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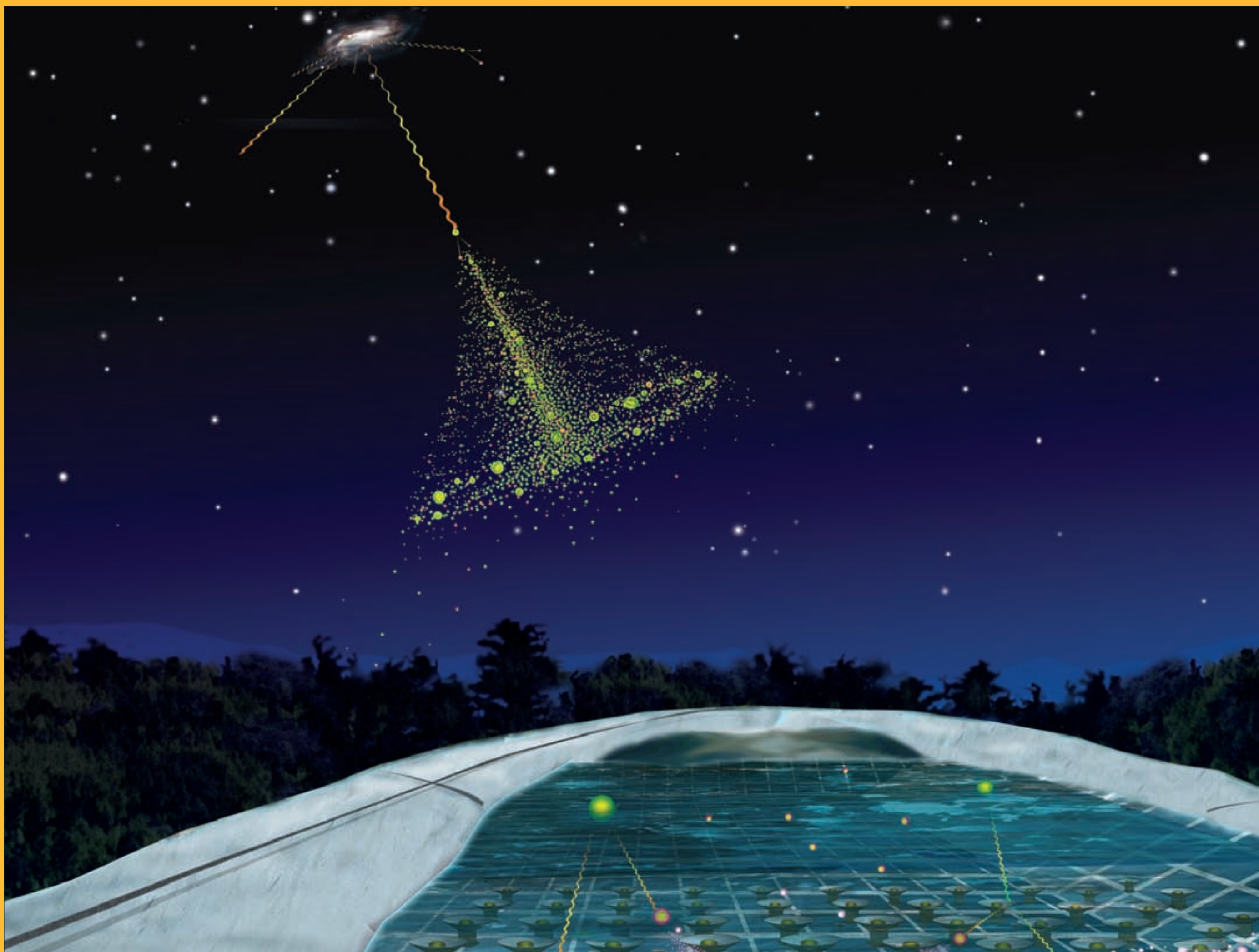

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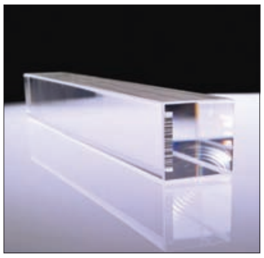

The final crystals are in place p6

Why is the solar corona so hot? p19

CERN becomes a star p35

Cover: The Milagro gamma-ray observatory detects high-energy gamma rays through the showers of particles they create in the atmosphere (p15). (Courtesy Aurore Simonnet, Sonoma State University.)

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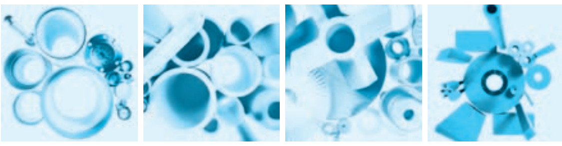

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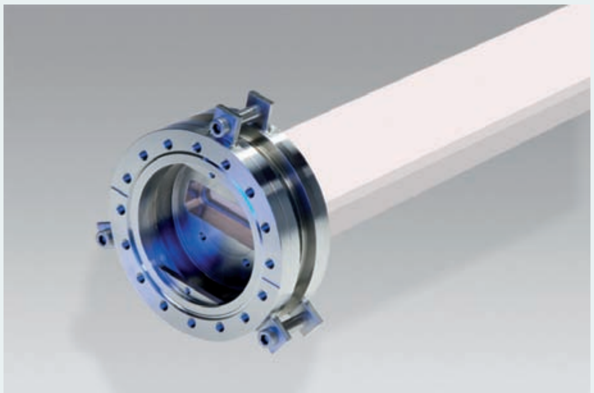

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MUON COOLING

MICE beam takes its first steps

The Muon Ionisation Cooling Experiment (MICE) project, an accelerator research experiment for a major component of a future neutrino factory, has achieved an important milestone with the successful transport of muons along the MICE muon beamline. The international team can now turn its attention to tuning the beam and working towards the demonstration of ionization cooling.

Neutrinos, though challenging to detect because they are only weakly interacting, have already proved to harbour indications of physics beyond the Standard Model. Observations of atmospheric and solar neutrinos have shown that they oscillate between three forms – electron, tau and muon. This can only occur if they have mass, although in the Standard Model they have no mass. To learn more about these mysterious particles requires a new way to generate high-intensity, high-energy beams of neutrinos of known characteristics, such as composition and energy.

A neutrino factory would store muons inside a decay ring with long straight sections pointing to large detectors hundreds, or thousands, of kilometres away. Neutrinos produced in the decay of the muons within these straight sections would travel through the Earth to the distant detectors. Studies have shown that such a facility can be built, but a number of challenges must be solved before a technical design can be completed. One major challenge arises because the muons, produced in the decays of pions, will need "cooling" to form bunches of particles with similar momentum and direction if they are to be accelerated and stored. The problem is that muons decay in about 2 μs.

Ionization cooling is the only technique that can cool the muons fast enough. In this process, passage through matter (liquid hydrogen) reduces the momentum of the muon, and one component of the momentum is then restored by acceleration with RF electric fields. Understanding the efficiency of this cooling technique requires a detailed knowledge of the behaviour of muons in many materials, for example in the windows of the vessel containing the liquid hydrogen.

Some of the MICE team assembled at RAL in front of the dipole, from left to right: Tony Jones, Danny Lordan, Alain Blondel, Paul Sinclair, Mike Zisman, George Sim, Chris Nelson, Paul Kyberd, Cyril Locket, Eamonn Capocci, Ashok Jamdagni, Matt Hills and Paul Barclay. (Courtesy STFC.)

The MICE project aims to demonstrate the technologies required for ionization cooling and prove that muons can be assembled into cold bunches small enough to allow the muon beam to be accelerated and stored. The MICE collaboration is designing, building and testing a section of a realistic cooling channel on a beamline on the ISIS facility at the Science and Technology Facilities Council's Rutherford Appleton Laboratory (RAL). Achieving this will give confidence that a full ionization-cooling channel, consisting of many cooling sections, can be designed and built economically.

The successful transport of the first muons along the new beamline is the latest of several significant steps the MICE team has taken since the formation of the collaboration in 2001, and more recently in commissioning the beamline. They have completed the installation and testing of the pion-production target in the ISIS proton synchrotron, built the pion decay line and installed beam counters and other equipment in the experimental hall. Over the coming months, the MICE spectrometer system will be installed and the experiments will finally begin. The cooling channel will be built over the next two or three years, culminating in the demonstration of ionization cooling in 2010.

● The MICE project is a major collaboration involving 150 scientists and engineers from across the world, with collaborators in Bulgaria, China, Italy, Japan, the Netherlands, Switzerland, the UK and the US.

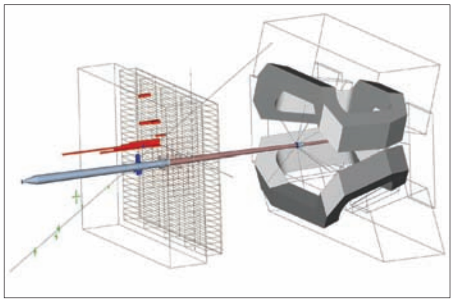
Sommaire

LHC EXPERIMENTS

LHCb measures its first cosmic-ray muons…

The LHCb team has for the first time measured cosmic rays passing through three of the experiment's subdetectors simultaneously, selected by muon triggers.

During a global-commissioning run on 3 April, the LHCb team used three of the experiment's subdetectors – the electromagnetic calorimeter (ECAL), the hadronic calorimeter (HCAL) and the muon system – to trace the paths of cosmic-ray muons. The successful detection of cosmic rays confirms that the different detectors are synchronized, that the software chain works and that the raw data make sense. The software enabled the LHCb team to see 3D reconstructions of the tracks of the muons passing through the subdetectors, illustrating the energy deposited in each of the activated calorimeter cells and the signals in the muon chambers.



Reconstruction of the track of a cosmic ray passing through LHCb's HCAL (dark blue), ECAL (red) and muon chambers (green crosses).

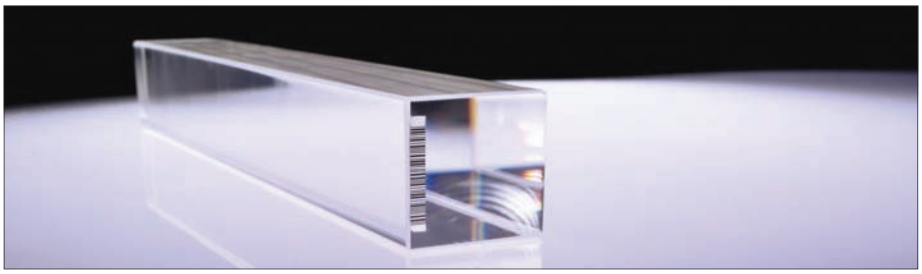
The LHCb detector looks different from the standard hadron collider detector because of its focus on heavy flavour particles, which are produced at predominantly low angles and in the same "forward" cone (*CERN Courier* July/August 2007 p30). The subdetectors are arranged in vertical planes along the beamline, more like a fixed-target experiment. This means that tests using cosmic rays, which are predominantly vertical, can only be carried out on certain subdetectors, such as the calorimetry and muon systems, which have large surface areas and can detect particles coming from all directions.

…while CMS completes crystal calorimeter

The final crystals for the CMS electromagnetic calorimeter (ECAL) arrived from China and Russia at CERN in March, completing a mammoth production process nearly 10 years after the delivery of the first production crystal in September 1998. These final crystals will be used to complete the endcaps of the ECAL, which contains more than 75 000 crystals.

The huge quantity of leadtungstate crystals used in the ECAL in CMS is the largest number produced for a single experiment. The superb quality of the crystals, in terms of both their optical properties and their radiation resistance, is the result of intense work and collaboration between the producers and ECAL groups, as well as the network of crystallography and solid-state physics experts from the Crystal Clear collaboration.

Five CMS institutes – CERN; the Italian National Agency for New Technologies, Energy and the Environment; the Swiss Federal Institute for Technology Zurich; the Institute for Nuclear Problems Minsk and Rome University I – have been prominent in monitoring and overseeing quality control of this long production process. The optical properties of each crystal were measured by custom-designed automatic equipment. Radiation resistance was systematically controlled through test sampling and required complex logistics coordinated by CERN and ETHZ for the Russian and Chinese crystals respectively. Many other institutes were also involved in their early development.



One of the last CMS endcap crystals, complete with its identification bar code.

The 61 200 crystals of the ECAL barrel were successfully installed inside CMS last year and the final phase will be the installation of the endcaps, which contain 14 648 crystals. The first endcap is due to be lowered into the cavern in June and the second endcap should follow later in the summer. More than 90% of the endcap crystals have already been qualified and equipped with their photo-sensors.

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

TRIUMF to establish Centre of Excellence for Commercialization and Research

The Centre of Excellence for Commercialization and Research award is a boost for TRIUMF. Left to right: AAPS vice-president corporate services Ann Fong; CECR programme manager Jean Saint-Vil; AAPS board chair Edward Odishaw; NCE associate vice-president Jean-Claude Gavrel; NSERC president Suzanne Fortier; TRIUMF associate director Jean-Michel Poutissou; TRIUMF director Nigel Lockyer; CIHR president Pierre Chartrand; AAPS chief executive officer Phil Gardner; AAPS chief finance officer Wayne Swim; AAPS project manager and University of British Columbia professor Doug Bryman. (Courtesy TRIUMF.)

TRIUMF, Canada's National Laboratory for Particle and Nuclear Physics, is one of 11 institutions to receive a $CD14.95 million award from the Canadian government after competing with 110 proposals in the Centres of Excellence for Commercialization and Research (CECR) competition, within the Networks of Centres of Excellence (NCE) programme. Advanced Applied Physics Solutions Inc (AAPS), a not-for-profit affiliate of TRIUMF, will initially commercialize technological innovation from TRIUMF, such as the laser-production of diamond-like carbon foils, and bring it to the marketplace. AAPS has been incorporated and is putting together a formalized business plan to pursue R&D projects with business venture partners in Canada, China, France and the US.

The award will provide seed funding to accelerate the testing of ideas and innovations developed in the course of TRIUMF's work as a laboratory for basic research. The mission of AAPS is to improve the quality of life of people worldwide by developing technologies emerging from worldwide subatomic physics research. AAPS will collaborate with academic, government, and industry stakeholders to research and develop promising technologies, bringing them to a commercially viable stage. These include developing a new underground imaging system to improve productivity in the natural resources sector, and other technologies with a range of applications, including medical-isotope production and pollution mitigation.

The NCE is an agency of the Canadian government that supports partnerships between universities, industry, government and not-for-profit organizations with a view to connecting leading-edge research with industrial expertise and strategic investments, in order to boost Canada's leadership in Science and Technology (S&T). Its goal is to create internationally recognized centres of commercialization and research expertise to deliver economic, health, social, and environmental benefits to Canadians, as well as to encourage entrepreneurial and advantages for people, and greater S&T investments from the private sector.

GRID COMPUTING

EGEE steps up a gear with a third phase of Grid infrastructure

Enabling Grids for E-sciencE (EGEE) is the largest multidisciplinary Grid infrastructure in the world, covering research fields from particle physics to biomedicine. Now the project has begun its third phase, EGEE III.

This phase aims to expand and optimize the Grid infrastructure, which is currently used more than 150 000 times per day by scientific users. Co-funded by the European Commission, EGEE III brings together more than 120 organizations to produce a reliable and scalable computing resource available to the European and global research community. At present it consists of 250 sites in 48 countries and more than 60 000 CPUs with more than 20 petabytes of storage, available to some 8000 users 24 hours a day, seven days a week.

These figures considerably exceed the goals planned for the end of the first four years of the EGEE programme, demonstrating the enthusiasm in the scientific community for EGEE and Grid solutions. Ultimately EGEE would like to see a unified, interoperable Grid infrastructure, and with this goal in mind it is working closely with other European and worldwide Grid projects to help to define the standards necessary to make this happen.

The tools and techniques used in one discipline can often be recycled and used elsewhere, by other scientists, or even in the world of business and finance, where EGEE is employed to find new oil reserves, simulate market behaviour and map taxation policy.

EGEE will hold its next conference, EGEE '08, in Istanbul on 22–26 September 2008. The conference will provide an opportunity for business and academic sectors to network with the EGEE communities, collaborating projects, developers and decision makers, to realize the vision of a sustainable, interoperable European Grid.

DARK MATTER

DAMA strengthens claim of annual modulation with new intriguing evidence

Nine years ago the DAMA collaboration announced intriguing evidence for an annual modulation in the signals in its detectors, which could be evidence of dark-matter particles in the galactic halo (*CERN Courier* June 1999 p17). Now, with results presented first at a conference in Venice in April, the team claims the observation of a similar signal with a larger detector, measuring more flashes in June than in December.

Such a modulation would be the consequence of the Earth's rotation around the Sun. There would be different detection rates for dark-matter particles when the Earth goes in the same direction as the flux from the galactic halo compared with when it goes against the flux, six months later.

The current experiment, DAMA/LIBRA, has been taking data at the Gran Sasso National Laboratory in Italy since March 2003. Located at almost 1 km deep, so as to be shielded against the cosmic-ray background, the experiment uses 25 crystals of sodium iodide, each with a mass of 9.7 kg and extremely high radiopurity. If a dark-matter particle collides in one of these, it should produce a faint flash of light, which is measured.

Taking the new data together with those from the previous results gives a total exposure of 0.82 tonne-years, and a result that suggests the presence of dark-matter particles in the galactic halo at a confidence level of 8.2σ (Bernabei *et al*. 2008). The effect observed is independent of the various theoretical models of dark matter, such as weakly interacting massive particles or axions. Currently, it remains that no other dark-matter experiment has detected the modulation, and so the hunt continues.

Further reading

R Bernabei *et al*. 2008 http://arxiv.org/pdf/0804.2741v1.

SCIENCEWATCH

Compiled by Steve Reucroft and John Swain, Northeastern University

Shrimps tell left from right in light

Linearly polarized light is common in nature and appears more or less any time that light is reflected. However, circularly polarized light is certainly more exotic, so it has come as something of a surprise to biologists to find the first animal that seems to be sensitive to this particular form of polarization.

Tsyr-Huei Chiou from the University of Maryland, and colleagues from the University of Queensland, Brisbane, and the University of California, Berkeley, have shown that a species of Indonesian mantis shrimp, *Odontodactylus cultrifer*, seems to recognize in which direction light is circularly polarized. This is a fourth way in which animals are sensitive to light, in addition to intensity, colour and linear polarization.

In addition to having a fin where the degree of redness varies depending on whether it is looked at through a right- or left-polarizing filter, these little creatures can actually be trained to recognize which of several tubes contains food, by sensing the circularly polarized light that the food container reflects. After a period of training where the food was in a tube lit by either left- or right-circularly polarized light, the subjects would continue to choose the correct tube even when no food was present.

Why these shrimps developed this strange ability is not known, but it could provide for a very private and low-noise communications channel to help find mates. It could also have evolved to deal with the murky environments that the shrimps have inhabited during the 400 million years since crustaceans of this kind first appeared on Earth.

*The peacock mantis shrimp (*O. scyllarus*), a close relative of* Odontodactylus cultrifer*, whose similar looking eyes can distinguish light that is circularly polarized in different directions. (Courtesy Michael James/Dreamstime.com.)*

Further reading

C Tsyr-Huei *et al.* 2008 *Current Biology* **18** 429.

Atomic neutrality

Are neutral atoms really neutral? A new experiment could look for tiny charges as low as 10^{-28} *e*, beating present limits by eight orders of magnitude, according to Asimina Arvanitaki and colleagues at Stanford University. The idea is to use lasers to split a beam of cold rubidium atoms into a superposition of two momentum states and then see how they interact with electric fields that could slightly slow down one component with respect to the other if a charge were present. A phase shift could give away the presence of a tiny charge. The effect sounds bizarre, but it is actually anticipated by some theorists.

Further reading

A Arvanitaki *et al.* 2008 *Phys. Rev. Lett.* **100** 120407.

Radioprotective drug leaves tumours sensitive

Lyudmila Burdelya of the Roswell Park Cancer Institute in Buffalo, New York, and colleagues have found a drug that protects normal cells from radiation while leaving cancer cells vulnerable. The compound, derived from salmonella, can protect mice and monkeys from radiation if administered before exposure to otherwise lethal doses of radiation, without making tumours less susceptible. It could prove useful both in case of accidental exposures to radiation, and as an adjunct to cancer radiotherapy.

