dynamical breaking of the chiral symmetry between left- and right-handed quarks; 98% of the proton's mass is produced by the binding energy between quarks.

The subtle role of spin-1/2 quarks in the proton is further highlighted by the proton-spin problem, as Fabienne Kunne of CEA/Dapnia described. Polarized deep inelastic scattering experiments at CERN, DESY and SLAC have revealed that only about 30% of the spin of the proton comes from the intrinsic spin of the quarks that it contains. Where is the "missing" spin and why is the quark contribution so small? Possibilities include a topological effect where the spin becomes in part delocalized in the proton, or sea quarks polarized against the direction of the spin of the proton. The COMPASS experiment at CERN, as well as spin experiments at RHIC and Jefferson Lab, are currently investigating these issues.

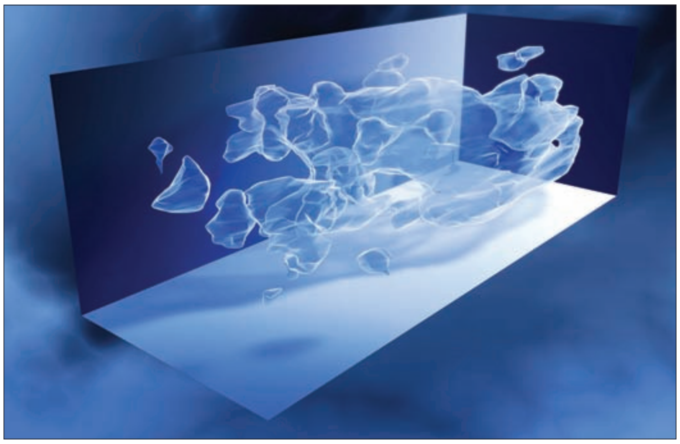
QCD and electroweak interactions are governed by Yang–Mills fields – the gluons and W and Z bosons, respectively. The interactions appear fundamentally different because of the large mass of the W and Z bosons. This means that the electroweak force has a short range of around 0.01 fm, which stops the electroweak coupling from increasing to be large enough in the infrared to produce confinement: electrons and neutrinos are not confined. Electroweak interactions are also characterized by parity violation and CP violation. Furthermore, only neutrinos with left-handed chirality are observed.

The origin of the W and Z boson masses is believed to be associated with the Higgs mechanism, a major target for LHC physics. The LHC's 14 TeV collisions will eventually cover the entire mass range, with an integrated luminosity of around 30 fb^{-1}. Joachim Mnich of DESY, Hamburg, presented the status of the collider and early expectations. The LHC experiments will also look for new physics such as the lightest supersymmetric-particle (LSP) candidate for dark matter, possible extra dimensions, and strong WW scattering if the Higgs mechanism proves to be an electroweak dynamical effect – topics described by Caroline Collard of the Laboratoire de l'Accélérateur Linéaire, Orsay. LHC physics and its interface with gravitational interactions pose many challenges. The Higgs mechanism required to explain the W and Z boson masses with no additional physics yields a cosmological constant larger than the observed value by a factor around 10^{54}.

Silvia Pascoli of Durham University talked about the neutrino sector, where evidence from solar, atmospheric and reactor experiments points to oscillations with a different mixing pattern from that of quarks. Oscillations between different neutrino species require small but finite neutrino masses. Open questions for future experiments include possible CP violation for neutrinos, the order of masses (is the flavour hierarchy the same as for quarks?), the absolute mass determination, and whether neutrinos are their own antiparticles.

The origin of cosmic radiation has been a mystery since its discovery by Victor Hess in 1912. Neutrinos have no electromagnetic interaction and do not bend in magnetic fields in space. Neutrino telescopes that look for point sources of neutrinos in space are probing the origin of cosmic rays, complementing studies at the Pierre Auger Observatory. These use kilometre-scale detectors in the sea or ice, which act as transparent media. Mieke Bouwhuis of Nikhef and Carlos de los Heros of Uppsala University presented the status and plans for ANTARES in the Mediterranean and IceCube at the South Pole, respectively.

These experiments, as well as those at the LHC, will look for new particles that help to explain the mysterious dark matter, described by Antonaldo Diaferio of Torino, which is needed to account for structure formation in galaxies and the large-scale structure of the universe. Galaxy rotation curves reveal that the variation of the velocity, v, of the stars with the distance, r, from the centre of the galaxy is approximately flat, rather than v^2 falling off as 1/r, which should occur if gravity couples only to the visible matter. Extra mass must be present and to explain this, either extra matter or some modification to gravity over large distances is required. It is a mystery whether this dark matter is made of fermions, bosons or of both. Possible candidates for dark matter include weakly interacting massive particles with no electromagnetic interactions, which behave almost like collisionless particles and yield cold dark matter in the outer halos of galaxies. Celine Boehm of the Laboratoire d'Annecy-le-Vieux de Physique Théorique described how, for dark matter at the tera-electron-volt scale, the LHC collisions might produce and reveal the conjectured fermionic LSP. If the dark matter is bosonic, new particles of lighter mass are possible. The 511 keV positron-annihilation radiation observed from the centre of the galaxy could be evidence for light-mass dark matter.



A three-dimensional map of the dark-matter distribution in a field of 2 square degrees. (Courtesy NASA, ESA and R Massey/Caltech.)

The nature of the missing galaxy mass and its connection to possible new physics is undoubtedly an open question. While the masses of the known fermions may depend on the same mechanism of electroweak symmetry breaking that produces the W and Z boson masses, the origin of dark-matter mass will involve new physics. The connections between particle physics and gravitation, taking us from the very small to the very large, promise to inspire much experimental and theoretical investigation in the decades ahead.

● The AFI symposium was organized in collaboration with the Frankreich Schwerpunkt and Italien Zentrum of the University of Innsbruck whose mandates are to develop and promote scientific and cultural relations between the West Austrian University and French and Italian experts and institutes. It was further supported by the BMWF, the Austrian Science Fund FWF and the University of Innsbruck. For more information see www.uibk.ac.at/italienzentrum/italienzentrum/afi-meeting.html.

Résumé

Un colloque fait le lien entre vide et Univers

Le premier colloque Autriche-France-Italie (AFI) intitulé « Du vide à l'Univers » a eu lieu à octobre 2007 à l'Université d'Innsbruck. Inspiré par les dernières avancées en physique des particules et en astrophysique, il s'est intéressé à l'exploration de la physique du vide, ses manifestations dans le monde subatomique et ses conséquences pour la structure à grande échelle de l'Univers. Le confinement des quarks, le boson de Higgs et d'autres recherches liées au LHC, les neutrinos, les rayons cosmiques et la recherche de la matière noire en astrophysique - autant de sujets qui pourraient apporter des éléments neufs sur la structure de l'Univers, que ce soit à l'échelle de la chromodynamique quantique ou à celle des téraélectron-volts.

Steven Bass, *University of Innsbruck.*

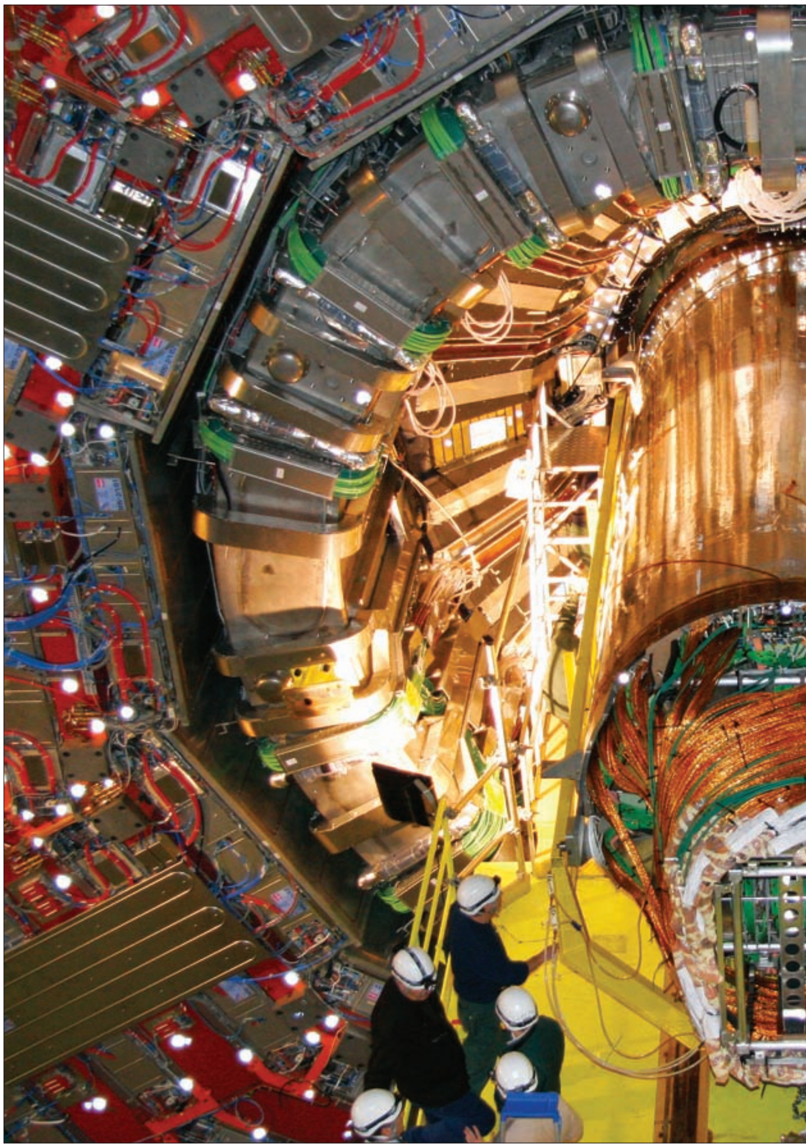
CMS installs the world's

With more than 200 m^2 of silicon sensors, the tracking system for CMS is a world-beater. **Geoff Ha**

In December 1999 the CMS collaboration made the daring decision to change its tracking detector from a design that included gaseous detectors to one constructed entirely from silicon sensors, using both microstrip and pixel technology. On 15 December 2007, teams working in the cavern at Point 5 on the LHC installed the microstrip tracking system into the experiment. The pixel detector will soon follow, completing the CMS Tracker and marking the culmination of eight years of careful work to design, prototype, construct and commission the largest silicon detector ever built.

The collaboration envisaged a tracking system 40 times larger than any existing silicon detector system, with a performance comparable to the vertex detectors used at LEP. The detector would house about 205 m^2 of silicon sensors (approximately the area of a tennis court) comprising 9.3 million microstrips and 66 million pixels. The aim was to achieve a precision of about 10 μm in spatial and vertex reconstruction resolutions – enough for excellent identification of heavy flavour hadrons – and excellent momentum measurement over a wide momentum range at the LHC. The readout would require 73 000 radiation-hard, low-noise microelectronics chips, almost 40 000 analogue optical links, 1000 power supply units and 500 off-detector readout and control modules. The complete system would be constructed in two halves from nine separate subdetector units: two each of microstrip inner barrels, outer barrels and endcaps, three pixel units in the form of a barrel system and two identical forward units (figure 1).

In June 2000, the LHC Committee approved the *Technical Design Report* for the new design and the project formally got underway. A collaboration of more than 500 physicists and engineers from 51 institutions based in Austria, Belgium, Finland, France, Germany, Italy, Switzerland, the UK and the US, as well as from CERN, took joint responsibility for the project. They agreed that the inner barrel would be constructed by an Italian consortium, the outer barrel system by CERN together with Finnish and US groups, and the two endcaps by European teams. Swiss groups would build the central barrel region of the pixel system and a US collaboration would provide the forward pixel units.



