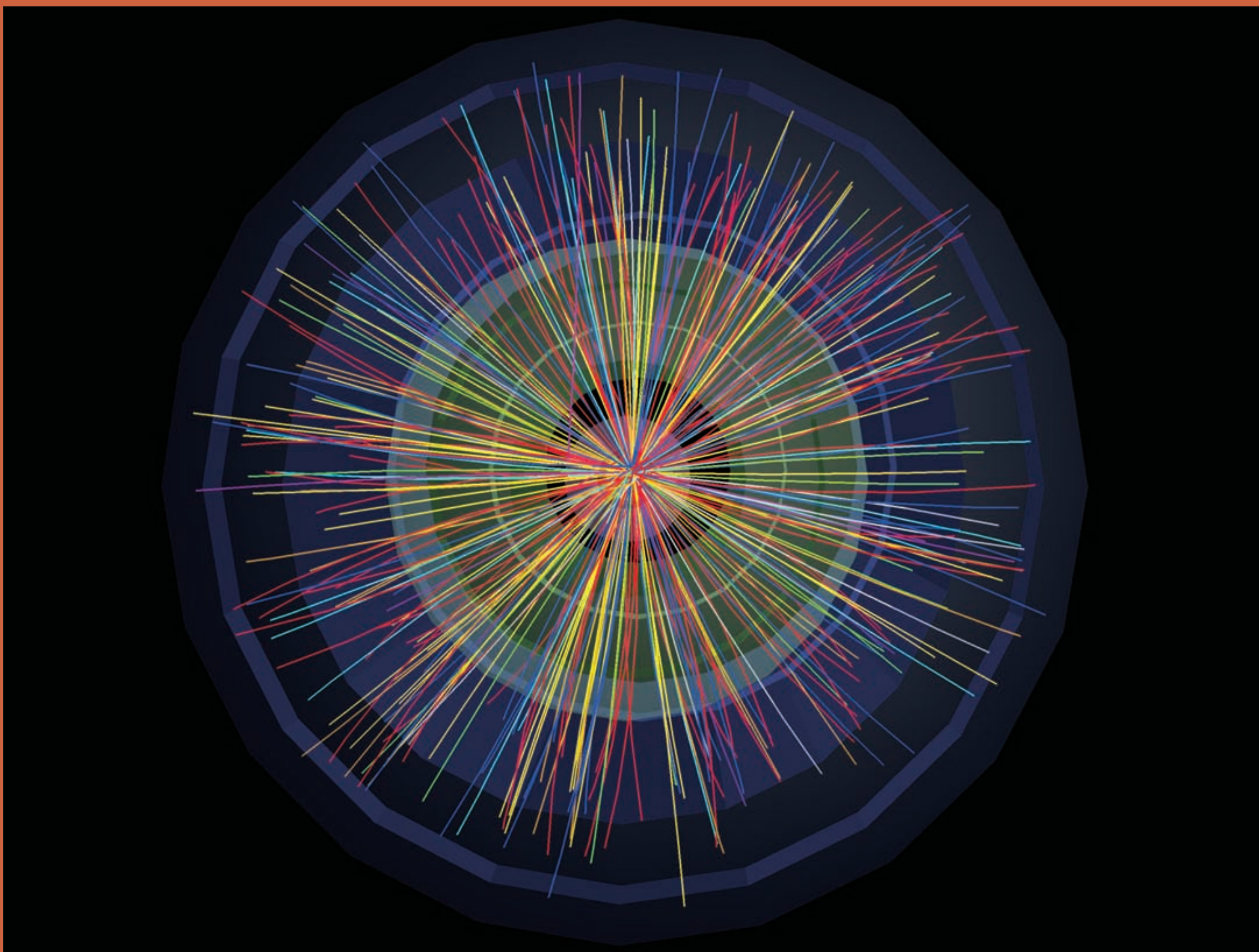
INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

CERN COURIER

VOLUME 50 NUMBER 10 DECEMBER 2010



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Produced for CERN by IOP Publishing Ltd
IOP Publishing Ltd, Dirac House, Temple Back,
Bristol BS1 6BE, UK
Tel +44 (0)117 929 7481

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General distribution Courrier Adressage, CERN, 1211 Geneva 23, Switzerland. E-mail: courrier-adressage@cern.ch
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UK Mark Wells, Science and Technology Facilities Council, Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1SZ. E-mail: mark.wells@stfc.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: creative_mailing@att.net
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

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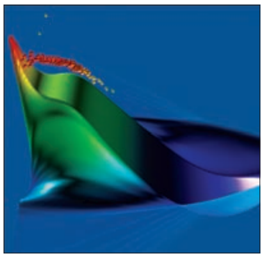

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Cover: One of the first lead–lead collisions in the ALICE experiment, which is optimized for the study of these heavy-ion collisions. The LHC started physics with lead ions on 8 November (p5).