Further reading

L G Burdelya *et al.* 2008 *Science* **320** 226.

A shocking sense of smell

Small electric shocks can be used to train humans to learn the difference between two mirror-image versions of a molecule. This work by Wen Li and colleagues at Northwestern University in Chicago and Evanston might seem rather uninteresting were it not that the two versions of the molecule in question apparently smell the same. While scents are known to smell differently depending on the chirality of the molecule involved, this new evidence indicates a human sense of smell that is more subtle than realized.

Further reading

W Li *et al.* 2008 *Science* **319** 1842.

RF really does make saltwater burn

A solution of 3% sodium chloride burns in a Pyrex test tube (left) and a PTFE tube (right) when ignited in the presence of 13.56 MHz RF radiation (Roy, Rao and Kanzius 2008).

In the wake of a spate of media-hype and YouTube videos showing salt water apparently burning, Rustum Roy and M L Rao of Pennsylvania State University have made a detailed study of the effect with its discoverer John Kanzius. While some details of the mechanism remain unclear, the basic idea is that intense radio waves at 13.56 MHz can dissociate water into hydrogen and oxygen which can be ignited to burn with a steady flame.

While not the free-energy-from-water source that some people wish would exist, this novel RF-driven and chemically active plasma could have interesting industrial and research applications.

Further reading

R Roy, M L Rao and J Kanzius 2008 *Materials Research Innovations* **12** 3.

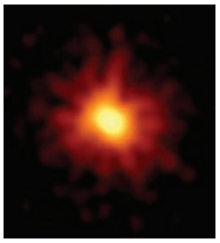
Compiled by Marc Türler, ISDC and Observatory, University of Geneva

Brilliant naked-eye GRB constrains theory

GRB 080319B is the plain name for an extraordinary gamma-ray burst (GRB) that was so bright that it could be seen with the unaided eye for 30 s. The detailed observation of the prompt optical emission and the follow-up monitoring of the afterglow place strong constraints on theoretical models.

For GRB hunters 19 March 2008 was a red-letter day. NASA's Swift spacecraft, which has been providing GRB highlights since its launch in November 2004 (*CERN Courier* December 2005 p20), detected a record of four bursts on a single day, the second of which, GRB 080319B, was the brightest ever observed. Luckily, after a journey of 7000 million years (redshift $z=0.937$), the GRB photons reached Chile at nighttime, where two wide-field optical cameras were patiently gazing at the sky. The strategy to observe the same region as Swift is monitoring allowed the TORTOREM and the Pi of the Sky collaborations to follow the evolution of the optical flash during the GRB. The brightness of GRB 080319B measured by the TORTORA camera mounted on the 60 cm robotic Rapid Eye Mount telescope at La Silla and by the Pi of the Sky apparatus at Las Campanas Observatory exceeded sixth magnitude, making this GRB the first cosmological object visible to the naked eye.

This observational breakthrough together with the usual multiwavelength afterglow observations of this extremely bright GRB provide an excellent opportunity for testing theoretical models. Based on their link to supernova explosions (*CERN Courier* September 2003 p15), it is widely agreed that long GRBs result from the core collapse of a dying star and are emitted by highly relativistic ejecta moving in a direction close to the line of sight. There is, however, an ongoing debate about the physical processes at the origin of the GRB and its long-lasting afterglow emission. In the standard "fireball" model, both the prompt GRB and its afterglow are synchrotron emission by electrons accelerated by shock waves in a relativistic jet. The prompt emission arises from internal shocks, while the afterglow is produced when the jet plunges into gas surrounding the dying star.



The extremely luminous afterglow of GRB 080319B imaged by Swift's X-ray (left) and optical/ultraviolet (right) telescopes. (Courtesy NASA/Swift/Stefan Immler et al.*)*

J S Bloom of the University of California and colleagues have difficulties in reconciling this standard scenario with the observed spectral and temporal variations of GRB 080319B. The simultaneous optical and gamma-ray fluctuations led P Kumar of the University of Texas and A Panaitescu of the Los Alamos National Laboratory to propose the same emission site for the optical photons and the gamma rays. However, as a single spectral component does not match the observed optical and gamma-ray radiation, they suggest that relativistic electrons produce optical synchrotron photons that they up-scatter to gamma-ray energies via inverse-Compton interactions. S Dado, from the Technion institute in Haifa and colleagues from CERN share the opinion that the gamma-ray emission is not of synchrotron origin but, in their "cannonball" model, the seed photons for Compton up-scattering are light from the supernova reflected towards a plasmoid that is ejected from the centre of the dying star by a newborn black hole.

Even though GRB 080319B does not decide on the issue of which of these three models is right, it provides stringent observational constraints that have to be accounted for by future GRB theories.

Further reading:

J S Bloom *et al*. submitted *ApJ* http://arxiv.org/abs/0803.3215.

S Dado *et al*. 2008http://arxiv.org/abs/0804.0621.

P Kumar and A Panaitescu submitted *MNRAS* http://arxiv.org/abs/0805.0144.

Picture of the month

To celebrate the 18th anniversary of the launch of the Hubble Space Telescope on 24 April 1990, a collection of 59 images of merging galaxies has been released. This astonishing view of Arp 148 in the constellation of Ursa Major – the Great Bear – approximately 500 million light-years away, shows a unique snapshot of an ongoing interaction between two galaxies.

The long-tailed galaxy on the left plunged through the centre of a spiral galaxy, producing compression waves associated with intense star formation, witnessed by the presence of massive young stars shining blue light. This is a typical scenario for the formation of such ring-shaped galaxies (*CERN Courier* June 2004 p15 and March 2006 p12). (Courtesy NASA/ESA/STScI/AURA (the Hubble Heritage Team) – ESA/Hubble Collaboration/University of Virginia, Charlottesville, NRAO, Stony Brook University (A Evans)/STScI (K Noll)/Caltech (J Westphal).)

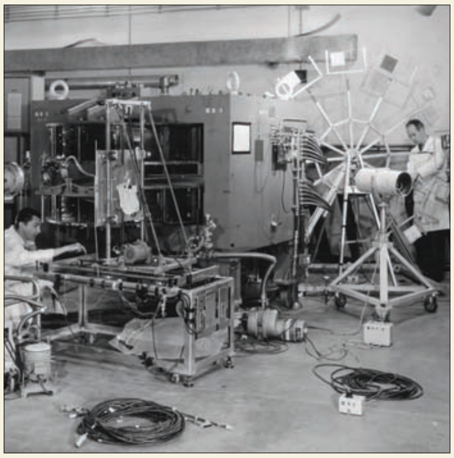
CERN COURIER ARCHIVE: 1965

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

CERN

April at the synchro-cyclotron

Except for the Easter holiday, the synchro-cyclotron operated regularly throughout April. One experiment, on which accelerator runs were completed during the month, was the so-called "Propion" experiment, conducted by a team of physicists from CERN, the Universities of California, Geneva and Grenoble, and ETH Zurich. This was to study the production of pions in the interaction of 600 MeV protons with various nuclei, with the dual aim of giving a better understanding of pion production processes in complex nuclei and of providing a better assessment of various methods of producing pion beams with the accelerator.



This photograph shows P Skarek (left), of CERN's MSC Division, and W Hirt, of the Eidgenössische Technische Hochschule, Zurich, working on the Propion apparatus. The wheel in the background holds various target materials which can be switched into the beam as desired. In front of the wheel is the television camera that allows the beam alignment to be checked from the control room. The equipment to detect and identify the outgoing particles was constructed in the Nuclear Physics Laboratory of the University of Geneva.

● Compiled from "Last month at CERN", pp83–84.

CERN Staff Insurance Scheme invests in housing

Since its foundation in 1956, the CERN Staff Insurance Scheme, which provides mainly for retirement pensions and related payments, has been primarily concerned with the accumulation of capital. Now, with the growth of the fund, a long-term investment policy has become practicable and for the last two years the Management Board has been working on one that would take into consideration both the particular character of the scheme and the international status of the organization.

At the same time, in spite of much new building, the shortage of housing in Geneva continues to be a problem. Since investment in property forms one of the means by which capital can be safeguarded against the risk of inflation, the purchase or construction of blocks of flats was seen to provide a solution of advantage both to the insurance scheme and to the inhabitants of Geneva. Several million Swiss francs are therefore now being devoted to this purpose. This news was made known on Monday 26 April at the ground-breaking ceremony on the site of the first block of flats to be erected by the Insurance Scheme, not far from CERN, in Grand-Saconnex.

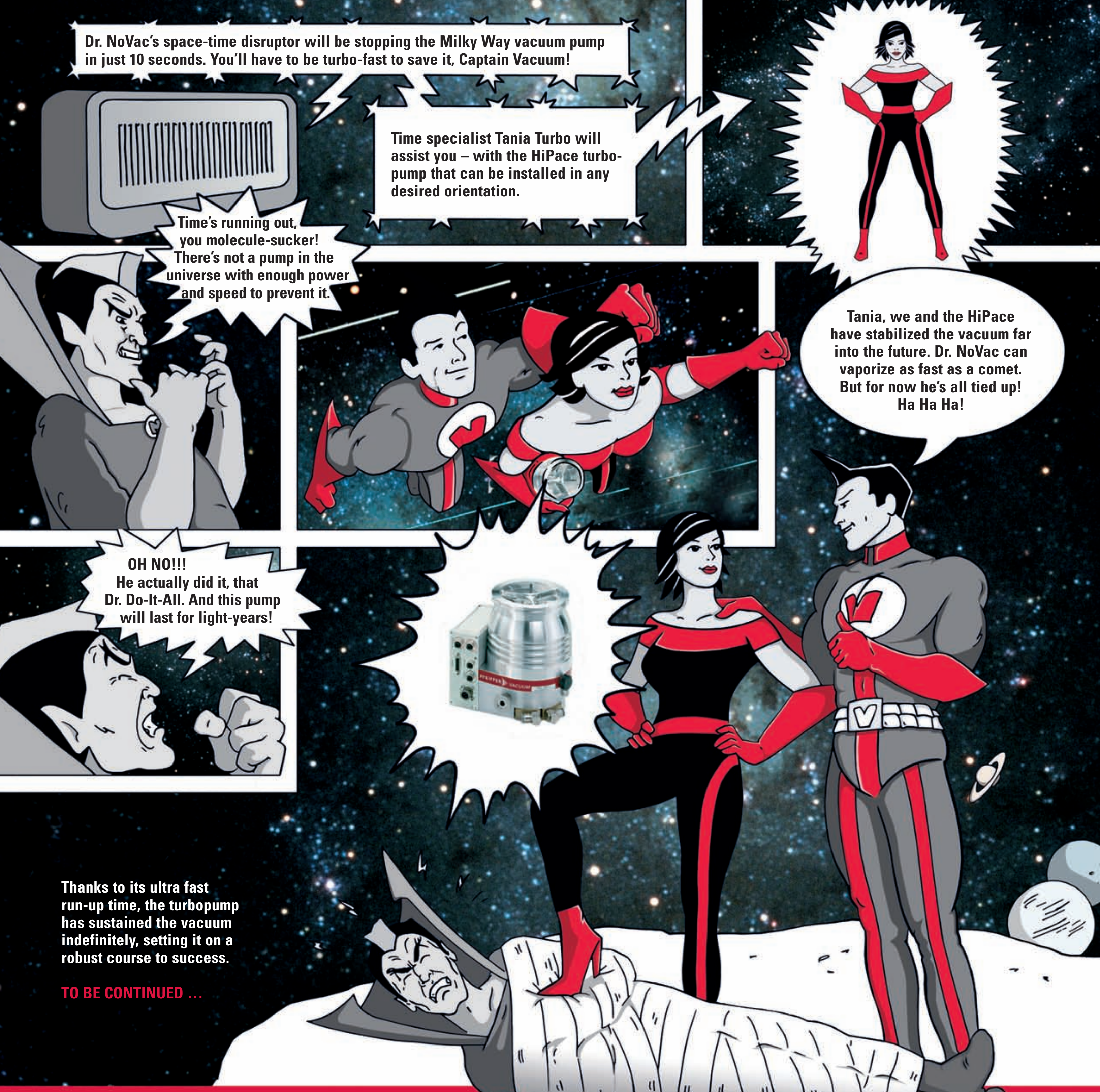
The ceremony, attended by many Cantonal and local government officials, representatives of financial and insurance bodies, the architects, members of the press, and people from CERN, was opened by Mr G H Hampton, CERN's Directorate Member for Administration and Chairman of the Management Board of the Scheme. After welcoming the guests, he pointed out that this project, although relatively modest, was a symbol of the desire among those at CERN to become more integrated into the life of the community in which they lived. Mr P Zumbach, chairman of the CERN Joint Housing Committee, stressed the fact that it was a deliberate policy of the committee, in all its schemes, to reserve a large part of the available accommodation for families who belonged neither to CERN nor to other international organizations. Mr F Peyrot, Head of the Department of Public Works in the Canton of Geneva welcomed the occasion and mentioned two points which he found of special importance – the fact that this new project was being financed wholly independently of the normal funds available in Geneva for such purposes, and the intention that even in flats and houses built with their own funds, CERN staff would be living among other inhabitants of the region and not in a closed community.

● Compiled from the article on pp85-86.

COMPILER'S NOTE

In 1964 the Fondation des immeubles pour les organisations internationales (FIPOI) was set up jointly by the Canton of Geneva and the Swiss Confederation with the purpose of making premises available to Geneva-based international organizations. As the June 1965 issue says (p88): "Although approved by all the political parties and many other bodies, the proposal to create the FIPOI was opposed by a group of citizens in the Canton who raised sufficient support for the measure to be submitted to public referendum. It was clear that opposition to the FIPOI was a protest against the presence and probable growth in Geneva of the international organizations. However, many influential voices were raised in their defence and there was clearly a good understanding of the prominent part they play in the life of Geneva. After a 36% poll (comparatively high for this kind of vote) the proposal to set up the foundation was supported by 31 813 against 25 804".

CERN's judicious housing policy was thus very much in keeping with the spirit of rapprochement that was developing at that time, and since the FIPOI was established, the Laboratory has regularly benefited from its generous financial support, usually in the form of interest-free loans.


Dr. NoVac's space-time disruptor will be stopping the Milky Way vacuum pump in just 10 seconds. You'll have to be turbo-fast to save it, Captain Vacuum!
Time specialist Tania Turbo will assist you – with the HiPace turbo-pump that can be installed in any desired orientation.
Time's running out, you molecule-sucker! There's not a pump in the universe with enough power and speed to prevent it.
Tania, we and the HiPace have stabilized the vacuum far into the future. Dr. NoVac can vaporize as fast as a comet. But for now he's all tied up! Ha Ha Ha!
OH NO!!! He actually did it, that Dr. Do-It-All. And this pump will last for light-years!
Thanks to its ultra fast run-up time, the turbopump has sustained the vacuum indefinitely, setting it on a robust course to success.
TO BE CONTINUED …

Milagro maps out gamma-ray frontier

For years a large reservoir of water in New Mexico has charted the galaxy at tera-electron-volt energies, revealing new gamma-ray sources and possible acceleration sites of cosmic rays.

Milagro – Spanish for miracle – was the first of a new generation of extensive air shower (EAS) detectors. Traditionally, EAS arrays have been composed of a discrete set of small detectors, spread over large areas. Typically active over approximately 1% of the enclosed area only, they were sensitive to cosmic gamma rays with energies of around 100 TeV and above. The combination of steeply falling source spectra and the absorption in flight of these high-energy gamma rays via interactions with the cosmic microwave background radiation meant that this first generation of instruments did not succeed in detecting any astrophysical sources. In contrast, imaging atmospheric Cherenkov telescopes (IACT), pioneered by Trevor Weekes at Mount Hopkins, led to the discovery of several tera-electron-volt gamma-ray sources, the first of which was the Crab Nebula, the remnant of a supernova that occurred in 1054 (Weekes *et al.* 1989). More recently an array of such detectors, the HESS telescopes in Namibia, have demonstrated the richness of the tera-electron-volt sky (*CERN Courier* January/February 2005 p30 and May 2005 p13).

Despite these difficulties, the advantages of EAS arrays, with their large instantaneous field of view (around 2 sr) and continuous operation, provided strong motivation to improve the technique. The key to success was to lower the energy threshold and simultaneously improve the ability to reject the abundant cosmic-ray background. Water Cherenkov technology, developed for underground proton-decay physics experiments such as the Irvine Michigan Brookhaven and Kamiokande detectors, led the way to this success.

When employed above ground as an EAS array, water Cherenkov technology enables the construction of an array that is sensitive over its entire area. The Cherenkov angle in water is 41° so an array of photomultiplier tubes (PMTs) placed at a depth comparable to their spacing can detect the Cherenkov light emitted from any electromagnetic particle entering the water volume. Moreover, the composition of an EAS at ground level is predominantly photons (which are around six times as numerous as electrons and positrons), and, as the depth of water above the PMTs is sufficient to convert these gamma rays to charged particles, these photons can also be detected by the PMTs.

The Milagro detector is located in the Jemez Mountains of northern New Mexico. It is operated by the Los Alamos National Laboratory in partnership with the National Science Foundation and the US Department of Energy Office of Science. Milagro uses a covered ▷

Fig. 1a. The principle behind the Milagro gamma-ray observatory. A high-energy cosmic gamma ray generates a shower of secondary cosmic rays, which are detected via Cherenkov radiation in the water. (Courtesy Aurore Simonnet, Sonoma State University.)

Fig. 1b. Aerial view of the Milagro gamma-ray observatory. The central reservoir is surrounded by 175 water tanks. (Courtesy Ulisse Bravar.)

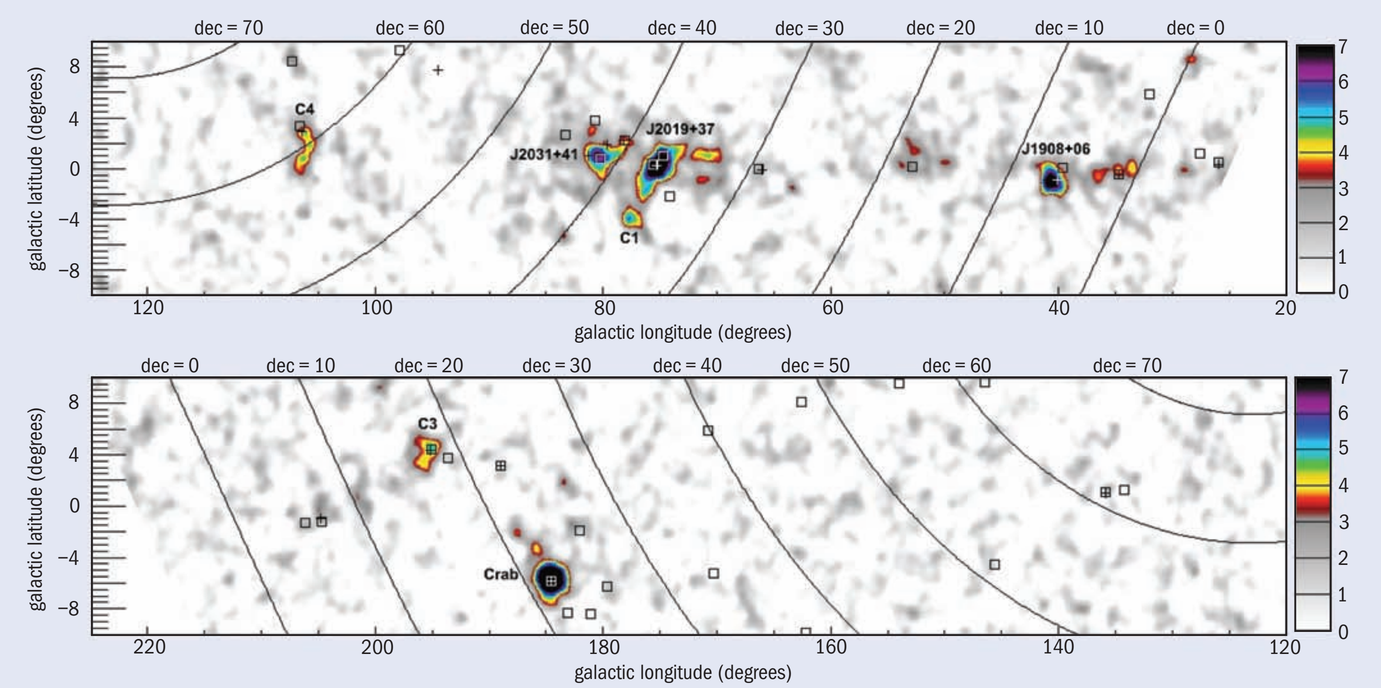


Fig. 2. The Milky Way at 20 TeV as seen by Milagro indicating both galactic longitude and declination (dec). The colour scale represents the statistical significance of each region of the sky and saturates at 7σ for clarity. The Cygnus region lies between galactic longitudes of 65° and 85°.

water reservoir that contains 2.5×10^7 litres of water and measures 80 m × 60 m, with a depth of 8 m. The reservoir is instrumented with 750 PMTs deployed in two layers. The top layer of 450 PMTs is beneath 1.5 m of water with a spacing of 2.8 m. This layer is used to reconstruct the direction of the primary gamma ray or cosmic ray by measuring the relative arrival time of the shower front to around 0.5 ns. The second layer of PMTs, beneath 6 m of water, is used to detect the penetrating component of any EAS initiated by hadronic cosmic rays. An array of 175 water tanks surrounds the central water reservoir. Each is 1 m high and 3 m in diameter and is lined with reflective Tyvek. A single 8 inch PMT mounted at the top of each tank looks down into the water volume.

