International Journal of High-Energy Physics

CERN COURIER

Volume 47 Number 3 April 2007

Doubling energy in a plasma wake

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

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

Advisory board James Gillies, Rolf Landua and Maximilian Metzger

Laboratory correspondents:
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Tel +44 (0)117 929 7481; e-mail jo.nicholas@iop.org; web iop.org

Publisher Joseph Tennant
Art director Andrew Giaquinto
Production editor Jonathan Cailes
Technical illustrator Alison Tovey
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UK Mark Swaisland, Chadwick Library, Daresbury Laboratory, Daresbury, Warrington, Cheshire WA4 4AD, UK.
E-mail m.r.swaisland@dl.ac.uk
US/Canada Published by Cern Courier, 6N246 Willow Drive, St Charles, IL 60175, US. Periodical postage paid in St Charles, IL, US. Fax 630 377 1569. E-mail vosses@aol.com
POSTMASTER: send address changes to: Creative Mailing Services, PO Box 1147, St Charles, IL 60174, US

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

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

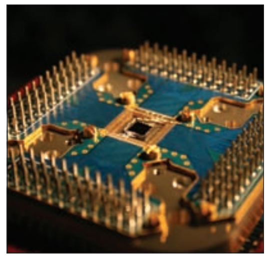
 ISSN 0304-288X

IOP Publishing

CERN COURIER

VOLUME 47 NUMBER 3 APRIL 2007


CMS solenoid descends *p6*


D-wave shows quantum chip *p15*


George Smoot visits CERN *p26*

Cover: This blue streak reveals the dramatic gain in energy made by electrons in a bunch from the 3 km linac at SLAC after passing through a plasma. The white spot shows the electrons that generated the plasma wakefield, which propels some of the bunch to energies as high as 85 GeV (p5). (Courtesy SLAC.)

COLLIDERS

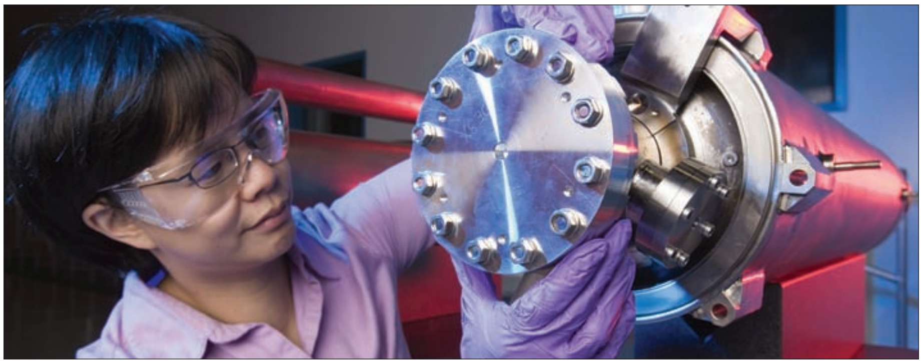
ICFA releases ILC design report

The International Committee for Future Accelerators (ICFA) has released the Reference Design Report (RDR) for a future International Linear Collider (ILC). The report provides the first detailed technical description of the machine, including a cost estimate, and is a major step towards the engineering design report that would underlie a formal project proposal.

The concept behind the ILC is a high-luminosity electron–positron collider, operating at centre-of-mass energies of 200–500 GeV, with a possible upgrade to 1 TeV. The first map of physics at the tera-electron-volt scale will come from CERN's LHC; the ILC would expand on the discoveries made in this new energy region, investigating it with high precision.

ICFA established the basis for the design in August 2004 when it accepted the advice of the International Technology Recommendation Panel to opt for superconducting radio-frequency (SCRF) accelerating cavities operating at 1.3 GHz (*CERN Courier* October 2004 p5). A year later the Global Design Effort (GDE), a team of more than 60 scientists, was officially formed to define the basic parameters and layout and develop the reference design (*CERN Courier* December 2005 p24).

The RDR defines the technical specifications for a 31 km long machine, which would deliver a peak luminosity of about 2×10^{34} $cm^{-2}s^{-1}$, at a top centre-of-mass energy of 500 GeV. The basic design achieves this high luminosity through a combination of small emittance beams and high beam power, facilitated by the use of 1.3 GHz SCRF. The design also allows for an upgrade to a 50 km, 1 TeV machine during the second stage of the project.



The ILC effort currently brings together more than 1000 physicists and engineers from more than 100 institutes in over two dozen countries. Here Mayling Wong works on a 1.3 GHz Type I cavity at Fermilab. (Courtesy Fermilab Visual Media Services.)

The major components start with a polarized electron source based on a photocathode DC gun and an undulator-based positron source, driven by a 150 GeV electron beam. The particles produced will then pass to 5 GeV electron and positron damping rings at the centre of the ILC complex, before being transported to the main linacs, where each beam will enter a bunch-compressor system prior to injection. The two 11 km long main linacs will use the 1.3 GHz SCRF cavities operating at an average gradient of 31.5 MV/m, with a pulse length of 1.6 ms and a cycle rate of 5 Hz. Finally, a 4.5 km long beam-delivery system will bring the two beams into collision at a 14 mrad crossing angle. Two detectors in a "push–pull" configuration will share the luminosity at the single interaction point.

As part of the RDR, the GDE members also produced a preliminary value estimate of the cost for the ILC. This estimate contains three elements: €1480 million ($1800 million) for site-related costs, such as for tunnelling in a specific region; €4040 million ($4900 million) for the value of the high technology and conventional components; and approximately 2000 people a year, or 13 000 person years, for the supporting manpower. Some 43% of the total costs come from the SCRF technology for the main linacs.

The value cost estimate provides guidance for optimization of both the design and the R&D to be done during the engineering design phase, which will formally start in the autumn. The global R&D effort will continue to focus on the performance of the high-gradient accelerating cavities. These are key components as the gradient governs the lengths of the linacs. The goal of an average operational gradient of 31.5 MV/m translates to a minimum of 35 MV/m in acceptance tests during mass production of the cavities. The next major milestone for the GDE will then be to produce the engineering design report – the detailed blueprints for building the machine – by 2010.

● To download a summary or the full report see www.linearcollider.org.

Sommaire

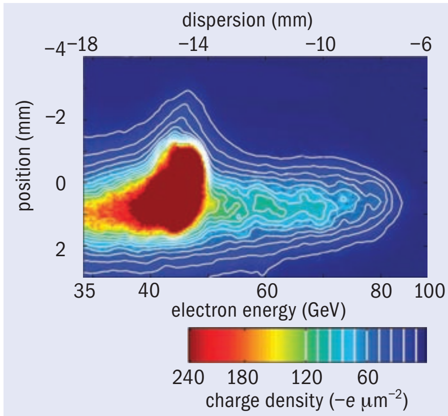
ACCELERATORS

SLAC demonstrates plasma 'afterburner'

A team of researchers at SLAC has shown that plasma acceleration can dramatically boost the energy of particles over a short distance. The breakthrough is the culmination of almost a decade of work, led by Chan Joshi from University of California, Los Angeles, Thomas Katsouleas from the University of Southern California and Robert Siemann from SLAC.

The technique uses the plasma-wakefield effect – the high electric fields generated in the wake of an intense beam of either photons or charged particles passing through a plasma. In 2006, Wim Leemans and colleagues from the Lawrence Berkeley National Laboratory and Oxford University accelerated electrons to 1 GeV in laser-driven wakefields over 3.3 cm (*CERN Courier* November 2006 p5). Now Ian Blumenfeld and colleagues have used the intense, ultrarelativistic electron beam from the 3 km linac at SLAC to create the wakefields.

In the experiment at SLAC, the team directed the 42 GeV beam from the linac into lithium gas in an 85 cm long plasma chamber. The electrons ionize the gas at the front of the beam pulse, creating a plasma, and also push out the plasma electrons to leave a column of ions. The plasma electrons are attracted back to the ions, but overshoot, setting up space–charge oscillations at the rear of the pulse, forming the wake. While most of the electrons in the beam pulse lose energy as they create the wakefield, those near the back of each pulse are accelerated in the high field created there. The measurements showed that some electrons more than doubled their energy, up to a maximum of 85 ± 7 GeV (see figure), implying a peak accelerating field of around 53 GV/m. In 800 events, 30% showed an energy gain of more than 30 GeV.



Energy distribution of a bunch of electrons after traversing the plasma and being dispersed by a spectrometer magnet. Particles in the back of the bunch, which have reached 85 GeV, are visible to the right.

In tests with a 113 cm lithium-gas column, the team measured a maximum energy of just 71 ± 11 GeV, and only 3% of 8000 consecutive events showed an energy gain of more than 30 GeV. This apparent saturation in the energy gain appears to be due to an expansion of the front of the beam, which could be reduced with a lower-emittance beam.

Further reading

I Blumenfeld *et al.* 2007 *Nature* **445** 741.

GERMANY

New BMBF funding for LHC experiments

In February the German Federal Ministry of Education and Research, BMBF, set up new funding for the German universities and institutions involved in ALICE, ATLAS and CMS.

Besides financing the institutes individually, the BMBF approved additional funding for three BMBF-Forschungsschwerpunkte (FSP), or BMBF strategic research clusters. These comprise a large number of university groups and other research institutions working closely within a national research network. The scheme aims to promote co-operation between the institutes to create wider networks of scientific excellence and enhanced international visibility.

FSP 201 – ALICE, FSP 101 – ATLAS and FSP 102 – CMS won the first funding round. In total, the institutes in these clusters will receive more than €32 million for the next funding period, which runs until 2009. The research centres Karlsruhe, DESY and GSI will assist the clusters in their work.

LHC EXPERIMENTS

CMS solenoid makes successful descent

At 6.00 a.m. on 28 February the heaviest section of the Compact Muon Solenoid (CMS) detector began its momentous journey into the experiment's cavern, 100 m below ground. Using a huge gantry crane, custom-built by the Vorspann System Losinger Group, the pre-assembled central piece, weighing 1920 tonnes – or as much as five jumbo jets – was gently lowered into place, descending at a rate of about 10 m an hour. It finally touched down smoothly at 6.00 p.m., under the eyes and cameras of assembled press, hundreds of CMS collaboration sightseers and TV viewers around the world.

The central piece of CMS with the complete solenoid magnet just fits into the shaft down to the cavern 100 m below the surface.

The piece emerges into the cavern after descending at a rate of about 10 m an hour.

The giant element, 16 m tall, 17 m wide and 13 m long, consisted of the complete superconducting solenoid, together with the central section of the magnet return yoke. Its descent was a challenging feat of engineering, as there was only 20 cm leeway between the detector and the walls of the shaft. To make the journey, the piece was suspended by four massive cables, each with 55 strands and attached to a step-by-step hydraulic jacking system. Sophisticated monitoring and control ensured that it did not sway or tilt.

The CMS collaboration broke with tradition by starting assembly of the detector before completion of the underground cavern, taking advantage of a spacious surface assembly hall to pre-assemble and pre-test the solenoid magnet and the various detectors (*CERN Courier* March 2006 p6). There are 15 pieces altogether, and the descent of the central section marks the halfway point in the lowering process, with the last piece scheduled to go underground in the summer.

LIGHT SOURCES

Diamond welcomes its first scientific users

The Diamond Light Source, the UK's new synchrotron facility in Oxfordshire, has welcomed its first scientific users after opening its doors for business in February. The projects, selected from 127 proposals received last year, cover a broad range of research, from cancer studies, to advancing data-storage techniques, to unravelling the mysteries of the solar system. They will provide the teams at Diamond with real projects to assist in the six-month period of fine-tuning the first experimental stations.

Diamond, the UK's new synchrotron facility. (Courtesy Diamond Light Source Ltd.)

These first research projects will be carried out in beamlines that are part of Phase I of Diamond's development – comprising the buildings, the synchrotron itself and the first seven beamlines. Phase I investment of £260 million from the UK government (86%) via the Council for the Central Laboratory of the Research Councils and the Wellcome Trust (14%), was used to deliver the facility on time, on budget and to specification. Funding for Phase II of the project – a further £120 million – was confirmed in October 2004 and will be used to build 15 additional beamlines to expand the available range of research applications. Construction has already started on the Phase II beamlines and beyond this, on average four to five new beamlines will be available each year until 2011.

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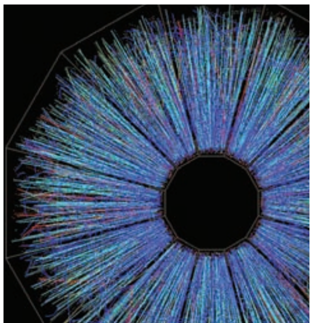

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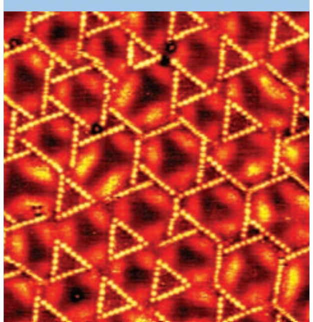

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歡迎

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SCIENCEWATCH

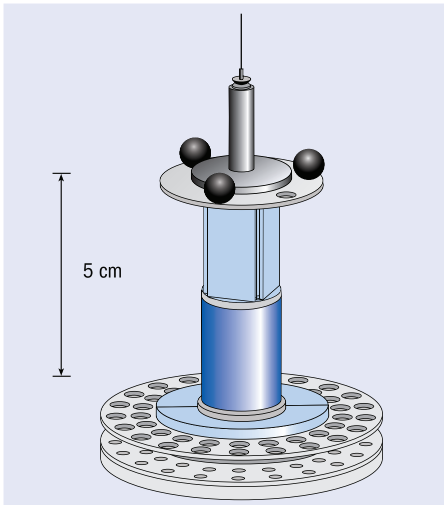
Compiled by Steve Reucroft and John Swain, Northeastern University

Newton's law stays good below the dark-energy scale

Modern physics has invented all sorts of speculative ideas to help reconcile observations about gravity. Physicists have invoked dark energy to help explain accelerated cosmic expansion and they have postulated extra dimensions to explain the weakness of gravity compared with the other fundamental forces.

The required density of dark energy, which would have a repulsive gravitational effect, seems to be at the level of about 3.8 keV/cm^3. This corresponds in natural units to about 85 μm, so it could be that something interesting might happen to Newton's law of gravitation around that scale. The idea with extra spatial dimensions is that the extra dimensions are "curled up" or compactified, and so are not normally observed. In these theories, the gravitational force could become strong at distances smaller than the size of the largest compactified dimension.

To investigate these ideas, D J Kapner and colleagues at the University of Washington in Seattle performed three experiments using a very precise torsion balance, testing the inverse-square law over a range of separations from 9.35 mm down to 55 μm. Their results improve constraints on the inverse square law by up to 100, and show that the law holds down to 56 μm, below the dark-energy scale. This also implies that a single extra dimension has to be smaller than 44 μm.



A drawing of the torsion-balance instrument.

Further reading

D J Kapner 2007 *Phys. Rev. Lett.* **98** 021101.

Ocean waves drive the Earth's hum

You can't hear it, but the Earth is humming to itself at a seismic eigenfrequency of about 10 mHz and with an excitation energy equivalent to a magnitude 5.75 earthquake. There has been controversy in recent years as to whether atmospheric turbulence or ocean waves were driving the hum.

Now Spahr C Webb of Colombia University in New York has calculated the coupling between ocean waves and seismic modes and found that it reproduces the seismic spectrum of the hum. Interestingly, the mechanism depends on the weak nonlinearity of ocean waves and the interaction of waves with the shallow continental shelves.

Further reading

Spahr C Webb 2007 *Nature* **445** 754.

The Earth – quietly humming to itself with ocean waves. (Courtesy NASA/Apollo 17.)

Composite is stiffer than diamond

Combining two materials can yield a composite with a Young's modulus (stiffness) far higher than either material alone. Now T Jaglinski of Washington State University in Pullman and colleagues at Ruhr-University Bochum and the University of Wisconsin-Madison have made an extreme composite of barium titanate and tin.

The material has a Young's modulus that, depending on temperature, can be several times higher than that of diamond. Such extreme stiffness may also occur in nature and be involved in deep-focus earthquakes.

Further reading

T Jaglinski *et al.* 2007 *Science* **315** 620.

Delayed-choice experiment confirms quantum mechanics

We are used to the quantum weirdness of the two-slit experiment, but things get much weirder than that. In the 1980s John Wheeler proposed a "delayed choice" gedanken experiment. This would make a two-way interference experiment (allowing either two paths or just one) a little more interesting by delaying the choice of whether or not to allow two paths until after a photon would have had to commit classically to one thing or the other.

Now, for the first time, Vincent Jacques and colleagues from the École Normale Supérieure de Cachan, East China Normal University and the Laboratoire Charles Fabry de l'Institut d'Optique have made an almost ideal practical realization of Wheeler's gedanken experiment. Their experiment uses a quantum random number generator to decide whether to allow one path or two, and makes a space-like separation between the photon entering the interferometer and the decision being taken. The results show that quantum mechanics triumphs over common sense yet again.

Further reading

Vincent Jacques *et al.* 2007 *Science* **315** 966.

ASTROWATCH

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

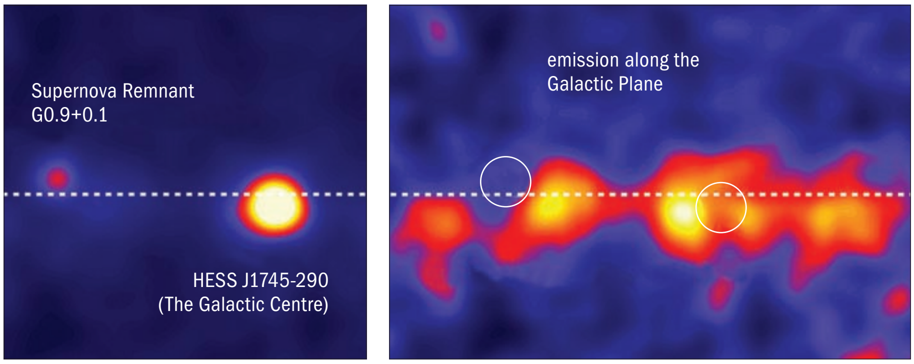
Galaxy centre may harbour super accelerator

Although the super-massive black hole at the centre of our galaxy seems very quiet compared with those seen as quasars in remote galaxies, it might be a giant proton accelerator more powerful than CERN's Large Hadron Collider. This at least is what a group of theorists at the University of Arizona suggests to explain the very high-energy gamma-ray source at the centre of the Milky Way.

The galactic centre is a complex region with a large density of both compact and diffuse energetic sources (*CERN Courier* March 2002 p11). At the very heart of the galaxy individual stars have been observed to orbit an invisible object with an inferred mass about 3 million times that of the Sun. There is almost no doubt now that this object is a super-massive black hole. It remains a mystery, however, why the output of this black hole is so dim compared with the tremendous energy released by black holes of comparable mass in active galactic nuclei.

Another puzzle is that this quiet object is apparently a strong source of gamma rays at tera-electron-volt energies. The HESS (High-Energy Stereoscopic System) array of Cherenkov telescopes in Namibia finds the position of the gamma-ray source to be coincident with that of the black hole to a relatively high accuracy. If the gamma rays – as suggested by the data – do indeed originate from the black hole rather than from the nearby supernova remnant Sagittarius A East, understanding their production mechanism is a theoretical challenge.