The final stage of insertion of the CMS microstrip tracker into the experiment was comp

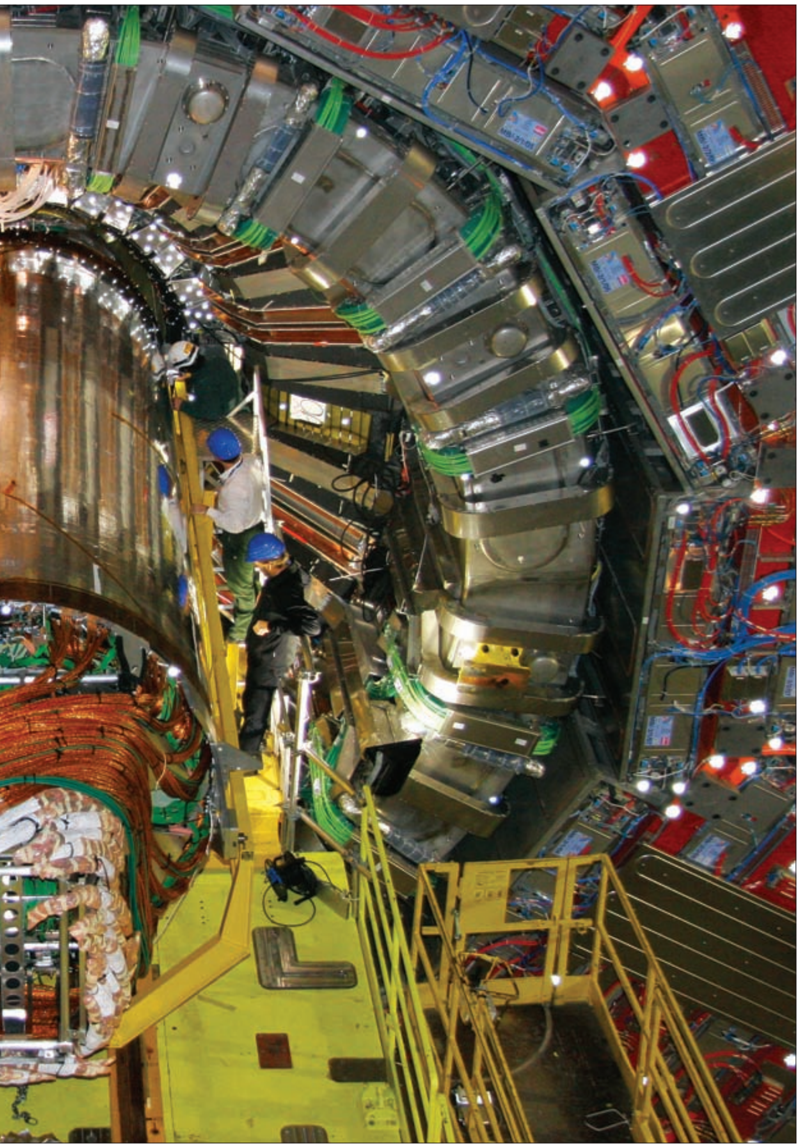
The assembly project

The detailed design of each of the subdetector units took several years, including extensive testing of prototype sensors, modules and the readout, cooling and power systems. Production of the microstrip detector modules began in November 2004 using the sensors, hybrids and electronic components developed during the earlier phase – all of which had been thoroughly studied and evaluated to ensure maximum reliability and performance. Production of these modules was complete by March 2006. Then, after further substantial testing and thermal cycling, they were ready for mounting onto low-mass carbon fibre substructures with pre-assembled cooling circuits.

The project also became a massive worldwide logistical activity. The microstrip sensors were manufactured in Japan, with contributions from Italian industry, and shipped to Europe and the US for evaluation. The sensors were then moved to other European and US destinations for construction into modules using customized automated assembly equipment that CMS engineers had devised; and they journeyed further still for assembly into sub-units such as rods for the outer barrel, shells and discs for the inner barrel, and petals for

s largest silicon detector

Hall and **Peter Sharp** describe some of the huge amount of effort that went into its construction.



mpleted in December 2007 over a period of two days. (Courtesy Michael Hoch/CERN.)

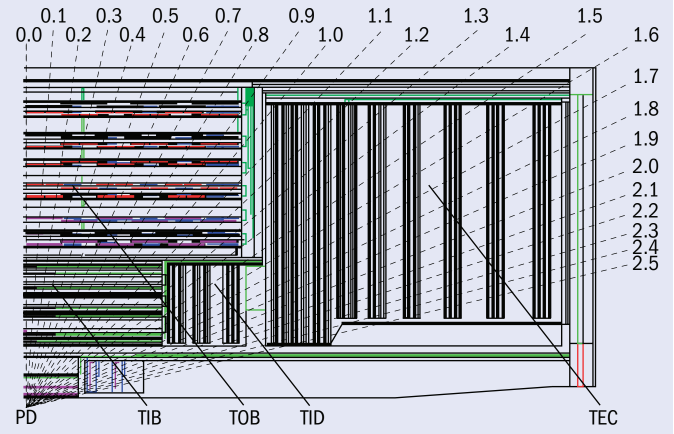


Fig. 1. A schematic diagram of a quarter of the detector showing the subdivision into the pixel detector (PD), and microstrips beyond a radius of about 20 cm. The microstrip system comprises Tracker inner barrel shells (TIB) and discs (TID), Tracker outer barrel (TOB) and Tracker endcaps (TEC). The diameter of the detector is 2.5 m, with a length of 5.4 m.

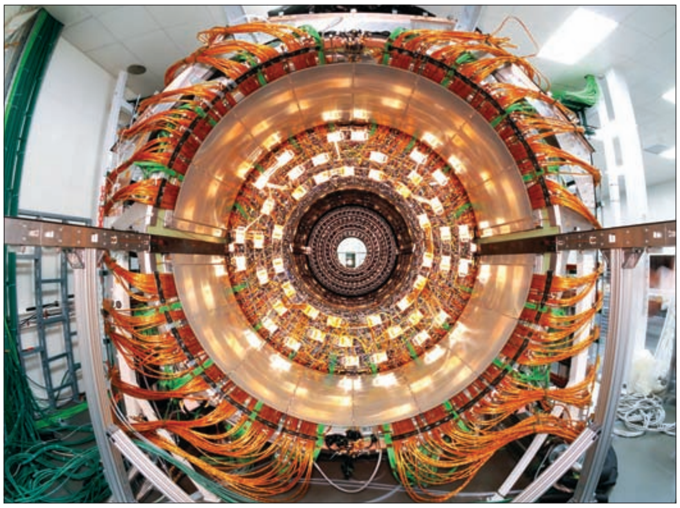
the endcaps. The pixel system involved a similar transporting of parts, starting with commercially manufactured sensors from Norway.

The electronic readout system relied on developments in radiation-hard electronics and innovations in optical links, technologies that evolved rapidly in the 1990s. The CMS system culminated with the APV25 – the first large readout chip for a particle-physics experiment to use 0.25 μm CMOS integrated circuit technology – and novel analogue fibre-optic links. Much of this development was the responsibility of groups in the UK and teams at CERN, who worked closely with other CMS groups to assemble the elements of the readout system. CERN designed a set of control and ancillary chips using 0.25 μm CMOS technology, extensively exploited both in the Tracker and throughout CMS.

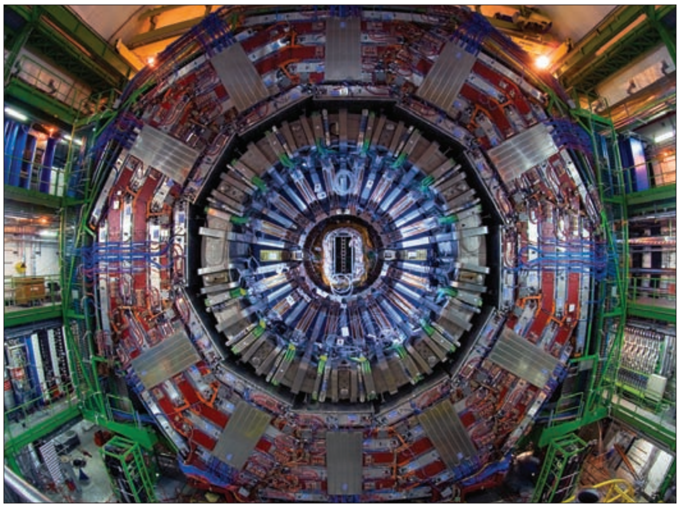
The automated assembly pioneered for this enormous system was vital for constructing thousands of modules quickly, so that the 15 200 required could be delivered on time. It also generated a huge interconnection requirement. Each module was assembled from one or two microstrip sensors, which had to be connected to the APV25 readout chip. The module chips also had to be bonded to their low-mass carrier. The intensive use of automatic-wire bonders met this demand and maintained consistent throughput with few delays, despite occasional variations in bond quality and rejection of sub-optimal modules.

The collaboration also subcontracted a great deal of the assembly work to industries in several countries, including Austria, France, Italy, Japan, Switzerland and the UK. In partnership with CMS institutes, the companies manufactured components and produced electronics boards, mounting and aligning semiconductor lasers, optical fibres, photodiodes, and analogue and digital electronics, including field-programmable gate arrays that were then state of the art. All modules were thoroughly tested in industry – often using CMS-constructed test equipment – then re-tested for acceptance in CMS laboratories. It is impossible here to do justice to the efforts of the CMS institutes, all of which took on significant tasks in assembly, evaluation and procurement.

Collaboration members constructed new facilities in many ▷



An end view of the microstrip tracker during assembly at the CERN Integration Facility. At this point, one half of the inner-barrel subdetector, which had come to CERN after being assembled in Italy, had just been inserted into place in the outer barrel system, with the endcap to follow.



A wide-angle end view of the entire CMS after installation of the Tracker, which is visible in the centre. The Tracker is surrounded by the electromagnetic and hadron calorimeters, then by an outer layer comprising the iron magnet yoke and muon detector system.

institutions for assembling the subdetectors, as well as expanding and utilizing large laboratories such as at CERN, Fermilab and Pisa. Aachen assembled one of the Tracker endcaps, while Florence, Pisa and Torino jointly integrated the inner barrels and discs. There were intensive reviews at all system levels for each stage of production and integration to ensure that quality and performance were maintained.

On the main CERN site, CMS built a facility to assemble the final detector and to provide an environment where a substantial fraction of it could be fully commissioned before final installation into CMS at Point 5. The Tracker Integration Facility is a 350 m^2 class 100 000 cleanroom, which was also used to integrate the entire outer-barrel system and the second endcap. Each subdetector underwent testing and thermal cycling before transportation to CERN. Further acceptance tests took place after arrival before final integration into the support structure.

The two halves of the outer barrel were built inside the Tracker support tube, which is a low-mass carbon fibre cylinder 5.4 m long and 2.5 m in diameter. The outer-barrel subdetector was completed in November 2006. The inner-barrel halves arrived at CERN in April and September 2006 for final testing before insertion into the outer barrel. The first half section was placed in position in December 2006 and the second half inner barrel and the endcap followed rapidly, with integration of the second endcap completed on 22 March 2007.

As each subdetector was assembled, the teams re-tested it to ensure that it continued to achieve the required performance. The integration facility included rack-mounted electronics, cooling and air-conditioning, which allowed the Tracker to observe cosmic-ray events before installation underground. This incorporated a quarter of the complete safety, control, power, data-acquisition and computing systems for the Tracker – destined eventually for the CMS caverns – including electrical and optical cables, which were to be re-used to keep down costs.