After seven years of operation, four of which included the array of outrigger water tanks, Milagro ceased operation in April this year. Its results have been impressive and ushered in a new era for ground-based gamma-ray astrophysics at tera-electron-volt energies, where the role of the EAS arrays is now clearly established.

Figure 2 shows a region around the galactic plane as observed by Milagro, where the median energy of the detected gamma rays is 20 TeV (Abdo *et al.* 2007b). It contains several noteworthy features. The sources marked JXXXX+YY, where XXXX and YY are the right ascension and declination, respectively, are three new sources that Milagro discovered. MGRO J2031+41 and MGRO J2019+37 lie within the Cygnus region of the galaxy. This direction points into our spiral arm and is rich with possible cosmic-ray acceleration sites, such as Wolf–Rayet stars, OB associations (a sign of star formation) and supernova remnants. The locations of these two sources are coincident with sources of giga-electron-volt gamma rays discovered by the Energetic Gamma Ray Emission Telescope (EGRET) on NASA's Compton Gamma Ray Observatory (the squares mark the locations of gamma-ray sources of more than 100 MeV reported in the 3rd EGRET catalogue). However, the true nature of the sources is still to be determined.

The third new source shown in figure 2 is MGRO J1908+06. This was subsequently observed by HESS, which measured a "hard" energy spectrum, falling more or less with the square of the energy. Preliminary analysis of Milagro data indicates that this source may be emitting gamma rays with energies in excess of 100 TeV, which would make it the highest-energy gamma-ray source detected to date and a likely site of cosmic-ray acceleration.

In addition to these three sources, there are four other regions in Milagro's view of the galaxy that are likely to be sources of tera-electron-volt gamma rays. Figure 2 shows three of these regions: C1, C3 and C4. C2, which is not indicated, lies just above C1.

The source candidate C4 is coincident with the Boomerang pulsar wind nebula, and the shape seen in tera-electron-volt gamma rays is similar to that observed at 100 MeV. C3 is coincident with the Geminga pulsar (although no pulsed emission is observed at tera-electron-volt energies), which, at a distance of 180 pc, is the closest pulsar to the Earth and the brightest source of giga-electron-volt gamma rays visible in the northern sky. Finally, C1 has no giga-electron-volt source in the vicinity and its nature is at present completely unknown. The air shower array operating at Yangbajing cosmic-ray observatory in Tibet has confirmed this source, in addition to the two others that lie in the Cygnus region. One interesting feature of these is that they appear to be extended, with diameters ranging from 0.25° to more than 1°. Large sources are difficult for IACTs to detect, possibly explaining why they have eluded detection until now, despite the fact that these regions had been examined by past IACT arrays, such as the Whipple Observatory and the High Energy Gamma Ray Astronomy experiment.

Figure 2 also shows a diffuse glow visible around the galactic plane, especially in the Cygnus region and at lower galactic longitude. This arises from the interaction of hadronic cosmic rays and high-energy cosmic-ray electrons with matter and radiation in the

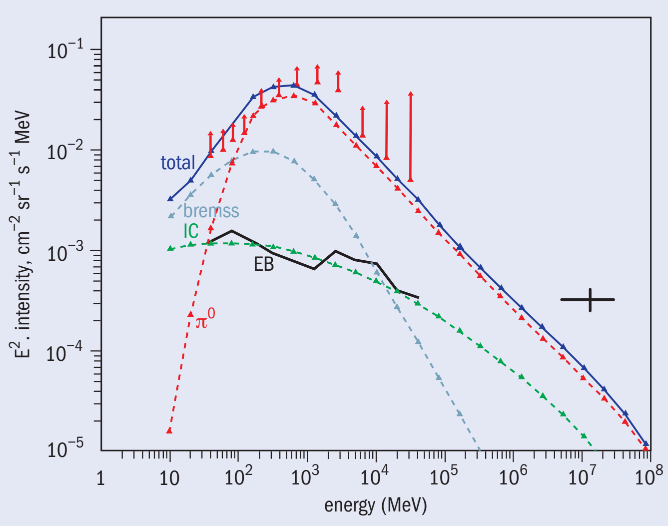


Fig. 3. The measured and predicted levels of the galactic diffuse emission within the Cygnus region. The red bars indicate the measurements made by EGRET and the black cross shows the measurement made with Milagro. The prediction is based on the "conventional" model of GALPROP (Strong et al. *2004), which uses the cosmic-ray spectrum and intensity measured at the Earth as the basis for the entire galaxy. The red curve is the contribution from cosmic-ray protons interacting with matter, the green curve is the contribution from high-energy electrons interacting with radiation in the galaxy and the light-blue curve is the contribution from high-energy electron bremsstrahlung. The dark-blue curve is the sum of the these contributions.*

galaxy. The interaction of cosmic-ray protons with matter leads to the production of neutral pions that subsequently decay into gamma rays. The high-energy electrons interact with low-energy (optical, infrared and cosmic microwave background) photons through Compton scattering to produce high-energy gamma rays. Prior to Milagro's measurements, EGRET observed this galactic diffuse radiation up to about 30 GeV and discovered an excess of diffuse emission over predictions based on the known matter density in the galaxy and the cosmic-ray rate and spectrum measured at the Earth. The explanation for this excess is still a matter of debate, with possible solutions including the annihilation of dark matter (*CERN Courier* December 2005 p17). A much greater intensity of high-energy electrons throughout the galaxy than is measured at the Earth, and a miscalibration of the EGRET response at high energies, are also possible explanations.

Figure 3 shows Milagro's measurement of the diffuse emission at 12 TeV in the Cygnus region (Abdo *et al.* 2007a). This measurement indicates that at tera-electron-volt energies the excess over expectations is even larger than it is at giga-electron-volt energies. While the cause of this excess is a matter of debate, possible explanations include cosmic-ray acceleration sites in the region, unresolved sources of tera-electron-volt gamma rays in the region, and the presence of very-high-energy electrons in the region. The resolution of this puzzle will require more detailed observations. Whatever the final explanation, it is clear that gamma-ray astronomy is an important tool in answering the nearly century-old problem of the origin of cosmic radiation.

While observations with Milagro have drawn to a close, plans for a new instrument are proceeding. A joint US–Mexico collaboration has proposed the High Altitude Water Cherenkov (HAWC) telescope to be located at Volcán Sierra Negra (Tliltepetl) near the site of the Large Millimeter Telescope in Mexico (figure 4). At 4100 m above sea level (compared with 2600 m above sea level for Milagro) and with a dense sampling detector that encloses around 22 000 m^2, HAWC is expected to be about 15 times as sensitive as Milagro and have an energy threshold of less than 1 TeV. Unlike Milagro, it will comprise 900 individual water tanks. Each tank will be 5 m in diameter and 4.6 m tall – much larger than those used by Milagro or the Pierre Auger Observatory in Argentina – and would have a PMT at the bottom looking up into the water volume. If built, the complete array will have an unprecedented level of sensitivity to the highest-energy particle accelerators in our galaxy, as well as the sensitivity needed to detect short flares from active galaxies and the ability to make a detailed map of the diffuse gamma-ray emission in our galaxy.

Fig. 4. A computer-generated image of the proposed HAWC telescope at Volcán Sierra Negra in the state of Puebla, Mexico. Pico de Orizaba or Citlaltépetl (the highest mountain in Mexico at 5636 m above sea level) is in the foreground and the Large Millimeter Telescope at the summit of Volcán Sierra Negra is in the background. (Courtesy Alex Carrillo.)

Further reading

A A Abdo *et al.* 2000a *Astrophysical Journal* **658** L33.
A A Abdo *et al.* 2007b *Astrophysical Journal* **664** L91.
A W Strong, I V Moskalenko and O Reimer 2004 *Astrophysical Journal*, **613** 962.
T C Weekes *et al.* 1989 *Astrophysical Journal* **342** 379.
For more about HAWC see http://umdgrb.umd.edu/hawc/.

Résumé

Milagro établit la frontière des rayons gamma

Au cours des sept dernières années, un grand réservoir d'eau au Nouveau-Mexique a permis d'établir la carte de la galaxie à des énergies de l'ordre du téraélectron-volt, mettant en évidence de nouvelles sources de rayons gamma et de possibles sites d'accélération de rayons cosmiques. Milagro (miracle en espagnol) a été le premier grand détecteur de gerbes atmosphériques de nouvelle génération. Ses résultats impressionnants ont marqué le début d'une nouvelle ère pour l'astrophysique gamma au sol à des énergies de l'ordre du téraélectron, montrant le rôle des grandes stations pour gerbes atmosphériques. Milagro n'est plus en service, mais un nouveau détecteur devrait voir le jour au Mexique.

Cyrus Hoffman *and* **Gus Sinnis**, *Los Alamos National Laboratory.*

The enigmatic Sun: a crucible for new physics

The nearest star to Earth harbours a surprising number of unexplained phenomena, despite its proximity. Could astroparticle physics, and in particular particles like the charismatic axion, hold the key? **Konstantin Zioutas** believes that they could.

The Sun, a typical middle-aged star, is the most important astronomical body for life on Earth, and since ancient times its phenomena have had a key role in revealing new physics. Answering the question of why the Sun moves across the sky led to the heliocentric planetary model, replacing the ancient geocentric system and foreshadowing the laws of gravity. In 1783 a sun-like star led the Revd John Mitchell to the idea of the black hole, and in 1919 the bending of starlight by the Sun was a triumphant demonstration of general relativity. The Sun even provides a laboratory for subatomic physics. The understanding that it shines by nuclear fusion grew out of the nuclear physics of the 1930s; more recently the solution to the solar neutrino "deficit" problem has implied new physics.

This progress in science, triggered by the seemingly pedestrian Sun, seems set to continue, as a variety of solar phenomena still defy theoretical understanding. It may be that one answer lies in astroparticle physics and the curious hypothetical particle known as the axion. Neutral, light, and very weakly interacting, this particle was proposed more than 25 years ago to explain the absence of charge-parity (CP) symmetry violation in the strong interaction (*CERN Courier* July/August 2006 p19).

So what are the problems with the Sun? These lie, perhaps surprisingly, with the more visible, outermost layers, which have been observed for hundreds, if not thousands, of years.

First, why is the corona – the Sun's atmosphere with a density of only a few nanograms per cubic metre – so hot, with a temperature of millions of degrees? This question has challenged astronomers since Walter Grotrian, of the Astrophysikalisches Observatorium in Potsdam, discovered the corona in the 1930s. Within a few hundred kilometres, the temperature rises to be about 500 times that of the underlying chromosphere, instead of continuing to fall to the temperature of empty space (2.7 K). While the flux of extreme ultraviolet photons and X-rays from the higher layers is some five orders of magnitude less than the flux from the photosphere (the visible surface), it is nevertheless surprisingly high and inconsistent with the spectrum from a black body with the temperature of the photosphere (figure 1). Thus, some unconventional physics must be at work, since heat cannot run spontaneously from cooler to hotter places. In short, everything above the photosphere should not be there at all.

Walter Grotrian, who discovered the hot solar corona in the 1930s. (Courtesy Rainer Arlt, Astrophysikalisches Institut Potsdam.)

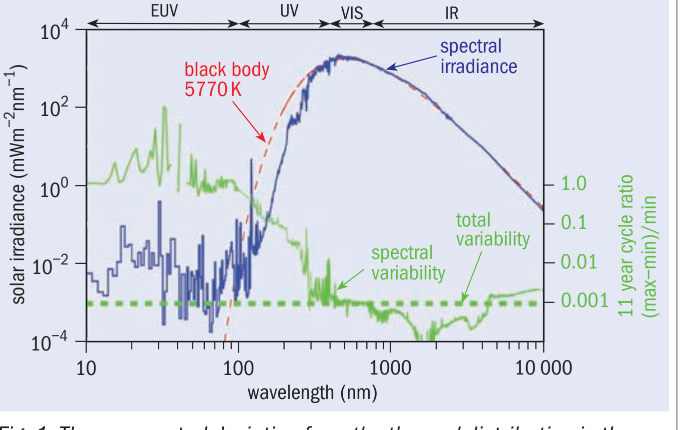


Fig. 1. The unexpected deviation from the thermal distribution in the extreme ultraviolet (EUV) and shorter wavelengths (not shown) in the solar spectrum constitutes the celebrated solar corona problem discovered by Walter Grotrian in 1939. The green curve shows the wavelength dependence of the 11-year solar cycle, indicating a threshold-like effect around visible UV energies. The non-thermal part in short wavelengths is much more pronounced in young sun-like stars. (Courtesy Judith Lean/NRL Washington.)

Another question is how does the corona continuously accelerate the solar wind of some thousand million tonnes of gas per second at speeds as high as 800 km/s? The same puzzle holds for the transient but dramatic coronal mass ejections (CMEs). How and where is the required energy stored, and how are the ejections triggered? ▷

Solar observatories past and present. Stonehenge in Wiltshire, southern England, left, constructed around 3000 BC. (Courtesy Markus Gann/ Dreamstime.com.) The CERN Solar Axion Telescope (CAST), right, which started operation in 2002 and is based on a prototype LHC dipole magnet.

This question is probably related to the mystery of coronal heating. And what is it that triggers solar flares, which heat the solar atmosphere locally up to about 10 to 30 million degrees, similar to the high temperature of the core, some 700 000 km beneath? These unpredictable events appear to be like violent "explosions" occurring near sunspots in the lower corona. This suggests magnetic energy as their main energy source, but how is the energy stored and how is it released so rapidly and efficiently within seconds? Even though many details are known, new observations call into question the 40-year-old standard model for solar flares, which 150 years after their discovery still remain a major enigma.

On the Sun's surface, what is it that causes the 11-year solar cycle of sunspots and solar activity? This seems to be the biggest of all solar mysteries, since it involves the oscillation of the huge "magnets" of a few kilogauss on the face of the Sun, ranging from 300 to 100 000 km in size. The origin of sunspots has been one of the great puzzles of astrophysics since Galileo Galilei first observed them in the early 1600s. Their rhythmic comings and goings, first measured by the apothecary Samuel Heinrich Schwabe in 1826, could be the key to understanding the unpredictable Sun, since everything in the solar atmosphere varies in step with this magnetic cycle.

Beneath the Sun's surface, the contradiction between solar spectroscopy and the refined solar interior models provided by helioseismology has revived the question about the heavy-element composition of the Sun, with new abundances some 25 to 35% lower than before. Abundances vary from place to place and from time to time in the Sun, and are enhanced near flares, showing an intriguing dependence on the square of the magnetic intensity in these regions. The so-called "solar oxygen crisis" or "solar model problem" is thus pointing at some non-standard physical process or processes that occur only in the solar atmosphere, and with some built-in magnetic sensor.

These are just some of the most striking solar mysteries, each crying out for an explanation. So can astroparticle physics help? The answer could be "yes", using a scenario in which axions, or particles like axions, are created and converted to photons in regions of high magnetic fields or by their spontaneous decay.

The expectation from particle physics is that axions should couple to electromagnetic fields, just as neutral pions do in the Primakoff effect known since 1951, which regards the production of pions by high-energy photons as the reverse of the decay into two photons. Interestingly, axions could even couple coherently to macroscopic magnetic fields, giving rise to axion–photon oscillation, as the axions produce photons and vice versa. The process is further enhanced in a suitably dense plasma, which can increase the coherence length. This means that the huge solar magnetic fields could provide regions for efficient axion–photon mutation, leading to the sudden appearance of photons from axions streaming out from the Sun's interior. The photosphere and solar atmosphere near sunspots are the most likely magnetic regions for this process to become "visible", as the material above is transparent to emerging photons.

According to this scenario, the Sun should be emitting axions, or axion-like particles, with energies reflecting the temperature of the source. Thus one or more extended sources of new low-energy particles (below around 1 keV), and the ubiquitous solar magnetic fields of strengths varying from around 0.5 T, as measured at the surface, up to 100 T or much more in the interior, might together give rise to the apparently enigmatic behaviour of a star like the Sun.

Conventional solar axion models, inspired by QCD, have one small source of particles in the solar core, with an energy spectrum that peaks at 4 to 5 keV. They therefore exclude the low energies where the solar mysteries predominantly occur. This immediately suggests an extended axion "horizon". Experiments to detect solar axions – axion helioscopes such as the CERN Solar Axion Telescope (CAST) – should widen their dynamic range towards lower energies, in order to enter this new territory.

The revised solar axion scenario must also accommodate two components of photon emission, namely, a continuous inward emission together, occasionally, with an outward radiation pressure. Massive and light axion-like particles, both of which have been proposed, can provide these thermodynamically unexpected inward and outward photons respectively. They offer an exotic but still simple solution, given the Sun's complexity.

The emerging picture is that the transition region (TR) between the chromosphere and the corona (which is only about 100 km thick and only some 2000 km above the solar surface) is the manifestation of a space and time dependent balance between the two photon emissions. However, the almost equally probable disappearance of photons into axion-like particles in a magnetic environment must also be taken into account in understanding the solar puzzles. The TR could be the most spectacular place in the Sun, since it is where the mysterious temperature inversion appears, while flares, CMEs and other violent phenomena originate near the TR.