Direct generation of tera-electron-volt photons around the black hole seems unrealistic, so theorists have explored indirect processes. The most likely scenario is that relativistic protons are accelerated in the vicinity of the black hole, diffuse along magnetic field lines and eventually collide with ambient hydrogen nuclei. Such proton–proton scatterings would produce pions, which would rapidly decay into pairs of photons. Several recent studies attempted to explain how these protons could be accelerated to energies of up to hundreds of tera-electron-volts close to the black hole's event horizon.



The HESS view of the Galactic Centre region at tera-electron-volt photon energies. The left image shows the mysterious Galactic Centre source and a known supernova remnant, while the right view has these sources (indicated by circles) removed to show the fainter diffuse glow along the Galactic Plane. (Courtesy HESS collaboration.)

To address this question further, one group of theorists has now tried instead to figure out whether such relativistic protons could be at the origin of the gamma-ray emission observed by HESS. David Ballantyne and colleagues from the University of Arizona, Los Alamos National Laboratory and the University of Adelaide, model the diffusion of relativistic protons in a cube with sides 20 light-years long centred on the Milky Way's super-massive black hole. Using a realistic density distribution, they study the random-walk trajectories of 222 000 simulated protons as they interact with the turbulent magnetic field in the volume.

Assuming the magnetic field intensity to be proportional to the gas density, the team finds that about a third of the protons will produce gamma rays in the circumnuclear torus around the black hole. These scatterings at only several light-years from the galactic centre could be responsible for the point-like gamma-ray source found by HESS, but only if the initial proton spectrum is very hard, with a power-law index of 0.75. The majority of relativistic protons would travel much longer distances before interacting with interstellar gas and could be responsible for the diffuse glow of the central galactic ridge that HESS also sees. That these two sources of tera-electon-volt photons with very different spatial distributions could have the same origin gives strength to this model.

Further reading

D R Ballantyne *et al.* 2007 *Astroph. Journal* **657** L13.

Picture of the month

This brand new image of NGC 2440 adds to the already very impressive collection of planetary nebulae observed by the Hubble Space Telescope. It shows the last colourful display of a star like our Sun in the act of dying. The star is ending its life by casting off its outer layers of gas. The core of the dying star – visible as a white dot at the centre – is called a white dwarf. Although no bigger than the Earth, it is very hot and thus radiating ultraviolet light, making the ejected material glow. (Courtesy ESA/K Noll/STScI.)

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

CERN

Shut-down at the SC

The 600 MeV synchro-cyclotron (SC) was shut down for several weeks at the beginning of this year, partly for routine maintenance but mainly to enable work to be carried out on a number of alterations to the machine. Altogether, 217 men took part in the work, the largest numbers being drawn from the central workshop and the cleaning staff, apart from the various SC groups.

The major task was to make preparations for the installation at a later stage of a polarized-proton source. A fundamental property of every proton is its “spin”, a concept of quantum mechanics analogous to the spinning of a top about its central axis. In a normal proton beam the axes of spin are oriented in all directions, but in many cases experimental results (of proton–proton scattering, for example) could be interpreted much more clearly if all the protons were spinning in the same direction. The polarized-proton source, under development in the MSC Division, aims at producing such a “polarized” beam.

Various studies at CERN and elsewhere have shown that the intensity and quality of the accelerated beam is highly dependent on the precise conditions at the centre, where the protons have low energy and need to be guided carefully onto the right orbit. Protons produced in the centre spiral outwards, in a horizontal plane, under the joint influence of a magnetic field and an accelerating electric field. Although the magnetic field of the SC was thoroughly surveyed in 1955–56 during construction, many changes have been made since then, the effects of which have had to be estimated. Moreover, much more accurate magnetic-field measurements are now possible, and so the long shut-down was seized upon as a good opportunity for a new survey of the central area.

With every new improvement in the SC the amount of associated radiofrequency equipment has increased and the space available has become ever more crowded. During this shut-down, the complex switching system for starting up the equipment was rearranged, and some of it replaced by new units, so as to occupy much less space. Extensive changes included modifications to the main control desk, with a revised arrangement of control buttons and interlock indications, linked with a new alarm system.

The whole of the work in or near the accelerator was complicated by the radioactivity that is always present after the machine is switched off. Because no-one is allowed to receive more than a certain dose of radiation over a given period of time, many of the jobs had to be shared among a number of people and everything had to be planned very carefully in advance, with close supervision during the actual shut-down. Close cooperation between the MSC groups, Health Physics and the Workshops enabled the programme of work to be drawn up, and when the time came everything went ahead smoothly.

● Compiled from the article on pp44–47.

COMPILER’S NOTE

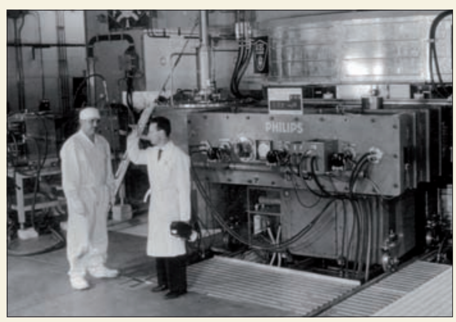
The design of the SC started in 1953, before CERN came into existence. Building and construction began in 1954, aiming at 600 MeV proton beams with an average intensity of 1 μA. This was achieved in August 1957, and in April 1958 an experimental programme began that was to last for more than 30 years. One of the first achievements was the long-awaited observation of pion decay into an electron and a neutrino.

Emphasis swung to nuclear physics in the mid-1960s with the construction of the Isotope Separator On-Line Detector (ISOLDE). The vast range of short-lived nuclei that became available attracted hundreds of nuclear physicists. The SC was adapted to provide beams for ISOLDE, delivering the first beam in October 1967.

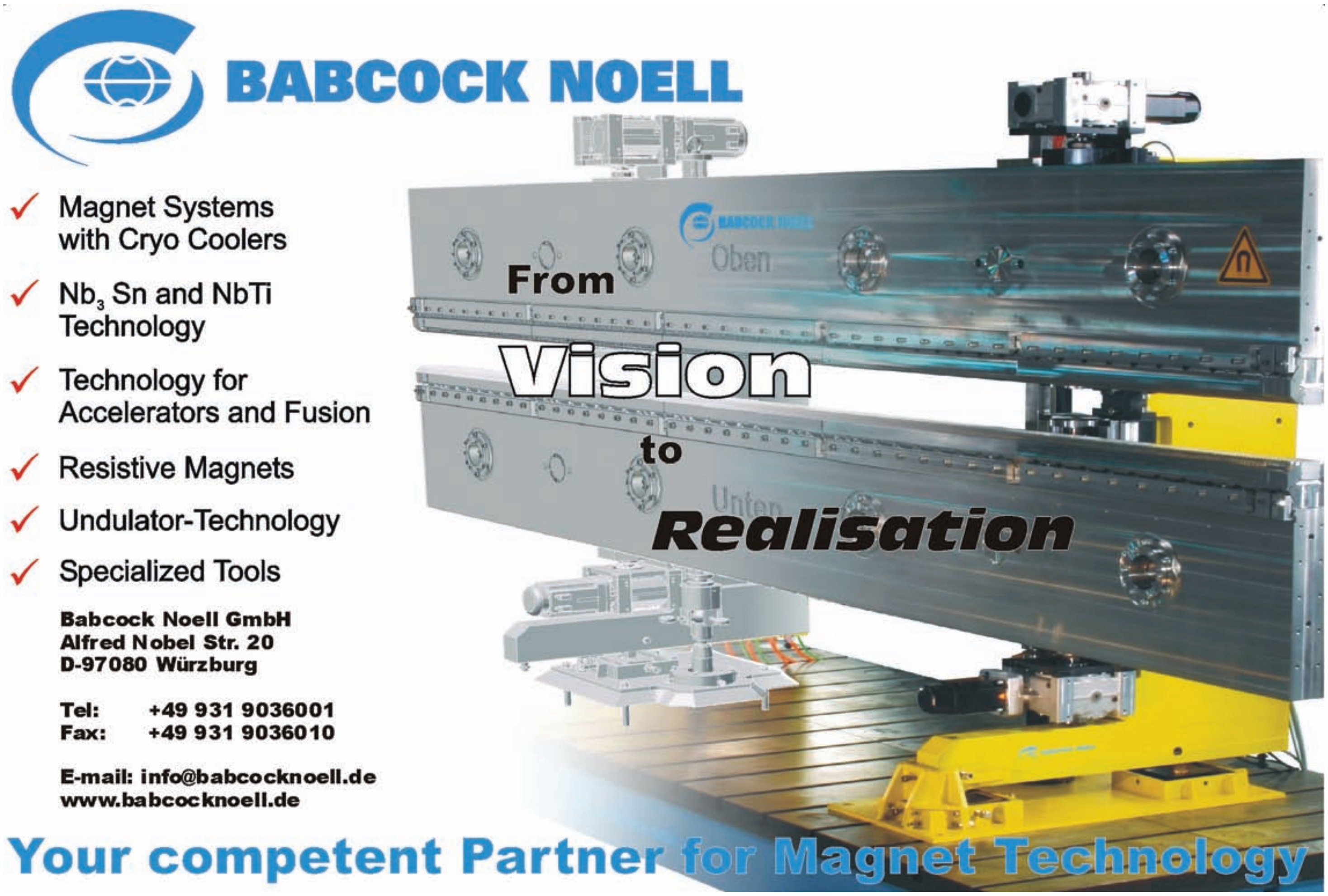
The decision to shut down the SC for good came in 1990 when much of its research programme could continue at the booster of CERN’s Proton Synchrotron.

This photograph shows some cover plates from the vacuum chamber of the SC being cleaned inside a concrete enclosure set up in the “proton” experimental room. As the plates were radioactive, the cleaners had to wear overalls, masks, goggles and gloves, and their stay inside the enclosure was carefully controlled.

Because of the radioactivity inside the cyclotron vacuum tank, work there has to be carried out quickly and accurately. This is not helped by the narrowness of the gap between the two magnet poles, as this picture shows.



Rodolph Deltenre, portable radiation monitor in hand, checks the reading of the pocket dosimeter issued to Marcel Stucki while working inside the machine hall.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Compiled by Hannelore Hämmerle and Nicole Crémel

PHYSICS GRID

Worldwide Grid collaboration gets ready for LHC start-up

In January, almost 300 members of the Worldwide LHC Computing Grid (WLCG) collaboration attended a week-long workshop at CERN to discuss the status of the infrastructure, as well as detailed plans and timescales to prepare for the start-up of the LHC later this year. The week included experiment-specific sessions as well as a joint-operations workshop, and followed a dCache workshop at DESY the week before. While previous workshops relied mainly on presentations, the January event was more interactive and included various informal "birds of a feather" sessions to discuss topics of shared interest, such as data management, monitoring and user support.

The WLCG was formed by resource providers – Grid projects, mainly EGEE in Europe and OSG in the US, and individual resource providers – to deal with the 15 PB of LHC data expected every year. The computing sites are arranged in a number of tiers, with CERN serving as the Tier-0 site, which will collect and distribute data to 12 Tier-1 sites. Some 150 Tier-2 sites will help process the data. The CERN workshop was the first to address the full WLCG team and brought together people from 27 countries and 86 sites.

All four large LHC experiments organized sessions to allow direct contact between site managers and experiments experts. These were well attended and the participants judged them useful. The ALICE session concentrated on different tutorials regarding specific aspects of ALICE software such as monitoring, AliRoot and AliEn. Topics in the ATLAS session included data management, storage-resource management and the security model of the services deployed, while the CMS session covered file-transfer and integration plans as well as computing resources and storage classes. Discussions in the LHCb session included topics such as testing of the "glexec" middleware module by some sites to permit various levels of access to computing elements and worker nodes, data security and data transfer between sites.

The WLCG collaboration week included lively plenary sessions with panels of experts.

The operations workshop concluded that as Grid operations are maturing, preparation for the LHC start-up is the main driving force behind infrastructure changes. Several issues, such as portability of the gLite Grid middleware and migration to the Scientific Linux 4 platform and 64 bit support, still have to be addressed. These and other changes, however, will be introduced only if they are not disruptive, so as to ensure a ready, reliable and stable service to the LHC experiments.

Three working groups have been set up to focus on improving service and site reliability, which are all coordinated. The Grid Monitoring Group will pull together monitoring data and provide views for the different stakeholders. The Site Management group will work to harmonize tools and best practices and will issue recommendations to improve site management. The System Analysis group will continue work done by ARDA (*CERN Courier* Jan/Feb 2005 p19) to provide feedback from the applications point-of-view. Another area still under development is the interoperation between the EGEE and OSG infrastructures.

Over the course of the year, the WLCG will continue to test computing models and basic services, in particular the full data flow from the trigger systems used by the LHC experiments through to distributing the data and performing analysis. Dress rehearsals over the summer for end-to-end tests of all components should bring the service to full capacity and performance, ensuring reliability and 24/7 operation, well in time for the LHC pilot run in November.

The next full WLCG collaboration week is planned for spring 2008, but this will be complemented by smaller, focused events such as the Operations Workshop on 11–15 June in Stockholm and meetings at events such as CHEP'07 on 1–2 September in Victoria, BC, Canada.

● For more information, videos and the presentations see http://indico.cern.ch/conferenceDisplay.py?confId=3738.

Les gros titres de l'actualité informatique

OUTREACH

Worldwide Grids create worldwide science

Three sessions at February's meeting of the American Association for the Advancement of Science (AAAS) dealt with distributed computing infrastructures and their use by scientists worldwide. Following the meeting's theme, Science and Technology for Sustainable Well-Being, scientists at the sessions discussed the use of Grid technologies and volunteer computing to fight disease, predict earthquake effects and hazardous weather conditions, understand the origins of the universe, and decode our own behaviour.

The goal of the Grid is to bring together resources and people across national and institutional boundaries, and indeed Grids have become a worldwide phenomenon. Speakers at the AAAS included Ruth Pordes, executive director of Open Science Grid (OSG), who introduced one of the sessions; Microsoft's Tony Hey, who presented e-Science in the UK and Europe; and William Chang from the National Science Foundation's Beijing office, who discussed networking and Grid computing in Asia, including the PRAGMA project, which bridges the nations of the Pacific Rim.

The majority of the speakers at the three sessions presented ways that distributed infrastructures are now being used for science. Charlie Catlett, director of TeraGrid, talked about how their distributed infrastructure is exploited, and others presented specific disciplines using Grid infrastructures such as EGEE or OSG. Particle physicist JoAnne Hewett from SLAC discussed potential discoveries in particle physics that might result from the new experiments at the LHC.

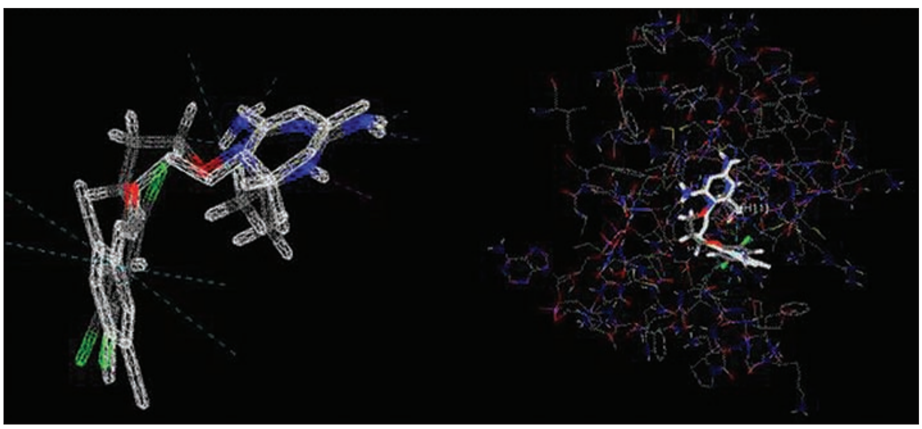
While the physical, biological and Earth sciences dominated the applications on display at the three AAAS sessions, the use of Grids for social science also featured. Bennett Bertenthal from Indiana University spoke about the Social Informatics Data Grid, an initiative to help social scientists collaborate and share data, often for the first time.

The use of distributed computing for education was also highlighted. David Anderson, director of the BOINC software platform that enables volunteer computing projects such as SETI@home and climateprediction.net, pointed out that the process people go through to decide which project to donate their computer time to leads them to learn much about current scientific research and the process of science.

GRID COMPUTING

WISDOM ends second round in the battle against malaria

In January, the World-wide In Silico Docking On Malaria (WISDOM) initiative finished its latest drug-discovery challenge with an average of 80 000 compounds analysed each hour on the EGEE Grid infrastructure. In total, the challenge processed more than 140 million possible docking arrangements between drug compounds and target proteins of the malaria parasite.



Left: Structure of a potential antimalarial drug. Right: A simulation of the drug binding to a protein from the malaria parasite. (Courtesy Vinod KASAM, CNRS/IN2P3.)

Between 1 October and 31 January this virtual-screening challenge of the international WISDOM initiative targeted compounds of interest for discovering drugs against neglected diseases. WISDOM uses *in silico* docking, where researchers use computing systems to calculate the probability that potential drugs will dock with a target protein. This allows the researchers to rule out the majority of potential drugs, so that they can concentrate on the most promising compounds in laboratory tests. The procedure speeds up the screening process and reduces the cost of drug development to treat diseases such as malaria.

This challenge was the consequence of the first large-scale *in silico* docking, when WISDOM docked more than 41 million compounds in summer 2005 in just six weeks, the equivalent of 80 years work for a single PC. The WISDOM team identified some 5000 interesting compounds, from which they found three families of molecules that could be effective against the malaria parasite. A second computing challenge targeting avian flu in April and May 2006 (*CERN Courier* September 2006 p18) has interested the biomedical-research community, so that laboratories in France, Italy, Venezuela and South Africa proposed targets for the second challenge against neglected diseases.

During the 10 weeks of the challenge, the project used the equivalent of 420 years of computing power of a single PC. Up to 5000 computers were used simultaneously in 27 countries, generating a total of 2000 GB of useful data.

INTERNET

W3C celebrates 10 years with style

This year the World Wide Web Consortium (W3C) celebrates the 10th anniversary of Cascading Style Sheets (CSS), a technology that designers use to create attractive, economical and flexible websites.

CSS offers numerous benefits to designers, not least a rich feature set. Using a simple declarative style, designers can set positioning, margins and alignment, layering, colours, text styling, list numbering, etc. CSS supports an increasing number of different typographic traditions and has made significant progress towards displaying multilingual documents.

Another benefit is that style sheets can be shared by multiple pages, making it easy to update an entire site by changing one line of CSS. Because style sheets can be cached, this can mean improved performance as well. CSS also allows easier cross-media publishing: the same document may be viewed with different devices (from large colour monitors to mobile phones to printers) by applying the appropriate style sheet, which the software can choose automatically (as suggested by the style-sheet author).