From March until August 2007, all aspects of the Tracker underwent testing, including safety, control and monitoring systems. Several million cosmic-ray events were recorded at five operating temperatures ranging between –15 °C and +15 °C. The data were reconstructed using the CMS-distributed computing Grid and were analysed throughout the world. All systems operated reliably during this five-month period and the collaboration verified that the assembled detector met the performance specifications.

Analysis of the cosmic-ray data shows that the performance of the microstrip tracker is excellent. The number of inactive strips is below one part in 2000; noisy strips do not exceed 0.5%. The signal-to-noise ratio, which depends on sensor thickness, was about 28 for 300 μm sensors. Measurements showed the track cluster finding efficiency to be better than 99.8%. All of these results meet or exceed expectations, which bodes well for LHC physics.

Final installation

At the CMS experimental area at Point 5, preparation for installing the Tracker began before the solenoid magnet was even lowered into the cavern in February 2007. Installation and testing of the cooling plants, power systems and off-detector readout electronics, as well as control and data-acquisition systems took place throughout 2007.

The final performance of the subdetectors in LHC collisions is crucially dependent on the electrical quality of the underground environment, which will only become fully understood after the experiment is complete. The Tracker's electronics are exquisitely sensitive to tiny signals and must be protected against unwanted noise. To achieve this, 32 interconnection units (patch panels) serving different sectors of the Tracker were installed at the edge of the CMS solenoid, through which all electrical power and cooling services – as well as optical fibres and monitoring wires – pass. The patch panels filter electronic noise and will permit *in situ* optimization of the detector's grounding. They also provide termination for cooling, optical links and electrical cables so that all services could be tested as far as possible in CMS before the Tracker arrived.

By late September 2007, the installation teams had completed the massive task of installing cooling systems for 450 loops, 2300 power and 400 fibre-optic cables. The microstrip tracker was transported overnight to Point 5 on 12 December and installation into CMS was completed over the following two days. Connection of the services from the patch panels to the Tracker, and commissioning the Tracker with the rest of CMS, will be completed this spring.

The pixel system

Although a physically smaller device, the pixel system has about a factor of seven more channels. Being at the centre of the detector, concern about minimum material budget and higher radiation levels necessitates even greater attention. Interconnection technologies – especially fine-pitch bump bonding, which were not yet mature for applications in particle physics – had to be studied and, in some cases, developed in CMS labs to allow construction of the detector. The pixel assembly project followed a similar course to the microstrip tracker, with significant transport of parts around the world. Fermilab was at the centre of US activity, and was where the final assembly of the forward system was completed following plaquette construction at Purdue University. The team at the Paul Scherrer Institute (PSI) assembled the barrel subdetector with the collaboration of Swiss universities. PSI also designed the pixel readout chip, while other chips were developed in PSI and the US; the pixel detectors have also exploited components from the microstrip tracker.

The pixel system is scheduled for insertion into CMS following the installation and bake out of the LHC beam pipe in April. The complete forward subdetector was transported to CERN from Fermilab in December 2007 and is now undergoing extensive system tests at the Tracker Integration Facility. The barrel subdetector is also complete and currently being commissioned at PSI. It will be transported to CERN in April.

● It goes almost without saying that this enormous project would not have been possible without support from the entire CMS Collaboration, CERN and many national funding agencies to whom we are extremely grateful.

Further reading

For the members of the Tracker Collaboration, see http://cmsdoc.cern.ch/Tracker/Tracker2005/TKdocuments/TrackerAuthorList2008.pdf. For more about the Tracker, see http://cmsdoc.cern.ch/Tracker/Tracker2005/. For more about the CMS detector, see http://cmsdoc.cern.ch/cms/Publications/detpaper/draft2.html.

Résumé

CMS installe le plus grand détecteur au silicium du monde

En décembre 1999, la collaboration CMS a pris une décision audacieuse: passer pour son trajectographe d'un système comprenant des détecteurs en milieu gazeux à un système constitué entièrement de capteurs au silicium (microrubans et pixels). Une collaboration de plus de 500 physiciens et ingénieurs basés dans différents pays (Allemagne, Autriche, Belgique, États-Unis, Finlande, France, Italie, Royaume-Uni et Suisse) a pris ce projet en charge. Le 15 décembre 2007, les équipes travaillant sur le LHC dans la caverne de CMS ont installé le trajectographe à microrubans. Le détecteur à pixels suivra bientôt. Ce sera l'aboutissement de huit ans de travail très minutieux pour créer le plus grand détecteur au silicium jamais construit.

Geoff Hall, *Imperial College London, and* **Peter Sharp**, *CERN and Imperial College London.*

ADVERTISEMENT FEATURE

saes getters

SAES Getters and CERN –
a 30 year long collaboration

SAES® Getters began collaborating with CERN in the late 70's, at the time of the design of the vacuum system of LEP, when a Non-Evaporable Getter (NEG) strip based on the SAES Getters St101® getter alloy was selected as the primary pumping system of the storage ring.

At that time, the collaboration work was mainly aimed at the optimization of the getter strip parameters to meet the specifications in terms of performance, quality and reliability required by the machine design. Optimization of the getter strip thickness in order to achieve sufficient speed and capacity and at the same time cope with the needed heating cycles requested for its activation at 740 °C was one of the key issues.

A total of about 22 km of such a strip was supplied by SAES Getters to CERN as a result of the successful optimization work.

From that moment non-evaporable getter strips began to be a standard pumping solution for the vacuum systems of storage rings, particularly for Synchrotron Radiation Sources and Colliders, requiring UHV-XHV conditions.

Following that initial success, CERN established itself as one of the centers of knowledge on non evaporable gettering, publishing a series of paper describing the pumping mechanism of the getter material surfaces.

In the 80's SAES Getters developed a new getter material, St707®, capable to be activated at lower temperature (350 - 400 °C) than St101 alloy. This permits the material to be activated at temperatures compatible with the baking temperature of vacuum systems, allowing the positioning of a much higher quantity of material in the vacuum system itself with obvious advantages in terms of pumping speed and capacity. St707 strip and St707 pump-based products have been used at CERN in machines such as LEAR and its ancillary equipment.

Merging together expertise and knowledge on non evaporable getters and sputtering, the latter matured in the frame of the development and production of the Niobium sputtered RF cavity for the LEP II, CERN developed and patented in the late 90's the thin film non evaporable getter coatings which can be applied by sputtering on the walls of the particle accelerator vacuum chambers, and then activated at moderate temperature (180 °C). This "integration" in a single element of the vacuum chamber, the "outgassing" source and of the pumping system, the getter film, was a breakthrough in the pumping technology for Particle Accelerator, which provides a number of advantages not only related to the pumping effect (e.g. improved secondary electron yield, lower desorption rates under dynamic conditions, improved pipe design)

SAES Getters signed a license agreement with CERN for the transfer of the technology of the thin film getters coatings and following a technology transfer program this solution is now marketed by SAES Getters under the trade name of "IntegraTorr®".

Several NEG coated chambers have been so far delivered by SAES Getters and installed in a variety of machines in Europe, US and Asia.

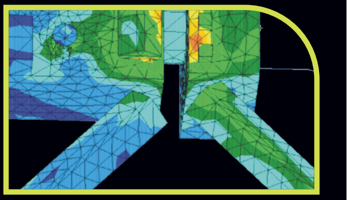
SAES products, also including gas purifiers, have been required in some experimental areas of the LHC machine.

High energy machine can benefit from NEG pumps (courtesy of CERN)

For more information:
Paolo Manini
SAES Getters
Business Manager Vacuum Systems
Phone: +39 02 93178284
e-mail: paolo_manini@saes-group.com
www.saesgetters.com

IET

The Knowledge Network



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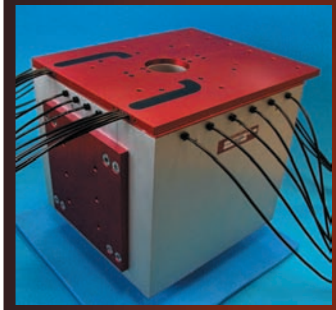

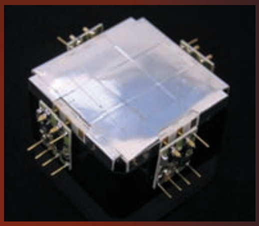

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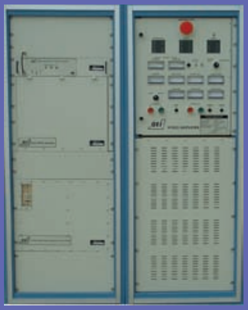

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CMS starts underground

Since last May the CMS collaboration has gradually integrated the various subdetectors into tests with cosmic rays, which exercise the complete data chain through to delivery for analysis around the world. **Darin Acosta** and **Tiziano Camporesi** report from CERN.

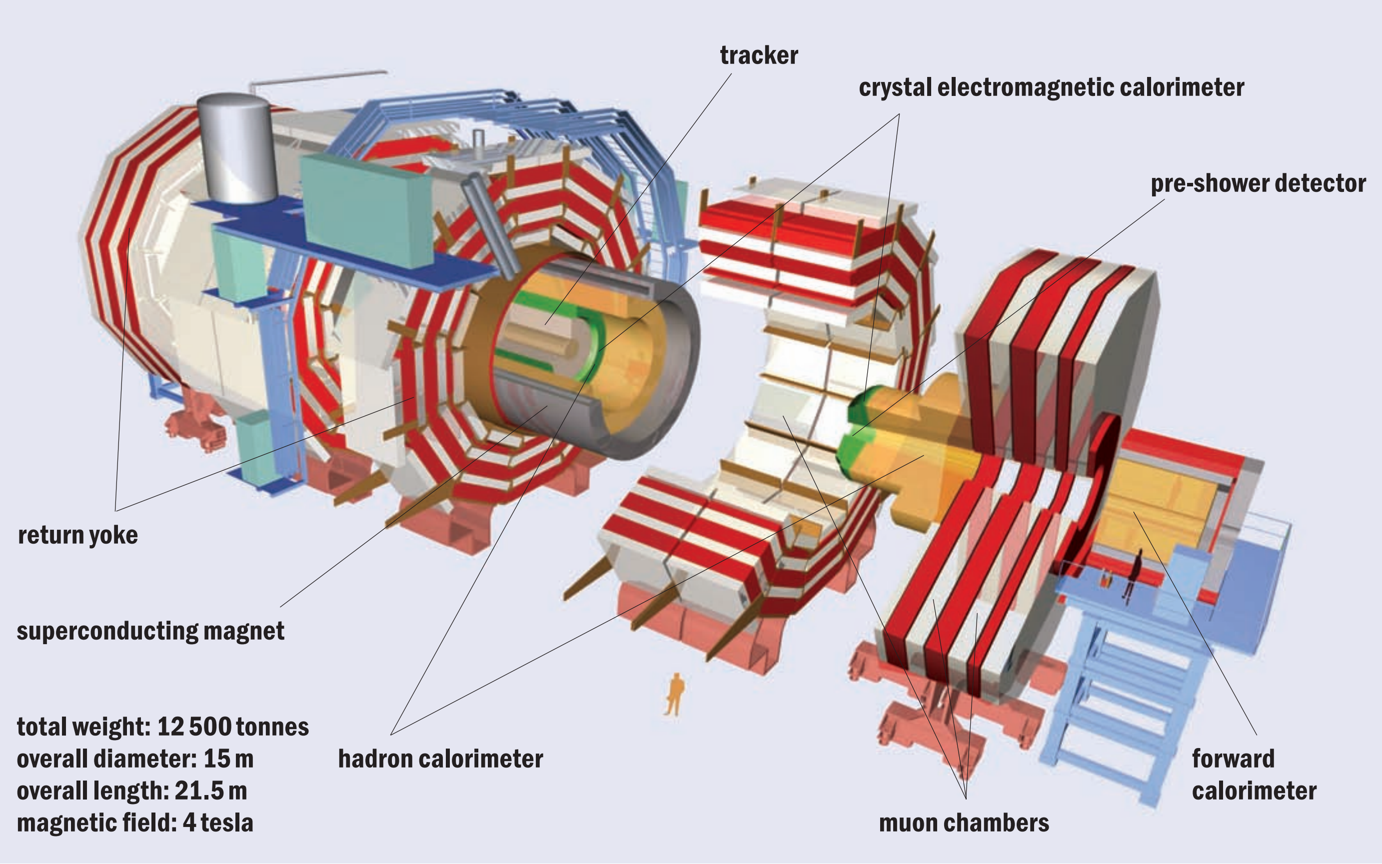


Fig. 1. The various subdetectors of CMS, showing the construction of the overall detector in "slices", which were first assembled above ground.