Astrophysicists generally consider the ubiquitous solar magnetism to be the key to understanding the Sun. The magnetic field appears to play a crucial role in heating up the corona, but the process by which it is converted into heat and other forms of energy remains an unsolved problem. In the new scenario, the generally accepted properties of the radiative decay of particles like axions and their coupling to magnetic fields are the device to resolve the problem – in effect, a real "από μηχανης θεός" (the *deus ex machina* of Greek

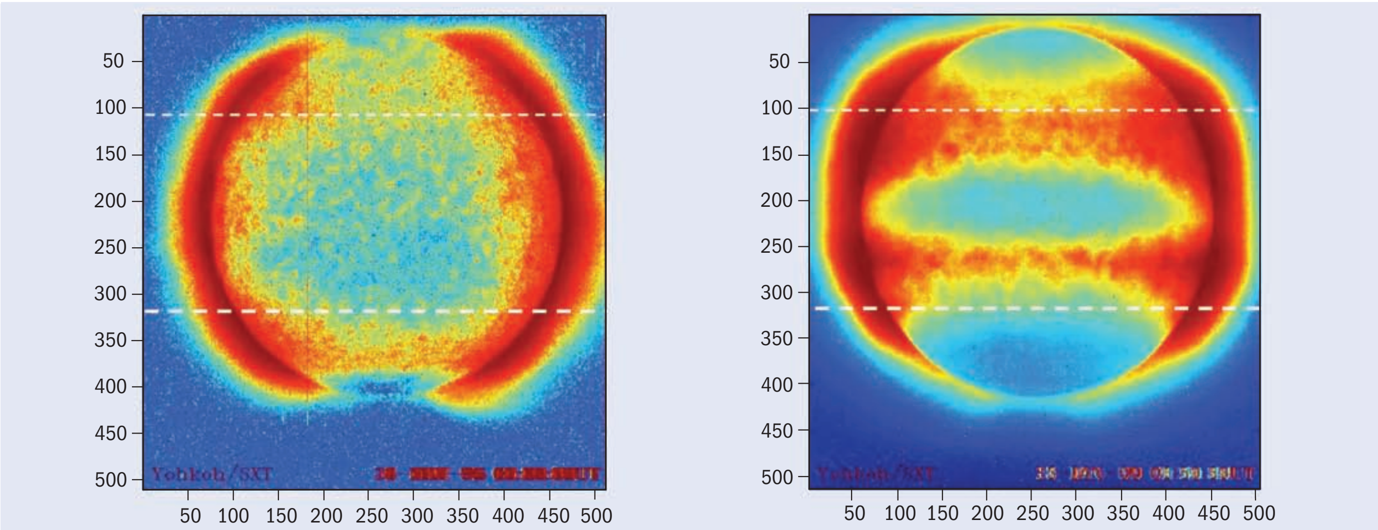


Fig. 2. Solar images at photon energies from 250 eV up to a few kilo-electron-volts from the Japanese X-ray telescope Yohkoh (1991–2001). Left: composite of 49 of the quietest solar periods during the solar minimum in 1996. Right: solar X-ray activity during the last maximum of the 11-year solar cycle. The dashed lines show the part of the solar disk where most activity takes place, indicating a different behaviour between the quiet and active Sun. (Courtesy V Anastassopoulos and M Tsagri/University of Patras.)

tragedy). The magnetic field is no longer the energy source, but is just the catalyst for the axions to become photons, and vice versa.

The precise mechanism for enhancing axion–photon mutation in the Sun that this picture requires remains elusive and challenging. One aim is to reproduce it in axion experiments. CAST, for example, seeks to detect photons created by the conversion of solar axions in the 9 T field of a prototype superconducting LHC dipole (*CERN Courier* March 2005 p7). However, the process depends on the unknown mass of the axion. Every day the CAST experiment changes the density of the gas inside the two tubes in the magnet in an attempt to match the velocity of the solar axion with that of the emerging photon propagating in the refractive gas.

It is reasonable to assume that fine tuning of this kind in relation to the axion mass might also occur in the restless magnetic Sun. If the energy corresponding to the plasma frequency equals the axion rest mass, the axion-to-photon coherent interaction will increase steeply with the product of the square of the coherence length and the transverse magnetic field strength. Since solar plasma densities and/or magnetic fields change continuously, such a "resonance crossing" could result in an otherwise unexpected photon excess or deficit, manifesting itself in a variety of ways, for example, locally as a hot or cold plasma. Only a quantum electrodynamics that incorporates an axion-like field can accommodate such transient brightening as well as dimming (among many other unexpected observations).

These ideas also have implications for the better tuning not only of CAST, but also of orbiting telescopes such as the Japanese satellite Hinode (formerly Solar B), NASA's Reuven Ramaty High Energy Solar Spectroscopic Imager and the NASA–ESA Solar and Heliospheric Observatory, which have been transformed recently to promising axion helioscopes, following suggestions by CERN's Luigi di Lella among others. The joint Japan–US–UK mission Yohkoh has also joined the axion hunt, even though it ceased operation in 2001, by making its data freely available (figure 2).

The revised axion scenario therefore seems to fit as an explanation for most (if not all) solar mysteries. Such effects can provide signatures for new physics as direct and as significant as those from laboratory experiments, even though they are generally considered as indirect; the history of solar neutrinos is the best example of this kind.

Following these ideas and others on millicharged particles, paraphotons or any other weakly interacting sub-electron-volt particles, axion-like exotica will mean that the Sun's visible surface – and probably not its core – holds the key to its secrets. As in neutrino physics, the multifaceted Sun, from its deep interior to the outer corona and the solar wind, could be the best laboratory for axion physics and the like. The Sun, the most powerful accelerator in the solar system, whose working principle is not yet understood, has not been as active as it is now for some 11 000 years. Is this an opportunity not to be missed?

Further reading

For more about axions see http://axion-wimp.desy.de/.

Résumé

Les énigmes du Soleil : un creuset pour la nouvelle physique

Bien que proche de la Terre, le Soleil recèle encore des phénomènes inexpliqués. La couronne solaire est particulièrement énigmatique : Pourquoi est-elle si chaude ? Quelle est la cause des éruptions solaires à proximité de la tache solaire ? Ces phénomènes pourraient être expliqués par la présence de curieuses particules hypothétiques appelées axions ou de particules analogues. Selon de nouvelles idées sur les axions solaires, certaines régions présentant des champs magnétiques solaires très élevés pourraient subir une mutation axion-photon efficace, conduisant à l'apparition soudaine de photons à partir des axions déversés par le Soleil. Ces nouvelles idées ont une incidence sur les observations du Soleil.

Konstantin Zioutas, *University of Patras* and *CERN*.

TRIUMF accelerates exotic radioisotope era

The ISAC-II facility in Canada leads the way in the provision of beams of rare isotopes, using superconducting acceleration technology to uncover the rich world of nuclei.

Nuclear science is undergoing a renaissance driven, not by the printing press or a breakthrough in visual art, but by an increasingly powerful set of beams of rare isotopes. Several nations around the world are competing to obtain the most exotic isotopes, the most intense beams and the most versatile detectors in pursuit of this exciting science. TRIUMF, Canada's National Laboratory for Particle and Nuclear Physics, has occupied a leading position in this race and has just taken a stride forward with the successful commissioning of its ISAC-II facility.

New patterns in the organization within the nucleus, such as neutron halos, neutron skins and new magic numbers that appear only off the line of stability, are prompting new questions and bringing scientists closer to a systematic understanding of nuclear structure. In addition, the new experimental field of nuclear astrophysics has brought new emphasis to the importance of understanding the sophisticated reactions that potentially gave rise to all of the elements in our universe beyond iron. As a visitor to TRIUMF recently noted, "Nuclear astrophysics is invaluable because it helps us understand why gold is so rare!"

To explore this rich world of nuclei, TRIUMF has designed, built and commissioned the second phase of its Isotope Separator and Accelerator (ISAC) facility, ISAC-II, with support from the Government of Canada and the Province of British Columbia. The new facility includes a superconducting linear accelerator to boost the energies of the exotic, heavy isotopes over the Coulomb barrier. This is the energy threshold at which the nuclei have sufficient energy to come close enough to others in targets for the short-range strong interactions to take effect.

TRIUMF began developing superconducting acceleration technology in 2001 and is now a leader in the field, with a demonstrated accelerating gradient significantly above that of other operating facilities. The new superconducting beamline of ISAC-II adds 20 MV of accelerating voltage to the existing ISAC accelerator chain (figure 1). Robert Laxdal and his team at TRIUMF have developed the high-quality, low-emittance beams with high reliability that are strong features of the new facility.

Researchers have already begun to queue up to take advantage of the new beams. First in line was an experiment led by Hervé Savajols of the Grand Accelerateur National d'Ions Lourds (GANIL) in France and Tanihata from TRIUMF and Japan. They used the MAYA detector from GANIL to study the unusual structure of ^{11}Li, which has as many as eight neutrons together with the three protons. When the first beams arrived on 5 January 2007 the experiment was ready within two hours and was taking data. For this experiment, only 11 of the 20 available superconducting niobium RF cavities were needed to accelerate the beam to the energy of 39.6 MeV required for the experiment.

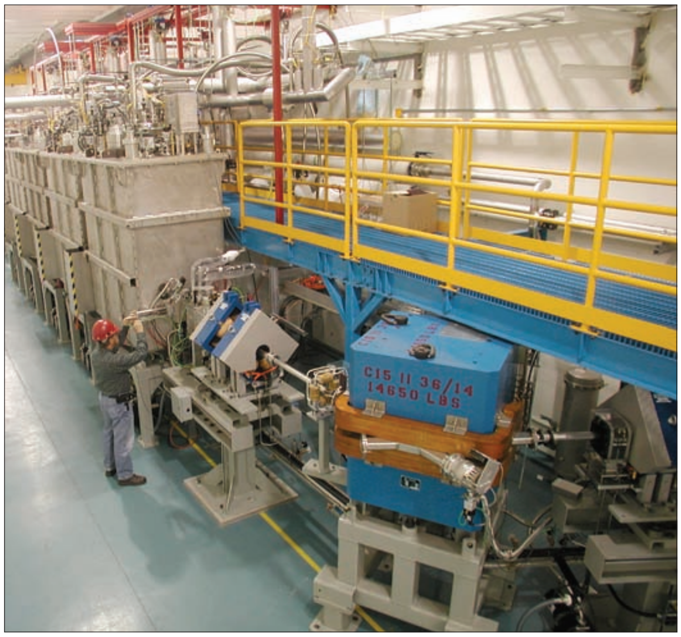


Fig. 1. The superconducting-accelerator modules along the ISAC-II beamline. The cavities, fabricated in Italy, are two-gap quarter-wave structures made from bulk highly purified niobium. The cavities and solenoid are cooled to 4 K using liquid helium delivered from a cryoplant in an adjacent room. One cavity delivers about 1 MV of accelerating potential but with only around 5 W of RF power, owing to the extremely low surface-resistance of the niobium. (Courtesy TRIUMF.)

^{11}Li is an extreme example of a halo nucleus, where two of the neutrons couple together to form an extended outer "halo", and the aim of this MAYA ISAC-II experiment was to study the pairing correlation between the two neutrons. Many of the two-neutron halo nuclei have an unusual structure and the correlation between two neutrons plays an important role in both the nuclear binding and structure. Although there have been several experiments to ▷

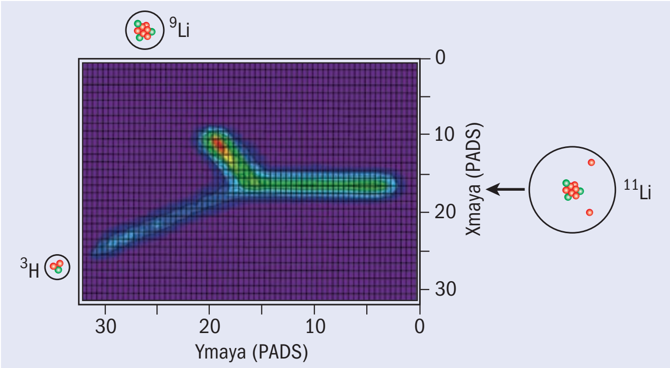


Fig. 2. Typical event tracks in MAYA for the reaction ^{11}Li+p -> ^{9}Li+^{3}H. Analysing the angular correlations of such reactions has yielded information for the transition to the ground state as well as the 2.69 MeV excited state in ^{9}Li. The different nuclei are also indictaed.

Fig. 3. The TIGRESS group in front of their recently commissioned detector in the new ISAC-II hall at TRIUMF. (Courtesy TRIUMF.)

study the break up of the nucleus, the correlation between the two halo neutrons is still not well understood.

At ISAC-II, MAYA studied the two-neutron transfer reaction ^{11}Li +p ->^{9}Li +^{3}H at a beam energy of 3.6A MeV (figure 2). This kind of reaction is believed to be the best tool for studying two-nucleon correlation in nuclei. ISAC-II delivered a stable ^{11}Li beam with an intensity of about 2000 ions/s to MAYA's active-target detector, in which isobutane gas of 150 mbar acts as both the proton target and tracking gas. A silicon-detector array and a caesium-iodide array within MAYA detected forward-going, high-energy particles that left the gas detection area. The active target provides almost 4π detection of the reaction, the thickest usable target, and an efficient detection of low-energy recoil particles. The experiment was performed by a collaboration between GANIL, the Argonne National Laboratory and TRIUMF.

Later in 2007, the TRIUMF-ISAC Gamma-Ray Escape Suppressed Spectrometer (TIGRESS) augmented by the auxiliary charged-particle detector BAMBINO was used at ISAC-II to measure the electromagnetic properties of low-lying states in the neutron-rich unstable nucleus ^{29}Na using the Coulomb-excitation technique. TIGRESS is a next generation array of high-energy-resolution, position-sensitive gamma-ray spectrometers (figure 3). BAMBINO is a segmented-silicon detector array, built by Lawrence Livermore National Laboratory (LLNL) and the University of Rochester. A team of scientists from TRIUMF, LLNL, the University of Guelph and 12 other institutions in Canada, the UK, and the US, collaborated on this measurement and were led by Ching-Yen Wu of LLNL.

For this experiment, minimizing the isobar contamination in the main exotic beam is a major challenge for the beam-delivery group. At the full capacity, up to 600 ^{29}Na ions per second were delivered at 70 MeV on a ^{110}Pd target. The magnitude of the electromagnetic transition rate for the first excited state in ^{29}Na, determined from this measurement, sheds light on the quenching of magic numbers in nuclei, which is crucial to our understanding of the effective nucleon–nucleon interaction in nuclear medium with extreme isospin. The final results will complement ongoing studies of similarly exotic systems such as ^{11}Li and provide insight into the production of heavy elements in exploding stars. Project leader Carl Svensson of the University of Guelph was recently awarded the prestigious EWR Steacie Memorial Fellowship of the Natural Sciences and Engineering Research Council of Canada for his work on TIGRESS.

After the first season of success, TRIUMF is eager to press further forward. It plans to add a complementary electron driver to the ISAC programme as well as a new beamline for protons on an actinide target, which is currently being developed. The nuclear-physics renaissance is in full swing.

Résumé

TRIUMF accélère la recherche sur les radioéléments exotiques

Pour explorer les richesses des noyaux, TRIUMF a conçu, construit et mis en service la seconde version de son installation ISAC (Isotope Separator and Accelerator – ISAC-II), avec le soutien du Gouvernement du Canada et de la Province de Colombie britannique. La nouvelle installation comprend un accélérateur linéaire supraconducteur visant à augmenter l'énergie des isotopes lourds exotiques au-dessus de la barrière de Coulomb. La ligne de faisceau supraconductrice ajoute 20 MV de tension d'accélération à l'actuelle chaîne d'accélérateurs ISAC. Les chercheurs sont impatients d'utiliser ces nouveaux faisceaux et les premiers à en bénéficier sont ceux qui étudient les noyaux riches en neutrons.

Timothy Meyer *and* **Marcello Pavan**, *TRIUMF.*

ALICE joins jet set

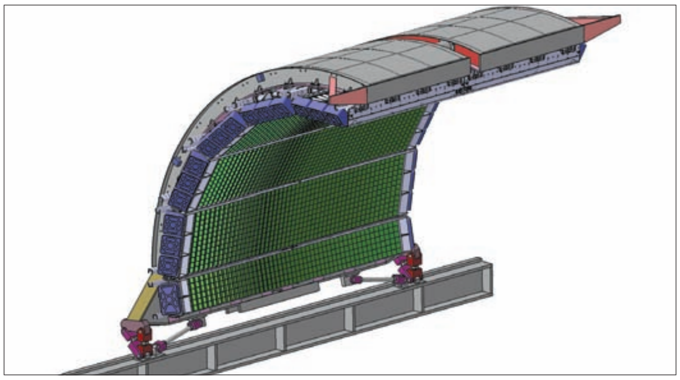
To study how high-energy particle jets interact in quark–gluon plasma, the ALICE collaboration is building a large electromagnetic calorimeter to be ready when the LHC runs with lead irons.

The best-known goal of the LHC is the exploration of the "energy frontier", using proton collisions at unprecedented beam energy and luminosity. Equally ground-breaking, the LHC will also explore the "energy density frontier" via the collision of lead nuclei at 5.5 TeV per nucleon pair. This is 30 times the collision energy of the Relativistic Heavy Ion Collider (RHIC) at Brookhaven, which is currently the world's highest-energy nuclear accelerator. The LHC will thus extend the study of the quark–gluon plasma (QGP) and phase transitions of the strong interaction into a qualitatively new regime of temperature and density.

One of the most striking results to emerge from RHIC is the discovery of "jet quenching" (*CERN Courier* September 2003 p18). Jets are the remnants of hard scattered quarks and gluons from the collision. They are collimated sprays of stable particles (pions, kaons and the like) that occur in all types of high-energy collisions. Jets are fundamental to QCD, the underlying theory of the strong interaction, and were clearly identified for the first time by the UA1 and UA2 experiments at the Sp$\bar{p}$S collider at CERN in the early 1980s. Heavy-ion collisions bring a new aspect to jet studies, because the hard scattering occurs in the midst of the hot QGP fireball. Consequently, the jet must plough through the plasma, interacting with it and losing energy, before emerging into vacuum and "fragmenting" into the stable particles seen in the detector. The process of energy loss in the plasma, known as jet quenching, modifies strongly the jet structure that is seen in proton–proton collisions. Such modifications can be calculated theoretically using perturbative QCD (pQCD), and a comparison of these calculations and jet measurements in nuclear collisions has provided an invaluable tool for looking into the early moments in the life of the QGP.

Soon after teams at the RHIC announced the initial results on jet quenching, researchers in Europe and the US began to explore ways to make similar measurements at ALICE, the only LHC detector expressly designed for high performance in the fearsome environment of high-energy nuclear collisions, where a single lead–lead collision can generate some 50 000 individual particles. The ALICE detector will measure a range of signals from the QGP, but its baseline design did not include a large-area calorimeter, which is essential for the study of jet quenching. However, the designers of ALICE had the foresight to reserve space for a calorimeter to be added as an important complement.

Detector requirements for jet quenching differ from those for more familiar measurements in high-energy physics, where hermetic calorimetric coverage is needed. The jet quenching signal lies in the modification of the distribution of particles within each jet, and this requires the sophisticated charged-particle tracking and particle identification capabilities that are specialities of ALICE. A large electromagnetic calorimeter (EMCal) would provide ALICE with a fast trigger for high-energy jets, together with a measurement of neutral particles in the jets (primarily neutral pions), which are not seen by ALICE's charged-particle tracking system.

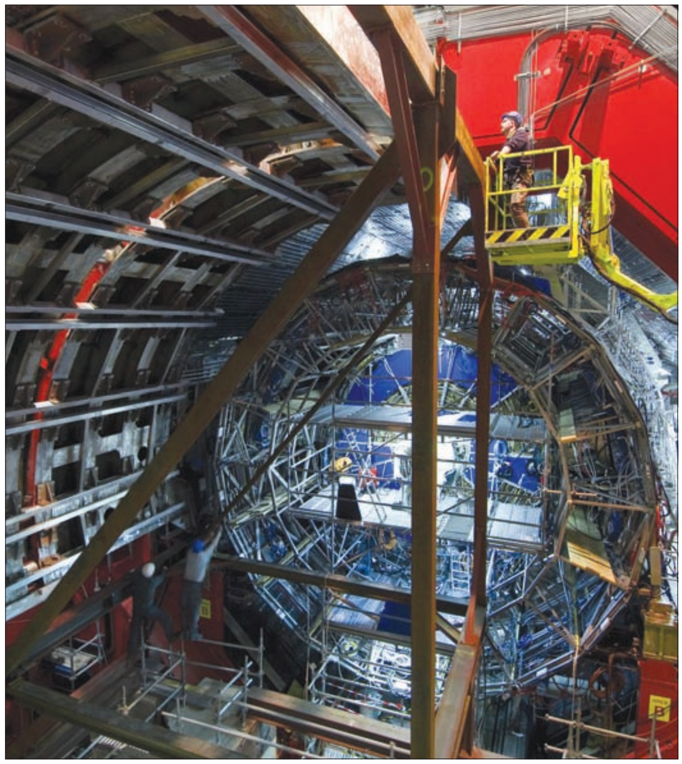


Engineering drawing of the EMCal with its mechanical support structure (grey) and electronics read-out (blue).

In 2005, US researchers interested in participating in the ALICE experiment requested funding from the US Department of Energy. They were then joined by groups from France and Italy, and in 2006 the international ALICE EMCal proposal was endorsed by the LHC committee. Funding is now in place on both sides of the Atlantic to complete the EMCal in time for the major lead–lead runs.