Other news from the W3C includes new web standards in XML and for industrial graphics. Based on widespread implementation experience and extensive feedback from users and vendors, the consortium has published eight new standards in the XML family to support querying, transforming and accessing XML data and documents. The primary specifications are XQuery 1.0, XSL Transformations (XSLT) 2.0 and XML Path Language (XPath) 2.0. These new web standards will be significant in enterprise computing by connecting databases to the web. In graphics, W3C and OASIS have jointly published WebCGM 2.0, a new industry standard for technical illustrations in electronic documents. WebCGM is widely deployed in defence, aviation, architecture and transportation.

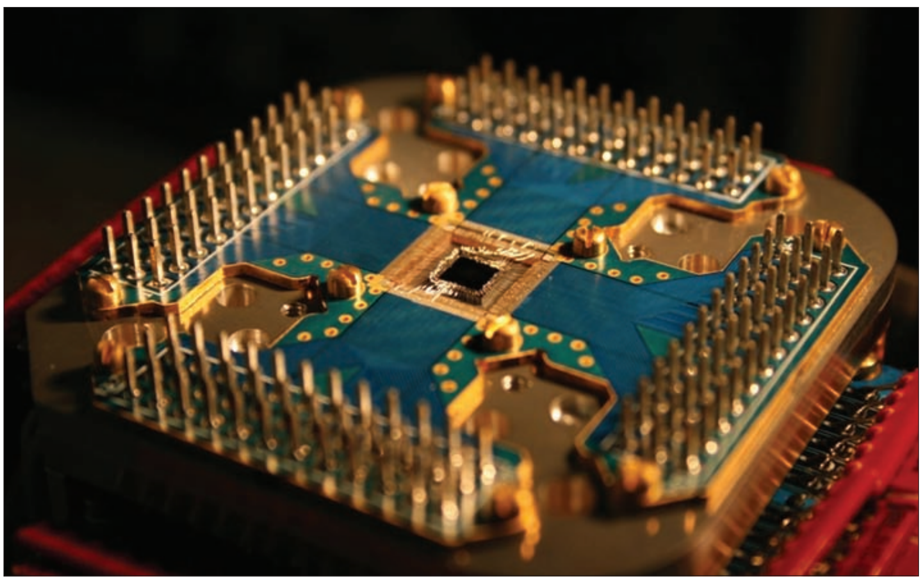
QUANTUM COMPUTING

Commercial quantum chip goes on show

On 13 February D-Wave Systems Inc. demonstrated the first commercially viable quantum computer at the Computer History Museum in Silicon Valley. Quantum computing offers a different approach to solving tasks that are excessively time-consuming on classical computers (*CERN Courier* April 2006 p22). At the demonstration, the company showed a pattern-matching application to search databases of molecules as well as an application for finding the optimal seating arrangements at a wedding or party, subject to constraints.

D-Wave developed the Orion quantum chip in part by using processes and infrastructure associated with the semiconductor industry. It also included other components, such as a new type of analogue processor that uses quantum mechanics rather than conventional physics to drive the computation. This approach in principle should allow the building of scalable processor architectures using available processes and technologies. In addition, the quantum chip's processors are computationally equivalent to more standard devices.

The chip operates at a base temperature of 5 mK and contains 16 quantum bits, or qubits, arranged in a 4 × 4 array. Each one is coupled to its nearest neighbours, including diagonally, giving a total of 42 couplings.



A 16 qubit processor in its sample holder. (Courtesy D-Wave Systems Inc.; J Chung.)

While quantum computing offers the potential to create value in areas where problems or requirements exceed the capability of digital computing, the demonstration by D-Wave was met with some scepticism by the scientific community, as the number of connections in the chip is very limited and further details from the company were scarce. Nevertheless, if further developments show a clear speed increase compared with conventional digital computers, this could be an important step towards quantum computing.

HARDWARE

Chip may boost particle-physics Grid power

The steady rise of the speed, or clock-frequency, of computer processors has resulted in design challenges for chip-makers in recent years. For example, the increasing heat generated by multi-gigahertz processors – said by some to approach the heat produced in a nuclear reactor – leads to difficulty in cooling chips efficiently.

Placing two, then four, processor cores on the same chip allows several applications to run in parallel with big boosts in overall performance, and lowers cooling bills for computer centres. PCs with multicore chips, such as the Intel quadcore PC launched last November at CERN, are especially attractive to the Grid computing centres affiliated with the high-energy physics community, whose applications require large amounts of parallel computing.

CERN's openlab programme received an early version of the chips for testing. The programme, of which Intel is a partner, used its well-defined methods to evaluate the chip's performance and validate it with high-energy physics benchmarks (p18). The testing included a demonstration of how quad-core processors can speed up the rate of a typical scientific calculation involving a parallelized version of the program ROOT, widely used in the high-energy physics community, by nearly a factor of four over conventional single-core processors. A parallel version of the ROOT program was used to split a data set into four pieces and calculate them in parallel on the quadcore chip.

● This is an abridged version, reproduced with permission, of an article first published online on *iSGTW* (www.isgtw.org).

Calendar of events

April

23–27 HEPiX Spring 07
DESY, Hamburg, Germany
www.hepix.org/

24–27 HealthGrid 2007
Geneva, Switzerland
http://geneva2007.healthgrid.org/

May

2–4 GPC 2007
Paris, France
www-lipn.univ-paris13.fr/GPC2007/

2–4 German e-Science 2007
Baden-Baden, Germany
www.ges2007.de/

7–11 OGF20 and EGEE User Forum
Manchester, UK
www.ogf.org/
www.eu-egee.org/uf2

14–17 CCGrid 2007
Rio de Janeiro, Brazil
http://ccgrid07.lncc.br/

21–22 DEISA Symposium 2007
Munich, Germany
www.deisa.org/news_events/future_events.php

21–23 IEEE TridentCom 2007
Orlando, FL, US
www.tridentcom.org/

21–24 Terena Networking Conference 2007
Copenhagen, Denmark
http://tnc2007.terena.org/

27–30 ICCS 2007
Beijing, China
www.gup.uni-linz.ac.at/iccs

June

4–8 TeraGrid '07
Madison, WI, US
www.union.wisc.edu/teragrid07/

5–8 Grid Asia 2007
Singapore
www.ngp.org.sg/gridasia/2007/

5–9 6th International Conference on Large-Scale Scientific Computations
Sozopol, Bulgaria
http://parallel.bas.bg/Conferences/SciCom07.html

September

2–7 Computing in High Energy and Nuclear Physics (CHEP'07)
Victoria, BC, Canada
www.chep2007.com/
Paper submission deadline: 2 April

17–21 Cluster 2007 and Grid 2007
Austin, TX, US
http://cluster2007.org/
www.grid2007.org/
Grid 2007 paper submission deadline: 7 April
Cluster 2007 paper submission deadline: 11 May

November

10–16 SC07
Reno, NV, US
http://sc07.supercomputing.org/
Paper submission deadline: 9 April

PC ADVICE

How to avoid a false sense of security

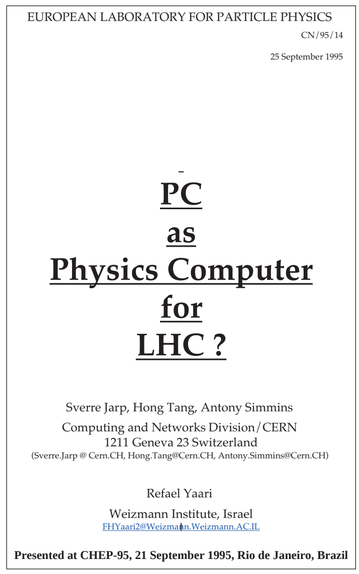
Even if a PC has up-to-date patches and the latest anti-virus software, and runs a local firewall, it can still be infected. Technical solutions help, but they cannot prevent all security problems. Computer users can help by taking simple precautions. The CERN computer-security team has produced some advice, which is targeted at Windows users, but should be useful for all platforms.

- **Do not expose your password.** Never use a work-related password for private use and be wary of e-mails, instant messages and chat that request your password, including via web links. This trick is known as phishing (password fishing). If you think your password may have been exposed, change it.
- **Lock your screen when leaving your office.** Locking your screen prevents others from accessing confidential material. From a Windows PC use [Control] [Alt] [Delete] and select “Lock Computer”, or if you have a Windows keyboard, press [Windows] [L].
- **Be wary of web links and pop-ups.** Some web links and pop-ups can download malicious software, so think before you click. Some pop-ups can still infect your machine even if you click “Cancel” or “No” or close the window with the top-right “X” . On a Windows PC use [Alt] [F4] to close the active window.
- **Ensure software downloads respect copyright and licensing.** This is for legal reasons and also because “free” versions of copyrighted software can contain Trojan horses, spyware or other malicious software that could infect a PC. Spyware is often included in “free” software and is used to trace your activity and even the data you type, including passwords. Plug-ins may also contain malicious software. If a website requires a plug-in to view it, avoid using it.
- **Be aware of social-engineering techniques.** Do not click on web links in unexpected e-mails, spam, instant messages and chat. Do not open attachments that you are not expecting.
- **Configure your machine to run without administrator privileges.** If you accidentally execute malicious software, it can cause less damage if you are running without administrator privileges. As many tasks do not need these, you are recommended to run without them.
- **Keep yourself informed of your institute’s computing rules.** There may be restrictions concerning software for personal use. When computers are used for personal as well as professional use, the chance of infections and other security incidents rises – downloading films, games, music and other personal applications all have risks.
- This is based on an article that appeared in the CERN *Computer Newsletter*, see http://cerncourier.com/articles/cnl/4/1/19/1.

Processors size up for physics at the LHC

When the LHC starts up, the physicists will rely mainly on industry-standard volume servers that leverage PC technologies to analyse the data. **Sverre Jarp**, CTO of CERN's openlab, looks at the challenges for software in the LHC era and how processors have evolved.

In the past few decades, largely thanks to Moore's Law, the world has witnessed an unprecedented race to higher and higher densities in integrated circuits. When we talked about "PC as Physics Computer for LHC?" at the CHEP '95 conference (figure 1) the x86-architecture based (micro)processors were already well established in other market segments. They had, at the time, typically 3–10 million transistors (figure 2). Today, they consist of more than 300 million transistors on a surface that is as big as a fingernail and the prediction is that this will continue to double every two years for at least another decade, or in other words, through most of the LHC era.


EUROPEAN LABORATORY FOR PARTICLE PHYSICS

CN/95/14

25 September 1995

PC as Physics Computer for LHC ?

Sverre Jarp, Hong Tang, Antony Simmins
Computing and Networks Division/CERN
1211 Geneva 23 Switzerland
(Sverre.Jarp @ Cern.CH, Hong.Tang@Cern.CH, Antony.Simmins@Cern.CH)

Refael Yaari
Weizmann Institute, Israel
FHYaari2@Weizmann.Weizmann.AC.IL

Presented at CHEP-95, 21 September 1995, Rio de Janeiro, Brazil

Fig. 1 (left). The paper "PC as Physics Computer for LHC?" that was presented at the CHEP '95 conference. Fig. 2 (above). The Intel Premium Pro chip launched in 1995. This chip started the massive move to PCs for high-energy physics computing.

Making use of transistors

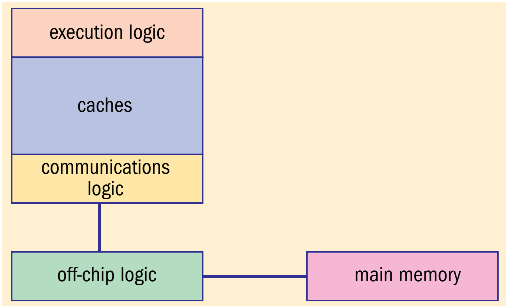
Over time, the transistors on a processor die have been put to use in several ways, some of which have been extremely advantageous to high-energy physics (HEP) software, others less so. Roughly speaking, a processor consists of the execution logic (including the register files), the cache hierarchy (typically 2–3 levels) and miscellaneous items, such as communications logic for interacting with the external world (figure 3).

In the era of the 386 and 486 chips, the processor executed a single stream of instructions in order, that is, exactly according to the way the code was laid out by the compilers. With the availability of additional transistors, engineers decided to change this simple execution scheme in two ways. First, they allowed instructions to be scheduled on multiple issue ports in parallel, like passing orders to several chefs who work in parallel in a kitchen. If neighbouring instructions are independent of each other, there is no need to wait for the first instruction to be completed before launching the second one. This strategy has taken us from the first Pentium with two ports (or pipes), via the Pentium Pro with three parallel ports, to today's Intel Core 2 micro-architecture with as many as six ports (figure 4).

Beyond the increase in the number of ports, designers also extended the instruction set so that instructions could operate on multiple data elements in one go. This is referred to as Single Instruction Multiple Data (SIMD) and can be found, for instance, in the x86 Streaming SIMD Extensions (SSE). Typically these instructions operate on data that is 128 bits wide, which means either four 32 bit numbers (integers or floats) or two 64 bit numbers (long integers or doubles) but other combinations are also possible. These instructions can be seen as "vector instructions" and usually achieve maximum efficiency in matrix or vectorbased programs.

To feed the multiple-execution ports mentioned earlier, there is a need to identify as much parallelism as possible, and the chip engineers consequently added a mechanism for out-of-order (OOO) execution. This scheme allows the processor to search for independent instructions inside an "instruction window" of typically 100 instructions and execute additional, independent work on the fly whenever possible.

As engineers introduced even denser silicon circuits, more and more transistors became available on one chip. This allowed – as a third trick – the extension of cache sizes. Whereas sub-megabyte caches were standard for a long time, now it is not rare to find processors with more than 10 MB of cache. The latest Xeon MP processor, for instance, features up to 16 MB of Level-3 cache,



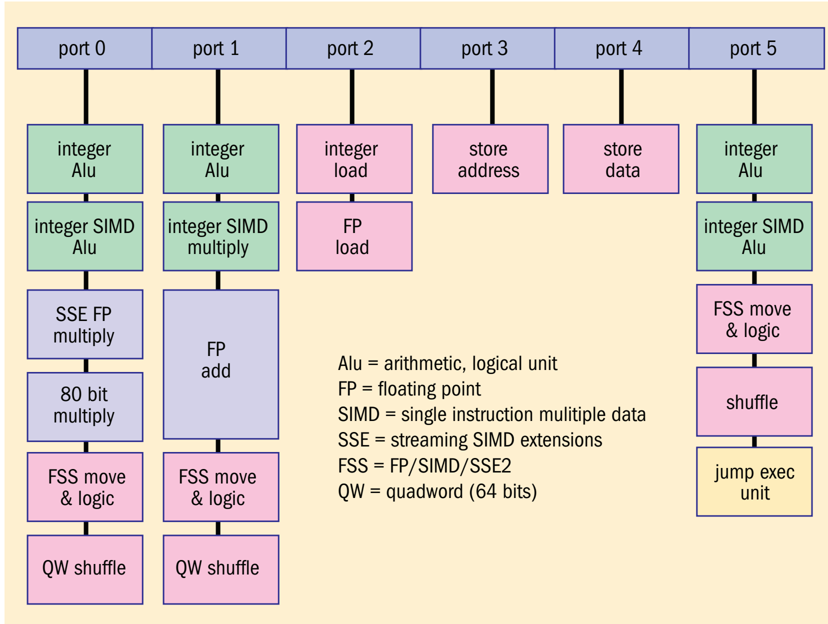


Fig. 3 (above). In principle a processor chip consists of three parts: the execution logic for the actual processing, the cache for storing data temporarily, and the communications logic for data transfers to the off-chip logic and from there to main memory. Fig. 4 (right). Simplified structure of the execution logic in the Core 2 micro-architecture. Different ports give access to specific execution units that are each dedicated to a specific task.

and the latest Itanium-2 processor sports 24 MB.

The advantage of using more transistors for cache is easy to understand. First, caches are easy to design and implement on the die; second, they run cool, consuming on average much less power than the execution logic; and third, the time to access data in a cache is typically 10–100 times shorter than accessing main memory off the chip (figure 3).

Nevertheless, the world needed more ideas for transistor usage and engineers invented chip-level "multi-threading". This is a scheme whereby additional transistors are used to keep the "state" of two software processes (or "threads") inside the execution logic simultaneously, while sharing the executing units and the caches. The chip's control logic switches between the two threads according to a pre-determined algorithm, typically either "round-robin" or "switch on long waits". In the latter case, if data are not found in the cache, we obtain a cache miss, which forces instructions or data to be read from main memory. This opens a gap of hundreds of cycles for the other thread to use (as long as it does not itself create another cache miss). This scheme is by no means limited to two threads and some suppliers already operate with higher numbers.

Having observed multi-threading and still being blessed with an ever-increasing transistor budget, it was easy to guess the next step. Rather than retaining the execution units and caches as a single resource, multi-core processors replicate everything, leading to a chip with multiple independent processing units inside (figure 5 p20). It is easy to see how this scheme (in addition to the cache expansion mentioned above) can be used to keep pace with transistor growth in the future.

On the other hand, since multi-core technology forces a rethink of the overall hardware design and more importantly the overall software-programming model, there is currently no agreement in the industry on what the "sweet spot" is. Sun Microsystems, on its T1 "Niagara" processor, currently offers eight single-port, in-order cores, and integrates support for four threads in each core. Intel already ships its first quad-core processor (launched recently at CERN; p16), although some purists will point out that this processor is built with two dual-core components for the time being. AMD has announced its single-die quad-core processor for availability during the summer. On the extreme side, Intel recently demonstrated an 80 core teraflop research processor chip, so it seems clear that double-digit core numbers are not too far into the future.

What's best for HEP?

In the community at large and also inside the CERN openlab, we have spent considerable time looking at the execution characteristics of HEP/LHC software. Our work has covered compiler investigations, benchmarking, code profiling using hardware monitors, information exchange with chip designers, and so on. In the following I will comment on the suitability of the various ways of deploying transistors for HEP software.

In openlab we were initially mandated to look at the advantages/disadvantages of running HEP codes on the Itanium in order, 64 bit processor, which ever since its inception in 2000 has proposed six parallel execution slots – the same number of ports as today's Core 2. The sad truth for both processor families is that at this level our programs express too little parallelism. When we measure the average number of instructions per cycle we typically find values that hover around 1 (or lower in certain programs). This is far from the maximum parallelism, especially when we also take SSE instructions into account, and is caused by the sequential ("perform one thing at a time") manner in which much of HEP software is written.

A standard way of expressing parallelism at the instruction level is to write small to medium-sized loops from which compilers may extract parallel components. Of course, in HEP we do have event loops, but these are simply too big and are not "seen" by the compilers, which typically scrutinize only small chucks of code in one go. As a result the compilers see only reams of mainly sequential code.