In July 2006, the huge segments of the CMS detector came together for the first time for the Magnet Test and Cosmic Challenge at the experiment's site near Cessy in France. Within days the commissioning teams were recording data from cosmic rays bending in the 4 T magnetic field as they passed through a "slice" of the overall detector (*CERN Courier* March 2007 p26). This contained elements of all four main subdetectors: the particle tracker, the electromagnetic and hadron calorimeters and the muon system (figure 1). Vital steps remained, however, for CMS to be ready for particle collisions in the LHC. These tests in 2006 took place at the surface, using temporary cabling and a temporary electronics barrack, 100 m or so above the LHC ring.

To prepare for the LHC start up, the segments had to be lowered into the cavern one at a time, where the complete system – from services to data delivery – was to be installed, integrated and checked thoroughly in tests with cosmic rays. The first segment – one of the two forward hadron calorimeters (HF) – descended into the CMS cavern at the beginning of November 2006 and a large section of the detector was in its final position little more than a year later, recording cosmic-ray muons through the complete data chain and delivering events to collaborators as far afield as California and China.

This feat marked an achievement, not only in technical terms, but also in human collaboration. The ultimate success of an experiment on the scale of CMS is not only the challenge of building and assembling all the complex pieces; it also involves orchestrating an ensemble of people to ensure the detector's eventual smooth operation. The *in situ* operations to collect cosmic rays typically involved crews of up to 60 people from the different subdetectors at CERN, as well as colleagues around the globe who have put the distributed monitoring and analysis system through its paces. ▷

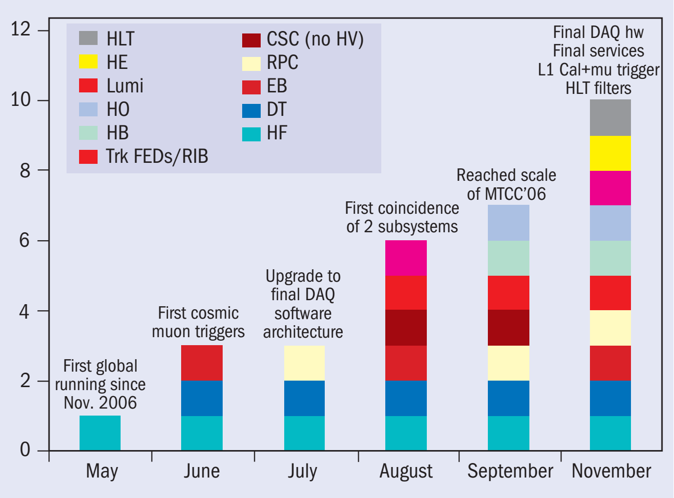


Fig. 2. As 2007 progressed an increasing number of the following subsystems participated in the global runs. HLT: high level trigger, HE: endcap hadron calorimeter, luminosity monitors, HO: outer hadronic calorimeter, HB: barrel hadron calorimeter, Trk FEDs/RIB: tracker front-end drivers/rod-in-a-box, CSC: cathode strip chamber, RPC: resistive plate chambers, EB: barrel electromagentic calorimeter, DT: drift tubes, HF: forward hadron calorimeter.

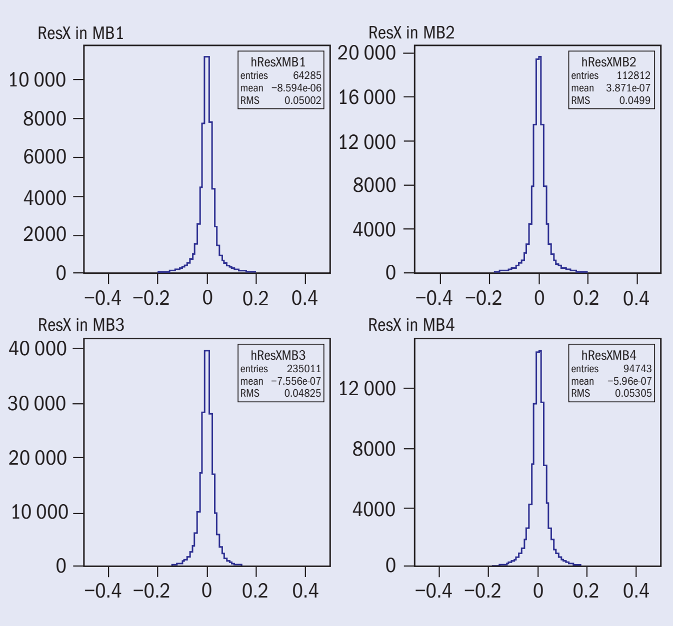


Fig. 3. Preliminary analysis of the cosmic data collected during a global run shows a single hit resolution of the drift tube chambers for detecting muons in the central barrel to be better than 250 μm.

The teams worked together, in a relatively short space of time, to solve the majority of problems as they arose – in real time.

Installation of the readout electronics for the various subdetector systems began in the cavern in early 2007, soon after the arrival of the first large segments. There were sufficient components fully installed by May for commissioning teams to begin a series of "global runs" – over several days at the end of each month – using cosmic rays to trigger the readout. Their aim was to increase functionality and scale with each run, as additional components became available. The complete detector should be ready by May 2008 for the ultimate test in its final configuration with the magnetic field at its nominal value.

At the time of the first global run, on 24–30 May 2007, only one subdetector – half of the forward hadron calorimeter (HF+), which was the first piece to be lowered – was ready to participate (figure 2). It was accompanied by the global trigger, a reduced set of the final central data acquisition (DAQ) hardware installed in the service cavern, and data-quality monitoring (DQM) services to monitor the HF and the trigger. While this represented only a small fraction of the complete CMS detection system, the run marked a major step forward when it recorded the first data with CMS in its final position.

This initial global run confirmed the operation of the HF from the run-control system through to the production global triggers and delivery of data to the storage manager in the cavern. It demonstrated the successful concurrent operation of DQM tasks for the hadron calorimeter and the trigger, and real-time visualization of events by the event display. The chain of hardware and software processes governing the data transfer to the Tier-0 processing centre at CERN's Computer Centre (the first level of the four-tier Grid-based data distribution system) already worked without problems from this early stage. Moreover, the central DAQ was able to run overnight without interruption.

The June global run saw the first real cosmic-muon triggers. By this time, the chambers made of drift tubes (DTs) for tracking muons through the central barrel of CMS were ready to participate. One forward hadron calorimeter (HF) plus a supermodule of the electromagnetic calorimeter (which at the time was being inserted in the CMS barrel) also joined in the run, which proved that the procedures to read out multiple detectors worked smoothly.

July's run focused more on upgrading the DAQ software towards its final framework and included further subdetectors, in particular the resistive plate chambers (RPCs) in the muon barrel, which are specifically designed to provide additional redundancy to the muon triggers. This marked the successful upgrade to the final DAQ software architecture and integration of the RPC system.

The first coincidence between two subsystems was a major aim for the global run in August. For the first time, the run included parts of the barrel electromagnetic calorimeter (ECAL) with their final cabling, which were timed in to the DT trigger. The regular transfer of the data to the Tier-0 centre and some Tier-1s had now become routine.

By September, the commissioning team was able to exercise the full data chain from front-end readout for all types of subdetector through to Tier-1, Tier-2 and even Tier-3 centres, with data becoming available at the Tier-1 in Fermilab in less than an hour. The latter allowed collaboration members in Fermilab to participate in remote data-monitoring shifts via the Fermilab Remote Operations Centre (*CERN Courier* December 2007 p42). On the last day of the run, the team managed to insert a fraction of the readout modules for the tracker (working in emulation mode, given that the actual tracker was not yet installed) into the global run, together with readout for the muon DTs and RPCs – with the different muon detectors all contributing to the global muon trigger.

The scale of the operation was by now comparable to that achieved above ground with the Magnet Test and Cosmic Challenge in the summer of 2006. Moreover, as synchronization of different components for the random arrival times of cosmic-muon events

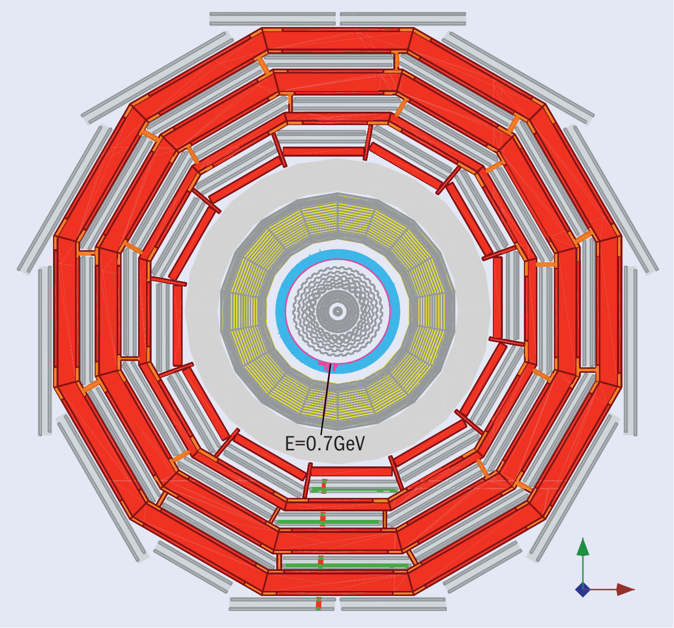


Fig. 4. A cosmic muon recorded during the global run in August illustrates the time synchronization of a supermodule of the electromagnetic calorimeter with the drift-tube muon system.