The ALICE EMCal is a lead-scintillator sampling calorimeter comprising almost 13 000 individual towers that are grouped into 11 "super modules" (SMs) for ease of handling and installation. The towers are read by wavelength-shifting optical fibres in a "shashlik" geometry, coupled to the same type of avalanche photodiode sensor that is used in the electromagnetic calorimeter in the CMS experiment at the LHC. The EMCal contains 100 000 individual scintillator tiles and 185 km of optical fibre, and it weighs about 100 tonnes. Three SMs will be constructed in Europe, with the remainder built in the US. As the SMs are completed they will be slipped into the EMCal support structure like cassettes. The support structure is a complex object: it weighs 20 tonnes and must support five times its own weight, with a maximum deflection of only a couple of centimetres.

The EMCal covers the full length of the ALICE time projection chamber and central detector and a third of its azimuth, and it is situated back-to-back with the smaller, highly granular lead tungstate calorimeter of the ALICE Photon Spectrometer. With the fast trigger provided by the EMCal, ALICE will measure jets in lead–lead and proton–proton collisions to energies well beyond 200 GeV, enabling a comprehensive set of measurements of jet quenching using ALICE's unique capabilities. ▷



Insertion of the EMCal support structure into ALICE, between the magnet (red) and the "space frame" that holds the time projection chamber and other detector elements. (Courtesy Mona Schweizer for CERN.)

Synchronization of this early upgrade with the ALICE construction and LHC operations schedule has been challenging. Much of the early work of the EMCal group focused on designing and building the mechanical support structure that had to be installed during the initial ALICE assembly (*CERN Courier* March 2008 p5). In addition, beam tests of mature prototypes at Fermilab, and at the SPS and PS at CERN, have verified the module performance. Attention is now turning to construction of the SMs, with the first modules available for installation in early 2009. The collaboration aims to complete the full detector in time for the LHC run in 2011 or if all goes smoothly, the run in 2010.

Résumé

Grâce à ses collisions d'ions plomb, le LHC permettra d'étendre

l'étude du plasma quarks-gluons à des températures et densités plus élevées. Le Collisionneur d'ions lourds relativistes (RHIC) de Brookhaven a déjà révélé que les « jets » de particules provenant de la diffusion des quarks et des gluons au cours de collisions d'ions lourds sont précieux pour étudier les premiers instants de la vie du plasma quarks-gluons. Les signaux essentiels interviennent lors de la modification de la distribution des particules dans chaque jet. Pour étudier ce phénomène, la Collaboration ALICE met actuellement au point un grand calorimètre électromagnétique, qui devrait être prêt pour l'exploitation du LHC avec des ions lourds.

Peter Jacobs, *Lawrence Berkeley National Laboratory, on behalf of the ALICE EMCal collaboration.*

ATLAS: where big w

The muon spectrometer of the ATLAS experiment at CERN is designed to be the largest a

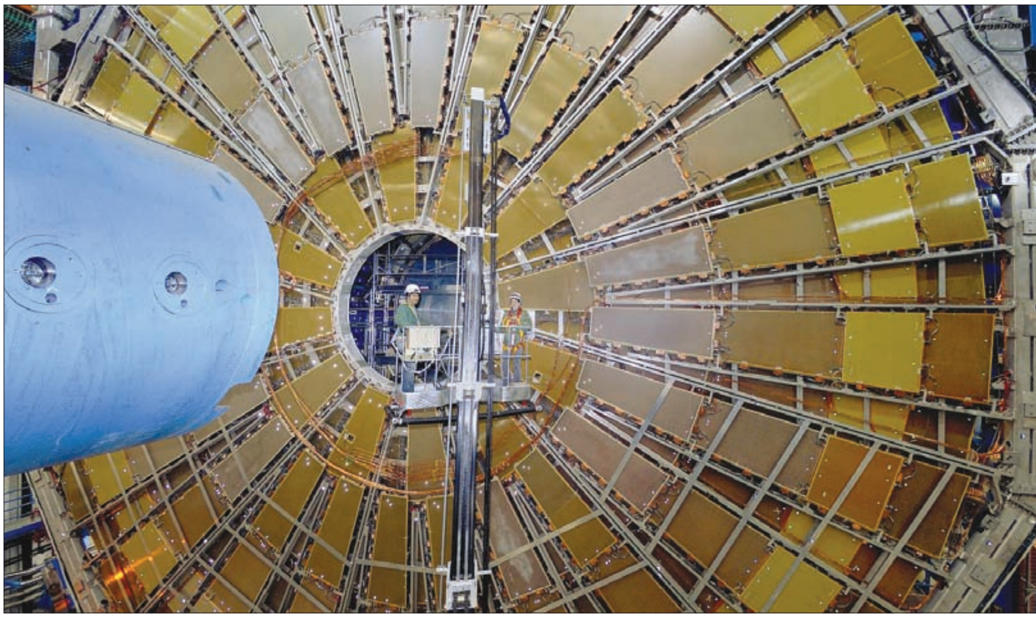


Fig. 1. (Left) Thin gap chambers (TGCs) form the electromagnetic pre-shower detector and hadron calorimeter in one of the endcaps at LEP. (Courtesy Keystone/Scie Photo Library/David Parker.) Fig. 2. (Right) In contrast to the OPAL endcap in figure 1, an ATLAS big wheel, containing TGCs, dwarfs the technician working at the cent

During the 1990s, visitors to the experiments at LEP were usually impressed by their size and complexity and, in particular, how different subsystems constructed in a variety of different countries could fit together. The LHC has now usurped LEP, and this impression has also been replaced by either a scream or complete silence, as visitors to the experiments are overwhelmed by the size and complexity. These differences can be clearly seen by comparing the same type of detector – thin gap chambers (TGCs) – as used for calorimetry and electron identification in the OPAL experiment at LEP (figure 1) with those used for the muon trigger in the ATLAS endcaps, in part of the system known as the ATLAS Big Wheels (figure 2).

The reason for this big change is that, while for the LEP experiments every collision was of interest, at the LHC only one collision in 10 million will be kept for further analysis. In particular, high-momentum muons constitute an important element in defining which events should be kept. For this reason the ATLAS Collaboration decided to construct a large muon spectrometer, based on superconducting air toroids, which allows the precise measurement of muon momenta down to small angles with respect to the proton beam direction.

The ATLAS muon wheels are a system of 10 movable and two fixed "wheels" of muon detectors grouped at three stations in each of the two endcaps of the ATLAS detector. The fixed wheels are outermost at each end, while the intermediate stations of big wheels are located just outside the endcap toroid magnet and the edges of the coils of the barrel toroid, and the inner stations of two small wheels lie between the endcap toroids and the calorimeter (figure 3).

Each intermediate station consists of four big wheels with a diameter of 25 m, which are formed from a number of sectors built using different types of muon chamber. The wheels can be moved longitudinally along the direction of the beamline in order to gain access to the central part of ATLAS for the purposes of installation and maintenance. At each end of the barrel, three wheels are used to trigger on high-momentum muons, while one wheel provides a measurement of their trajectories in the bending plane with a precision of a fraction of the width of a human hair. The construction of such large devices was too ambitious a project for a single institution or country, so international collaborations were formed within ATLAS that ran across countries, cultures and religions, and where motivation played a cohesive role.

There are almost 1500 trigger modules on the six trigger big wheels and these were built by a collaboration between China, Israel and Japan. They are formed from TGCs, which are read out in two dimensions through wires and strips. These detectors, based on the technology used in the OPAL experiment, are constructed from lightweight composite materials combined with four million gold-plated tungsten wires. Three custom-built laboratories were made available for their construction at Shandong University, KEK and the Weizmann Institute.

The TGCs are fast and accurate enough to provide a selective

vheels are really big

t and most accurate ever built. Huge wheels of muon chambers form the endcap system.

Science
centre.

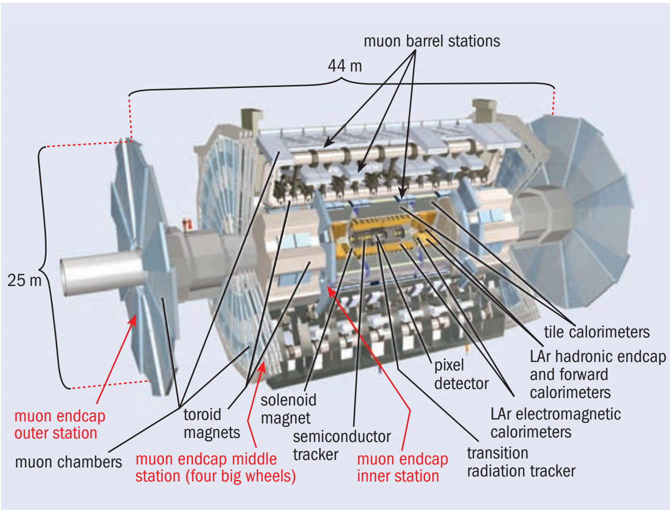


Fig. 3. Schematic of the ATLAS detector showing the positions of the three stations of muon detectors on the endcaps.

trigger, which combined with the trigger electronics designed and constructed in Japan, is capable of identifying muons with large transverse momentum and to associate them with a specific bunch crossing of the LHC, occurring at a frequency of 40 MHz. The measurement of muon tracks in the non-bending plane (along an approximately azimuthal direction) is necessary for the ultimate determination of muon momenta by the chambers in the precision wheel that accompanies each set of trigger wheels.

The TGC units underwent a long series of quality-control tests. In particular, every detector was scanned with cosmic muons in one of three different laboratories (Kobe, Technion and Tel Aviv) to ensure a high uniformity of response. The majority of the detectors were also exposed to a 3 kCi ^{60}Co source for half an hour, and finally, after transportation to CERN, they were operated for three weeks, to avoid early breakdown. This series of tests resulted in a failure rate of 1 in 1000 after the detectors were mounted on the frames. The two failed chambers were then replaced by spares.

The two precision big wheels are equipped with monitored drift tubes (MDTs), which are also present in all other stations in the endcap and in the barrel regions of the spectrometer. These detectors, developed and constructed for the ATLAS muon spectrometer by a collaboration of many institutes from Europe, Russia, the US and China, are based on drift tubes with a diameter of 3 cm and various lengths. The MDTs are arranged in two multilayers and operated at a pressure of 3 bar. They measure muon tracks with a precision of some 40 μm.

The accuracy of the spectrometer is fully exploited with a complex alignment system jointly designed and implemented by ▷

Fig. 4. Members of the Israeli, Japanese and Pakistani teams involved in assembly and integration of the TGC sectors for the trigger big wheels.

Fig. 5. Members of the US and Pakistani teams involved in the assembly and integration of the MDT sectors for the big wheels for precision tracking. (Courtesy ATLAS Collaboration.)

groups from France, Germany, Holland and the US. Optical devices mounted on all detectors and on reference components installed on each station of the spectrometer are capable of establishing the relative alignment of towers of detectors with a precision of about 40 μm. The system is used to correct for offsets from the nominal positions, and also for mechanical deformations induced in detectors and support structures by gravity, magnetic fields and temperature variations. These effects are small compared with the dimensions of the structures, but they may be significant on the scale of the precision of the detectors.

The 160 MDT chambers in the two precision big wheels were constructed in three production centres in the US. They are formed from a total of nearly 61 000 drift tubes, with lengths ranging from 0.8 m near the centre to 5.7 m near the outer boundary, where the largest chambers measure 1.9 × 6.0 m^2. The alignment system in the precision big wheels was constructed by a collaboration of US and German institutes, and it exploits eight calibrated bars installed on each wheel and equipped with optical devices.

All of the MDT chambers were the subject of an extensive series of tests before and after shipment to CERN, including checks of gas tightness, dark current and noise, followed by a full chamber scan using cosmic muons. The geometrical accuracy in the construction of the detectors was tested at the production sites by various methods, and by a direct measurement performed on a sample of chambers in a dedicated X-ray tomograph facility at CERN.

The assembly and commissioning of the 104 sectors forming the eight big wheels was a complex and intensive activity. This took place on the Meyrin site at CERN from spring 2005 to July 2007. The relatively light support structures were designed at CERN, following an initial study carried out in Russia, and they were manufactured in Israel and Russia. The assembly was performed in four working areas, and several teams contributed to the different tasks of mechanical assembly (teams from Pakistan, using assembly jigs that had been manufactured in Pakistan, together with a team from Israel), installation of services and detectors (teams from China/Israel and the US), tests of detectors and trigger electronics (Japan/Israel and the US), and engineering, survey, handling and general coordination (CERN, with the contribution of a team from JINR-Dubna). The tests performed covered all aspects of the detectors and their read-out and control systems, and they included the use of radioactive sources and cosmic rays. Out of a total of 430 000 TGC and MDT read-out channels, the number of non-operational channels was found to be at the level of a few in 10 000.

From July 2006 to September 2007, one by one the sectors were transported to Point 1 for installation in the ATLAS cavern. Sectors were then mounted against the end walls of the hall and connected to each other to form the wheels (figure 6). The mechanical accuracy of about 1 mm achieved in the construction of the sectors was essential for the smooth and fast assembly of the wheels, which was coordinated by engineers from CERN and performed by teams of the ATLAS Technical Coordination. Absolute positions of the various detectors were measured by the CERN surveying team, using photogrammetry, making it the first time that such methods had been used for such large surfaces. Alignment systems were available to confirm the assembly accuracy and the stability of the wheels when supported on two points and moved on rails. Moving the wheels was itself an exciting operation, dealing with flexible disks of about 30 tonnes in weight, 25 m diameter and as thin as 30 cm.

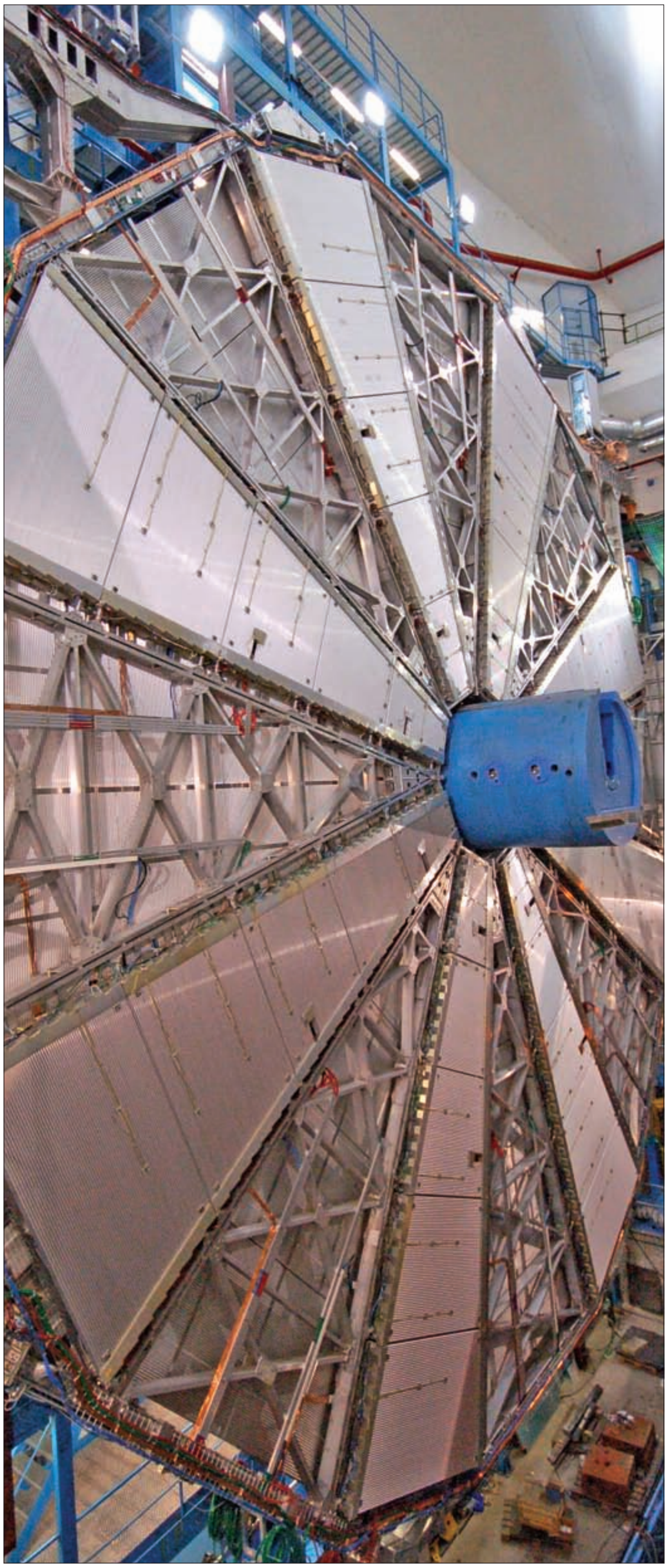


Fig. 6. The partially complete installation of MDT sectors in a big wheel for precision tracking. (Courtesy ATLAS Collaboration.)

Following installation the full commissioning of the big wheels has progressed well, with the connection of services and

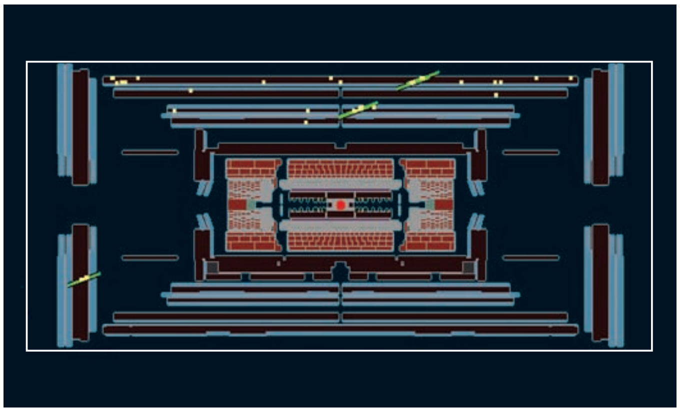


Fig. 7. Event display showing a cosmic ray crossing the barrel and endcap stations of the muon spectrometer, recorded during an ATLAS global commissioning run.

integration in the read-out and in the trigger systems being completed in spring 2008. Data from both trigger and precision chambers in the muon endcaps have been available in the combined cosmic runs of the muon spectrometer and ATLAS since summer 2007 (*CERN Courier* September 2007 p23). Figure 7 shows an example of a cosmic muon track recorded in the big wheels during one of the cosmic runs.

The endcap region of the ATLAS muon spectrometer has also been completed recently with the inner stations of small wheels (*CERN Courier* April 2008 p5). For the fixed wheels in the outer station, which consist of precision chambers, most of the detectors were present by December 2007. Final installation should soon be completed together with the beam-pipe and the shielding of the endcap region, as the ATLAS collaboration prepares for the first beams of the LHC.

Résumé

ATLAS: les grandes roues portent bien leur nom

Le spectromètre à muons de l'expérience ATLAS du CERN devrait être le plus grand et le plus précis jamais construit. Les bouchons comprennent huit grandes roues de 25 m de diamètre, formées de secteurs construits à partir de différents types de chambres à muons. À chaque extrémité, trois roues assurent le déclenchement lors du passage de muons à impulsion élevée et une roue mesure leur trajectoire avec une précision de l'ordre d'une fraction de la largeur d'un cheveu humain. Ce projet de construction de grande envergure ne pouvait être réalisé par une seule institution ou un seul pays. Des collaborations internationales, extrêmement diverses en termes de pays, cultures et religions, ont par conséquent été formées.

Giora Mikenberg, *Weizmann Institute, and* **Sandro Palestini**, *CERN, on behalf of the ATLAS collaboration.*

ADVERTISING FEATURE

CECOM Rome - Italy

CECOM was founded in 1964 in Rome by Cesare Ceracchi. Its growth was due to the prestigious collaboration between several organizations and companies, e.g. CERN, INFN, ENEA, several universities in Italy, Elettronica Spa and Avio Spa. Excellence, precision, quality, flexibility and frontier technology have made CECOM a leader in mechanics and UHV applications.

Since the early 1980s CECOM has divided its work between the fields of scientific research and civil–military/aeronautics. These applications have characterized CECOM's skills: the stringent requirements of aeronautic applications, in terms of performance, reliability, lifetime and quality assurance have been joined to the flexibility required by the research applications (development of prototypes, UHV requirements, special tests), thus improving CECOM's knowledge and abilities.