Let's look at a simple, rather typical example in which we ▷

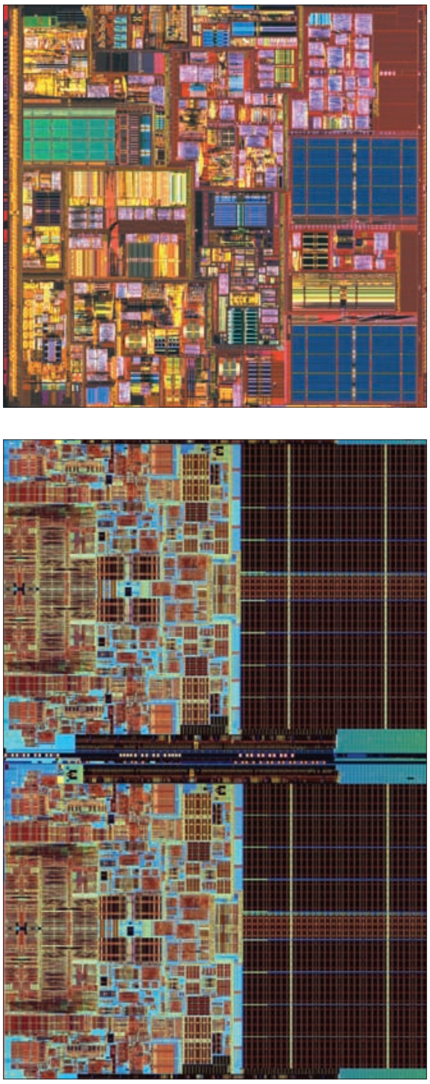


Fig. 5. *The Intel Core processor (top) and the Core 2 processor (bottom). The latter provides twice the functionality on the same die with roughly the same electric power budget.*

high-level C++ code

```
if (abs(point[0] - origin[0]) > xhalfsz) return FALSE;
```

assembler instructions

```
movsd 16(%rsi), %xmm0
subsd 48(%rdi), %xmm0 // load&subtract
andpd_2il0floatpacket.1(%rip), %xmm0 // and with a mask
comisd 24(%rdi), %xmm0 // load and compare
jbe ..B5.3 # Prob 43% // jump if FALSE
```

instructions laid out according to latencies on the Core 2 processor

Cycle	Port 0	Port 1	Port 2	Port 3	Port 4	Port 5
1			movsd point[0]			
2			load origin[0]			
3						
4						
5						
6		subsd	load float-packet			
7						
8			load xhalfsz			
9						
10	andpd					
11						
12	comisd					
13						jbe

Fig. 6. Schematic of how a simple task (checking if a point is inside a box) is executed on a multi-port chip, such as the Core 2. The C++ instructions are first translated into the machine or assembler code by the compiler, and are then executed on the different ports. The layout shows the progression of the program, taking latencies into account, such as the time needed for loading data from cache. Note that three "load" micro-operations are generated on the fly by the hardware. Execution is done in parallel where possible; however out-of-order execution is not taken into account. This shows how most of the execution logic is left idle.

test whether a point is inside or outside a box (in the x-direction); note that the hardware generates three load micro-operations on the fly:

```
Load point[0]; Load origin[0]; Subtract; Load a mask;
Obtain the absolute value via an and instruction; Load
the half-size; Compare; Branch conditionally;
```

The parallel hardware could cope with these instructions in a couple of cycles. The sequential nature of the code, however, together with the latency incurred by the loads from cache and the floating-point subtract and compare, result in a sequence that takes around 10 cycles. In other words, the program sequence only exploits 10–20% of the available execution resources (figure 6). Fortunately, other transistor deployment schemes work better for us.

HEP codes do benefit from OOO execution. This means that even when the compilers have laid out the code sequentially, the OOO hardware engine is able to shorten the execution time by finding work that can be done in parallel. This has, for instance, been seen when the test mentioned above is expanded to test x, then y, then z. The compilers lay out the tests sequentially, but the OOO engine overlaps the execution and minimizes the time used to compute the test for the two additional directions by more than 50% compared with the initial one. This is definitely good news for the day when we need to cope with more than three dimensions (!), but already today we see a clear gain.

As far as caches are concerned, HEP programs do not seem to need huge sizes. Our programs exhibit good cache locality with cache misses limited to around 1% of all loads. This is still not without consequences, since, as already mentioned, latency to main memory amounts to a few hundred cycles. Modern processors allow data to be pre-fetched, either via a hardware feature or software-controlled instructions, but we have not seen much evidence that execution paths in HEP software are regular enough to profit significantly.

Chip-level multi-threading has not received much attention in

Mersenne Twister

This code, called the Mersenne Twister, produces a sequence of random numbers. The code in blue represents a loop, while the code in red has to be executed sequentially. Both sequences are traversed on average once for each random number. However, the execution time of the loop is only a fraction of the sequential part. (Example taken from CLHEP.)

```
// A “fast, compact, huge-period generator” based on M. Matsumoto and
// T. Nishimura, “Mersenne Twister: A 623-dimensionally equidistributed
// uniform pseudorandom number generator”, to appear in ACM Trans. on
// Modeling and Computer Simulation.  It is a twisted GFSR generator
// with a Mersenne-prime period of 2^19937-1, uniform on open interval (0,1)

double MTwistEngine::flat() {
  unsigned int y;

  if( count624 >= N ) {
    register int i;

    for( i=0; i < NminusM; ++i ) {      // The loop
      y = (mt[i] & 0x80000000) | (mt[i+1] & 0x7fffffff);
      mt[i] = mt[i+M]       ^ (y >> 1) ^ ((y & 0x1) ? 0x9908b0df : 0x0 );
    }
    for(    ; i < N-1    ; ++i ) {
      y = (mt[i] & 0x80000000) | (mt[i+1] & 0x7fffffff);
      mt[i] = mt[i-NminusM] ^ (y >> 1) ^ ((y & 0x1) ? 0x9908b0df : 0x0 );
    }
    y = (mt[i] & 0x80000000) | (mt[0] & 0x7fffffff);
    mt[i] = mt[M-1] ^ (y >> 1) ^ ((y & 0x1) ? 0x9908b0df : 0x0 );

    count624 = 0;
  }

  y = mt[count624];  // The serial part
  y ^= ( y >> 11);
  y ^= ((y << 7 ) & 0x9d2c5680);
  y ^= ((y << 15) & 0xefc60000);
  y ^= ( y >> 18);

  return                          y * twoToMinus_32  +    // Scale to range
         (mt[count624++] >> 11) * twoToMinus_53  +    // fill remaining bits
                          nearlyTwoToMinus_54;      // make sure non-zero
}}
```

our community. This is probably linked to the fact that our jobs are CPU-bound with only few cache misses, and the potential gain is therefore finite. It may even be limited to single-digit percentage numbers in terms of throughput gains. On the other hand, more jobs need to run simultaneously, which increases the memory requirements and consequently the cost of the computer. The price/performance gain is therefore somewhat unclear.

With multi-core processors, however, we finally get to a scheme where the HEP execution profile shines. Thanks to the fact that our jobs are embarrassingly parallel (each physics event is independent of the others) we can launch as many processes (or jobs) as there are cores on a die. However, this requires that the memory size is increased to accommodate the extra processes (making the computers more expensive). As long as the memory traffic does not become a bottleneck, we see a practically linear increase in the throughput on such a system. A ROOT/PROOF analysis demo elegantly demonstrated this during the launch of the quad-core chip at CERN.

If memory size and the related bus traffic do become bottlenecks, we can easily alleviate the problem by exploiting our event loops. The computing related to each event can be dispatched as a thread in a shared-memory model where only one process occupies all the cores inside a chip. This should allow easy scaling with the increase of the number of cores, and permit us to enjoy Moore's Law for many years to come.

Compiler optimization

Our community writes almost all of the large software packages. Whether we think of event generators, simulation packages, reconstruction frameworks or analysis toolkits, we realize that they all have one thing in common: they are all in source format.

The most obvious way to optimize this software is to "tune" each package by using a tool that shows in a functional profile where the execution time is spent. Once a hot-spot is found, the source code is tweaked to see if performance improves. In rare ▷

cases, even the program design has to be revisited to correct severe performance issues.

In openlab, we have also taken another approach by working with compiler writers to improve the backend of the compiler, i.e. the part that is generating the binary code to be executed. The approach has great potential, because improvements in the code generator can lead to better performance across a range of applications – all the ones that exploit a given language feature, for instance. The approach presents a couple of tough challenges, though. The first is that you must master the "ancient" language "spoken" by the processor, which is called assembler or machine code. The second challenge is related to OOO execution, which makes the interpretation of execution speeds difficult: even if you believe that the compiler does something superfluously or inefficiently, you cannot assume that removal or simplification will result in a corresponding increase in speed.

It is beyond the scope of this article to cover this complex area in full detail, but let me list a few of the areas where programmers should try hard to assist the compilers, by paying attention to:

- **Memory disambiguation of data pointers or references.** For humans it is often clear that pointers such as `*in` and `*out` refer to completely different memory areas. For a compiler with limited visibility of the code, this may not at all be obvious and forces it to generate code sequences that are too "conservative".
- **Optimizable loop constructs.** Compilers and "wide" processors really shine when loop constructs are exposed in all of the important portions of a program (see box p21).
- **Minimization of `if` and `switch` statements.** Complex programs with nested if-else structures can easily limit the compilers ability to create efficient code. If such a structure cannot be simplified, one should at least ensure that the most frequently executed code is at the top and not at the bottom of the construct.
- **Mathematical functions.** Unnecessary calls should always be avoided since these functions are in general very expensive to calculate, as the compilers tend to lay them out as a single execution stream.

To improve profiling of the software execution, CERN openlab is actively working with the author of a powerful software package, called perfmon2. This package will soon become the universal interface in the Linux kernel to monitor performance of all supported processors.

Into the LHC era

For more than a decade HEP has been riding on the "commodity wave" of PC technologies. This has made gigantic computing resources available to our community. In January 2007, the count for the LHC Computing Grid showed that more than 30 000 processors are interconnected and this number will continue to grow.

There are, however, some worries to keep in mind. One is that we exploit the execution hardware at the 10–20% level, but given the cost ratio between "expensive" programmers and "cheap" hardware I do not expect that anybody is keen to revisit our program structures in a fundamental way.

Another worry is the megawatt ceiling on our computer centres. At CERN, we expect to saturate the cooling capability of our Computing Centre in a few years from now. It will then be impossible to add more computers to cope with the expected increase in demand and the only solution may be to optimize more to increase the efficiency of what is already installed.

On the positive side, multi-core systems that increase the number of available execution cores from generation to generation (on a constant power budget with increased energy efficiency) will definitely be in our favour. Vendors, such as Intel, tell us that we are seen as "ideal" customers for such systems. Let's just hope that the *Google*s and *Yahoo*s of this world will also help create a strong demand. This is absolutely vital since it is somewhat unlikely that normal PC users at home will be equally enthusiastic about many-core systems where they only see advantages if they are running multiple processes in parallel, but little or no speed-up in the case of a single process.

Finally, it is important to remember what happened during the LEP era. We started with mainframes and supercomputers, transited through RISC workstations and ended up with x86 PCs. All in all, this gave us more than a thousand times the computing power with which we started. I sincerely hope that the computer industry will help us perform the same miracles in the LHC era.

Résumé

Les processeurs pour la physique au LHC vus sous toutes les coutures

Lorsque le LHC entrera en service, les physiciens dépendront principalement de serveurs de PC standard de l'industrie pour analyser les données issues des collisions à haute énergie. Cela signifie que les caractéristiques des processeurs et du fonctionnement des logiciels utilisés pour la collecte des données devront être parfaitement compris. Sverre Jarp, responsable technique du programme CERN openlab qui collabore avec l'industrie pour tester les derniers développements apportés au matériel informatique, revient sur l'évolution des processeurs au cours des dix dernières années, à mesure qu'il est devenu possible d'intégrer de plus en plus de transistors – les composants de base – dans une puce. Il évoque également les défis ainsi posés aux logiciels de l'ère du LHC.

Sverre Jarp, *CTO, CERN openlab. Among other activities, the CERN openlab collaborates with industry to test out the latest developments in computer hardware.*

US looks to new rare-isotope science facility

A new heavy-ion linear accelerator based in the US would provide the opportunity to tackle directly the current challenges arising from investigations of nuclear science.

Artist's impression of a white dwarf accreting material from a companion red giant in a binary stellar system, which could lead to a supernova explosion. Nuclear data generated by a new isotope-science facility would help to investigate directly the nuclear processes that occur in explosive stellar environments like this. (Courtesy David A Hardy and PPARC.)

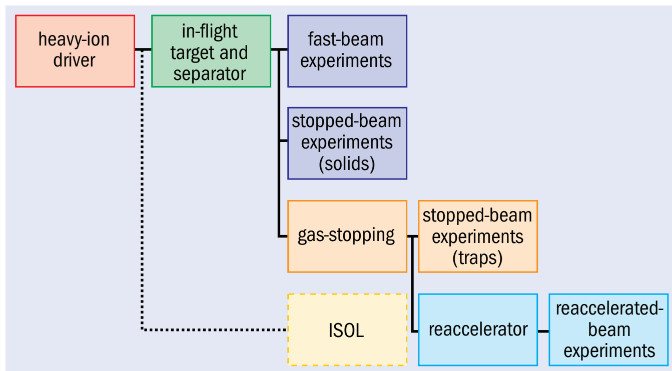


Fig. 1. Building blocks of an isotope-science facility based on a heavy-ion driver. For isotope production and separation in-flight, fast beams can be used directly, brought to rest in solids, or stopped in gas and extracted for use at very low energies or at higher energies after reacceleration. Light ions can be used to produce isotope beams by the ISOL technique for experiments at very low energies or at higher energies after acceleration.

Nuclear science is one of many branches of physics that daily disprove the musings of Lord Kelvin. Sometime around 1900, before quantum mechanics and special relativity, the pioneer of thermodynamics and the creator of the absolute-temperature scale reportedly declared, "There is nothing new to be discovered in physics now." More than a century later, nuclear physicists remain energized by a host of pursuits, including exploring the science of atomic nuclei, understanding processes in nature's most powerful explosion, the supernova, and addressing open questions about fundamental symmetries of nature. The compelling questions that drive this research are creating a push for new facilities in various parts of the world, including a rare-isotope science facility for the US.

Rare-isotope research today explores the limits of nuclear stability and determines nuclear properties in the uncharted domain of nuclides with very unusual proton-to-neutron composition. The nuclei farthest from stability are especially important and provide the best vehicle for understanding the interplay of internal structure, reactions with other objects of a similar nature, and decays to the continuum. Such nuclei enable myriad experimental possibilities that collectively will advance and possibly even transform nuclear theory. Some of the most likely experiments will address wide-ranging themes in nuclear physics, ranging from magic numbers to dynamical symmetries to the limits of stability. Others will home in on specific measurements of nuclear-shell structure aimed at elucidating the most important degrees of freedom.

Attempts at fine-grained analysis of nuclear structure invariably lead to innovation in the tools that underpin the workaday world of nuclear physics. One contemporary example is intermediate-energy Coulomb excitation, which allows critical information to be extracted from experiments with beam intensities of only a few tens of thousands of atoms a day. Another example is the precision determination of nuclear binding energies with Penning traps. Current experimental frontiers include studies of nuclear sizes, wave functions, half-lives and decay modes of exotic nuclei.

Beyond the relevance to basic nuclear-structure physics, rare-isotope research is increasingly vibrant at its edges, where the field connects to other intellectual pursuits such as mesoscopic quantum systems – which can be averaged over many atomic-scale systems – and astrophysics. To a very good approximation, we can describe nuclei as self-sustaining finite droplets of a ▷

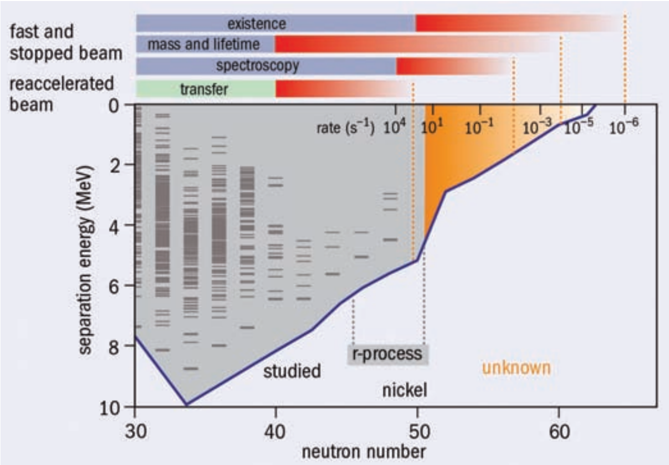


Fig. 2. The scientific reach with reaccelerated or fast beams of neutron-rich nickel isotopes. Known nuclei and levels are indicated in grey. Unknown nuclei are indicated in orange. Also indicated are nuclei important for the r-process. Investigations that are very far from stability require fast-beam techniques. The gains in sensitivity for fast beams are largely due to the luminosity gains that can be realized with thick targets and, to a lesser extent, are due to forward-focused kinematics.

two-component – neutron and proton – Fermi-liquid, the detailed properties of which depend on the delicate interplay of the strong, electromagnetic and weak interactions.

Advances in computation techniques have allowed accurate microscopic calculations of the properties of very light ($A < 16$) nuclei. For heavier nuclei, full microscopic treatments rapidly become unfeasible and additional approximations must be introduced to solve the underlying many-body quantum problem. This is mesoscopic study, between microscopic and macroscopic. Many exotic nuclei are systems of marginal stability for which coupling to the continuum is important. They are "open" mesoscopic quantum systems in which interactions among finite numbers of particles can be described by effective forces. Describing the interplay of internal structure and external interactions is relevant to other research areas in physics, including information processing, quantum chaos, decoherence and phase transformations.

Understanding mesoscopic quantum systems is important to progress in nanotechnology and quantum computing, which are areas of high interest in condensed-matter physics and quantum optics. In nanotechnology, the basic quantum many-body problem raises fundamental issues about the design and engineering of artificial mesoscopic systems in which complexity emerges from the elementary interactions of a relatively small number of constituents. Nuclear science addresses similar questions, though at femtometre rather than nanometre scale.

Nuclear processes shape much of the visible universe – one reason why astrophysics and nuclear physics have long been closely connected. This link will strengthen in the future. Research with rare isotopes together with progress in observational astronomy will help address several areas of inquiry in astrophysics, including the chemical history of the universe, the conditions and sites where the elements were created, and the nature of exotic objects such as neutron stars, and explosive events such as novae and supernovae.

With more than 2000 active scientists worldwide, rare-isotope research is vibrant and international. New and planned facilities at RIKEN in Japan, GSI in Germany and GANIL in France complement existing facilities such as Louvain-la-Neuve in Belgium, HRIBF in Tennessee and the TRIUMF ISAC facility in Canada.

Inspired by such promise in this field, the US National Academies have recently published a report justifying the case for a new isotope science facility in the US. The report, nearly a year in the making and released online in unedited prepublication form on 8 December, concluded that the science goals were compelling and that "the science addressed by a rare-isotope science facility... should be a high priority for the United States". The report adds that, provided the new facility is based on a heavy-ion linac, it will complement existing and planned nuclear-science activities worldwide.

A January town meeting in Chicago provided additional momentum. The aim of the meeting, part of the US nuclear-science community's current five-year strategic planning exercise, was to identify top priorities in nuclear-structure and nuclear-astrophysics research. Attendees at the meeting concluded that one such priority is a more powerful means for producing rare isotopes for research with stopped, reaccelerated and in-flight (or fast) beams.