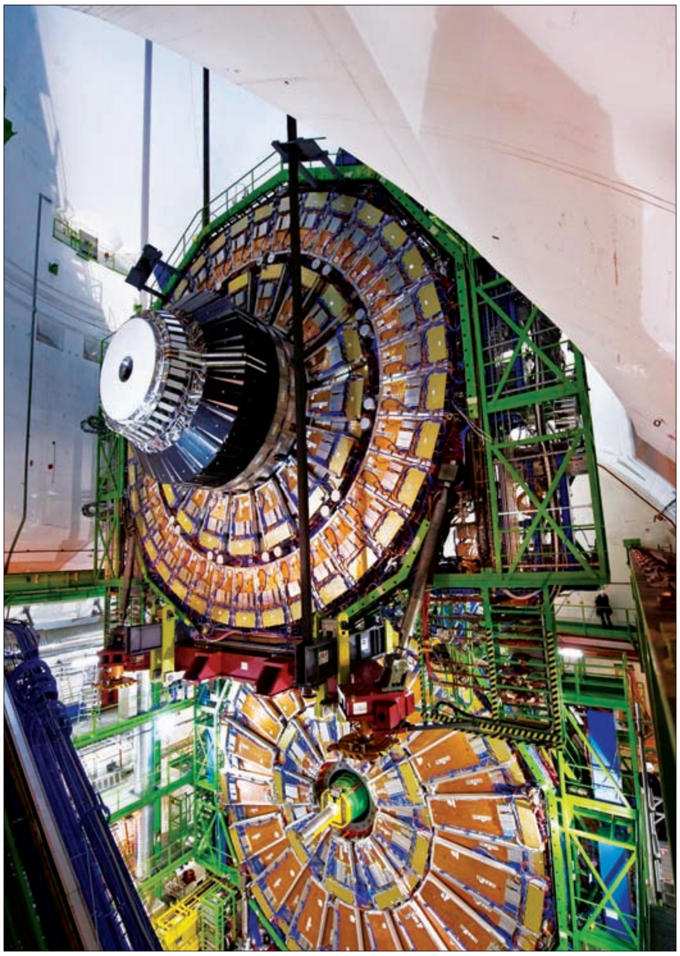


Fig. 5. The final section of CMS goes into the cavern on 22 January 2008.

is more complex than for the well timed collisions in the LHC, the ease in synchronizing the different triggers during this run was a good augur for the future.

The global-run campaign resumed again on 26 November. The principal change here was to use a larger portion of the final DAQ hardware on the surface rather than the mini-DAQ system. By this time the participating detector subsystems included all of the HCAL (as well as the luminosity system), four barrel ECAL supermodules, the complete central barrel wheel of muon DTs, and four sectors of RPCs on two of the barrel wheels. For the first time, a significant fraction of the readout for the final detector was taking part. The high-level trigger software unpacked nearly all the data during the run, ran local reconstructions in the muon DTs and ECAL barrel and created event streams enriched with muons pointing to the calorimeters. Prompt reconstruction took place on the Tier-0 processors and performed much of the reconstruction planned for LHC collisions.

To exercise the full data chain, the November run included a prototype tracking system, the “rod-in-a-box” (RIB), which contained six sensor modules of the strip tracking system. The experience in operating the RIB inside CMS provided a head-start for operation using the complete tracker once it is fully installed and cabled in early 2008 (see p22). The team also brought the final RPC trigger into operation, synchronizing it with the DT trigger and readout.

Installation in the CMS cavern continued apace, with the final segment – the last disc of the endcaps – lowered on 22 January 2008 (figure 5). The aim is to have sufficient cabling and services to read out more than half of CMS by March, including a large fraction of the tracker.

All seven Tier-1 centres have been involved since December, ranging from the US to Asia. In April, this worldwide collaboration will be exercised further with continuous 24 hour running, during which collaboration members in the remote laboratories will participate in data monitoring and analysis via centres such as the Fermilab ROC, as well as in a new CMS Centre installed in the old PS control room at CERN. By that stage, it will be true to say that the sun never sets on CMS data processing, as the collaboration puts in the final effort for the ultimate global run with the CMS wheels and discs closed and the magnet switched on before the first proton–proton collisions in the LHC.

● The authors are deeply indebted to the tremendous effort of their collaborators in preparing the CMS experiment.

Résumé

Le détecteur de CMS se prépare sous terre

Depuis novembre 2006, les énormes segments du détecteur CMS ont été descendus un par un dans la caverne d’expérimentation, 100 m sous terre. En mai, les équipes de réception ont commencé une série de tests généraux, plusieurs jours par mois, en utilisant les rayons cosmiques pour déclencher le système de lecture. Le but était d’accroître la fonctionnalité et l’échelle à chaque fois, au fur et à mesure de l'installation de nouveaux composants. En novembre 2007, une grande partie du détecteur enregistrait des muons cosmiques, faisant passer les données par toute la chaîne pour livrer des événements à des collaborateurs bien éloignés, en Californie ou en Chine. Un exploit à saluer non seulement du point de vue technique, mais aussi du point de vue humain…

Darin Acosta and **Tiziano Camporesi**, *CERN.*

Participants at MENU2007 pose outside of the central library of the Research Centre Jülich. (Courtesy Forschungszentrum Jülich/R U Limbach.)

Symmetries and hadron dynamics go on the MENU

MENU2007, the International Conference on Meson–Nucleon Physics and the Structure of the Nucleon, focused on common aspects, including the physics of charm and light quarks.

Hadron physics investigates one of the open frontiers of the Standard Model: the strong interaction for large gauge couplings. Experimentally, there are currently two major strategies. Precision experiments study symmetries and their violations with the aim of extracting fundamental quantities of QCD, such as the quark masses. Studies of the excited states and their decays, on the other hand, try to establish the ordering principles of the hadronic spectra to shed light on the problem of the confinement of the quarks.

The common aspects in both the charmed sector and the light quark sector were the major reason to bring together 350 experts from high-energy physics and nuclear physics to the 11th International Conference on Meson–Nucleon Physics and the Structure of the Nucleon (MENU 2007), which took place on 10–14 September 2007 at the Research Centre Jülich. The plenary sessions provided a broad review of the field, while invited and contributing speakers covered special topics, such as spin physics, meson and baryon spectroscopy, lattice calculations and in-medium physics, in five parallel sessions.

The light quark sector

Jürg Gasser, of the University of Bern, opened the conference with a review talk on chiral effective field theory, the standard tool for hadron physics in the threshold region. Lattice calculations have come into contact with chiral perturbation theory (χPT) by obtaining values for the low-energy constants $\bar{l}_3$ and $\bar{l}_4$. The DIRAC and NA48 experiments at CERN have tested the predictions of χPT by studying the level shifts of pionium and the decay of charged kaons into three pions. Rainer Wanke, of Mainz University, reported on the recent high-statistics data from NA48/2. The data have allowed the extraction of the S-wave pion–pion scattering length with great precision from studies of the Wigner cusp in the two-pion subsystem, as Ulf-G Meissner and collaborators predicted in 1997. The results agreed with the χPT predictions after inclusion of isospin-breaking effects.

Johan Bijnens of Lund University emphasized in his review on η physics that the decays of both the η and the η' mesons are good laboratories to study non-dominant strong interaction effects. The slope parameter α in the neutral three pion decay of the η is a puzzling challenge, as χPT does not explain the sign of the slope parameter, even when pushed to next-to-next-to-leading order, while non-perturbative approaches do. Magnus Wolke of the Research Centre Jülich showed Dalitz plots for the decay of the η into three neutral pions, which the WASA-at-COSY Collaboration obtained in the first production run in April/May 2007. The WASA detector was transferred from Uppsala to Jülich in 2005 (*CERN Courier* April 2005 p8). Cesare Bini of the Sapienza Università di Roma reviewed recent KLOE results featuring the η mass, measurement of η–η' mixing, the slope parameter of the η decay and results on the scalar mesons $f_0(980)$ and $\alpha_0(980)$ seen in ϕ-decay. Patrick Achenbach of Mainz showed the first results on η' decays into η and two neutral pions from the CB-TAPS experiment at the MAMI-C electron accelerator at Mainz. Catalina Curceanu presented the recent progress on kaonic hydrogen by the SIDDHARTA collaboration at the DAΦNE facility, which will allow physicists to obtain the antikaon–nucleon scattering lengths.

Effective field theory is beginning to make an impact on traditional nuclear physics with a consistent treatment of two-nucleon and three-nucleon interactions. Theorists have for many decades considered three-nucleon forces as a possible explanation for the unsolved problem of the saturation properties of nuclear matter. Kimiko Sekiguchi of RIKEN, Stanislaw Kistryn of the Jagiellonian University Krakow, and Daniel Phillips of Ohio University showed how the possibilities of studying polarized proton–deuteron reactions provide a direct experimental access to the three-nucleon force. In addition, the progress in applying lattice methods to study hadrons, hadron–hadron interactions and eventually nuclei, figured in the talks by Silas R Beane of the University of New Hampshire, Uwe-Jens Wiese of the University of Bern, and Andreas Schäfer of the University of Regensburg.

The charm sector

The decay of heavy mesons produced by the present generation of electron–positron colliders sheds new light on the light meson sector because the scalar mesons $f_0(980)$ and $\alpha_0(980)$ are found in the decay products, for example in the reaction $D^0 \rightarrow \bar{K}^0\pi^+\pi^-$, as Michael Pennington of Durham University stressed in his talk. Joseph Schechter of Syracuse University presented effective Lagrangian methods for the light scalar meson sector. The new charmed mesons $D_s(2317)$ and $D_s(2460)$, together with the charmonia-like states X, Y and Z, can be considered as unexpected contributions from B-factories, as Ruslan Chistov from ITEP Moscow pointed out in his overview of results from the Belle experiment at KEK. B-decays suppress the background contributions and offer large branching fractions, thus allowing an angular analysis to obtain quantum numbers. Walter Toki of Colorado State University discussed the recent results on the X(3872) and Y(3940) mesons from the BaBar experiment at SLAC and on the Z(4430) discovered by Belle, which apparently do not fit into the conventional quark–antiquark model for mesons. The Z(4430) may be a hadronic molecule made of a $D^*(2010)$ and a $D_1(2420)$ or a tetraquark, and, if confirmed, would be as exciting as the first charged hidden-charm state (*CERN Courier* January/February 2008 p7).

Matthias Lutz from Gesellschaft für Schwerionenphysik, Darmstadt, and Craig Roberts of Argonne discussed various aspects of hadron spectroscopy, while Ulrich Mosel of the University of Giessen highlighted recent theoretical progress in modelling the medium-dependence of nucleon resonances. Ulrike Thoma of the University of Bonn reported on evidence for two new Baryons – a $D_{15}(2070)$ and $D_{33}(1940)$, seen in η production on the nucleon at the ELSA facility at Bonn. Bing-Song Zou, of the Chinese Academy of Science, Beijing, observed that J/ψ decay is an ideal isospin filter for studying baryons, allowing the identification of the elusive Roper resonance as a visible bump, quite in contrast to pion–nucleon scattering. The Roper resonance is the first excited state of the nucleon with the quantum numbers of the nucleon. Results from the Beijing Spectrometer experiment show a surprisingly small Roper mass of 1360 MeV.

Haiyan Gao of Duke University showed how quark–hadron duality studies in charged pion photoproduction can be used to obtain information about resonances in the energy region above 2 GeV. Kai Brinkmann of Technical University Dresden reviewed results from the cooler synchrotron COSY at Research Centre Jülich, in particular the negative result for the search for pentaquarks, while Takashi Nakano reported on the recent status of experiments at the SPring-8 synchrotron radiation facility in Japan. Mikail Voloshin, of Minnesota, reviewed the decay of charmed hadrons and pointed out the open opportunities to improve our knowledge of the Kobayashi–Maskawa matrix element V_{ub}. Ikaros Bigi, of Notre Dame du Lac, focused on D^0 oscillations, which open a unique window on flavour dynamics.

The future will see exciting new machine developments. Naohito Saito discussed progress at the new Japan Proton Accelerator Research Complex, while the European project for the Facility for Antiproton and Ion Research was covered by Paolo Lenisa from the Università di Ferrara, Mauro Anselmino of INFN Torino and Johan Messchendorp of KVI Groningen. Anthony Thomas presented the 12 GeV upgrade for the Continuous Electron Beam Accelerator Facility (CEBAF) at Jefferson Lab, and Günther Rosner of the University of Glasgow gave an overview of physics with the CEBAF Large Acceptance Spectrometer.