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In partnership we can manage other technologies – such as vacuum brazing, vacuum firing, EB welding, presswork, galvanic treatments, laser cutting, plasma cutting, sputtering, and the development of electrical systems – which are aimed at the commissioning of turnkey units.

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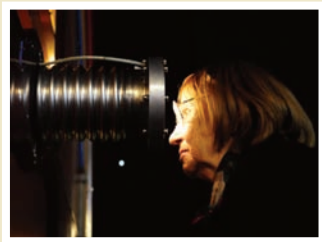
- INFN, ENEA, DIAMOND LIGHT SOURCE (beam stoppers, photon shutters, RF cavity, aluminium vacuum chamber, vacuum vessels and components).
- CELLS (bellows and vacuum chambers for the straight sections are in progress).
- CCRLC, CNR, DESY, ELETTRA.

For further information visit us in June at EPAC-08 in Genoa (booth n. 3&4), or see our website at **www.cecomweb.com.**








Impressions of the LHC 2008 open days

On 5 and 6 April crowds worthy of an international football championship final took advantage of the last opportunity to visit the LHC tunnel and the experiment caverns before the first injection of beams into the machine, scheduled for summer. A team of 15 photographers was on hand to record this record-breaking event.

The LHC tunnel.

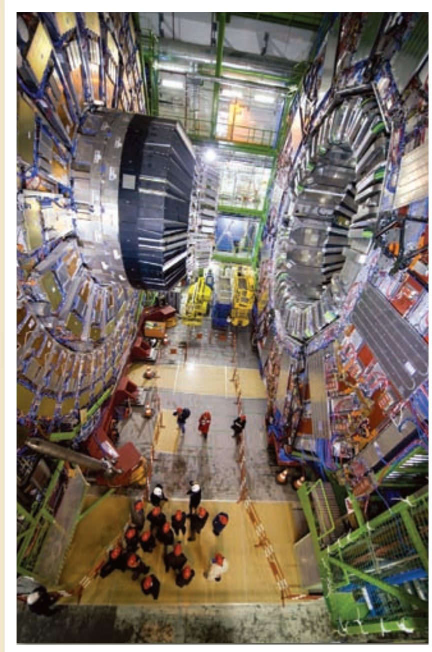
The ATLAS experiment.

The ALICE experiment.

The first visitors arrived long before the gates opened.

The LHCb experiment.

The Computer Centre.



The CMS experiment.

There were crowds and queues for all the activities throughout the day, including many children (see also Inside Story p58).

The magic of superconductivity and cryogenics attracted mainly children and families, including for certain some future scientists. The girl above preferred stepping off the levitating scooter, in order to understand its superconducting mechanism, to the simple pleasure of levitating in air. (Demonstration provided by MaNEP, University of Geneva.)

The presenter of the France3 science programme for children "C'est pas sorcier" toured the communes around the LHC ring to meet the public on board a CERN lorry carrying a dipole magnet. Children flocked to see him throughout the day. At the end of a busy day he said: "I am a proton, I feel as though I have toured the LHC ring at the speed of light!"

As partners in the open days, the town halls of the 11 communes situated around the LHC ring and access areas were officially welcomed in the Globe of Science and Innovation by CERN's director-general, Robert Aymar (top), after opening the visit points around the LHC on 5 April. Each of the communes received a section of a superconducting LHC dipole as a souvenir of the LHC 2008 open day event.

Among the star visitors, physics Nobel laureates Anthony Leggett (top) and Georg Bednorz gave lectures. They were impressed by the size of the world's largest superconducting installation as well as the crowds of young children asking them questions at their lectures during the day.

First evidence of Higgs at CERN! Peter Higgs (right) decided to visit CERN on the weekend of 5–6 April expecting a calm visit — not knowing an open day had been planned. Visiting on 5 April, with CERN personnel and families, he said he was "impressed by the scale of the LHC detectors".

As many as 1532 members of CERN personnel and the user community volunteered as guides, hostesses and first-aiders over the two days. Without their hard work and enthusiasm, the open days would not have been possible.

Open day statistics

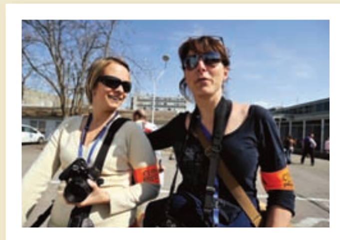
Visitors:
- 5 April (CERN personnel and family/friends): 23 000 of which 11 000 visited the tunnels (LHC + SPS).
- 6 April (general public): 53 000 of which 23 000 visited the tunnels (LHC + SPS).

Media:
- 56 media from 13 different countries with 85 journalists visiting on site, resulting in 200 press articles

Lectures:
- 53 lecturers (including two Nobel laureates), and 20 conference rooms running in parallel on the CERN site and in the communes around the LHC ring.

Website:
- 155 000 visits and 8 million hits in four months of the open day website, http://lhc2008.web.cern.ch/LHC2008/.

The CERN Fire Brigade, supported by local first aid associations (Samaritans and Croix Verte) deployed first-aiders and first aid stations at the various sites around LHC ring. Despite the huge numbers of people, no accidents were recorded, and the only visitors to the fire brigade came to see the old vehicles!



Max Brice (above left), the CERN photographer, led a team of 15 photographers recording the open day event, with Fabienne de Bruin, Marc Burkhalter, Sylvain Chapeland, Patricia Cini, Pierre Gildemyn, Michael Hoch, Pamela Jueni, Claudia Marcelloni, Martin Moojman, Mona Schweitzer, Mike Struik, Thierry Wenger, Denver Whittington and Patrick Wullschleger.

Visitors snapped up the chance to buy a piece of history: a keyring containing a piece of the LHC's superconducting cable.

Among the unusual jobs requested of the LHC site managers was the inflating of eight large helium balloons (4.5 m diameter), one per LHC site. Deflating them was by no means an easy task!

OPEN DAY SPONSORS

CERN would like to thank the following for their invaluable support: **Main Sponsors:** Air Liquide, Alstom Power, ASG Superconductors SpA, Babcock Noell GmbH, Ineo, Intel, Linde Kryotechnik AG, LUVATA, ORACLE, UBS. **Sponsors:** CECOM, Force10 Networks, La Mobilière, Peugeot Gerbier, Sun Microsystems (Suisse) SA, TRANSTEC Computer AG, Western Digital. **Associate Sponsors:** ACCEL, ArcelorMittal, BRUUN & SORENSEN, Carlson Wagonlit, Cegelec, Dell SA, E4 computer engineering S.p.A., EOS, Ernesto Malvestiti SPA, IBM, IEEE, Infortrend Europe Ltd., INIZIATIVE INDUSTRIALI SRL, Italkrane, Kaneka, La Tour Reseau de Soins, Migros, National Instruments, ProCurve Networking by HP, SERCO, Société Générale, Sunrise Communications AG, Super Micro Computer Inc., Xerox. **Supporters:** A+Z Bürosysteme GMBH, Carbagas, CES, ECHO Magazine, ETM, GATE Informatic SA, Plansee Metall GmbH, SIG, Thales. **Institutional Sponsors:** Camera di Commercio Italiana in Svizzera, Communauté de Communes du Pays de Gex, Commune de Meyrin. **Media Sponsors:** Le Temps, Radio Lac, Worldradio.ch. **Open Days Friends:** C'est pas sorcier, Crédit Agricole Centre-est, Collège du Léman, CNAO Foundation, European Scientific Institute, European Physical Society, European Synchrotron Radiation Facility, ETH Zurich, Fédération d'Improvisation Genevoise (FIG), Kodak, Materials with Novel Electronic Properties, Terapia con Radiazion Adroniche (TERA) Foundation, Université de Genève.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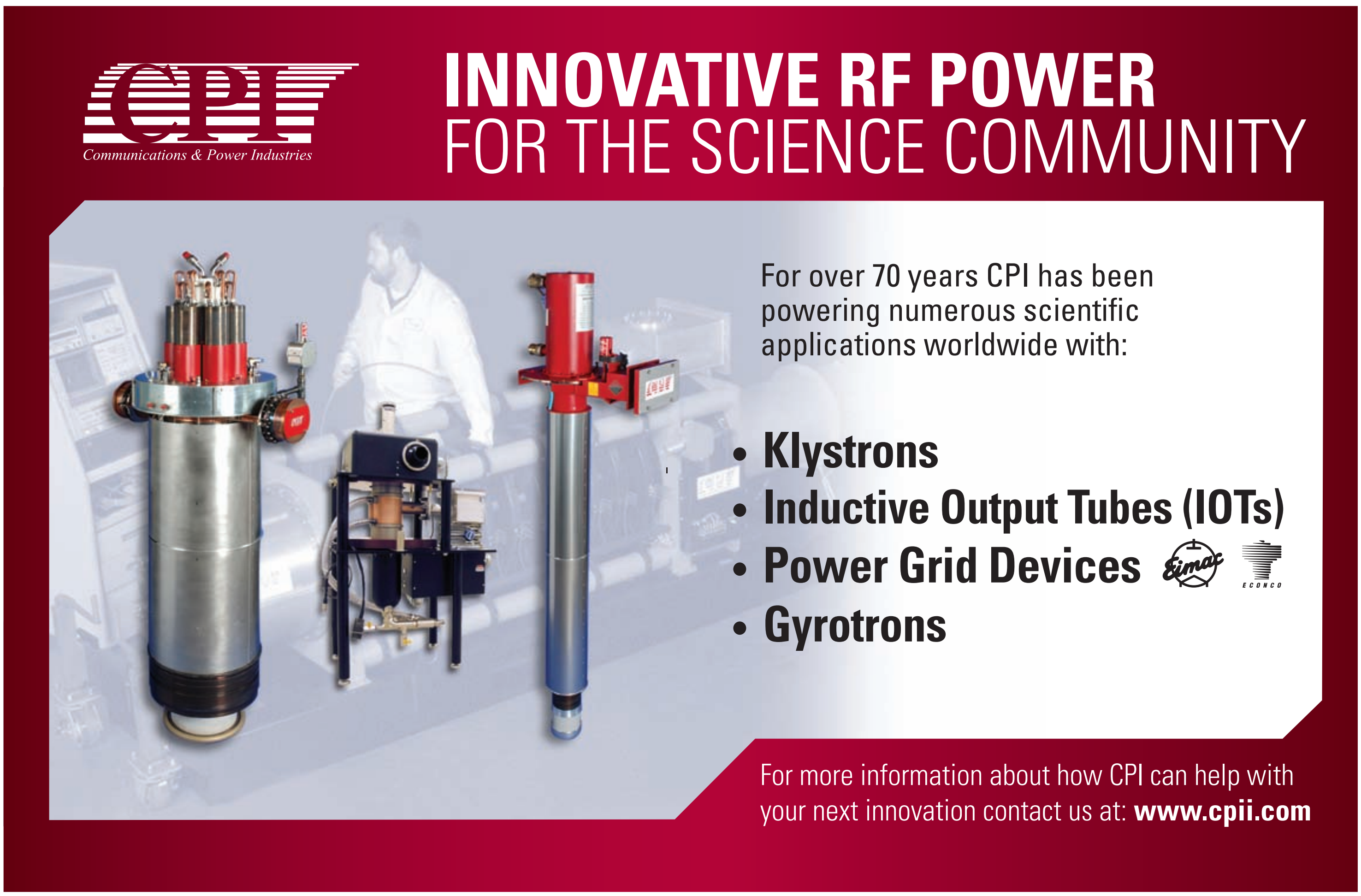
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APPOINTMENTS

Montgomery to take the helm at Jefferson Lab

Hugh Montgomery is to become director of the US Department of Energy's Thomas Jefferson National Accelerator Facility (Jefferson Lab). Currently the associate director for research at Fermilab, he begins his new duties on 2 September. He succeeds Christoph Leemann, director from 2000 and who announced his retirement in 2007.

Montgomery's career has been firmly grounded in particle physics, in particular with muon scattering experiments at CERN and Fermilab, and in the D0 experiment at Fermilab. He received his PhD from Manchester University in 1972, and served on the scientific staff of the Daresbury Nuclear Physics Laboratory and the Rutherford High Energy Laboratory until 1978. He then joined the staff at CERN, before moving to Fermilab in 1983. He became associate director at Fermilab in 2002, overseeing the particle physics and particle astrophysics research programmes at the laboratory.

"After almost 25 years at Fermilab, this move certainly represents a major change in my life," Montgomery commented on the news. "The new position will be an enormous challenge for me, but also an enormous opportunity to which I am looking forward."

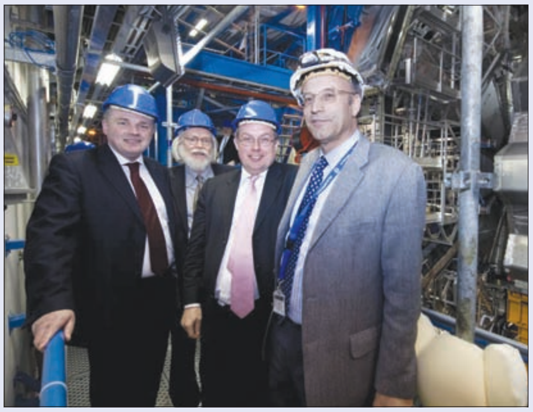
Montgomery will be only the third director in Jefferson Lab's 23-year-old history. He will also serve as president of Jefferson Science Associates, LLC, which is a joint venture between the Southeastern Universities Research Association and Computer Sciences Corporation Applied Technologies, created specifically to manage and operate Jefferson Lab for the scientific user community.

Hugh Montgomery. (Courtesy Jefferson Lab.)

VISITS

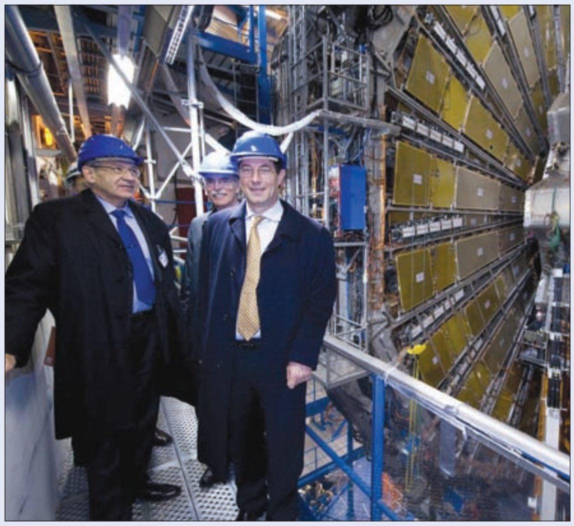
Lars Leijonborg, centre, the Swedish Minister for Higher Education and Research, was welcomed by CERN's chief scientific officer, **Jos Engelen**, left, and ATLAS spokesperson, **Peter Jenni**, on 10 March. The minister toured the control room, the ATLAS experiment and the LHC tunnel before meeting with Swedish staff at CERN.

Ian Pearson, UK Minister for Science and Innovation, left, made his first trip to CERN on 15 April. He toured the ATLAS experiment with CERN theorist, **John Ellis**, second on the left, UK ambassador **Simon Featherstone**, second on the right, and ATLAS spokesperson, **Peter Jenni**. He also visited the LHC tunnel, attended a presentation on the LHC Computing Grid Project and met with British scientists and journalists.



On 10 April UK Shadow Minister for Culture, **Ed Vaizey**, second from the left, toured the CMS experiment with **Peter Sharp**, CMS tracker project manager, left, **Tijinder Virdee**, CMS spokesperson, second on the right, and **Geoff Hall**, CMS physicist from Imperial College. The minister also toured the ATLAS experiment and met with British staff members, as well as theorist **John Ellis**.

On 2 April, the newly appointed Swiss State Secretary for Education and Research, **Mauro Dell'Ambrogio**, right, Swiss Secretariat for Education and Research, **Emmanuel Jenni**, left, and Diplomatic Counsellor, **Jean-Pierre Ruder**, were welcomed to CERN by ATLAS spokesperson, **Peter Jenni**. They toured the ATLAS experiment and the adjoining LHC tunnel before attending presentations by Swiss students working on the CMS and LHCb experiments



AWARDS

New South Wales honours Fritzsch with Dirac Medal

Harald Fritzsch has been awarded the Dirac Medal of the University of New South Wales. Fritzsch, who is Sommerfeld Professor of Physics at the University of Munich, Germany, received the medal at the University of New South Wales, Australia, on 15 April, when he also gave the Dirac Lecture 2008, talking on the Fundamental Constants in Physics. Previous Dirac medal winners and lecturers include Nobel Laureates Robert Hofstadter, Carlo Rubbia and Kenneth Wilson.

Fritzsch has received the honour for his work on the theory of QCD with Murray Gell-Mann from Caltech. The two physicists began a lifelong collaboration while Fritzsch was still a graduate student in Germany. In 1972 they wrote the first paper on the gauge theory of strong interactions, which they later named quantum chromodynamics, or QCD. For the past 35 years Fritzsch has continued to work on this theory and has investigated many of its features, including scaling violations and the spin problem.

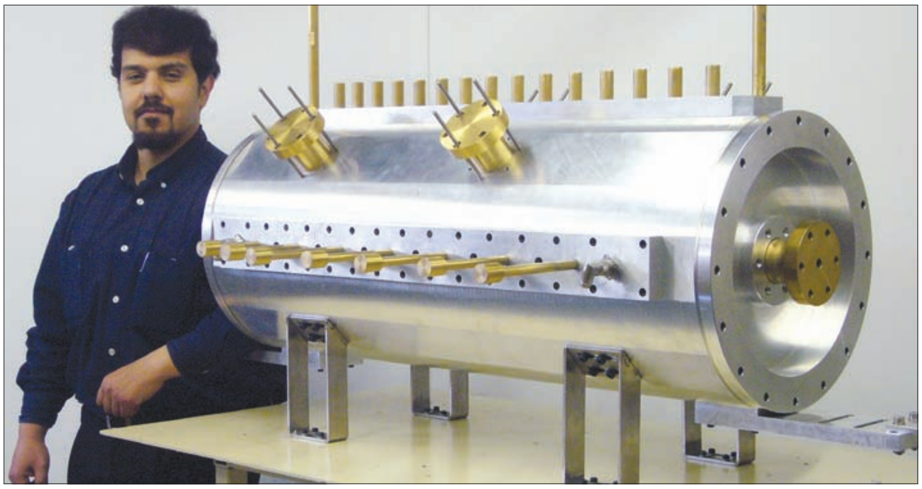
Harald Fritzsch. (Courtesy UNSW.)

The Silver Dirac Medal for the Advancement of Theoretical Physics is awarded by the University of New South Wales on the occasion of the Public Dirac Lecture. The lecture and the medal commemorate the visit to the university in 1975 of Paul Dirac, when he gave a series of five lectures that were subsequently published as *Directions of Physics*. Dirac donated the royalties from this book to the university, for the establishment of the Dirac Lecture series.

ACCELERATORS

Saudi student designs protype accelerating structure for Linac4

In January 2006 Saudi Arabia and CERN signed a co-operation agreement that provided young Saudi scientists with the opportunity to participate in the multi-lateral fundamental research effort that is such an important feature of the organization. Some months before the actual signature Nader Alharbi became the first person from Saudi Arabia to work at CERN, in research for his doctoral thesis. Now his efforts are bearing fruit, as CERN has received a model designed by Alharbi that is being used to verify the design of the Drift Tube Linac (DTL) for the recently approved Linac4 project. The model is the first prototype accelerating structure designed and built in an Arabic country.



Nader Alharbi and the "cold" (low-level RF power) model built in Saudi Arabia. (Courtesy F Gerigk.)