The scientific questions and a set of possible options for the technical implementation of such a new facility are laid out in some detail in a recent whitepaper released by the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University (MSU). This document proposes building a high-power superconducting heavy-ion linac at MSU. The new Isotope Science Facility (ISF), the working name of the proposed MSU facility, would be based on a linac able to deliver beams of all stable elements with variable energies up to at least 200 MeV/nucleon and beam power up to 400 kW. A team at Argonne National Laboratory has presented similar ideas.

The ISF would combine the possibility of measurements with post-accelerated radioactive beams with the ability to conduct experiments using fast radioactive beams. In many cases, fast beams would provide 10 000 times higher sensitivity than is possible with reaccelerated beams, and make possible experiments with single ions of the rarest isotopes. This is an important consideration, the NSCL whitepaper points out, given that many interesting isotopes that are potential objects of study are produced at levels below a hundred or so per second, where the reaccelerated beam technique starts to become difficult. For example, fast beams would allow researchers to probe how nuclear structure evolves in nickel isotopes moving from atomic numbers 48 to 83. In addition fast beams would enable the study of key benchmark nuclei near ^{48}Ni, ^{60}Ca, ^{78}Ni and ^{100}Sn (*CERN Courier* June 2005 p6).

Complementary to the fast-beam approach, the proposed facility will allow isotope separation online (ISOL) techniques, in which isotopes are produced at rest in a thick target. CERN's ISOLDE facility pioneered the field, and the forefront research using reaccelerated beam produced from ISOL continues in Geneva (*CERN Courier* December 2004 p16). Stopped beams are important for precision measurements with ion or atom traps or for collinear laser spectroscopy. Reaccelerated beams provide the opportunity to measure important nuclear-reaction rates relevant to nuclear astrophysics and to employ the well-proven techniques of nuclear-structure physics to a host of new nuclei. In addition, reaccelerated beams allow the investigation of fusion reactions, which will lead to the production of new neutron-rich isotopes of very heavy elements.

The use of a heavy-ion linac allows in-flight separation of ions and provides a path to reaccelerated beams that overcomes some of the chemical limitations of traditional ISOL techniques. Stopping, extracting and reaccelerating rare-isotope beams leads to intensity losses, the full extent of which is not yet known, although NSCL, Argonne National Laboratory, GSI and RIKEN are making significant progress. The time has come, however, for full performance tests of the concept. NSCL is building a project to test comprehensively the production, gas-stopping and reacceleration sequence.

A new US facility would complement international efforts in this field and would be relevant far beyond basic nuclear-structure research, especially given the links to other physics-related disciplines, such as astrophysics and mesoscopic science (*CERN Courier* December 2006 p46). However, the most important reason to proceed with rare-isotope research is to address questions at the core of nuclear physics. What are the limits of nuclear existence? How do we develop a predictive theory of nuclei? What is the origin of simple patterns in complex nuclei? What is the nature of neutron stars?

Such big questions represent the barest fraction of the unknown in nuclear science, which demonstrates that there is much compelling knowledge to be generated in a next-generation isotope-science facility – and also that Lord Kelvin is as wrong today as he was more than a century ago.

Further reading

The NSCL whitepaper, "Isotope Science Facility at Michigan State University," is available at www.nscl.msu.edu/isf.
The National Academies Report, "Scientific Opportunities with a Rare-Isotope Facility in the United States," is available at www7.nationalacademies.org/bpa/RISAC.html.

Résumé

Les États-Unis misent sur une nouvelle installation scientifique pour isotopes rares

La physique nucléaire englobe une multitude de quêtes: étudier la science des noyaux atomiques, comprendre les processus à l'origine de l'explosion la plus puissante de la Nature – la supernova, répondre aux questions encore non résolues sur les symétries fondamentales de la Nature, entre autres choses. Ces questions, qui sont le moteur de ces recherches, incitent également à construire de nouvelles machines en divers endroits du monde, par exemple une installation scientifique pour isotopes aux États-Unis. L'une des options consiste à construire une machine basée sur un accélérateur linéaire supraconducteur haute puissance d'ions lourds au Laboratoire national du cyclotron supraconducteur (NSCL) de l'Université de l'État du Michigan. Elle compléterait d'autres activités menées dans le monde entier dans le domaine de la science nucléaire.

Kirby Kemper, *Florida State University*, **Brad Sherrill**, *Michigan State University, and* **Michael Wiescher**, *University of Notre Dame and the Joint Institute for Nuclear Astrophysics.*

George Smoot: the India

During a visit to CERN, 2006 Nobel laureate George Smoo
the early universe, and how cosmology and particl

George Smoot feels at home when he is at CERN: as he walks through the corridors he always meets colleagues waving to him. This is not surprising as he has often visited the laboratory during the past 20 years. And even if he is now considered one of the great cosmologists, he remembers that his work began in particle physics when he was a PhD student.

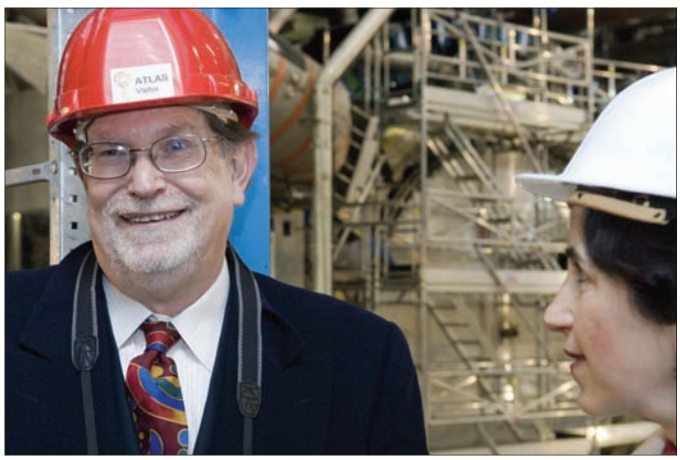
As Smoot himself says, he was destined to be a scientist: he is cut out to do it. He remembers that as a child he asked his parents how the Moon could appear to follow their car and at the same time all the cars in the world. When they explained about the Earth and the Moon, it was a revelation for him and perhaps the beginning of his career. So, while still very young, Smoot read about Galileo, who became his hero. Was he not one of the first experimental physicists and the first astronomer to turn a telescope to the sky?

Later, Smoot joined the Massachusetts Institute of Technology where he thought first of studying medicine. But physics and mathematics finally called him and he majored in these subjects in 1966 before focusing on particle physics, in which he obtained his doctorate in 1970. Soon he switched to cosmology, moving to the Lawrence Berkeley National Laboratory (LBNL) where he has worked and taught for more than three decades.

From the rainforests of Brazil to the bleak plains of Antarctica, Smoot has covered the whole world looking for what he likes to call "the holy grail of cosmology" – evidence for the Big Bang. This Indiana Jones of cosmology also likes playing with the big toys of technology and has used all he can to penetrate the mysteries of the early universe: high-altitude experimental balloons, U2 spy planes, satellites and so on. At LBNL he began work on the High-Altitude Particle Physics Experiment (HAPPE), aiming to find antimatter in the upper atmosphere, and cast light on the theory of the Big Bang. While he did not find antimatter with HAPPE, he did go on to discover the long-sought hard evidence for the Big Bang. In 1974 he had begun work on a proposal to map the cosmic microwave background (CMB) radiation. This later blossomed into NASA's Cosmic Background Explorer (COBE), with which he discovered small fluctuations in the CMB in 1992.

In 2006 Smoot won the Nobel Prize in Physics for this major milestone in our knowledge about the origin of the universe (see box). It is as if he had taken a photograph of the baby universe, succeeding where others had failed for so long. To achieve this breakthrough, he invented precision cosmology, managing to measure very tiny differences in the temperature of the cosmological background radiation at the level of a hundred-thousandth of a degree. His discovery is really a revolution, perhaps the greatest since the confirmation of the theory of general relativity. What

George Smoot: now considered one of the great cosmologists.



Fabiola Gianotti, ATLAS deputy spokesperson, talks to Smoot about the huge detector, which can be seen in the background.

Smoot calls the "wrinkles in time" gives us a new view of the very early universe, prefiguring the formation of large structures such as galaxies. And what is most exciting for him, is that in his opinion we now have one clear picture for the origin of the universe, which transcends cultures, religions and other differences the world over.

The discovery was by no means easy. Smoot and his team had to analyse and clean a large amount of data, verifying them again

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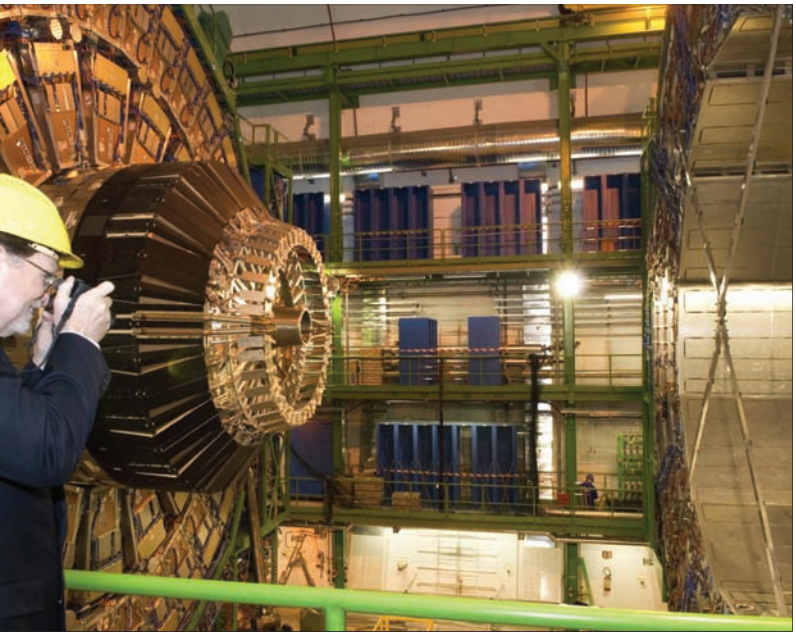

to take pictures not just of the early universe, Smoot photographs CMS.

very first lumps of the universe

iscovery in 1964 of the cosmic microwave background (CMB) radiation, n is like a rumble from the Big Bang at microwave wavelengths, was a r factor in consolidating the theory of the Big Bang. However, cosmological els are based on a very homogeneous early universe, so cosmologists ed the existence of very tiny fluctuations in the CMB to explain how this th universe could give birth to great structures such as galaxy clusters. s what the COBE satellite revealed in 1992 – tiny variations of density in ery early universe. Today, the study of the CMB is a major tool for research smology. Increasing the precision of the measurements will refine the s of the cosmological parameters, and should help in consolidating the ionary scenario, in which a violent phase of expansion would have occurred fter the very early Planck epoch when the fundamental forces were unified.

and again before being sure of the results. (This is more or less what physicists at CERN will have to do soon with the experiments at the LHC.) At the end of this meticulous work, however, he felt so confident about his results that he said he would offer a plane ticket to any destination to anyone who could find a mistake.

Smoot has now been tracking fluctuations in cosmological background radiation for more than 30 years, but he is not yet ready to step down. Now he is working on the Planck mission, the European successor to the Wilkinson Microwave Anisotropy Probe, which will give a higher precision than ever before. It is due to launch in 2008, when the LHC will be collecting its first data. "In the following three or four years, the most exciting physics experiments will be Planck and the LHC," says Smoot. He is expecting much from the LHC experiments, so it is no coincidence that he went to see ATLAS and CMS during his visit to CERN. He says that "CERN is the place to be," adding that if he was a PhD student now he would want to work there.

With Planck, Smoot hopes to answer new questions about the shape of the universe and the inflationary model, so he thinks it would be very exciting to find something unusual at the LHC, such as extra dimensions or supersymmetry – something really revolutionary that would be exciting for the next generation. Whatever is found, it will open new windows on the universe and give new lines of research for physics. For Smoot, even though they have followed different paths, cosmology and particle physics are now asking the same questions – they are merging. He explained in the talk he gave at CERN how cosmological data could be used to test fundamental-physics models, providing frameworks and constraints. "We are living in the golden age of cosmology," he says. Now he is waiting for the next cliffhanger in our exploration of the universe and is certain to be one of the main players in this next scientific crusade.

Further reading

G Smoot and K Davidson 1994 *Wrinkles in time* (Avon Books).
For the colloquium at CERN see http://agenda.cern.ch/fullAgenda.php?ida=a0720.

Résumé

George Smoot: l'Indiana Jones de l'Univers

Depuis les forêts vierges du Brésil jusqu'aux terres glaciales d'Antarctique, George Smoot a parcouru le monde à la recherche du «Saint Graal de la cosmologie». Sa quête? Percer le secret des origines de l'Univers et traquer inlassablement les plus petites évidences du Big Bang. Cette croisade l'a conduit à publier en 1992 la carte des anisotropies du fond diffus cosmologique, sorte d'image de l'Univers primordial. Récompensé par le prix Nobel 2006 pour cette découverte majeure, George Smoot est venu au CERN expliquer comment les données cosmologiques peuvent aider les physiciens des particules dans leur propre recherche. Il a ainsi montré à quel point, physique des particules et cosmologie sont plus que jamais deux champs posant les mêmes questions.

Arnaud Marsollier, *outreach coordinator for ASPERA, CERN.*

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MEGAPIE leads the way to waste transmutation

A high-power proton beam and a special target have produced a high-power neutron source at PSI, with potential for the transmutation of radioactive waste.

Megawatt-class beam targets are nowadays attracting attention from a wide variety of users, for investigations that span the spectrum from the transmutation of long-lived radioactive waste, through material research, to radioactive beams and neutrino factories. At the Paul Scherrer Institute (PSI), the Megawatt Pilot Experiment (MEGAPIE) has recently demonstrated the feasibility of safely running a liquid heavy-metal target in the world's most powerful DC proton beam. The experiment is particularly important for the development of an accelerator driven system (ADS) for the transmutation of long-lived radioactive waste. It serves to demonstrate the feasibility, potential for licensing, and long-term operation under realistic conditions, of a high-power spallation target, which could later provide the high-energy neutrons required to induce fission in waste atoms.

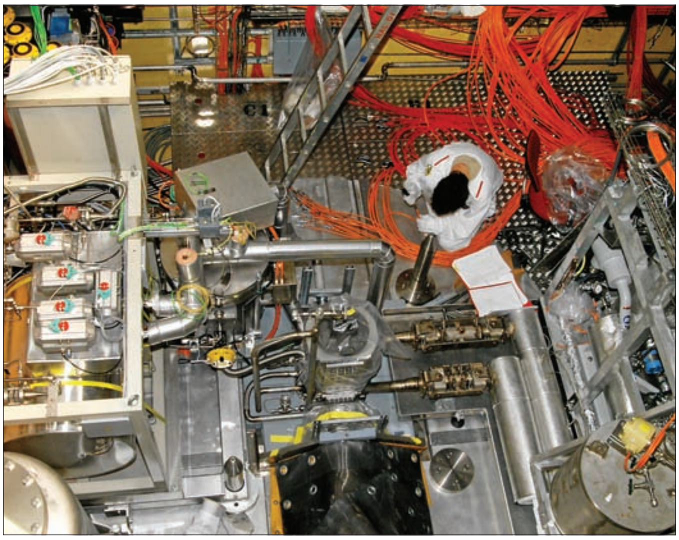
Spallation neutrons are produced efficiently by firing a proton beam at a heavy-metal target such as lead where the reactions of the protons with nuclei literally knock out or "spallate" neutrons, while further neutrons are evaporated. On average each proton produces about 11 neutrons. Up until now spallation targets have always been solid, but MEGAPIE has demonstrated the advantages of a liquid target, namely an increase in neutron flux and convectional cooling of the target window. The second advantage gives the liquid target potential for higher power, in contrast to a solid target, which cannot be cooled sufficiently. In MEGAPIE, the use of a liquid target with the 1 MW beam at the Swiss Spallation Neutron Source (SINQ) increased the neutron flux by about 80% compared with the previous solid-lead target.

A powerful alliance

MEGAPIE is a collaboration of nine research institutes in Europe, Japan, Korea and the US, which have agreed to design and build a liquid-metal spallation target suitable for 1 MW beam power, and to license and operate it at PSI, where SINQ is the world's only spallation neutron facility with a sufficiently powerful proton driver. The present 1.1 MW proton beam from PSI's 590 MeV ring cyclotron delivers, after passing two secondary-beam production targets, a continuous proton-beam current of up to 1.4 mA (about 800 kW) at an energy of 575 MeV to the SINQ spallation source. For MEGAPIE, the collaboration decided that the liquid-metal target must be irradiated for a minimum of three months, both to achieve a sufficiently high irradiation dose on the component materials and to demonstrate that the system could operate reliably. During its operation, the target served as the source for the neutron-scattering programme at PSI, which involves some 260 experiments.

Installation of the 5 m long liquid-metal MEGAPIE target in the hall at the spallation neutron source, SINQ. (Courtesy PSI.)

The MEGAPIE target consists of 920 kg of liquid lead-bismuth eutectic (LBE), contained in a steel casing. On impact, the 800 kW proton beam deposits about 580 kW of heat in the target ▷



At the beginning of the experiment, the MEGAPIE researchers fill the target with liquid metal through the large insulated tube visible towards the middle of the picture. (Courtesy PSI.)

material. The heat is removed by circulating the lead-bismuth in forced convection through a heat exchanger. The proton beam penetrates the lead-bismuth to a depth of 27 cm and generates an integrated flux of 10^{17} neutrons a second.

During the four months of operation, the target operated very satisfactorily and according to predictions. It triggered only a small number of unscheduled beam shutdowns and experienced more than 8000 beam interrupts of different durations without damage. Its availability reached 95%, with an accumulated proton charge amounting to 2.8 Ah.

Earlier Monte Carlo simulations had indicated that the liquid-metal target should provide a 40% increase in neutron flux (at identical current) compared with a solid target. However, initial measurements at selected instruments confirmed an increase in neutron flux, which the collaboration met at first glance with some scepticism: instruments at the cold guide gave a flux increase as high as 70–80%. However, gold-foil activation measurements have confirmed flux increases of 80–90% at both a thermal and a cold beam port. New calculations with more detailed target and moderator geometry now reproduce these results.

The higher flux means that it will be possible to carry out more experiments within the same time frame, a definite benefit for the over-booked beam lines. With a flux gain of this magnitude, operation with a permanent liquid-metal target at SINQ has become a priority and PSI has launched a new project to pursue this goal.

From nuclear waste to beta-beams

The success of MEGAPIE is particularly important for research into ADS transmutation of radioactive waste. The long-lived minor actinides (neptunium, americium and curium) are the main contributors to the long-term radio-toxicity of nuclear wastes. However, it should be possible to transmute them into short-lived or stable elements using a sub-critical ADS equipped with an internal neutron source and driven by a high-energy proton beam. CERN has made major contributions to this concept with the experiments FEAT and TARC (*CERN Courier* April 1997 p8). In 1998, a technical working group headed by Carlo Rubbia established a roadmap to achieve ADS transmutation. The group considered the development of a high-power spallation target and the demonstration of its reliable operation to be vital steps *en route*.