Willem Van Oers of Manitoba University gave a lively address as the representative of the International Union of Pure and Applied Physics, who together with Forschungszentrum Jülich, Deutsche Forschungsgemeinschaft, Jefferson Lab, and the Hadron Physics I3 FP6 European Community Programme made this conference possible.

● The next MENU conference will be held in two years' time in Newport News, Virginia, in 2010.

Further reading

The slides of the talks of plenary and parallel sessions can be found online at www.fz-juelich.de/ikp/menu2007/Program.shtml. The proceedings will be published on the econf archive at SLAC by March 2008.

Résumé

Au MENU, les symétries et la dynamique des hadrons

Les points de convergence entre le domaine des quarks charmés et celui des quarks légers ont été l'occasion de rassembler 350 experts de la physique des hautes énergies et de la physique nucléaire. Les sessions plénières ont permis de passer largement en revue ce domaine, et, lors de cinq sessions menées en parallèle, différents sujets ont été abordés par des intervenants: physique du spin, spectroscopie des mésons et des baryons, calculs sur réseau.

Siegfried Krewald *and* **Hartmut Machner**, *Forschungszentrum Jülich.*

FACILITIES

FAIR gets the green light at GSI

In a joint communiqué signed on 7 November, representatives of the partner countries have announced the go-ahead for construction of the international Facility for Antiproton and Ion Research (FAIR) at GSI, Darmstadt. The project can now get underway and should be completed on schedule. Construction work is due to start in the winter of 2008/09, with the project finalized by 2015/16.

FAIR, which will be connected to the existing accelerator facility at GSI, will give researchers an opportunity to carry out new experiments to investigate matter and the nature of the universe. They will not only have the opportunity to investigate antimatter, but also to investigate the processes involved in supernovae and search for new forms of matter to try to resolve the mystery of dark matter in the universe. FAIR will feature an accelerator capable of generating antiproton and ion beams of an unparalleled intensity and quality. There will be a double-ring accelerator at the heart of the facility, 1100 m in circumference, connected to a complex system of storage rings and experimental stations. The current GSI accelerators will serve as preaccelerators for the new facility.

GSI first submitted the proposal for FAIR back in 2001. This was produced in co-operation with 700 scientists from Germany and other countries. The Scientific Council first assessed the project on behalf of Germany's Federal Ministry of Education and Research (BMBF), recommending that it should receive funding. The BMBF gave the go-ahead in 2003 on the condition that at least 25 per cent of the costs come from international partners. Since then, more than 2500 researchers worldwide have worked on the development and planning of the new accelerator and experimental facilities, and partner countries have been integrated into the FAIR project via a memorandum of understanding (MOU).

These international preparations led to the communiqué being signed on 7 November. The total costs for the construction of FAIR will amount to €1.2 bn. Germany, the State of Hesse and the remaining 14 partner countries have initially agreed to release funding of €940 m for the initial phase, with Germany bearing 65 per cent of those costs, the State of Hesse 10 per cent and the partner countries jointly 25 per cent. The partner countries are China, Germany (including the State of Hesse), Finland, France, Georgia, the UK, India, Italy, Austria, Poland, Rumania, Russia, Sweden, Slovenia and Spain.

Representatives of FAIR's partner countries after signing a declaration on 7 November at GSI, with the German federal minister of education and research, Annette Schavan (middle), and the minister-president of the State of Hesse, Roland Koch (middle left). (Courtesy G Otto GSI.)

LABORATORIES

Dapnia changes name to become the IRFU

The Dapnia laboratory at Saclay, outside Paris, has changed its title to the Institute for Research into the Fundamental Laws of the Universe (IRFU). The change of name is the result of a process launched by the director-general of the Commissariat à l'Energie Atomique (CEA), aiming to give the divisions of the CEA more appropriate designations in terms of research, especially in English. To this end, the various departments of the different directorates at the CEA are becoming so-called "institutes".

The new name of IRFU retains the essence of the former description: Laboratoire de recherche sur les lois fondamentales de l'Univers – Laboratory for research into the fundamental laws of the universe.

The name change will have no other consequences for the institute; it affects neither its internal structure nor its operational capabilities. Nor does it efface Dapnia's history since 1991, of which IRFU members will continue to be proud.

COLLABORATION

CERN and Malta join forces

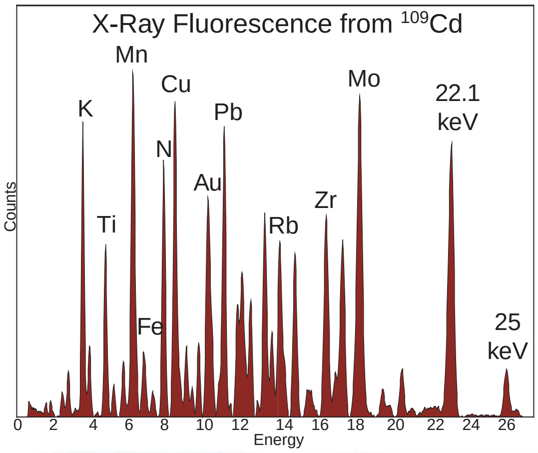
On 10 January, the prime minister of Malta, Lawrence Gonzi, visited CERN to sign a co-operation agreement between the organization and the government of Malta. The agreement is the starting point of a negotiation process that will ultimately lead to a collaboration in which Maltese scientists and engineers will contribute to CERN's scientific and technical programmes.

In anticipation of the agreement, the University of Malta has already collaborated in the development of the LHC in the form of the field description for the collider. This system is an integral building block of the feed-forward system of the machine and is based on magnetic measurements of the LHC superconducting magnets in cryogenic conditions. In addition, several students from the university recently participated in CERN's summer student programme.

Accompanied by government officials and delegates from the University of Malta, Gonzi acknowledged that the collaboration with CERN would be an excellent demonstration of the quality of Maltese personnel in hi-tech engineering and IT-based technologies. It would also provide plenty of excellent training opportunities for Maltese students.

In addition to meeting with CERN's director-general, Robert Aymar, the Maltese delegation toured the CMS experiment accompanied by spokesperson Tejinder Virdee, and also visited the Superconducting Magnet Test Facility with Nicholas Sammut, Malta's representative at CERN.

Signing the co-operation agreement between Malta and CERN. Left to right: Juanito Camilleri, rector of the University of Malta; Lawrence Gonzi, prime minister of Malta; Robert Aymar, CERN's director-general; Nicholas Sammut, Malta's representative at CERN.



INDUSTRY

ATLAS recognizes pixel suppliers with award

At a ceremony at CERN on 28 November, the ATLAS collaboration presented awards to two companies that had produced sensor wafers for the pixel detector. The CiS Institut für Mikrosensorik of Erfurt, Germany, supplied 655 sensor wafers containing a total of 1652 sensor tiles, while ON Semiconductor provided 515 sensor wafers (1177 sensor tiles) from its foundry at Roznov in the Czech Republic. Production of the tiles has seen yields of 94% – an exceptional achievement given the required characteristics.

The large pixel detector for ATLAS required expertise in highly specialised integrated microelectronics and precision mechanics. Each 10 cm^2 tile contains 46 000 active channels. These extremely sensitive, high-quality sensors are installed closest to the collisions and will be among the parts most exposed to radiation. They were designed to withstand a radiation dose 10 times higher than was possible at the time the work began.

Left to right: Peter Zdebel, senior vice-president and chief technology officer of ON Semiconductor, Hans-Joachim Freitag, head of the CiS Institut für Mikrosensorik, with Peter Jenni, ATLAS spokesperson.

AWARDS

Young ALICE man scoops top award

Artem Harutyunyan. (Courtesy A Harutyunyan.)

Artem Harutyunyan, 23, of the Yerevan Physics Institute and a member of the software team for the ALICE experiment at CERN, has been recognized in 2007 as the best Master Student of Armenia in the field of information technology. He receives the award for excellence in academic studies and for a series of developments for AliEn, the Grid environment at ALICE. The work, which started in 2003, includes porting of the client part to Windows, updating the security system and introducing the banking service. He received the award from the Armenian president.

IOP honours Webber, Green, Pendlebury and Singh

Bryan Webber. (Courtesy A Horie-Webber.)

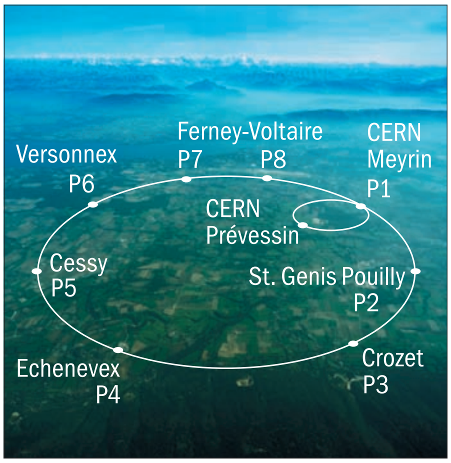
The UK's Institute of Physics (IOP) has awarded Bryan Webber of Cambridge University with the 2008 Dirac medal for outstanding contributions to theoretical, mathematical and computational physics. Webber receives the award "for his pioneering work in understanding and applying quantum chromodynamics, the theory of the strong force."

The IOP awarded the 2008 Chadwick medal for distinguished research in particle physics to Keith Green of Rutherford Appleton Laboratory and Michael Pendlebury of Sussex University. They are honoured "for their outstanding contributions to the measurement of the neutron electric dipole moment, and of other fundamental properties of the neutron".

A third award related to particle physics went to writer and broadcaster Simon Singh, who received the Kelvin medal for outstanding contributions to the public understanding of physics. Singh began his career with a PhD in particle physics from the University of Cambridge, where he worked on the UA2 experiment at CERN.

OUTREACH

CERN seeks guides for open days



CERN is calling for volunteers to help organize two exceptional open days in April, one for CERN employees and their families on Saturday 5 April; and another for the general public on the following day. This will be the last chance for the general public to get up close to the LHC and its experiments.

In addition to visiting the surface facilities, visitors can go underground to see the accelerator and will have access to the caverns where the experiments are located. In addition, most of the points around the ring will be open.

The success of these two exceptional days will require volunteers to give guided tours of all these areas. Many guides will also be needed at the LHC points, for the activities at the surface and to look after the reception and information points. The aim of these open days is to give the local population the opportunity to discover the fruits of almost 20 years of work at CERN.

The organizers are hoping for some 2000 volunteers, all of whom will be given prior training and will be provided with suitable clothing for the Open Day and a meal and a souvenir on the day itself.

● If you are a staff member, a retiree or one of CERN's user-community, and would like to volunteer, you can sign up at https://espace.cern.ch/Volontaires08/. For more information, see http://cdsweb.cern.ch/journal/?name=CERNBulletin&issue=04/2008&ln=en.

STUDENTS

Bergen launches first mini winter school at CERN

The new year began well for 14 students from Bergen who came to CERN on 9–11 January to participate in the first Bergen mini winter school. The aim is to introduce undergraduate students from Norway to particle physics and to show them CERN, Europe's largest research centre in that field.

The three-day school was packed with lectures and visits. Augusto Ceccucci, Jos Engelen, Gian Giudice, Steinar Stapnes and Frank Zimmermann from CERN, and Anna Lipniacka from Bergen, provided highly interesting lectures, covering topics from particle detectors to physics beyond the Standard Model. In addition, CERN's Alvaro de Rújula and John Ellis gave excellent evening and "end-of-school" talks. The students where equally enthusiastic about the many visits, organized by Ole Rohne (ATLAS), Daniel Denegri (CMS), Hans Braun, Erik Adli (CTF3), Christian Carli (LEIR), Susanne Koblitz (COMPASS), Lasse Normann (LHC control room) and Sverre Jarp (Computing Centre).