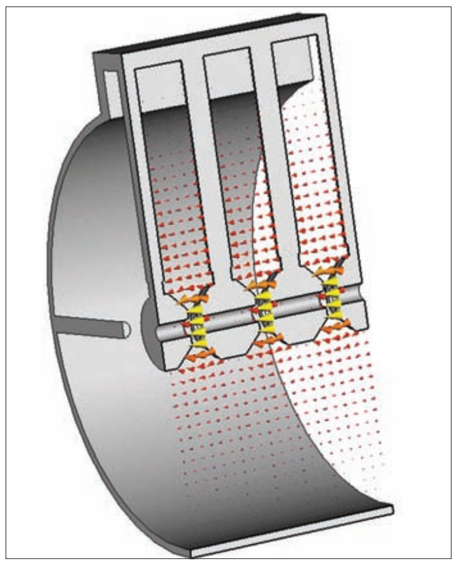
Linac4 is a new 160 MeV proton linac for CERN, which will replace and improve on the ageing Linac2 (50 MeV). The construction of Linac4 starts this year, with regular operation foreseen for 2013. It is the first step in the proton-injector upgrade required for the planned luminosity upgrade of the LHC. The DTL, which accelerates protons from 3 to 50 MeV, is one of four different accelerating structures used in Linac4. Even though the principle of the DTL is well established – the first DTLs began operation more than 60 years ago – the mechanical construction and the tuning process remain one of the most challenging areas for Linac4, especially as it is designed for a high average duty cycle.

Late in 2006 CERN agreed with HRH Turki Al-Saud, vice president of the King Abdulaziz City for Science and Technology (KASCT) in Riyadh, that Alharbi would design a low-power model of the DTL for Linac4 (*CERN Courier* March 2007 p38). The model was subsequently constructed in Saudi Arabia and recently delivered to CERN for measurements.

The DTL for Linac4 is of the classic Alvarez type, meaning that the structure is operated in the so-called 0-mode. This is the lowest resonating RF mode of the DTL cavity, which provides an electric field of equal phase (0-mode: 0 degree phase difference between the gaps) in all accelerating gaps, as the figure shows. In order to stabilize the electric field a second chain of resonators is added to the DTL, consisting of a series of posts (post-couplers) having a specific length, diameter and distance to the drift tubes.

Alharbi first simulated the experimental set-up with a 3D electromagnetic code, which indicated that stabilization should be possible. In past projects, owing to the complexity of the geometry, the stabilization could only be tested experimentally since neither the software nor the computer power were up to the task. The DTL for Linac4 was one of the first accelerators where a promising prediction was made via 3D simulations. In the second stage, Alharbi designed a so-called "cold model" (cold, because only low-level RF power is used) to test whether stabilization with post couplers is also feasible in a "hands-on" model. The mechanical design that Alharbi conceived allows for an easy exchange of the drift tubes and tests of different drift tube geometries with the same resonator.

Alharbi's drawings were then transferred to Saudi Arabia, where he closely followed the construction of the model at Alfanar, a subcontractor of KASCT. After delivery to CERN, the model confirmed the simulations and thus validated the design approach for the Linac4 DTL. As a result field stabilization for the Linac4 DTL will be based on Alharbi's simulations, verified with the prototype from Saudi Arabia.



Three gaps of the DTL showing the electric fields in the accelerating regions between the drift tubes.

OBITUARIES

Vincent Lepeltier 1942–2008

Vincent Lepeltier, Laboratoire de l'Accélérateur Linéaire (LAL), Orsay, suddenly passed away on 17 March 2008, a few days after the meeting of the Global Design Effort for an International Linear Collider (ILC) in Sendai, Japan.

Vincent was a world expert in gaseous detectors, especially time projection chambers (TPCs), for more than 20 years. Starting in the 1980s, he worked on all aspects of the TPC for the DELPHI experiment at LEP, and especially on its drift-velocity monitoring, which was crucial for obtaining a good longitudinal resolution. Then in 1996, after a successful participation in the FFTB experiment at SLAC in the early 1990s, he moved on to lead the small LAL–LBNL–Cincinnati group that designed and built the miniTPC for the commissioning of the PEP-II collider at SLAC. He found much pleasure in working on this cheap and robust 20 cm-long chamber, which was built to understand and monitor the background produced in the early days of PEP-II running. This chamber benefited from all of Vincent's DELPHI experience, but also had several innovative features, such as an original, slanted pad design. It performed so well that, when PEP-II commissioning was over, people from the Brookhaven National Laboratory

Vincent Lepeltier. (Courtesy LAL)

asked Vincent to bring the chamber close to the STAR detector, and so the chamber also helped to commission RHIC.

This experience of building large and small TPCs naturally led Vincent to work for the ILC TPC. The ILC is a very demanding environment for a TPC since extremely good spatial resolution is required over long drift distances. The two-track separation also has to be much better than achieved in LEP detectors. Vincent, together with his colleagues from Orsay and Saclay, proved that these problems can be solved using gaseous microdetectors, such as Micromegas, as TPC endplates. They built a series of successful prototypes, forming the TPC baseline for the ILC.

Vincent was a valued colleague and a good friend and we will miss both his professional and humane qualities very much. His constant smile, good humour and great kindness will always be remembered, as will his enthusiasm, which was so apparent during the last conversation I had with him in Sendai where we discussed his future plans concerning ILC. Vincent had an attractive personality and made many good friends in our community, as testified by the very large number of sympathy messages received from all over the world, which have been passed on to his wife and three children.

One of Vincent's best friends and colleagues was Mike Ronan who unfortunately passed away in 2006 (*CERN Courier* October 2007 p42). Perhaps Vincent and Mike have been able to meet and if so, they are sure to be discussing again the design of the ILC TPC. The best way that we can honour Vincent's memory is by trying to build the ILC in a timely way and to use, as one of its central detectors, a superb TPC that he would have loved to work with. It is a challenge but we owe it to Vincent to succeed.

Guy Wormser, Laboratoire de l'Accélérateur Linéaire.

MEETINGS

The **4th Patras Workshop on Axions, WIMPs and WISPs** will be held at DESY in Hamburg on 18–21 June. The workshop will address the physics case for these particles beyond the Standard Model and review collider as well as astrophysics experiments. New laboratory experiments searching for WIMPs, sub-eV axion-like particles and other WISPs will be discussed. Another focus will lie on recent theoretical developments concerning the extension of the Standard Model towards lowest energies. For further information, see http://axion-wimp.desy.de.

EUROEM 2008: European Electromagnetics will take place on 21–25 July at EPFL Lausanne, Switzerland. It provides a forum within the international scientific and engineering community for electromagnetics. It brings together the 16th High Power Electromagnetics Conference, the 9th Ultra-Wideband, Short-Pulse Electromagnetics Conference and the 9th Unexploded Ordnance Detection and Range Remediation Conference. For further information, see http://www.euroem.org.

The **20th International Symposium on Very High Energy Cosmic Ray Interactions (ISVHECRI)** will be held in Paris (University Paris-Diderot), France, 1–6 September. The symposium will be focused on very high energy (VHE) hadron collisions in the LHC energy range and the problems of the extrapolation at ultra-high energy (UHE).

The main topics will cover accelerator data and hadronic interactions, models and theories, emulsion chamber experiments, UHE cosmic rays, exotic phenomena, dark matter, VHE cosmic rays,air shower secondaries, origin of cosmic rays, and gamma/neutrino astrophysics. For further information, see www.apc.univ-paris7.fr/ISVHECRI2008/.

The **10th International Workshop on Tau Lepton Physics** will be held on 22–25 September at the Budker Institute of Nuclear Physics, Novosibirsk, Russia. The workshop will focus on the recent progress in tau lepton and neutrino physics. There will be no parallel sessions. Invited and

Beate Naroska 1943–2008

Beate Naroska, particle physicist, prominent scientist, engaging teacher and an enthusiastic mentor for many young researchers, passed away on 17 February this year.

After studying physics at Göttingen, Beate obtained her diploma and PhD from the University of Hamburg with the measurement of photoproduction on protons and nuclei, in work performed in the group of Martin Teucher using DESY's bubble and streamer chambers. At HERA, 30 years later, she was able to extend these measurements to much higher energies.

From 1971 to 1978 she worked at CERN's Intersecting Storage Rings in Carlo Rubbia's group. She concentrated on the high-energy features of proton–proton scattering, in particular on soft diffraction, and worked on the development of multiwire proportional chambers with two-dimensional readout by charge division and timing.

In 1978 she returned to DESY and joined the JADE experiment shortly before the e^+e^- collider, PETRA, started operation. She took responsibility for the time-of-flight (ToF) system that was needed to suppress the cosmic-ray background and led the project to perfection. The ToF system, together with JADE's large muon chambers, allowed her to make a precision measurement of the forward–backward asymmetry of μ-pair production that pointed to a large Z-mass, well before the direct-mass measurement at

Beate Naroska. (Courtesy J Meyer.)

the $Sp\bar{p}S$. By the mid-1980s PETRA achieved centre-of-mass energies close to 50 GeV and the asymmetry measurements were extended to τ- and b-production. They confirmed electroweak theory beautifully and proved that the b-quark is a member of a doublet. Thus it was clear: the top-quark had to exist.

Beate summarized the main physics results from the PETRA collider in the paper "e^+e^- Physics with the JADE Detector at PETRA", published in *Physics Reports* (B Naroska 1987 *Phys Rep* **148** 67). This was accepted as habilitation thesis at the University of Hamburg, where she became professor for experimental physics in 1989. She was an enthusiastic and dedicated teacher, putting high demands on her students, and attracted many of them to make their diploma- and PhD-theses in her group.

At HERA Beate was one of the leading scientists of the H1 collaboration. She concentrated on the study of the strong force using heavy quark production. Her preferred experimental tool remained the lepton tag, be it for J/Ψ- and Υ-production or for open charm and beauty tagging. She authored numerous publications on the photo- and electro-production of vector mesons and heavy quarks as well as on the charm structure function of the proton.

In 2000 she spent a sabbatical semester at CERN on the HARP experiment and contributed to the precise measurement of particle production cross-sections with high relevance for neutrino beams. She has been instrumental in starting Hamburg University's participation in the OPERA experiment at Gran Sasso that uses the CERN Neutrinos to Gran Sasso beam.

Beate served on numerous advisory committees, such as the DESY Scientific Council until 2007, the Funding Committee for Particle Physics of the German Ministry of Science, and the Selection Committee of the Alexander von Humboldt Foundation.

Her untimely death was a very sad event and a great loss to many of us who will miss a dear friend.

Her friends and colleagues at Hamburg.

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contributed talks will be presented at the plenary sessions. It will be followed on 26–27 September by a two-day meeting on the Super–tau–charm factory. For more information, see http://tau08.inp.nsk.su; or contact Anton Poluektov; fax +7 383 330 7163; or e-mail tau08@inp.nsk.su.

The next **Crimean Conference on New Trends in High-Energy Physics** (experiment, phenomenology and theory), will be held in Yalta, Crimea, on 27 September–4 October. Co-organized by the Bogolyubov Institute for Theoretical Physics and the Joint Institute for Nuclear Research, the conference will cover topics ranging from new physics at the LHC to applied nuclear physics. For further information, see http://crimea.bitp.kiev.ua. Applications should be sent to: Crimean Conference, BITP, Kiev-143, 03680 Ukraine; e-mail crimea@bitp.kiev.ua; fax: +38544 5265998.

The **International Conference on Particle Physics: In memorium of Engin Arik and her colleagues** will be held at Bogazici University, Instanbul, Turkey, on 27–31 October. The meeting, which is in honour of the physicists who died in the Turkish plane accident in November 2007, will cover LHC physics, neutrinos and dark matter, accelerator physics and spin physics. The deadline for abstracts is 15 July. For further information, see http://icpp-istanbul.boun.edu.tr.

The **11th Topical Seminar on Innovative Particle and Radiation Detectors** will take place at the University of Siena, Italy, on 1–4 October 2008. Attendance will be by invitation: interested physicists should write to the organizing committee, indicating name, address, affiliation and, if applicable, the title of a contribution. The deadline for submitting an abstract is 15 July. A limited number of grants covering the conference fees are available for young PhD students wishing to attend the conference. For further information, see http://www.bo.infn.it/sminiato/siena08.html.

LETTERS

Appropriate credit
The *News* section of the January/February 2008 issue contains an article describing our results on the two-proton radioactivity of ^{45}Fe, obtained with the optical time projection chamber (OTPC). Unfortunately some important information, which may be particularly interesting to *CERN Courier* readers, was not given. The credit for developing and building the novel OTPC goes to Wojciech Dominik and his co-workers in the High Energy Physics Group at the University of Warsaw, Poland. Dominik mastered the techniques of particle detectors while working at CERN in the 1980s. Indeed, the basic idea of detecting tracks of particles by recording light with a CCD device was conceived at CERN, and Dominik was co-author of a pioneering paper on this work (G Charpak *et al*. 1988 *Nucl. Inst. Meth.* **A269** 237). Currently, we are developing a new version of the OPTC with an application of gas electron multiplier foils. For this endeavour, collaboration with the CERN Gas Detector Group led by Leszek Ropelewski has been crucial.
Marek Pfutzner, University of Warsaw.

Observing the Chudakov effect
I read with interest about the symposium celebrating the centenary of the birth of an outstanding Polish physicist, Marian Miesowicz (*CERN Courier* April 2008 p34). It stated that Miesowicz was the first person to demonstrate experimentally the so-called Chudakov effect (the "charge suppression" of the ionization near the origin of high-energy electron–positron pairs). In fact, I was the author of the first publication on the matter (D H Perkins 1955 *Phil Mag* **46** 1146). Following a suggestion by a colleague, David King, I measured a total of seven pairs of mean energy 150 GeV and three of mean energy 2.5 TeV, found in cosmic rays and clearly showing an effect and its energy dependence. At the time, I had not heard of Chudakov nor of his prediction (A E Chudakov 1955 *Izv. Akad. Nauk.*USSR **XIX** 651). Just as with the positron, the effect was indeed discovered by experiment, untrammeled by theoretical prejudice!

I did discuss my findings with Dick Dalitz, on one of his visits to Bristol from Birmingham, and his theory student Hugh Burkhardt wrote his thesis on the subject (H Burkhardt 1958 *Nuov.Cim.* **9** 375). J Iwadare, as well as I Mito, H Ezawa, and G Yekutieli also published theoretical papers on the process.

The experimental results of the Cracow group were published one year after mine (W Wolter and M Miesowicz 1956 *Nuov. Cim.* **4** 648). They corroborated my findings and their results were more detailed and comprehensive than mine. It may also be of interest to remark that in QCD, there can be an analogous process of colour charge suppression in high-energy hadronic collisions.
Don Perkins, Oxford.

NEW PRODUCTS

AMS Technologies has announced that SDS HV has expanded its range of miniature HV modules, with the DA, DE and APD series. Owing to their pulse discharge ability they are suitable for applications such as photomultipliers and hybrid photon detectors. The modules provide 0–6 kV and power output up to 6 A with input voltage of 5–24 V. AMS also now provides liquid level sensors from Cynergy3 Components Ltd, available in a variety of materials, and suitable for temperatures up to 180 °C. For more information, tel +49 89 89 5770; or e-mail salesinfo@ams.de.

Maxon Motor AG has launched a new intelligent positioning controller in the EPOS family. The EPOS2 is designed to control brush and brushless DC motors with encoder. Using 32-bit digital signal processor technology, it can carry out complex mathematical algorithms efficiently. Online commands can be made using CAN Master or a PC via USB or RS232 interface. For further information, tel +41 666 1500; fax +41 666 1650; e-mail info@maxonmotor.com or see www.maxonmotor.com.

Megatech has introduced the PTI-90, a lightweight, portable, infrared thermal-imaging camera. The camera records images using a laser pointer to provide easy association between the image and the target. It incorporates a high-resolution LCD display and viewfinder, and a microbolometer detector for accurate temperature measurement over a range of –20 to 2000 °C. For further information contact Peter White, tel +44 1543 500044; or e-mail peterw@megatechlimited.co.uk

Pfeiffer Vacuum has developed a line of rotary vane pumps, the PentaLine, for use in the low to medium vacuum range down to 10^{-3} mbar. The new pumps have speeds of up to 35 m^3/h, and use only 50% of the power of conventional rotary vane pumps. Another new series is the HiPace line of compact, powerful turbopumps, with speeds ranging from 10-700 l/s. The improved rotor design gives very good compression for light gases. For more details, see www.pfieffer-vacuum.net.

PI (Phyik Instrumente) LP has announced a new miniature ceramic motor, the P-653 piezo liner motor slide. Only 8 mm long, it offers a travel range of 2 mm and sub-micron resolution. Motion is controlled by TTL pulses applied to the driver electronics. The devices are ideal for applications where quantities are high and space is at a premium. For further information, see www.pi-usa.us; or e-mail info@pi-usa.us.

Specialized Imaging Ltd has introduced the SIM-D ultrafast framing camera, a new compact system that combines easy use and maintenance with high performance. Features include an optical periscope for focus adjustment, comprehensive triggering facilities, accurate timing control, a wide range of output signals and full remote control via Ethernet. For more details, tel +44 1442 827728; fax +44 1442 827830; e-mail info@specialized-imaging.com; or visit www.specialized-imaging.com.

CORRECTION

The Sciencewatch article on paper capacitors ("Paper becomes a supercapacitor and power source") featured in the November 2007 issue of *CERN Courier*, mistakenly claimed that the Rensselaer Polytechnic Institute is located in Troy, New Jersey, US. It is of course located in Troy, New York, US.

DITANET

Open Positions at the Marie Curie Initial Training Network DITANET

DITANET aims for developing beyond-state-of-the-art diagnostic techniques for accelerator facilities and to train young researchers within a European network between several major research centers, leading Universities, and partners from industry.

DITANET covers a wide range of multi-disciplinary topics such as

– beam profile measurements of ion and electron beams,
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– high-resolution beam position measurements.

DITANET is currently aiming to recruit a pool of talented, energetic, strongly motivated, young scientists with a degree in physics or a closely related field at both the Early Stage Researcher (17) and Experienced Researcher (3) level. Women are especially encouraged to apply.

Each researcher will benefit from a wide ranging training program that will take advantage of both local and network-wide activities, as well as of schools, conferences, and workshops. Most positions are for starting on August, 1st 2008 or soon thereafter.

You will find more information about DITANET and the application details at: http://www.ditanet.uni-hd.de

Contact and further detail:
Dr. Carsten P. Welsch
Kirchhoff Institute for Physics, University of Heidelberg, Im Neuenheimer Feld 227, D-69120 Heidelberg
carsten.welsch@kip.uni-heidelberg.de

The ESRF (European Synchrotron Radiation Facility) is a multinational research institute, employing 600 staff, located in Grenoble. The ESRF is financed by 18 countries and carries out fundamental and applied research with synchrotron (X-ray) light.

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For further information, please consult:
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Interested candidates may send a fax (+33 (0)4 76 88 24 60) or e-mail (recruitm@esrf.fr) with their address, to receive an application form, which can also be printed from the web. Deadline for applications: 18 August 2008.

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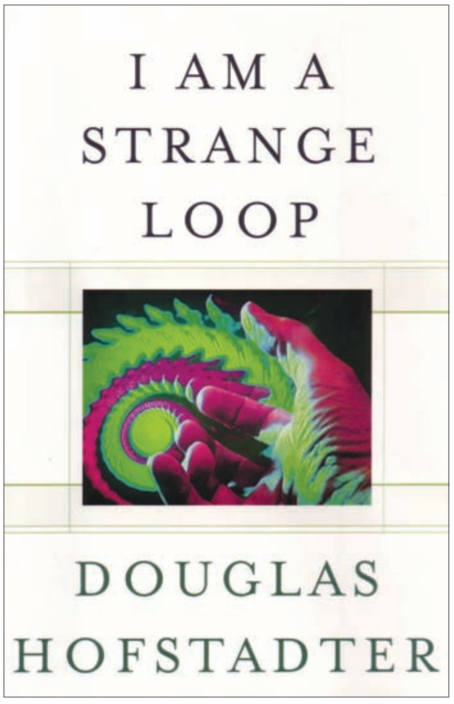


I Am a Strange Loop by Douglas Hofstadter, Basic Books. Hardback ISBN 9780465030781, £15.99 ($26.95).

Douglas Hofstadter is a truly exceptional person. His remarkable academic life followed a path that reflected his evolving interests in mathematics (graduation in 1965), physics (PhD in 1975), and cognitive sciences (his main field of research ever since). He is also captivated by literature, music, philosophy and other forms of high-level human creativity – probably because they are particularly beautiful expressions of consciousness, a more elusive activity that somehow emerges from within our "thinking machine", the brain.