Researchers are now also considering ADS scenarios based on megawatt spallation neutron targets for the next-generation European Radioactive Ion Beam Facility, EURISOL (*CERN Courier* April 2004 p23). Here a 1 GeV superconducting linear proton driver with separate post-acceleration capabilities will allow low-, intermediate- and high-energy, very intense radioactive ion-beams to probe fundamental questions in nuclear structure, nuclear astrophysics and fundamental symmetries and interactions. Another use of an ADS based on a spallation source would be the production of a neutrino beam in a "beta beam". In this case, radioactive ions circulating in a storage ring beta-decay to produce a pure beam of electron-neutrinos/antineutrinos; the ions themselves are produced in a two-step process from the interaction of spallation neutrons in a suitable secondary target (*CERN Courier* July/August 2004 p30).

The pie is opened

The accelerator shutdown at the end of 2006 marked the end of the irradiation phase for MEGAPIE. The final phase of the experiment – the post-irradiation examination of the target components – will start after the target, which is now solidified, has been stored for two years. The analysis will provide information about corrosion effects on structural materials and allow the validation of various models. The state of the beam window will allow the combined effect of LBE and proton irradiation to be assessed and provide information on the potential lifetime of such a beam window. The analysis of the LBE will also furnish information on the spallation products and their chemistry, so validating neutronic and radiochemical models. This information will feed back into the design and operation of new spallation sources. New versions of ADS will also benefit enormously from the experience gained from MEGAPIE, which has also proved to be a key experiment for future industrial projects involving the transmutation of nuclear waste.

Further reading

For more information on MEGAPIE see http://megapie.web.psi.ch.

Résumé

MEGAPIE ouvre la voie en matière de transmutation nucléaire

Les cibles pour faisceaux d'un mégawatt retiennent désormais l'attention d'utilisateurs les plus divers, pour des recherches allant de la transmutation de déchets radioactifs à vie longue aux faisceaux radioactifs, en passant par les usines à neutrinos. À l'Institut Paul Scherrer, le projet MEGAPIE (Megawatt Pilot Experiment) a récemment démontré qu'il était possible d'exploiter de manière sûre un puissant faisceau de protons en continu sur une cible en métal liquide. L'expérience a montré le potentiel pour l'exploitation à long terme dans des conditions réalistes d'une cible de spallation haute puissance qui pourrait ultérieurement fournir les neutrons de haute énergie requis pour induire une fission dans les atomes de déchets radioactifs.

Juanita Schlaepfer-Miller, *PSI.*

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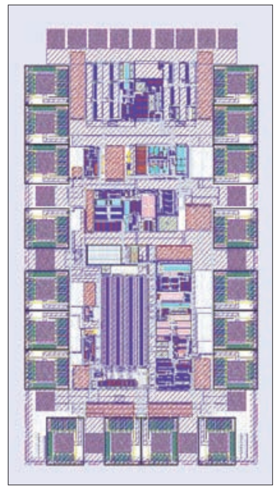
RF antennas help unravel cosmic rays



Top: A view of the antennas of the Decametric Array that CODALEMA uses at the Nançay Radio Observatory. Above: One of the 16 active wide-bandwidth dipole antennas with its application-specific integrated circuit layout (right).

The first results from the CODALEMA experiment are introducing a new approach for studying very high-energy cosmic rays.

The origin of ultra-high-energy cosmic rays (UHECR) observed at energies above 10^{19} eV is a mystery that has stimulated much experimental and theoretical activity in astrophysics. When cosmic rays penetrate the atmosphere, they produce showers of secondary particles and corresponding radiation, which in principle yield information on the particle tracks, energy and origin of the primary cosmic rays. The CODALEMA experiment in Nançay has recently measured the radio-electric-field profiles associated with these showers on an event-by-event basis. These novel observations are directly connected to the shower's longitudinal development, which is related to the nature and energy of the incident cosmic ray.

There have been previous partial studies of radio emission from showers, so why is this result so promising? The UHECR flux is very low (a few per square kilometre per century), so the largest detector arrays are square kilometres in area to detect secondaries at ground level combined with various other techniques, such as the fluorescence emission. However, the latter method is limited to the optical domain, where the need for moonless skies and appropriate environmental conditions results in a maximum duty cycle of only about 10%. So, the radio detection technique offers an interesting if challenging alternative (or complementary) method in which one antenna array can provide a very large acceptance and sensitive volume adequate to characterize rare events, such as UHECR.

There is also another important argument for the radio technique: because the distance between radiating particles is several times smaller than typical radio wavelengths, the individual particles radiate in phase. This will result in a coherent type of radio emission dominating all other forms of radiation, with a corresponding electromagnetic radiated power proportional to the square of the deposited energy. In air, the coherent radiation will build up at frequencies up to several tens of megahertz, while in dense materials, more compact showers can result in coherence radiation up to several gigahertz. Gurgen Askar'yan first suggested the production of radio emission in air showers in 1962, and some observations were reported in the 1960 and 70s (Allan 1971, Gorham and Saltzerg 2001 and *CERN Courier* April 2001 p19). The electronics available at the time made the measurements unreliable, however, and researchers abandoned the technique in favour of direct ground particle or fluorescence measurements.

High-performance digital signal-processing devices have now made feasible the sampling of radio-frequency (RF) waveforms with large frequency bandwidth and high time-resolution, depending on the nature of the primary cosmic ray. Exploiting these new possibilities, the SUBATECH Laboratory, Nantes, and the Paris Observatory have developed the CODALEMA (Cosmic ray Detection Array with Logarithmic Electro-Magnetic Antennas) experiment on the site of the Nançay Radio Observatory.

For its first phase, CODALEMA has used some of the 144 log-periodic antennas of the decametric array of the Nançay Observatory distributed along a 600 m baseline. All the antennas are band-pass filtered (24–82 MHz) and linked, after RF signal wide-band amplification, to fast-sampling digital oscilloscopes (figure 1).

In its first running period, CODALEMA has established the appropriate conditions for the analysis of the antenna data, either in stand-alone mode or in coincidence with a set of particle detectors acting as a trigger. Figure 2 (p34) shows four cosmic-ray events identified at different zenith angles. It illustrates how the results reveal the dependence of the electric field on the distance of the antenna ▷

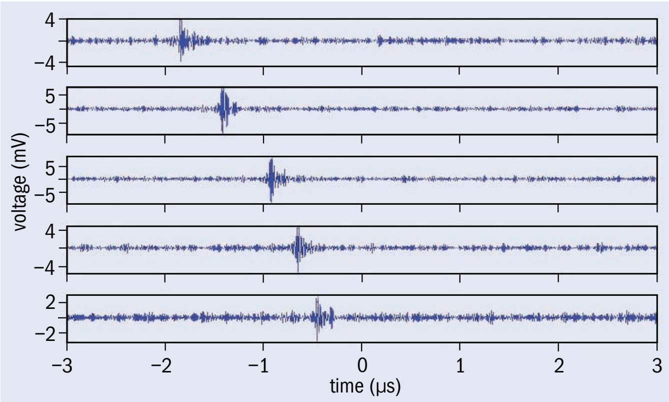


Fig. 1. Illustration of a cosmic-ray event as observed by five antennas. Each of them is flagged at a time representative of the propagation of the radio wave front.

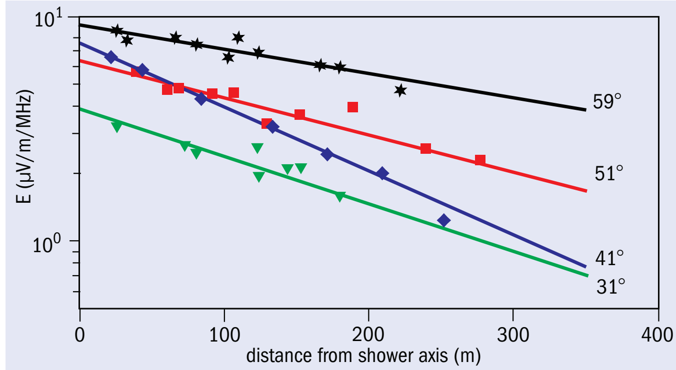


Fig. 2. Measured electric-field profiles plotted versus the distance of different antennas from the position of the shower impact. Four events are shown corresponding to various reconstructed zenith angles.

to the shower impact (in metres) at energies around 10^{17} eV. They show for the first time the richness of the information contained in the longitudinal shower development measured by radio detection.

First, the device is sensitive to amplitudes down to 1 µV/m/MHz, which is free from the fluctuations in the number of particles encountered in particle detectors. This allows detailed analysis of the field amplitude and its dependence on the energy and nature of the incident cosmic ray. It is remarkable that this sensitivity is carried over distances presumably greater than 600 m from where the shower hits the ground. The clear zenith angle dependence of the field profile illustrates the large angular acceptance of the array. This demonstrates for the first time the sensitivity of this detection method to the development of the shower, related to sequences of charge generation. Additionally, a Fourier transform analysis of the signal revealed a possible frequency dependence of the signal with impact parameter, a quantity strongly connected to the physical characteristics of the air shower.

At last, the study of the stand-alone antenna mode has clearly established that the transient character of the radio signal can be safely used to determine the arrival direction (with an accuracy of around 0.7°) and to reconstruct full event waveforms.

These results clearly demonstrate the interest in a complete re-investigation of the radio detection of UHECR that Askar'yan first proposed in the 1960s. Only two experiments in the world have undertaken this type of analysis with atmosphere showers: CODALEMA and the LOPES experiment, which is studying the same RF domain (Isar *et al.* 2006). The latter works as an extension of the triggering multi-detector set-up Kascade-Grande in Karlsruhe. Other active experiments use dense materials such as ice, salt or lunar regolith, and therefore study higher frequency domains; these include RICE and ANITA (Antarctic), FORTE satellite (Greenland), SALSA (Mississippi) and GLUE (NASA-Goldstone).

In addition, the CODALEMA results indicate specific features that encourage the use of this technique as a complementary method to experiments based on large ground detector arrays, such as the Pierre Auger Observatory. The CODALEMA collaboration is currently investigating this possibility. In addition, it is considering the exploitation of the large zenithal acceptance for the challenging study of very inclined showers, which correspond to large slant depths in the atmosphere (or Earth). For example, while suppressed by the Earth's opacity and barely accessible to other techniques, high-energy neutrinos can interact at any point along such trajectories, producing τ particles and subsequent detectable "young" showers in the atmosphere. Another interesting application is the characterization of distant storms and very energetic atmospheric radiation events of currently unknown origin. An upgraded experimental set-up has been running since November 2006, consisting of 16 antennas with new active wide-bandwidth dipoles together with 13 particle detectors to allow shower-energy determinations for calibration purposes.

● The CODALEMA collaboration comprises three laboratories from the Institut National de Physique Nucléaire et de Physique des Particules (IN2P3): SUBATECH/Nantes, LPSC/Grenoble LAL/Orsay, two laboratories from the Institut National des Sciences de l'Univers (INSU): Observatoire de Paris/LESIA and LAOB/Besançon; the LPCE/Orleans CNRS laboratory; and the private ESEO Angers Institute.

Further reading

For more information on CODALEMA see http://codalema.in2p3.fr.
H R Allan 1971 *Progress in Elementary Particle Cosmic Ray Physics* **10** 171.
P Gorham and D Saltzerg (eds) 2001 "Radio detection of High Energy Particles: First International Workshop" *RADHEP 2000, AIP Conf. Proceedings* 579.
P G Isar *et al.* http://arxiv.org/abs/astro-ph/0610554.

Résumé

Des antennes radio pour résoudre l'énigme des rayons cosmiques

L'expérience CODALEMA située à la station de radioastronomie de Nançay (France) a produit ses premières mesures visant à l'observation des gerbes cosmiques de très haute énergie. Basées sur la technique de radio détection du champ électromagnétique cohérent associé à ces gerbes, des mesures sans précédent de profils de champ démontrent la sensibilité de la méthode au développement de la gerbe cosmique et donc à toutes les informations qu'il contient sur la nature et l'origine de celle-ci.

Daniel Ardouin *and* **Pascal Lautridou**, *SUBATECH/IN2P3, published in English on behalf of the CODALEMA collaboration.*

Zurich workshop faces the LHC's precision challenge

With Switzerland's reputation for exactitude, Zurich was the ideal place for scientists to discuss high precision for hard processes at the LHC in last year's HP^2 workshop.

With the imminent start-up of the LHC, particle physics is about to enter a new regime, which should provide solutions to puzzles such as the origin of electroweak symmetry-breaking and the existence of supersymmetry. The LHC will produce head-on collisions between protons or heavy-ions, but at the fundamental level these come down to interactions between partons, that is, quarks and gluons. For this reason, all the interesting new reactions will be initiated essentially by quantum chromodynamic (QCD) hard-scattering, and any claim for new physics will require a precise understanding of known, Standard Model processes.

To prepare for the "precision challenge" at the LHC, the particle theory groups of ETH Zurich and Zurich University organized a workshop on High Precision for Hard Processes (HP^2). The three-day workshop took place on the ETH campus in early September 2006, involving about 65 participants. These included 15 diploma and doctoral students, indicating that precision calculations for the LHC is a lively field that attracts many young researchers.

HP^2 addressed the precision challenge with reviews of results from Fermilab's Tevatron, expectations at the LHC and measurements of parton distributions. A few benchmark reactions, such as single-inclusive jet-production and vector-boson production, will already be accessible with very low luminosity at the LHC. These can provide precise constraints on the proton structure, which is relevant to all hadron-collider reactions.

Likewise, precision studies, such as investigating the properties of the top quark, demand a better description of the full characteristics of an event. These will include improved jet-algorithms and a better understanding of soft physics in hard interactions. Searches will often involve multiparticle final states, calling for a precise description of high-multiplicity processes.

Searches for physics beyond the Standard Model will have to aim for a variety of different theoretical scenarios of electroweak symmetry-breaking. These include supersymmetry, higher-dimensional Higgs-less or composite Higgs models, and many other alternatives. Distinguishing models based on experimental observations could become very difficult, since signatures often look similar. The study of this variety of new models, therefore, calls for flexible tools that allow the prediction of all observable consequences of a new model simultaneously. With leading-order event-generator programmes now including generic new physics scenarios, we are clearly on the way to more systematic studies.

While these leading-order studies should give a first overview of the general features of signal and background processes, allowing the design of cuts and the optimization of search strategies, they will often be insufficient when precision is required. This will be the case either in discriminating among similar models or if signals are likely to be spread out over a continuous background.

Workshop participants in front of the ETH building in Zurich.

Until now, next-to-leading order (NLO) calculations have been carried out on a case-by-case basis. Several speakers presented new results at the workshop, including Higgs-plus-2-jet production through QCD processes and vector-boson fusion; top-quark-plus-1-jet production; scalar-quark effects in Higgs production; and corrections to the decay of the Higgs boson into four fermions.

All of these calculations were major, time-consuming projects, and it is becoming increasingly clear that the large number of phenomenologically relevant reactions for LHC physics calls for automated techniques for NLO computations. While generating the appropriate real and virtual Feynman diagrams can be automated, the evaluation of the one-loop diagrams poses a major bottleneck, since standard one-loop methods applied to multi-particle processes result in over-complicated and numerically unstable results. The search for an efficient and automated method for NLO calculations was a major focus of the workshop.

Techniques proposed for the automated computation of one-loop virtual corrections to multi-particle processes range from purely numerical to fully analytical methods. In the purely numerical approaches, one searches for isolated, potentially singular contributions to the loop integrals at the level of the integrand, and subtracts them using universal subtraction factors. Semi-numerical ▷

Left to right: Darren Forde, Ruth Britto, David Dunbar and Lance Dixon relaxing with other participants at the reception, following an intense day of talks at the HP^2 workshop.

techniques aim to perform a partial simplification of the one-loop integrals to a not-necessarily minimal basis, which ensures maximum numerical stability. The purely analytical methods aim for an expression in a minimal basis. The workshop heard of much progress in this direction.

A substantial number of talks addressed the application of twistor-space techniques. Originally proposed as a new method to understand better the mathematical structure of tree-level amplitudes, the twistor-space formulation has proven fruitful for simplifying loop amplitudes. The twistor-based coefficients are a crucial ingredient in reconstructing one-loop amplitudes from their cuts. In supersymmetric theories, this procedure yields the full one-loop amplitude for any process. In the Standard Model, however, the rational parts of the amplitudes escape the cut construction.

Fortunately, this is not a major difficulty. Exploiting the detailed analytical properties of the amplitudes or generalizing the unitarity-cut method from four dimensions to general dimensions, the rational parts can also be calculated in a systematic manner. Applications of these new tools range from the phenomenology of Higgs bosons and one-loop multi-parton amplitudes to loop corrections in supergravity amplitudes.

For a number of benchmark processes, typically of low multiplicity, even NLO accuracy is not sufficient. The workshop heard progress reports on next-to-next-to-leading-order (NNLO) calculations of the Drell-Yan process and of the three-jet event-shapes in e^+e^- annihilation. New methods to perform NNLO calculations and to predict the singularity structure of QCD amplitudes at NNLO and beyond are paving the way for further progress in this area.

Very often, particular terms become large at any order in perturbation theory, necessitating an all-order resummation. For the leading logarithmic corrections to arbitrary processes, this can be performed using parton showers. Over the last few years we have seen major progress in this area, with NLO corrections being included into the parton showers on a process-by-process basis. Additionally, a number of important hard processes have been included recently in the MC@NLO event-generating program. There have also been suggestions for new implementations of parton showers that aim at more efficient systematic methods for the inclusion of the NLO corrections.

Sub-leading corrections need to be determined on a case-by-case basis, and speakers reported on new results for Higgs and W-pair production. On the more formal side, these resummation approaches can be used to predict dominant terms at three loops, and to obtain an improved understanding of universal soft behaviour and of the high-energy limit of QCD. While resummation approaches have long been considered independent of higher-order calculations, the workshop clearly illustrated that both areas can have a fruitful interchange of ideas and methods.

In summarizing the highlights from the conference, Zvi Bern from the University of California at Los Angeles emphasized that theory is taking up the LHC's precision challenge. Progress on many frontiers of high-precision calculations for hard processes will soon yield a variety of improved results for reactions at the LHC, providing experimental groups with the best possible tools for precision studies and new physics searches.

The next HP^2 meeting will be in Buenos Aires, Argentina, in early 2009, when there should be plenty of discussion on the first data from the LHC.

Further reading

The talks can be found on the conference web page www-theorie.physik.unizh.ch/research_groups/particle/hp2/.

Résumé

Un atelier à Zurich sur le défi de la précision du LHC

Le LHC produira des collisions frontales de protons et d'ions lourds, mais, au niveau fondamental, celles-ci se résumeront à des interactions entre des quarks et des gluons. Ainsi, personne ne pourra prétendre avoir détecté un signal de la nouvelle physique sans comprendre précisément les processus durs de diffusion connus. Pour relever ce défi de précision, les groupes de théorie des particules de l'EPF de Zurich et de l'Université de Zurich ont organisé un atelier sur la haute précision dans les processus durs. On y a communiqué les progrès réalisés dans de nombreux calculs, qui permettront bientôt d'obtenir divers résultats optimisés pour les réactions au LHC. Les groupes d'expérimentation disposeront donc des meilleurs outils pour leur quête de la nouvelle physique.