Students enjoy a bright day for a photo at CERN, with organizers Heidi Sandaka, right, and Anna Lipniacka, centre back. (Courtesy Martin Jäkel.)

The organizers were pleased that so many Norwegian students had travelled as far as CERN to learn more about physics, and hope that the mini school will inspire further studies. It is hoped that more students will join the school from other parts of Norway next year.

NEW PRODUCTS

Aerotech has announced the ANT-20G goniometer stages. These provide a compact, high-speed and high throughput solution for single or multi-axis angular positioning and alignment applications where free access is required at the central point of rotation. The motor design allows a calibrated positioning accuracy to ± 10 arc-sec (± 5 μrad), with repeatability to ± 0.5 arc-sec (± 2.5 μrad). Resolution with full encoder multiplication is to 0.013 arc-sec (0.063 μrad). For more information, contact Cliff Jolliffe, tel +44 118 940 9400; fax +44 118 940 9401; or e-mail cjolliffe@aerotech.co.uk.

Cedip Infrared Systems has unveiled the ALTAIR Li system, a high-performance focal-plane array camera and digital-image processing software that provides thermal images of stress in materials and structures under dynamic, transient or random loading conditions. The system has applications including fatigue limit testing, thermo-mechanical studies, and provides information on the damage mechanism involved. For more information, tel +33 160 370 100; e-mail cedip-marketing@cedip-infrared.com; or see www.cedip-infrared.com.

ETL group has launched a new range of Meteorological Measurement Systems, which includes the MET4 and MET4A. These provide high-accuracy data from barometric pressure, temperature and relative-humidity sensors. Both have a pressure resolution of better than 1 microbar with a total accuracy of ± 0.08 hPa over the extended barometric range of 500 to 1100 hPa and a temperature resolution of better than 0.01 °C. Installation hardware and software are included. For more information, contact Derek Noble, tel +44 178 447 2130; or e-mail sales@explorocean.com.

Oerlikon Leybold Vacuum has unveiled a new product line of sputter ion pumps, in the form of highly efficient diode pumps organized for noble gases in UHV applications down to 10^{-12} mbar. They are available with pumping speeds (N_2) from 30 l/s to 400 l/s. The vacuum is free of hydrocarbons from the UHV to XHV range, and the pumps feature an integrated degassing system (except model IZ 30) and installation in any orientation. For more information, contact Christina Steigler, tel +49 221 347 1261; fax +49 221 347 31261; e-mail Christina.Steigler@oerlikon.com; or see www.oerlikon.com.

Vector Fields has launched the Optimizer, a new intelligent design optimization tool for electromagnetic modelling, and simulation software that will automatically find the best solution to a design problem. The Optimizer selects and manages multiple goal-seeking algorithms to eliminate the need for manual intervention. It works in conjunction with the Opera electromagnetic design package, which has dedicated solvers in areas such as superconducting magnets and particle beams. For more information, see www.vectorfields.com; tel +44 186 537 0151, fax +44 186 537 0277; or e-mail info@vectorfields.co.uk.

OBITUARY

Engin Arik 1948–2007

We lost Engin Arik in a tragic plane accident on 30 November 2007. She was flying to Isparta to participate in a workshop about a possible Turkish accelerator design. Her two students, Ozgen Berkol Dogan and Engin Abat, accompanied her and her colleagues, Sener Boydag, Iskender Hikmet and Mustafa Fidan, from Dogus University.

Engin Arik worked tirelessly towards her goal of seeing Turkey a full CERN member. (Courtesy Metin Arik.)

Arik received her BSc in physics from Istanbul University in 1969. She started her career in science as a graduate student at the University of Pittsburgh where she received her MS (1971) and PhD (1976) degrees in physics. She participated in the E583 experiment at Brookhaven and wrote her thesis on Y* production in sigma-nucleus reactions.

During her postdoctoral study at the University of London, Westfield College, she participated in fixed target experiments using pion beams at the Rutherford Appleton Laboratory and CERN. She contributed significantly to the measurement of observables in $\pi^+p \rightarrow K^+\Sigma^+$.

She joined Bogazici University Physics Department in 1979, where she was a faculty member until her untimely death, except for a brief period in industry in 1983–85. While teaching at Bogazici University, she also performed research with the very limited resources available for experimental high-energy physics in Turkey. At the beginning of the 1990s, she joined the CHARM II experiment at CERN and later participated in the CHORUS and Spin Muon Collaboration (SMC) experiments together with the group she put together from Bogazici and other universities in Istanbul. During this period, there was a movement for Turkey to become a full member of CERN instead of an associate member. From the beginning, Arik was a very strong supporter and she strove hard to achieve this goal. Turkey is still an associate member, but there are some hopeful developments in a positive direction and her contribution in this was significant.

Even though there were great difficulties in finding the necessary funds for the students and colleagues in her group to participate in experiments at CERN, she always had a very optimistic view and joined collaborations such as CHORUS, SMC, ATLAS and the CERN Axion Solar telescope at the earliest possible moment.

In addition to the experiments at CERN, Arik also participated in the Comprehensive Nuclear Test Ban Treaty Organization as radionuclide officer while stationed in Vienna from 1997 to 2000. During weekends and holidays, she commuted between Vienna, Geneva and Istanbul, and continued her research. For the past few years, she was very active in a study to propose and design an accelerator facility in Turkey. Indeed, she had taken the fatal plane flight to attend the fourth workshop on this subject.

Arik was also mother to two children and a grandmother of two grandchildren. She was hopeful that her grandson, who often conversed with her about physics, would also become a physicist. With her untimely death, the Turkish experimental high-energy physics community has lost one of its most prominent senior members and one of its driving "engin(es)". We will sorely miss her.

Erhan Gülmez, Bogazici University.

RECRUITMENT

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A research group of the Laboratory for Nuclear Science at MIT is currently leading an international collaboration of universities building a scientific detector for deployment on the International Space Station. The present phase of the work is ongoing at the European Center for Nuclear Research (CERN) in Geneva, Switzerland. The group is seeking a candidate to carry out physics and organizational responsibilities including participation in data taking and detector monitoring, accounts monitoring, maintaining communications with appropriate offices at CERN and MIT, as well as other duties in support of the efficient running of the MIT team. Skills necessary include interest in experimental physics, proficiency with computers, effective communication skills in English and proficiency in French.

Candidate must also be able to travel at short notice to Europe, U.S. and Asia and spend various durations of time at CERN, MIT, the Kennedy Space Center and the Johnson Space Center. Must be able to function well under time pressure in a highly technical environment.

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Several postdoctoral research positions are available at the Laboratory for High Energy Physics of the Swiss Federal Institute of Technology in Lausanne (EPFL) in the areas of detector R&D for scintillating fibre tracker with Silicon PMTs, and physics analysis of the LHCb data together with the responsibility to operate a CPU farm at EPFL, or to participate in the Silicon detector operation. We are actively working on Heavy Flavour Physics in the LHCb experiment at CERN, and also starting R&D in the area of FPGA-based readout electronics and precision tracking detectors. Applicants must have a PhD degree in high energy physics or a related field with relevant experience, and be less than 35 years old. The positions are available now and the initial appointment will be for one year, renewable up to a total of four years. Applications will be reviewed upon receipt until the positions are filled. Enquiries and applications, including CV and names of three references, should be sent via e-mail to our secretariat: **Erika.Luthi@epfl.ch**

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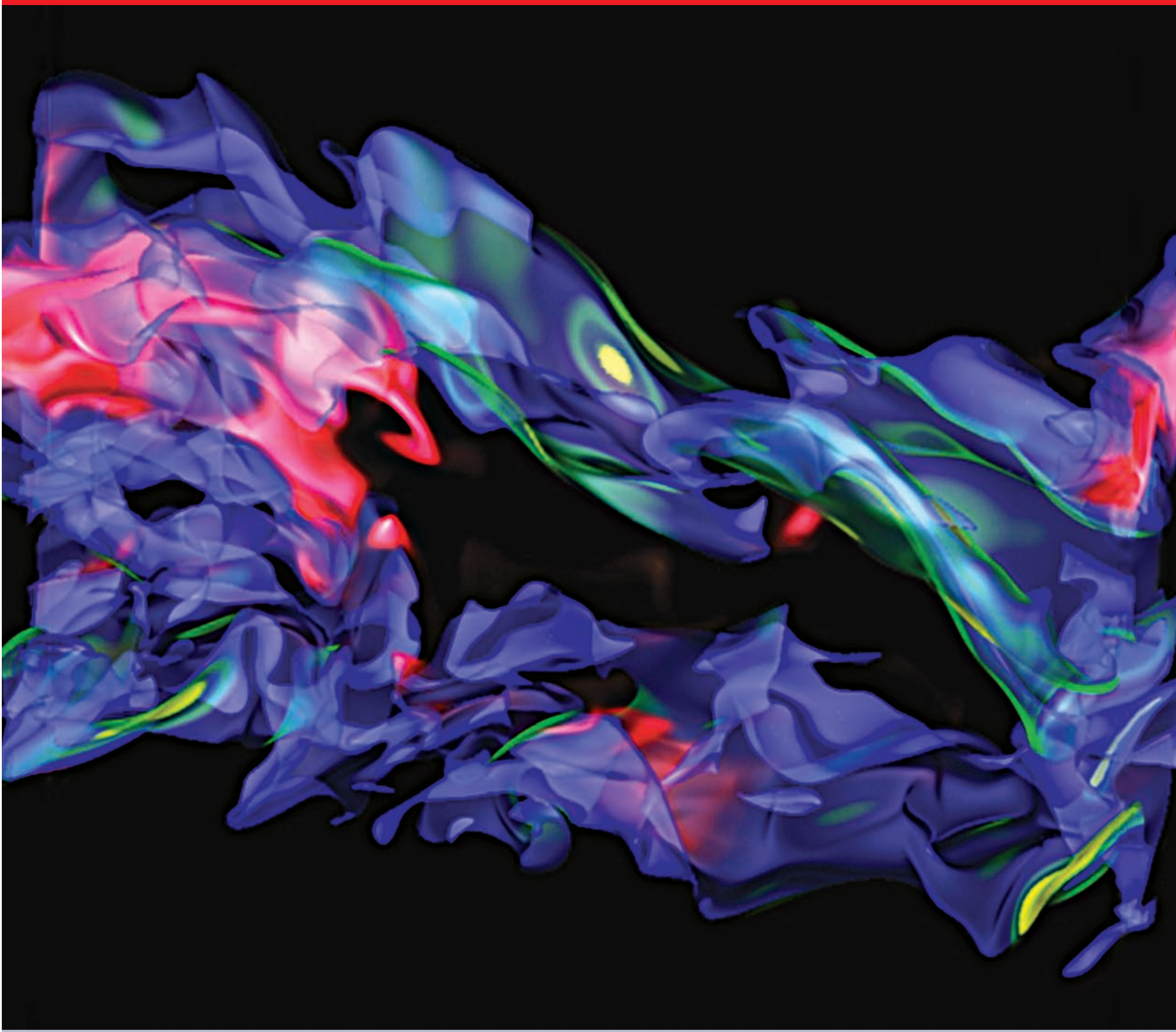