Hofstadter is best known for having written *Gödel, Escher, Bach: an Eternal Golden Braid* (*GEB*), undoubtedly an inspired masterwork that was immediately recognized as a breakthrough in scientific literature. Despite being a brilliant and original work, most readers of *GEB* might feel uneasy when asked to summarize in a few sentences the main message of this unusual "metaphorical fugue on minds and machines in the spirit of Lewis Carroll", which lasts for 777 (plus 22) pages. This is not a criticism. Many works of art can be appreciated, enjoyed and admired, even if we fail to grasp the main idea inspiring the artist. Maybe revolutionary breakthroughs – in art and certain areas of science – are naturally difficult to master at first and remain somewhat foggy in the minds of the "amateur". In any case, *GEB* is certainly at the top of the list of books that I would take with me to a desert island. It has enough content and structure – not to mention depth and broadness – to provide thought-provoking reading for a very long time, and being alone on a desert island is an ideal setting for asking what we mean when we say "I". Frankly, I've never read *GEB* in its full extent, from cover to cover. I prefer to see it as a collection of great wonders that visitors can enjoy in several possible sequences, even skipping a few of them. It's impossible to visit all "great wonders of the world" in a single lifetime.

This browsing attitude (jumping back and forth between chapters and sections) or even opening the book at a random page and enjoying a few pages, is probably a good indication that I am one of the many readers who Hofstadter had in mind when he grumbled that *GEB* has been misperceived as "a hodgepodge of neat things with no central theme". Apparently, this was one of the factors that triggered him to embark on the braiding of *I Am a Strange Loop* – 432 pages devoted to the "I" theme, 28 years after the eternal golden braid of *GEB*. I presume he would have finished much earlier had he not become a victim of his own (recursive) Hofstadter's Law: It always takes longer than you expect, even when you take into account Hofstadter's Law. I would also have written this review long ago, if I were not an enthusiast of this law...

In this more recent work, Hofstadter revisits several of *GEB*'s topics, such as Gödel's inspiring work on self-referential systems and "self-engulfing TV screens", now magnificently represented in colour and with higher resolution than before, which provide a striking illustration of a self-referential loop (despite the absence of the "black hole" seen in the original screenings). However, the new book focuses on the scientific, philosophic and spiritual issues related to the ever-elusive nature of mind and consciousness. The author recognizes this as a daunting task: "our very nature is such as to prevent us from fully understanding its very nature."

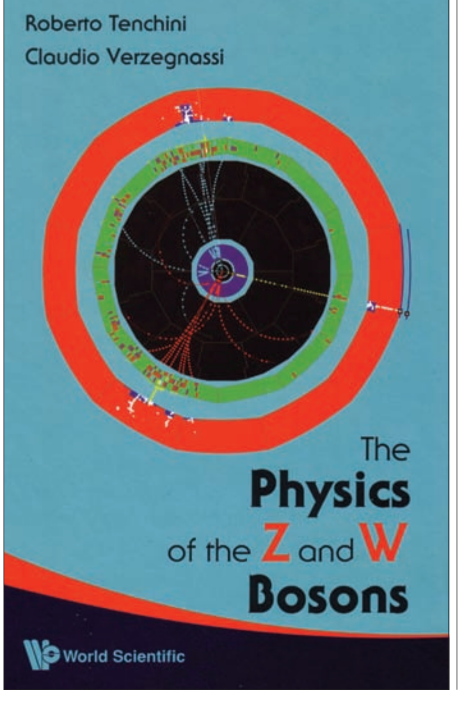
GEB's emblematic actors (Achilles, Tortoise and other mythical characters who had metaphorical dialogues interspacing the main chapters) are absent in *I Am a Strange Loop*, giving it a seemingly more relaxed fluidity and somewhat reducing the "hodgepodge" feeling. The feeling is not entirely gone, however, and we can use another of Hofstadter's pictorial expressions to qualify it as "a random-looking swirl of pockmarked, bluish-white globs that reminded me a bit of some kind of exotic cheese...".

Like the topic it addresses, *I Am a Strange Loop* has elusive parts and hard-to-follow concepts, but it retains a surely poetic (even beautiful) literary exquisiteness, providing delightful reading that I do not remember experiencing with any other scientific book. I wholeheartedly recommend it to anyone interested in "the mind's I" and to those looking for a scientific book written at the highest literary level. A warning, though: you may want to have a good English dictionary within arm's reach. I should also recommend reading *The Mind's I* by Hofstadter and Daniel Dennett, another delightful selection of "fantasies and reflections on self and soul", which will trigger your mind into wondering "what is the mind, who am I, can machines think?", through extraordinary stories and disturbing commentaries.

Carlos Lourenço, CERN.

The Physics of the Z and W Bosons by Roberto Tenchini and Claudio Verzegnassi, World Scientific. Hardback ISBN 9789812707024, £48 ($89).

This book presents a nice review of

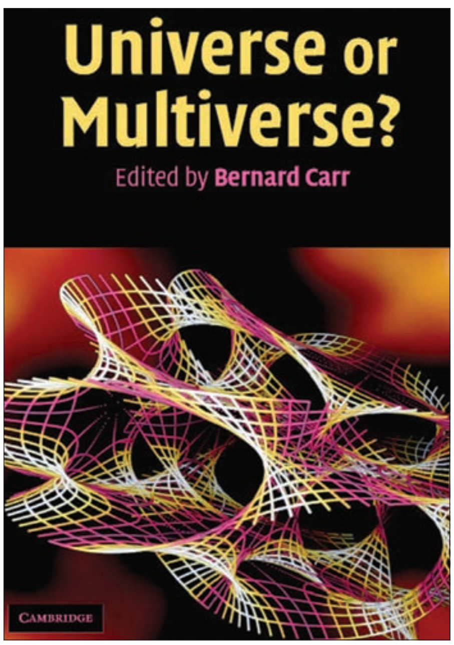


LEP physics written by two distinguished physicists, a theorist and an experimentalist, who both had a prominent role in that important scientific endeavour. In fact, since LEP – together with the SLAC Linear Collider and the Tevatron – was essential for the precise experimental verification of electroweak theory, to describe those epoch-making accomplishments adequately, one has to go deep inside the workings of the physics of the Standard Model. This book, therefore, is nothing more than a particularly effective and original presentation of electroweak interactions, theory and experiment, but from a different angle compared with ordinary textbooks.

The formalism of the theory is introduced in detail from the beginning of the book, followed by a derivation of the crucial predictions to be tested. The authors then describe the relevant features of the LEP machine and detectors, together with the experimental strategies. Finally, a summary of the results and their significance is discussed.

Along the way the reader is led directly to appreciate the close interplay between the predictions obtained by the work of a generation of theorists and the highly sophisticated experimentation designed and performed by the LEP collaborations, which was needed for the ultimate test of the predications. In this respect the book provides a brilliant account of the actual way of doing particle physics nowadays, told by the scientists involved. It follows that this volume is also a good introduction to the next phase of particle physocs, which will soon start at CERN with the LHC.

Guido Altarelli, CERN.



Universe or multiverse? Edited by Bernard Carr, Cambridge University Press. Hardback ISBN 0521848415, £45.

While "universal" usually refers to the whole creation, the word multiverse indicates the ensemble of other possible universes in which the constants of physics are different from our universe. In this book, eminent particle physicists and cosmologists (Steven Weinberg, Stephen Hawking, Frank Wilczek and Andrei Linde among others), as well as philosophers, discuss different views on the multiverse. It consists mainly of a collection of contributions to a 2003 conference, which have been adapted to a semi-popular level by the authors and to bring in the most recent developments in theoretical cosmology.

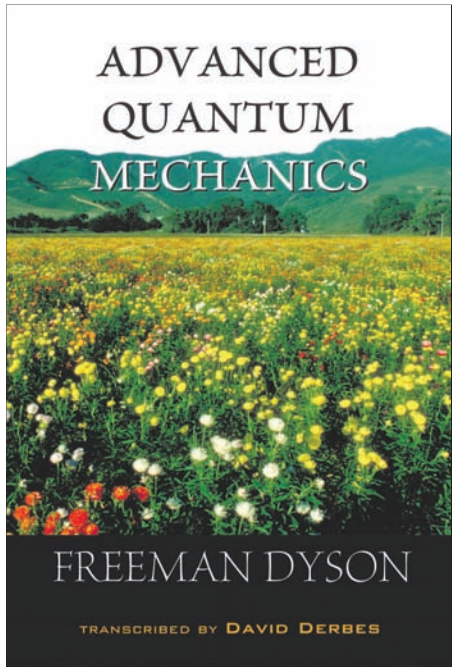
The anthropic principle is the underlying theme throughout the book. Some of the authors support the anthropic principle in a multiverse context; some are less comfortable with it. The main question – why is the universe is the way it is? – is intimately related to the anthropic principle. Are we living in a tiny fraction of the universe? Or in a particularly selected member of an ensemble of possible universes? How does the presence of observers select a particular branch of the wave function of the universe? The arguments are addressed from points of view of cosmology, particle physics and philosophy.

Another key issue is that the multiverse cannot be observed, so is not experimentally verifiable and therefore may not be "scientific" in a strict sense. However, we do observe cosmic accelerated expansion. In an inflationary scenario, and following a Copernican approach, this implies that there are regions of this universe – even if it is only one – that we will never be able to explore, since they are beyond the limit our horizon will ever reach. Are they, then, not physical? On the other hand, the multiverse may be the outcome of a more general theory, such as string theory or M-theory, which can be tested in other aspects – and therefore falsifiable – in the Popperian sense.

These are just some of the topics the authors discuss in detail. The book is divided into four parts. After an overview section, the astrophysical and cosmological points of view are presented, followed by particle-physics aspects and philosophical topics (a theistic perspective is also introduced), although this separation is not clear-cut.

Reading this book is a complex and rich experience. As an experimental cosmologist, I found it stimulating to reflect on the theoretical counterpart of my everyday experience. The level of the book requires a significant background in physics, although an effort is made to explain the details. While it is definitely not a textbook, I find it useful as recommended reading as an introduction for undergraduate students.

Luca Valenziano, INAF/Istituto di Astrofisica Spaziale e Fisica Cosmica, Bologna, Italy.



Advanced Quantum Mechanics by Freeman Dyson, transcribed by David Derbes, World Scientific. Hardback ISBN 9789812706225 £31 ($58). Paperback ISBN 9789812706614, £15 ($28).

Freeman Dyson is perhaps best known for his work in the early days of QED, showing the equivalance of the approaches of Richard Feynman, Julian Schwinger and Sin-Itiro Tomonaga. The book *Advanced Quantum Mechanics* is an account of early lectures that Dyson gave at Cornell in 1951, which have been transcribed by David Derbes.

This book is likely to be of interest mainly to historians of science. I have long believed (and still believe) that there is much to be gained from going back and reading the original works by founders of a field. For example, I think that Feynman's books *Quantum Electrodynamics* and *Theory of Fundamental Processes* are still interesting and useful to both beginning students and researchers, even though much of the material is dated. That said, after trying hard to find gems in this book, I must say that it's not in anywhere near the same class. This might sound harsh, but it was perhaps to be expected of a book that tries to sketch out the basic ideas of a brand new field just as it was beginning to be understood.

The one thing I did think was done rather well was the relativistic treatment of the spectrum of the hydrogen atom, which is found algebraically and, to my mind, rather elegantly and efficiently. The treatment of fluctuations in fields had some nice points – in particular the suggestion to look at a paper (L P Smith 1946 *Phys. Rev.* **69** 195) that treats QED in a cavity and the approach to the classical limit.

Some of the heuristic and semi-classical arguments in dealing with radiative corrections may be of interest for a classroom discussion. In particular, an approximate treatment of electron–positron pair creation from the decay of an excited nuclear state would be an interesting subject to discuss – both as it appears in this book, as well as how it might be treated using more modern methods. That said, the subject of QED has advanced so far from when the material was originally presented that I would argue that this is rather weak motivation for buying the book. In any event, the same material is also available online, at http://arxiv.org/abs/quant-ph/0608140.

John Swain, Northeastern University.

Books received

Essential Quantum Mechanics by Gary E Bowman, Oxford University Press. Hardback ISBN 9780199228928, £45 ($90). Paperback ISBN 9780199228935, £22.50 ($55).

Quantum mechanics – central not only to physics, but also to chemistry, materials science, and other fields – is notoriously abstract and difficult. *Essential Quantum Mechanics* is a uniquely concise and explanatory book that fills the gap between introductory and advanced courses, or between popularizations and technical treatises.

By focusing on the fundamental structure, concepts, and methods of quantum mechanics, this work emphasizes both physical and mathematical understanding. A modern perspective is adopted throughout – the goal, in part, being to gain entry into the world of "real" quantum mechanics, as used by practicing scientists. This book should be useful for undergraduate and graduate students in quantum mechanics, mathematics, materials science, and chemistry.

The day the world came to CERN

Lucio Rossi, who led the task force charged with organizing the LHC 2008 open days, looks back on a memorable experience with the general public.

When I agreed to take on the challenge of organizing two open days just before the LHC tunnel was to close for the final stages of commissioning the machine, I was determined that they should provide an experience that people would never forget. Whether it was on 5 April for the families and friends of those who work at CERN, or on the following day for the general public, this would be the last chance to go underground, to see the immensity of the LHC and the four major experiments. The question was: would the people come?

The family and friends day had already proved a resounding success, with nearly double the expected number of visitors. Then I woke up to see what the public open day would bring. When I arrived at 7.30 a.m. people were already gathering in front of the Globe. At 7.45 a.m. the first phone rang in the Information and Coordination Centre (ICC) and from then on there was uninterrupted frantic activity, as ultimately some 53 000 people visited the 37 different points on show.

At 10.00 a.m. I began my first tour of the visit points, starting at the Meyrin site where I was delighted to see a large crowd in front of the central workshops and a long orderly queue of people waiting to visit the superconducting and cryogenic laboratories. In the LHC magnet workshops the crowds were smaller than at other locations, and the small groups of people were able to spend a long time with CERN personnel. They really seemed to appreciate being able to look at the magnet components and to almost touch them.

Out round the LHC ring I passed Point 4 when the "LH... C'est pas sorcier" dipole was there with Fred, the presenter of *C'est pas sorcier*, a popular science programme on French TV. A crowd of children and parents were watching his performance: a spectacle within the spectacle. Driving on to Point 5, I could see the long line of cars that reached back to the village of Cessy. The police had already closed the road at 10.00 a.m. as there were many more people than the site could handle. I was comforted by the praise and thanks from the police for our organizational prowess, plus it was good to hear from them that everyone was well behaved and orderly. Thankfully, the huge crowds were not causing chaos: the decision we had made to move the public event from Saturday to Sunday was clearly a winner.

The open day task force with an LHC dipole in front of the Globe of Science and Innovation.

At midday, it was on to Point 6, the furthest from the main site, hidden in the woods between Versonnex and Bossy, with only the LHC machine and no experiment to see. I was amazed to find a 600 m line of cars parked on both sides of the road – it was then that I finally began to appreciate the magnitude of the day's success. Here I watched children (of all ages) happily taking rides on the historical vehicles of CERN's fire brigade.

By 12.30 p.m. I was back in front of the Globe for a live interview for TSR, the local Swiss TV station, against a background of long queues of patient people going to Point 1 and the ATLAS experiment. Then it was over to restaurant 2 on the main site for lunch with the two Nobel laureates, Georg Bednorz and Anthony Leggett, who had come to give talks about their work on superconductivity. They were really impressed that so many of the public had come to see the offspring of their discoveries. As I left the restaurant I encountered people leaving the Computer Centre where they had found out about the wonders of the Grid; computer-fanatics had clearly found their paradise.

In the afternoon I set off on a second visit of the tour points, starting with Point 2 and the excellent exhibition on the ALICE experiment. Here I could appreciate the effort taken to care for the disappointed people, as the team explained the limited capacity of the visit, and even arranged for special visit days afterwards. At Point 4 I saw again the incredible success of the physics amusements, organized in collaboration with a team from ESRF–Grenoble. At Point 5 the flexibility of the volunteers at the CMS experiment had made it possible to successfully deal with 3500 underground visits, and at Point 6 people were still being encouraged to stay in the long queue – indeed, this one ended very late, with the last person taken by special bus at nearly 9.00 p.m. At Point 8 at about 6.00 p.m., the nearby supermarket car park was almost full of cars with people still trying to visit LHCb or the LHC tunnel. Back at Point 1 at 6.30 p.m. the queues were finally thinning out and I had to encourage and thank the first-aiders (volunteers from benevolent organizations from the Geneva area on the Sunday) who seemed almost frustrated by their non-activity; it's difficult to do a job where success is measured in terms of having nothing to do.

On returning to the ICC after 7.00 p.m., I found that everyone was exhausted from answering telephone calls, but they were still explaining how to shut a visit point, or how to move the buses to rescue the remaining people. I was exhausted but satisfied, and could see that the others were also tired but happy. And that made it for me: that everywhere the volunteers from CERN were happy, having lived through a unique experience.

Lucio Rossi, CERN.

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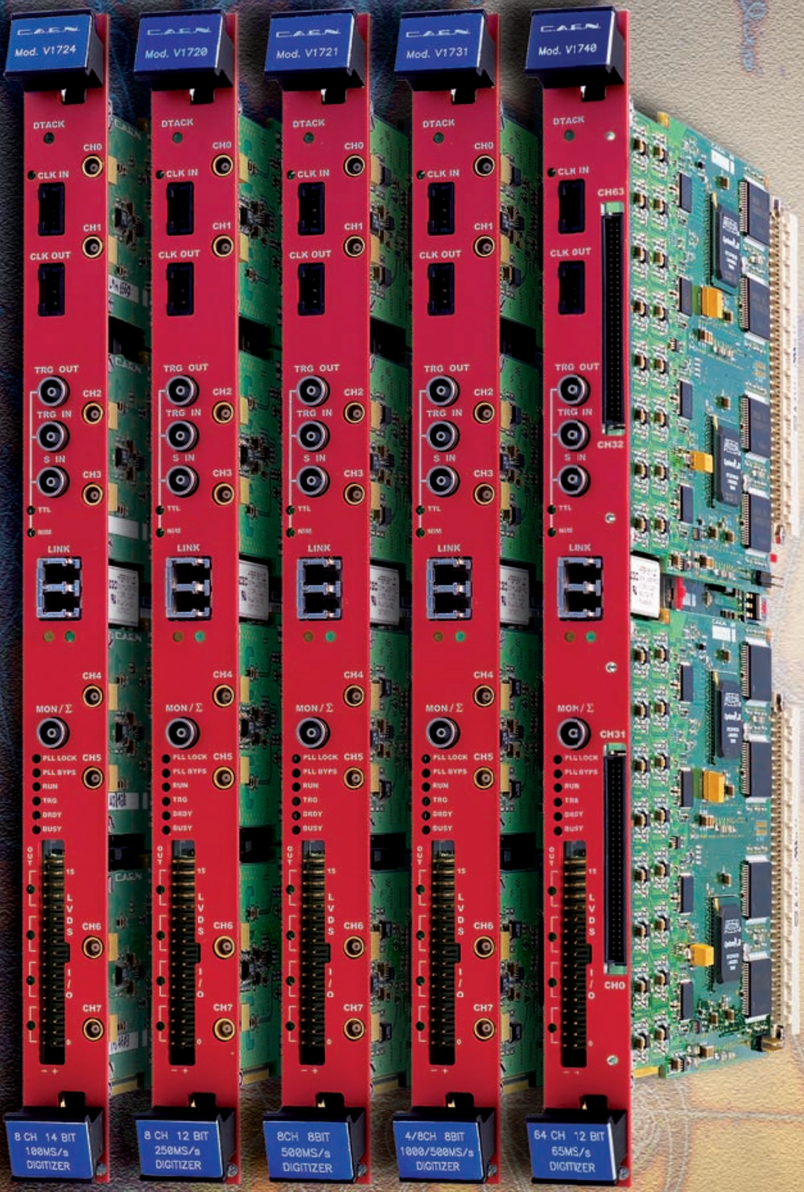

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