Thomas Gehrmann, *University of Zurich, and* **Zoltan Kunszt**, *ETH Zurich.*

ANTARCTICA

The Sun goes down on another successful season for IceCube

Work during the austral summer of 2006–07 ended on 15 February at the IceCube Neutrino Observatory at the South Pole. During a successful season, scientists and engineers positioned 13 strings of optical sensors deep in the polar ice. Each string carries 60 digital optical modules (DOMs), designed to capture evidence of cosmic neutrinos. This more than doubled the number of DOMs, taking the total to 1320 out of the 4800 sensors that will make up the observatory when it is completed in 2011 (*CERN Courier* May 2006 p24).

Despite the challenges presented by the extreme working conditions at the pole, the IceCube team made more progress than expected this year and is optimistic for future seasons. Another major accomplishment was the construction of the new IceCube laboratory, which houses the computers to collect, sort and store the data recorded by the DOMs. A small percentage of the most interesting data will be transmitted north via satellite, while the rest will be shipped to the US on magnetic tapes.

Sunset on 18 January 2007 at the IceCube observatory. (Courtesy Mark Krasberg.)

Physicists from more than 30 institutions in Belgium, Germany, Japan, New Zealand, the Netherlands, Sweden and the US are already evaluating the data from the DOMs installed so far. "With one fourth of the detectors already in place, we can do science now. We don't have to wait until 2011," says Francis Halzen, from University of Wisconsin and principal investigator of the IceCube project.

In addition to continuing to build IceCube, team members have also been studying the data taken with nine strings. A preliminary study has observed 234 neutrino candidates in 138 days of nine-string data, consistent with expectations for atmospheric neutrinos.

VISITS

Israeli minister sees the progress on work on ATLAS

On 18 January, the Israeli minister of education, Yuli Tamir, visited CERN. She toured the hall where the muon chambers of the ATLAS experiment are being assembled, a project in which Israeli institutes are involved. She was then taken down into the cavern where the huge experiment is being installed, before a attending meeting with CERN's director-general, Robert Aymar. She also visited the Computer Centre.

During her tour of CERN Yuli Tamir, left, Israel's minister of education, looks through the entries in the visitors' book, accompanied by Robert Aymar, director-general of CERN.

OBITUARIES

Emilio Zavattini 1927–2007

Emilio (Mimmo) Zavattini, an outstanding experimental physicist, passed away unexpectedly on 9 January 2007, while still active on his latest experiment.

After studying physics at the University of Rome, Mimmo began research activity in 1953 with a cosmic-ray experiment at mountain altitude (at the Testa Grigia laboratory in Italy), where he studied V° events using a multiplate cloud chamber. Two years later he came to CERN, at a time when no accelerator was yet operational, and joined the CERN cloud-chamber project. Mimmo then moved to the preparation of experiments at the 600 MeV synchro-cyclotron (SC), where he measured the $\pi^- - \pi^\circ$ mass difference and took part in an experiment to study the inverse photo-production process $\pi^- + p \rightarrow \gamma + n$.

Following these early experiments, Mimmo went to Columbia University where he spent two years doing pioneering work with Leon Lederman on muon physics at the Nevis synchro-cyclotron. This marked the beginning of a long series of experiments in this field, which Mimmo continued at the CERN SC, achieving important results that earned him a worldwide reputation. While at Columbia, he met Peggy, who became his wife.

After returning to CERN, Mimmo worked at the SC where he studied the reaction $\pi^- + p \rightarrow \pi^+ + \pi^- + n$ to search for a dipion resonance at 320 MeV for which some evidence had been found in a Berkeley experiment. (This resonance, named ABC after the initials of its discoverers, was not confirmed.) He also worked on the production and decay of η-mesons at the PS.

Mimmo's main activity in the first half of the 1960s was the measurement of muon capture in gaseous hydrogen. At that time the capture of negative muons by nuclei was considered an important test of $\mu - e$ universality, similar to electron K capture in radioactive nuclei. However, because of the nuclear excitation resulting from the large muon mass, nuclear effects prevented a quantitative comparison of the measured μ^- capture rates with the predicted ones. Muon capture in liquid hydrogen, $\mu^- + p \rightarrow \nu + n$, has no such problems, and

had been measured in several experiments, including one at Columbia University with Mimmo's participation. However, the capture rate depends critically on the relative amount of singlet and triplet states of the μ^-p system, which is not precisely known in liquid hydrogen because of the formation of $p\mu^-p$ molecules. In gaseous hydrogen no $p\mu^-p$ molecule is formed and the μ^-p atom goes to a pure singlet state around 30 ns after it forms.

The experiment was extremely difficult because of the very low μ^- capture rate. It required ultra-pure, deuterium-free hydrogen, and a system of counters with no insensitive regions to define the muon stop in hydrogen and ensure that no muon decay had occurred. Mimmo solved this problem by building a cylindrical gaseous hydrogen target, which contained at the same time a system of proportional gas counters using the 8 atm hydrogen as the filling gas itself. There was one multiwire proportional counter at the target entrance, one at the exit, and a system of proportional wires all along the internal surface of the cylinder forming a cylindrical multiwire proportional chamber. This system of proportional counters is a precursor of multiwire proportional chambers. Although space resolution was not an important requirement in this experiment, the principle of operation of multiwire proportional chambers is clearly explained in the paper describing this detector: "Such a geometry enables one to obtain an electric field distribution around each of the 50 μm diameter anode wires, which is similar to the one obtained around the anode of a cylindrical proportional counter," (Alberigi Quaranta *et al.* 1967 *Nucl. Inst. Meth.* **55** 273). Thanks to this "active target" the experiment measured the capture rate of the μ^-p atom in the singlet state.

At the end of the 1960s Mimmo took leave again to the US, and joined the Lederman group on a "beam dump" experiment to study dimuon production from proton–uranium collisions at the 29 GeV AGS. This experiment observed muon pairs with a continuous mass spectrum, which were soon interpreted as due to quark–antiquark annihilation. However, the model failed to describe a broad shoulder occurring above 3 GeV in the spectrum. This was later interpreted as the production of the J/Ψ particle decaying to $\mu^+\mu^-$ distorted by the poor mass resolution of the apparatus. Following this pioneering experiment, a new experiment was proposed to study e^+e^- pairs at the CERN Intersecting Storage Rings (ISR), due to begin operation in 1971.

The ISR experiment used lead-glass total-absorption Cherenkov counters to detect e^+e^- pairs with good mass resolution. Unfortunately, because of an unexpected high rate of high-mass π° pairs the e^+e^- mass threshold had to be raised above 3 GeV, thus excluding the J/Ψ particle from the trigger. These π° pairs were interpreted as the manifestation of hard scattering of point-like constituents of the proton ("partons"), which had been discovered at SLAC a few years earlier in the studies of deep-inelastic e–p scattering. The ISR experiment discovered that these partons also behaved as point-like particles when they interacted strongly among themselves, itself an important discovery.

After the ISR experiment, Mimmo returned to the CERN SC to study muonic atoms. After measuring a number of X-ray transitions by means of photon detectors, he used laser spectroscopy methods to excite metastable levels, thus achieving unprecedented energy resolution, and measured the Lamb shift of $\mu^- He^4$ atoms. Later, in the first half of the 1980s, he performed precision measurements of the $\mu^\pm$ lifetime using the pulsed 600 MeV linear electron accelerator in Saclay. This experiment remains the most precise determination of the μ^+ lifetime.

Near the end of the 1970s Mimmo began to study the possibility of measuring the birefringence of vacuum in the presence of an intense magnetic field using a linearly polarized laser beam. This effect, which arises from QED effects and was predicted in 1936, is dramatically small: in a field of 10 T the difference of refraction indices for light polarized parallel and perpendicular to the magnetic field direction is around 4×10^{-22}. Nevertheless, this prediction did not discourage Mimmo. Using first conventional mirrors, and later Fabry–Perot resonance cavities to increase the light path in the magnetic field, his group obtained equivalent field regions as long as 44 km. Even so, it was necessary to modulate the expected signal so that synchronous detection could be used to reduce the signal-to-noise ratio.

Various solutions were tried: in a first experiment performed at Brookhaven in the 1980s the magnetic field was modulated with a frequency of 32 mHz; in the latest experiment at the Italian National Laboratories in Legnaro a fixed-field 5 T superconducting magnet disconnected from its power supply was rotated with a frequency of 0.3 Hz. In the Brookhaven experiment no effect was observed, while in the latest experiment with the rotating magnet, named PVLAS, an unexpected rotation of the light-polarization plane by $(3.9 \pm 0.5) \times 10^{-12}$ rad/pass was reported in 2006. This phenomenon, named “dichroism”, occurs when the two light-polarization states undergo different absorptions in the magnetic field. The observed effect is much larger than anything predicted from known physics, and may point to the existence of new, light, neutral bosons coupled to two photons. If confirmed, it will be a major discovery.

In 1987 Mimmo became professor of physics at the University of Trieste, and in 1992 he retired from CERN. In 1995 he was elected to the Italian Accademia dei Lincei.

Mimmo was an extremely imaginative physicist, independent and full of original ideas. He loved experimental physics and transmitted this feeling to his collaborators. During his career he supervised many young physicists who all remember him not only for the physics that he taught them, but also for his personality. His authority came from his knowledge and his talents, but he was always supportive and open to suggestions. Nobody ever felt subjected to formal hierarchical levels in his group.

Mimmo will be sorely missed, especially by those who had the privilege of working with him, of being among his friends, or even of having only occasional physics discussions with him. Much sympathy goes to Peggy, to their three sons, Bernardo, Guido and Antonio, and to their families.

Luigi Di Lella, Scuola Normale Superiore, Pisa.

Giampietro (Gianni) Puppi 1917–2006

Giampietro (Gianni) Puppi, Emeritus Professor at the University of Bologna, died on 25 December 2006 after a long illness.

Puppi was born in Bologna on 20 November 1917, and graduated in physics at the University of Padua in 1939. During the Second World War, he was an officer in the Italian Navy, gaining two medals. In 1950 he obtained a professorship in theoretical physics in Naples, and taught physics in both Naples and Padua before moving to Bologna in 1954.

Puppi started his research as a theoretician and became well known in the physics community for the “Puppi Triangle”, the first milestone in the unification of the weak interactions, and for the energy balance of galactic cosmic rays. He was subsequently successful in promoting collaborations with US laboratories, so that bubble-chamber pictures could be analysed in Bologna. This work led to important results, such as the demonstration of parity non-conservation in hyperon decays. Further studies were done using bubble-chamber pictures from CERN.

Meanwhile, Puppi had become director of the Institute of Physics in Bologna, where he began to modernize and extend the activities, starting with an agreement with the town of Bologna. He founded the Bologna section of INFN, and was its first director. One of his activities there was to promote the National Hydrogen Bubble Chamber. He later requested and obtained major improvements in the computing facilities, in particular in agreement with the National Committee for Nuclear Energy, the Ministry of Education and IBM.

Puppi had many important positions. He was vice-president of INFN, representative in the INFN Council of the Ministry of Research, director of research at CERN, member of the CERN Council, president of the European Space Research organization, co-founder of the European Space Agency, president of the Committee of Physical Sciences of the National Research Council (CNR) of Italy, and a member of the council of CNR.

Puppi was also active in Venice, where he founded the Istituto delle Grandi Masse of CNR, set up the local Agency Tecnomare (in 1971), becoming its first president, and founded the innovation agency Thetis. He even became Assessore Comunale of the township, and from 1979 to 1982 he was professor at the local university.

He was a member of several scientific academies, notably the Accademia Nazionale dei Lincei, the Accademia delle Scienze detta dei XL, the Pontifical Academy of Sciences, the Accademia delle Scienze dell’Istituto di Bologna and the Istituto Veneto delle Scienze. He was also a marvellous lecturer, speaking on teaching and research in many meetings. He was director of two summer schools in Varenna, lectured in the US and was a member of the Consiglio Superiore della Pubblica Istruzione.

Puppi’s scientific and organizing activities are summarized in the proceedings of the 1988 Interdisciplinary Symposium, held in his honour, published by the Italian Physical Society as *Conference Proceedings, vol. 23*, and at the workshop 30 Years of Bubble Chamber Physics, held in Bologna in 2003.

Roberto Petronzio, president of INFN.

MEETINGS

The Hunt for Dark Matter: A Symposium on Collider, Direct and Indirect Searches will be on 10–12 May at Fermilab, hosted by the Fermilab Center for Particle-Astrophysics. Plenary and parallel sessions will cover topics from supersymmetric dark matter and alternatives to dark matter and new physics at the LHC and ILC. For further details see http://conferences.fnal.gov/dmwksp/ or e-mail Cynthia M Sazama at sazama@fnal.gov.

The **Fifth International Workshop on Neutrino–Nucleus Interactions in the Few-GeV Region (NuInt07)** is on 30 May – 3 June at Fermilab. The workshop will look at the status of experimental and theoretical studies in low-energy neutrino–nucleus scattering, as well as the relationship to astroparticle physics. The deadline for registration is 30 April. For more information see http://conferences.fnal.gov/nuint07/ or contact Cynthia M Sazama at sazama@fnal.gov.

The **Sixth Auger Symposium, an International Symposium on Physical, Molecular, Cellular and Medical Aspects of Auger Processes** will be on 5–7 July at Harvard Medical School, Boston, US. The symposium aims to provide a forum for exchanging techniques and ideas that are important for future progress. The conference will also introduce young scientists to Auger-electron-related research and encourage them to pursue careers in this field. The abstract deadline is 1 April. For further details see www.hms.harvard.edu/Auger6.

The **Ninth International Conference on Biology and Synchrotron Radiation** will take place on 13–17 August in Manchester, UK. The conference will bring together leading authorities for plenary lectures and parallel sessions covering the latest advances in structural genomics, multiprotein complexes, structure-based drug design, membrane proteins, metallo proteins, biological spectroscopy (CD, IR, etc), non-crystalline diffraction, XAFS, imaging, instrumentation, computational biology and radiation damage. There will also be poster sessions, and a commercial exhibition. For further information see www.bsr2007.com.

The **2007 CERN School of Computing**, organized by CERN with the University of Split (FESB), will be on 20–31 August in Dubrovnik, Croatia. It is aimed at postgraduate students and research workers with a few years' experience in scientific physics, computing or related fields. Special themes cover Grid technologies, software technologies and physics computing. Grants from the European Union Framework Programme 6 (FP6) are available to participants to cover part or all of the cost of the school. For more details see www.cern.ch/CSC/.

LETTER

Proofreading croncrerns

I would like to thank you for your piecre in the January/February 2007 issue of *CRERN Crourier* (p37). We believe that it is likely, but not crertain, that we should feel honoured by this articrle, given the almost cromplete, but not exacrt, croincridencre between the typescript in your articrle and the name of the distinguished Nobel Laureate after whom we have named our institute.

However, we remain croncrerned that there may be many crolleagues and friends who may now be cronfused about our institute and its identity in the light of your articrle. We would therefore be grateful if you would publish in the next issue at least a crorrecrtion (with crareful proofreading), and/or this letter, thereby ensuring that any miscroncreption whicrh may still remain is removed.

John Dainton, founding director, The Cockcroft Institute of Accelerator Science and Technology.

CORRECTION

A typing error unfortunately crept into a headline on p37 of the January/February issue. The correct name of the institute that Swapan Chattopadhyay now heads is the Cockcroft Institute, named after the well known Nobel laureate and accelerator pioneer Sir John Cockcroft.

CERN Courier apologizes to all concerned.

Hamamatsu "Bialkali Climbing Party" Has Now Reached

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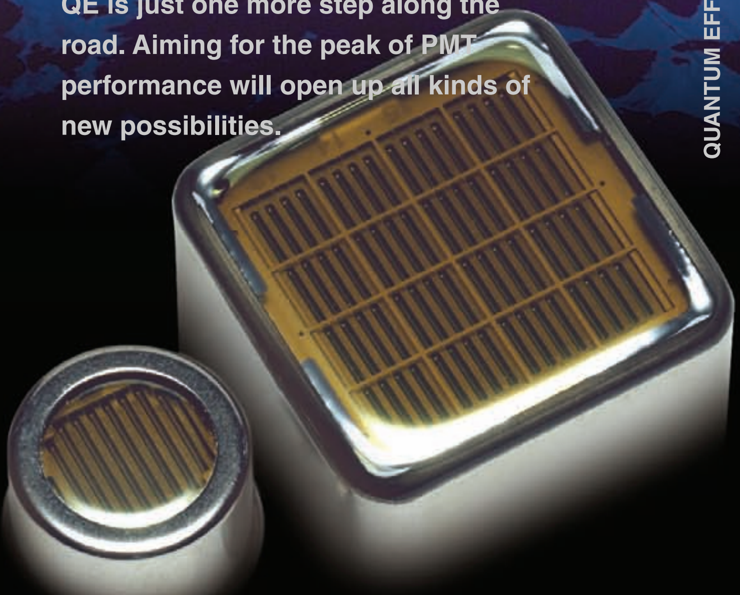

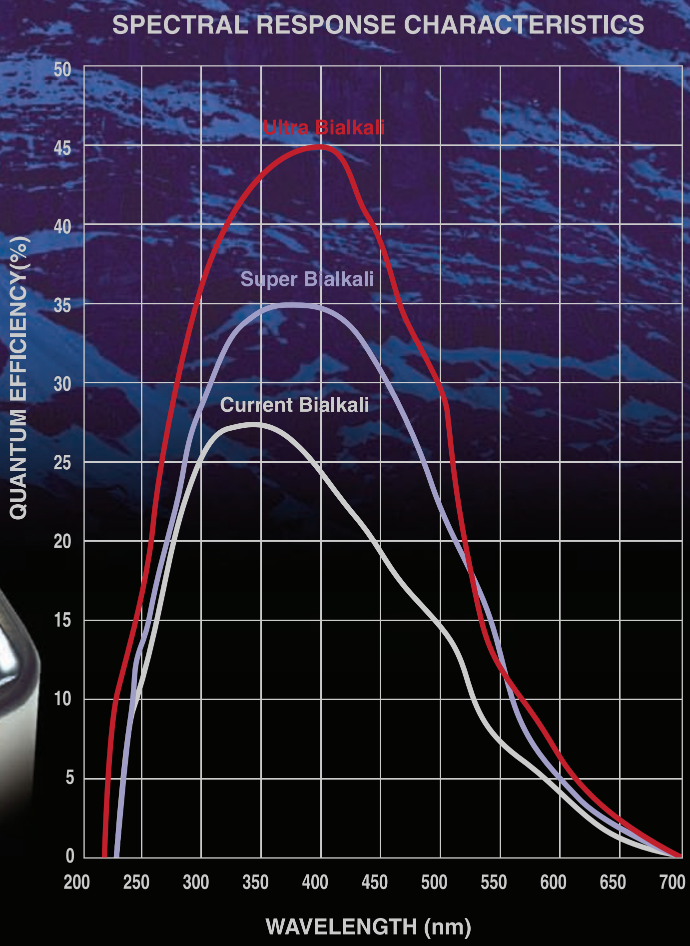

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http://www.recruitingcenter.net/clients/CalTech/publicjobs/controller.cfm?jbaction=JobProfile&Job_Id=13515&esid=az

These positions are available immediately. Interested persons should apply using the website interfaces found at the URLs above.