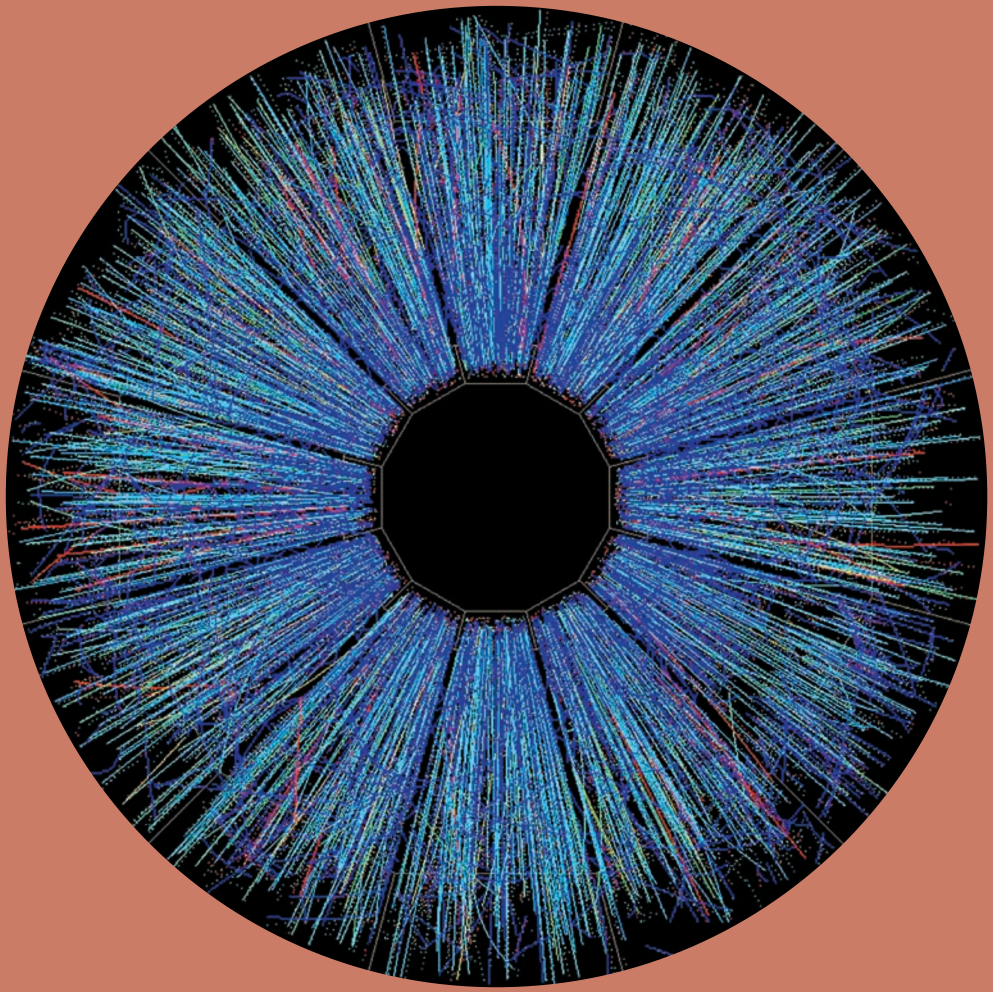


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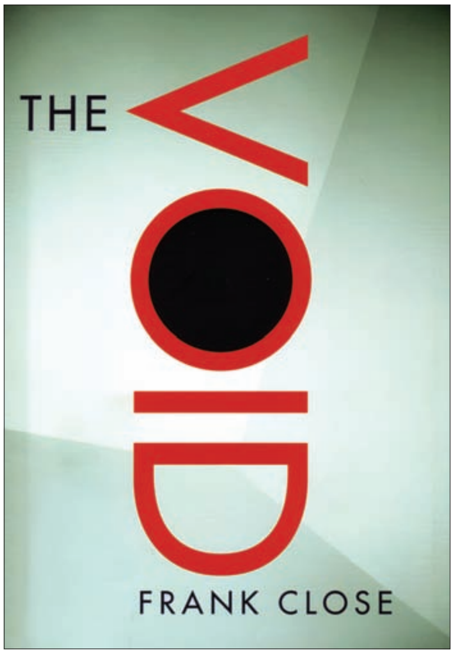
BOOKSHELF

The Void by Frank Close, Oxford University Press. Hardback ISBN 9780199225903, £9.99 ($19.50).

This is a small book – you can read it in an evening – about the intriguing subject of "nothing". Close takes us through history from the earliest philosophers, who concluded that "Nature abhors a void", through the period of arguments about the non-existent Ether, up to the present time, where the void is considered to be a seething quantum-mechanical foam. He describes how the concepts of space and time are linked to the different ideas of "the Void" and ends with current speculations: maybe our entire universe is a quantum fluctuation with near-zero total energy. I learnt that the different forces are influenced by the structure of the void and that some constants of nature may be the random result of spontaneous symmetry breaking, both of which added to my very tenuous non-grasping of the Higgs question.

So far so good. Fortunately, I had already read a number of texts around the subject, for some passages are difficult to grasp because of the sometimes ungrammatical sentences – page 35 gets my all-time prize for totally confusing the reader.

It is unclear to me who the target audience is; the level required to understand the text ranges widely depending on the chapter. Close sometimes uses advanced concepts without explanation and has to rely on more than a little familiarity with the mysteries of quantum mechanics. As with most popular books of this type, those mysteries remain whole, although I must say in favour of *The Void* that it manages, for once, to leave out Schrödinger's cat.



I also wonder if the text has been proof-read. Here are just two examples from too large a set: though Close was once head of communications and public education at CERN, he tells us that CERN started in 1955 (it was 1954) in a sentence that cannot be parsed in any language. I share some of his criticisms of CERN's exhibition centre, but find it difficult to accept that for an entire page he uses "La Globe", when the correct French is "le Globe" as can be read on CERN's public website. Did no-one spot this? Fortunately for the author, but unfortunately for the publishing business, this book is not alone in being the victim of such sloppiness.

So, *The Void* is well worth reading; then send in your corrections.

Robert Cailliau, Prévessin.

Singolarità spaziotemporali. Al di là e al di qua dell'orizzonte degli eventi by Luigi Foschini, Aracne. Paperback ISBN 9788854813526, €13.

Luigi Foschini is an Italian researcher working at the Istituto di Astrofisica Spaziale e Fisica Cosmica, Bologna, which is part of the Italian Institute of Astrophysics. His scientific papers cover several different fields, but he is mainly involved in the analysis of relativistic astrophysics data.

Foschini presents a short history of physics to explain that the concept of something that inexorably traps everything was not introduced with Albert Einstein's general relativity theory. Instead, John Michell in 1783 computed the mass of an object that could trap light, by using Isaac Newton's gravitational formula and Ole Rømer's discovery that the velocity of light, c, is non infinite and requires that the escape velocity be larger than the measured value of c. Foschini goes on to describe the work by Karl Schwarzschild that leads to the modern concept of black holes as singularities in the solution of Einstein's equations for a non-rotating spherical system in general relativity.

His book *Singolarità spaziotemporali* has a twofold aim: it explains what space–time singularities are and what their observable effects are; and it provides the reader with an up-to-date picture of astrophysical research.

In particular, one explicit purpose of the book is to educate the reader that "black holes" is a misnomer, and should be avoided, especially in scientific publications. Indeed, John Wheeler coined the name in the 1960s, before Stephen Hawking realized that they do emit radiation (though usually very faint), and therefore they are not really "black".

The second half of the book focuses on the properties of active galactic nuclei and their classification. Here, the author describes aspects of research currently under study and emphasizes the importance of correlating measurements made using different techniques. In my opinion, this is the part that makes the book seem fresh and in some sense unique. Usually, books aimed at a broader public do not mention topics at the forefront of research. I appreciated that Foschini dared to do so.

Although I am Italian, I think it a shame that the book is written in Italian, as it does not reach a large number of potential readers. In addition, it includes a few formulae, which is usually sufficient to discourage many people. The author explicitly states that there is a limit to simplification if one wants to avoid dangerous distortions of the concepts he is trying to explain. This is certainly true, but I think a few deeper explanations would have been helpful, thus avoiding the need to consult the references for further reading.

Diego Casadei, New York University and CERN.

Why particle physics needs stability

Peter Mättig reflects on the recent news of funding cuts in the US and UK, and argues the case for a more stable process for funding of large-scale international projects.

A premature end to SLAC's B-factory, a stop to UK investment in the International Linear Collider (ILC) project and more than 300 lay-offs at Fermilab and SLAC – 2007 ended on a bad note (*CERN Courier* January/February 2008 p6). Do these cuts in the US and the UK signal a general downturn for particle physics? No! In the UK they are the combined result of organizational changes and an emphasis on national facilities (p8). In the US they arose from disputes in congress; and there at least, the US president's budget for FY2009 looks more positive. The reasons for these cuts are thus too specific to call them a trend – all the more since, for example, KEK's five-year plan strongly endorses ILC research and funding has increased recently in countries such as Germany.

We have seen frequent ups and downs in funding over the decades. So is it business as usual? Not quite. Nowadays, these ups and downs must be seen in the framework of global co-operation and the interdependence of projects in particle physics.

The size and cost of our facilities are so large that they can only be realized in a truly international context: a machine like the LHC will exist only once in the world. Equally, it would be inefficient to clone billion-euro projects for future neutrino physics, super B-factories or astroparticle physics. Moreover, the R&D necessary for high energies and intensities for future accelerators – and for future detectors – can only be performed in a stable and organized worldwide effort.

In theory, everyone agrees that a global distribution of responsibilities is the most cost–effective approach, allowing particle physics to make the best use of worldwide interests and expertise, and guaranteeing a broad and complementary exploration of our field. Making this a reality, however, is another business. It requires agreements at a transnational level and, in particular, reliability and continuity of support.

Here we evidently have a problem: although international in character, funding of high-energy physics projects is, and will be, largely national. There are few internationally binding treaties like the one for CERN, generating a stable financial situation. Most agreements are memoranda of understanding or even less formal. Common goals are subject to the "good will" of national funding and therefore to changing economical situations and national political and scientific priorities. Particularly vulnerable are the projects that require significant R&D without clearly defined financial contributions.

In addition there is the mere fact that supporting national facilities is politically easier than financing international ones. Which representative would lobby for a project that is not in their country or constituency? Surely it is better to cut the ILC than the local research facility.

Consider the example of the ILC more closely. The consensus is that it will be the next big machine, and that there will be only one machine. Even if the ILC is not imminent, R&D is mandatory to optimize costs and come to a technically sound proposal. Following this ideal, the worldwide community formed a global network and began to develop special expertise (p15). The UK, for example, was leading the effort on damping rings, beam delivery and positron sources. Ceasing support for ILC R&D in the UK therefore cuts a large hole in the international network. Who can take over – and at what cost? Yes, stopping R&D saves money in the short term, but in the long term it will cost more. Maybe even more damaging, a loss of confidence in pursuing projects internationally could result.

What can we conclude? Well, the first point is rather trivial: particle physics is part of society. We are not free from general economic constraints and we have to compete with important social, political, ecological and scientific goals. We can only progress if we repeatedly make it clear what it is we give back to society in return.

However, we really need a more organized way of setting internationally agreed priorities, with more binding definitions of national responsibilities and financial commitments for large-scale projects, including their R&D phase. The CERN Council strategy group, together with the funding agencies in the CERN council, is an important tool and should be a step towards a transcontinental equivalent. Note however: even this is no guarantee for reliability, as is evident from the termination of US contributions to the ITER project.

CERN, as any other laboratory hosting a large-scale facility, should see itself as an important part of a large network, serving the interests of its members and contributing states. Universities and national laboratories should not be seen as an appendix, but as key participants. We should work actively to make it evident in all countries that contributing to CERN eventually feeds back into domestic technological and scientific progress.

An excellent and successful LHC project is key to further international co-operation in particle physics. If nature reveals new effects and causes public excitement, many problems we face now will be easier to solve.

Peter Mättig, University of Wuppertal and chair of the German committee on high-energy physics.

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