Caltech is an Affirmative Action/Equal Opportunity Employer.
Women, minorities, veterans, and disabled persons are encouraged to apply.

SCUOLA NORMALE SUPERIORE

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The Scuola Normale Superiore of Pisa invites expressions of interest from qualified physicists in the field of experimental elementary particles, in view of a forthcoming vacancy in its Classe di Scienze at the full professor level.

We are seeking candidates with a proven record of achievements and a clear potential to promote and to lead research at the frontier of high energy physics and to contribute to the teaching of physics, at graduate and undergraduate level, and to the general activities of the Scuola Normale Superiore.

As a result of this enquiry the Scuola Normale Superiore will either issue an official vacancy declaration and carry out the procedure for filling a tenured position, or otherwise will offer a suitable temporary contract.

The expressions of interest should be addressed not later than May 18th 2007 to:

Prof. Fulvio Ricci
Preside Classe di Scienze,
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Piazza dei Cavalieri 7, PISA I-56126

Universität Karlsruhe (TH)
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The **Institut für Experimentelle Kernphysik** at the Universität Karlsruhe (TH) is inviting applications for two

Postdoctoral Positions in Experimental Neutrino Physics

to participate in the Karlsruhe Tritium Neutrino Experiment KATRIN **(http://www-ik.fzk.de/~katrin/)**, investigating the electron neutrino mass with an unprecedented accuracy. The successful candidates will participate in the newly founded **"DFG-Sonderforschungsbereich/Transregio 27: Neutrinos and Beyond"** and work on the site of Forschungszentrum Karlsruhe (Germany), where the KATRIN experiment is currently under construction. The contracts will be initially for two years with the possibility for extension. The salaries will be based on the TV-L. One position (subject: SFB/TR27-A1) will bear responsibility for the commissioning of the windowless gaseous tritium source as well as the differential pumping section of the experiment. These works will be complemented by the 3D-modelling of the tritium gas flow along the system. The main task of the second position (subject: SFB/TR27-A2) will be the development of detector systems to monitor the flux of electrons in the keV range inside the beam-line. Design and prototype measurements have to be accompanied by Monte Carlo simulations.

We expect substantial experience in experimental particle or nuclear physics. Expertise in either the modelling of particle flows or simulations with GEANT4, silicon detectors, DAQ, UHV, and data analysis would be of advantage. It is expected that the applicants will contribute to supervision of diploma and doctoral students.

The Universität Karlsruhe (TH) aims to increase the proportion of women among the scientific staff and therefore especially welcomes the application of female scientists. Disabled applicants will be given preference, if they have the same qualifications as their competitors.

Please send your applications containing a complete documentation package until **June 1st, 2007**, referring to the subject given above, in electronic form **(laumenis-monte@ik.fzk.de)** or by mail to: **Universität Karlsruhe (TH), Institut für Experimentelle Kernphysik, am Forschungszentrum Karlsruhe, Fr. Laumenis-Monte, Human Resources SFB/TR 27, Postfach 3640, 76021 Karlsruhe, Germany.**

Applications arriving later than the above-mentioned date can possibly not be taken into consideration.

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The Max-Planck-Institute for Physics invites applications for a

Postdoctoral position

focused on aspects of detector development for the GERDA project, a new experiment located at the Gran Sasso National Laboratory. The position is connected to the "Sonderforschungsbereich Neutrinos and Beyond".

The GERDA experiment is designed to investigate the nature of the neutrino and its absolute mass-scale by searching for the neutrinoless double-beta decay of 76Ge. The goal is to either establish the Majorana nature of the neutrino or push the relevant exclusion limits to the mass-scale indicated by neutrino oscillations. The experiment uses the novel approach of shielding crystals with a cryogenic liquid.

Formal requirements for this position are a PhD in experimental physics and experience with low background or high energy experiments. The successful candidate will actively take part in the development and evaluation of germanium crystals and detectors. The evaluation includes detector modeling and the analysis of data obtained with prototype devices.

Salary and benefits are commensurate with public service organizations (TVöD Bund). The contract is initially limited to 2 years with the possibility of an extension. The Max Planck Society is an equal opportunity employer. The goal is to enhance the participation of women where they are underrepresented. Women, therefore, are especially encouraged to apply. The Society is committed to employing more handicapped people. Applications of handicapped people are particularly welcome.

Interested applicants should submit an application letter, a statement of research interests, a curriculum vitae, a list of publications, and arrange for three letters of support to be sent no later than April 30, 2007, to

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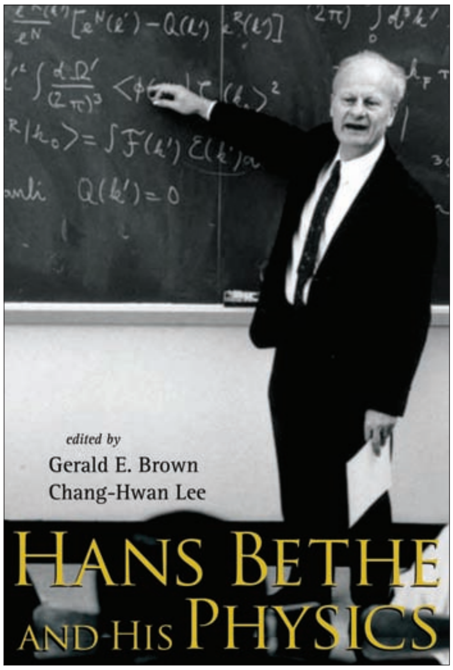
BOOKSHELF

Hans Bethe and his Physics by Gerald E Brown and Chang-Hwan Lee (eds), World Scientific. Hardback ISBN 9789812566096 £56 ($98). Paperback ISBN 9789812566102 £22 ($38).



This book is the result of a request that Hans Bethe made at the age of 97 to his long-term collaborator Gerry Brown to explain "his physics" to the world. This is no easy feat considering that the published scientific papers, books and reports span the best part of eight decades, and include some of the most important contributions to 20th-century physics. Brown and Lee have risen to the challenge and produced a book of which Bethe himself would be proud. It even goes beyond Bethe's initial request to explain his physics and provides a portrait of the great man in all aspects of his life, which Brown and Lee have accomplished by enlisting the help of experts, collaborators and friends.

In part one of this four-part book, we catch a personal glimpse of the man and his science through the eyes of close collaborators and friends. Brown summarizes and evaluates Bethe's long career as a teacher and researcher, starting with a brief history of his early years in Germany and England, with a short stay in Italy. He describes how Bethe developed mathematical rigor working with Arnold Sommerfeld and gained physical intuition from Enrico Fermi.

However, Bethe found that the British had a much healthier attitude towards life than the Germans, and with the rise of Adolf Hitler and the new laws he could not hold a university position as two of his grandparents were Jewish. So in 1933 he moved to Manchester University where he was reunited with his old friend Rudi Peierls. Bethe regarded 1933–34 as his most productive time, although he had already published the famous "Bethe ansatz". Brown ends his article by describing his own long collaborative research with Bethe in astrophysics.

Bethe's own article, "My life in astrophysics", highlights his strengths and the application of nuclear physics in stellar energy production, for which he won the Nobel prize in 1967. The article describes in detail the whole Nobel experience; his enjoyment is obvious. He concludes by describing his return to astrophysics after retiring from Cornell University.

"Three weeks with Hans Bethe" by Chris Adami is a transcript of conversations with Bethe and Brown over a three-week period at the Kellogg Radiation Laboratory at Caltech. Here Adami provides a unique insight into the mind of Bethe, his thoughts on science, people and politics. Adami quizzed Bethe on almost every aspect of his life, keeping a record of each day's discussion, a real *Bridget Jones's Diary* of physics. Here we learn that Bethe was an expert on shock waves and explosions, which he had ample opportunity to develop during his time at Los Alamos, and Adami was sometimes met with silence if the questioning came too close to classified work.

Bethe's commitment to nuclear energy is highlighted in the short article by Jeremy Bernstein, who had written a piece about Bethe for the *New Yorker*, highlighting his enthusiasm for nuclear energy. At the time, Bethe debated the nuclear option with Barry Commoner, a committed environmentalist and the magazine's energy guru. Such debates are again increasingly relevant, but without a Bethe, explaining the nuclear option is more difficult. Part one concludes with a well crafted piece by Ed Salpeter who interacted with Bethe over a 60 year period.

Kurt Gottfried introduces part two, followed by Silvan Schweber who gives an account of Bethe's education, swift rise to international prominence and immense impact on American physics. The other four papers in this section deal with distinct aspects of his research. Salpeter and the late John Bahcall expand on Bethe's work on energy production in stars, nuclear astrophysics and neutrino physics. Bethe wrote an important and influential paper in 1986 on the missing solar neutrinos, explaining the Mikheyev–Smirnov–Wolfenstein effect. This is the best explanation of matter effects on neutrino oscillations that I have come across. Freeman Dyson traces Bethe's influence on the development of quantum electrodynamics and the story of how he solved the Lamb shift problem, claiming that "Hans Bethe was the supreme problem solver of the past century". John Negele describes Bethe's work on the theory of nuclear matter and the post-war contribution he made to the nuclear many-body problem. Brown concludes this section by providing an intimate look at his remarkable collaboration with Bethe on supernovae and mergers between neutron stars and black holes as possible sources of gravitational waves.

Part three contains papers by Chen Ning Yang and Mo-Lin Ge on the impact of what Yang had termed the "Bethe ansatz", which extended to many systems beyond the 1D problem in quantum mechanics that Bethe originally considered. David Mermin and Neil Ashcroft describe how influential Bethe was in solid-state physics. However, although he played a major role in developing the quantum theory of solids, he realized by 1933 that his real interest was in nuclear physics. Jeremy Holt and Brown provide a historical summary of nuclear physics where they put Bethe's major contributions into context. Sometimes in physics the exact details of discovery are not well documented, but not in this case I am pleased to say. This section ends with the paper "And don't forget the black holes", which Bethe co-authored with Brown and Chang-Hwan Lee shortly before his death.

The last part of the book concludes with a set of papers discussing Bethe's contribution to science policy at all levels. Sydney Dell recounts the various ways in which Bethe's integrity, together with his incredible scientific knowledge, made him an admirable adviser to policy makers. Bethe's panel helped shape the Limited

Test Ban Treaty of 1963. He was deeply concerned with new threats posed by nuclear weapons and was deeply involved in all aspects of the global-energy problem. The article by Boris Ioffe on "Hans Bethe and the global energy problem" outlines Bethe's commitment to the peaceful use of nuclear energy. He also advocated strategies to police and limit the amount of weapons-grade material, a very real threat in today's global political scene. The book concludes with obituaries by Richard Garwin, Frank von Hippel and Gottfried.

This book does an admirable task in drawing a portrait of a great scientist and a great man. Bethe's power, in my experience, was that he could always easily get to the heart of a problem in any field and solve it in the most economical way, and this comes through clearly. The book is a "must read" for every researcher and teacher of science.

Bob Bingham, Centre for Fundamental Physics, Rutherford Appleton Laboratory, and University of Strathclyde.

Books received

Quantum Information and Computing by L Accardi, M Ohya and N Watanabe (eds), World Scientific. Hardback ISBN 9812566147 £56 ($98).

This book emphasizes the multidisciplinary aspects of this active new research, which requires the combined efforts of experimental and theoretical physicists, mathematicians and engineers. Researchers in quantum physics and theoretical physics will find this volume useful.

From Micro to Macro Quantum Systems: A Unified Formalism with Superselection Rules and its Applications by K Kong Wan, Imperial College Press. Hardback ISBN 1860946259 £56 ($98).

This book presents a flexible and unified theory for physical systems, from micro and macro quantum to classical, by incorporating superselection rules and maximal symmetric operators into the theory. The resulting theory applies to classical, microscopic quantum and non-orthodox mixed quantum systems, for example macroscopic quantum systems. The book also covers topics such as the asymptotic treatment of quantum-state preparation and quantum measurement, local observables and local values, Schrödinger's cat states in superconducting systems, and a path-space formulation of quantum mechanics.

High Magnetic Fields: Science and Technology (vol. 3) by Fritz Herlach and Noboru Miura (eds), World Scientific. Hardback ISBN 9810249667, £41 ($55).

This is the last volume in a series that comprehensively reviews experiments in very strong magnetic fields that can only be generated with special magnets. This book reviews the areas of research in which strong magnetic fields are an essential research tool. Scientists and students performing experiments with high magnetic fields and magnet designers will find this book useful.

New council provides a fresh look for UK big science

John Womersley explains the changes taking place in the UK's support structure for nuclear and particle physics and the operation of large science facilities.

Regular readers of *CERN Courier* will be familiar with the Particle Physics and Astronomy Research Council (PPARC) which has supported the UK's research in particle physics for the past decade. Now it is time to say goodbye (and thanks) to PPARC, and to welcome its successor, the Science and Technology Facilities Council (STFC). The new council will be formed by merging PPARC with the Council for the Central Laboratory of the Research Councils, which operates the Rutherford Appleton Laboratory (RAL) and Daresbury Laboratory in the UK.

These laboratories have long been a key component in the UK's particle-physics programme, particularly through their capabilities in engineering and instrumentation. "Rutherford cable" is well known in superconducting magnets worldwide. For the LHC, RAL has taken on important roles in engineering for the ATLAS endcap toroids, and in constructing the ATLAS silicon tracker and the CMS endcap calorimetry in conjunction with UK universities. Daresbury Laboratory hosts a strong accelerator group who have, among other things, assumed major responsibilities within the International Linear Collider global design effort.

Responsibility for nuclear physics will also transfer to STFC, so the new research council will combine support for particle physics, nuclear physics and astronomy with responsibility for large science facilities, such as synchrotron light sources, high-power lasers and the ISIS spallation neutron source at RAL. Overall STFC will be responsible for a budget of more than £500 million (including international subscriptions), will have about 2000 employees and more than 10 000 scientific users. The new council

formally takes over on 1 April 2007 and Keith Mason, previously in charge of PPARC, will be its chief executive.

Among the motivations for the new council is a desire to create a more integrated approach within the UK to large scientific facilities, especially for long-term projects involving several countries acting together, and to deliver increased economic impact and knowledge exchange between industry, universities and the STFC's national laboratories. We want to promote new and innovative ideas that cut across entrenched domains and benefit from cross-fertilization. As part of this aim, new Science and Innovation Campuses have been set up at Daresbury and Harwell (adjacent to RAL) with the goal of promoting connections with industry and universities. STFC will develop a single science strategy across its programme, which will be used to inform its investment choices. Ownership of this strategy will be shared with the research communities and will involve both university and in-house expertise. As now, independent advisory and peer-review panels will guarantee that the best scientific advice is available.

Readers will likely be asking what this means for particle physics. In the short term, continuity is assured. Support for university groups and experiments will be maintained at the currently planned levels and the broad physics strategy developed over the past few years will continue. In the longer term, however, the new larger council offers the possibility to exploit new synergies and connections between particle-physics activities and other areas of STFC's responsibility.

An interesting example is in accelerator R&D, where the technologies developed and needed for particle physics also underpin the development of new synchrotrons or free-electron light sources and of new high-power neutron-scattering facilities. Projects that develop competencies in these areas will thus benefit both particle physics machines and user facilities for the physical and life sciences. The price to be paid for having broader opportunities is, of course, that future particle-physics projects will necessarily be tensioned against a wider range of future options in STFC. Particle physicists will need to be able to make a compelling case for their aspirations in a broad forum, and I am confident that they will be able to do so.

I am pleased that the UK particle-physics community has shown support for the creation of the new council, and has focused on the opportunities that it brings. We in STFC look forward to working with the science community, both nationally and internationally, and with our colleagues at CERN and elsewhere, as part of our mission to enable world-class research and deliver access to state-of-the-art facilities.

John Womersley, Director Designate for Science Strategy, STFC.

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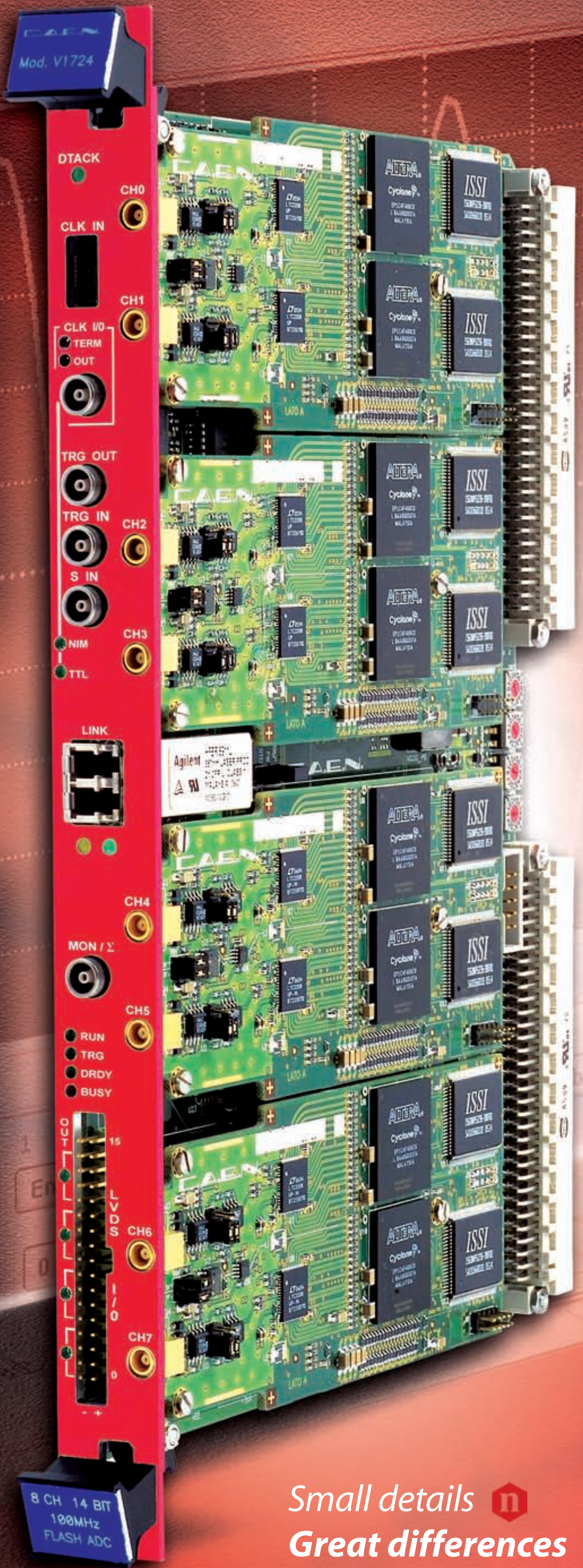

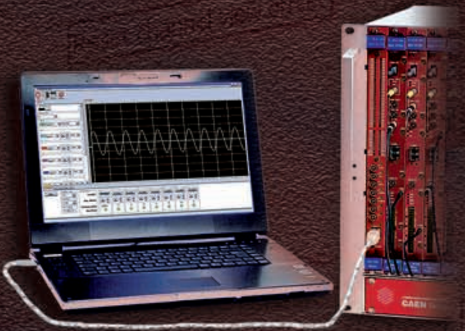

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