NEWS

LHC NEWS

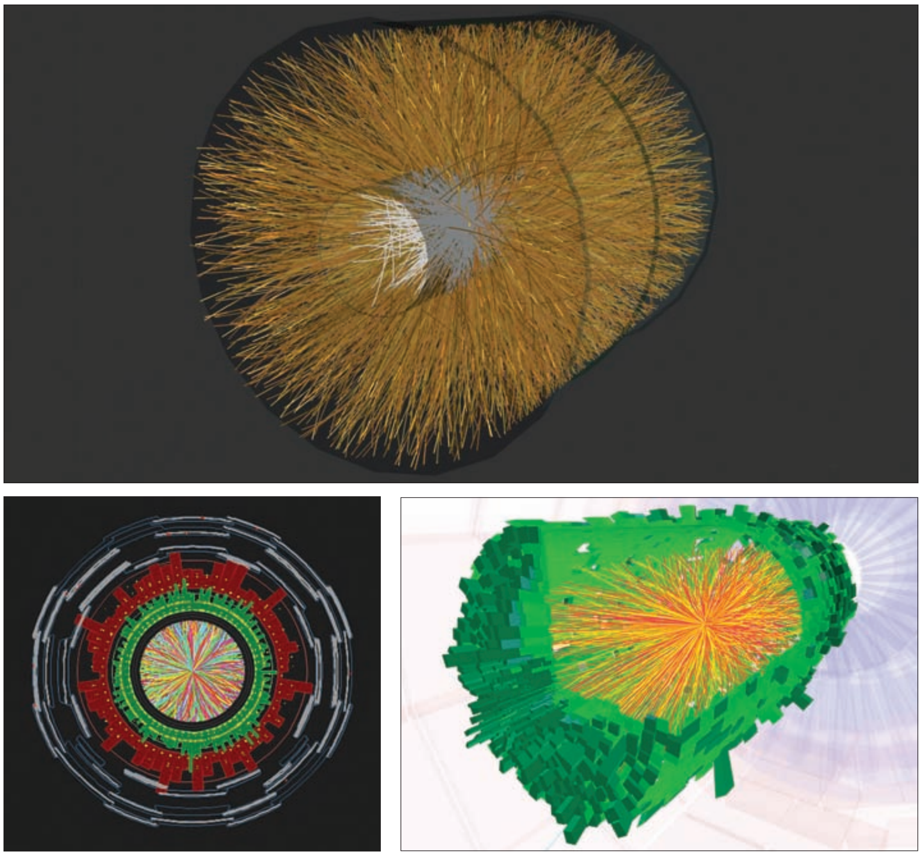
LHC begins physics with lead ions

Four days is all that it took for the LHC operations team at CERN to complete the transition from protons to lead ions in the LHC. After extracting the final proton beam of 2010 on 4 November, commissioning the lead-ion beam was underway by early afternoon. First collisions were recorded at 0.30 a.m. on 7 November, and stable running conditions marked the start of physics with heavy ions at 11.20 a.m. on 8 November.

Since the first proton collisions occurred at 7 TeV in the centre-of-mass at the end of March, the machine and experiment teams have achieved all of their objectives for the first year of proton physics in the LHC at this record energy. A major target for 2010 was to reach a peak luminosity of 10^{32} cm^{-2}s^{-1}. This was achieved on 13 October, with two weeks to spare. Before proton running came to an end the machine had reached twice this figure, allowing experiments to double the amount of data collected in the space of only a few days. For the rest of the year the LHC is moving to a different phase of operation, with lead ions being brought into collision in the machine for the first time.

Operating the LHC with lead ions is completely different from operating it with protons. From the source to collisions, operational parameters have to be re-established for the new type of beam. For lead ions, as for protons before them, the procedure started with threading a single beam round the ring in one direction and steadily increasing the number of orbits before repeating the process for the other beam.

Once circulating beams were established, they could be accelerated to the full energy of 287 TeV per beam – an energy much higher than for proton beams, because the lead ions contain 82 protons. Another period of careful adjustment was needed before lining the beams up for collision, and then finally declaring that nominal data-taking conditions had been established. The three experiments recording data with lead ions, ALICE, ATLAS and CMS, can now look forward to continuous lead-ion running until CERN's winter technical stop begins on 6 December.



First lead-ion collisions from, clockwise from top, ALICE, CMS and ATLAS.

Lead-ion running opens up an entirely new avenue of exploration for the LHC programme, probing matter as it would have been in the first instants of the universe's existence. One of the main objectives is to produce tiny quantities of such matter, which is known as quark-gluon plasma, and to study its evolution into the kind of matter that makes up the universe today. This exploration will shed further light on the properties of the strong interaction, which binds the particles called quarks, into bigger objects, such as protons and neutrons.

Following the winter technical stop, operation of the collider will start again with protons in February and physics runs will continue through 2011.

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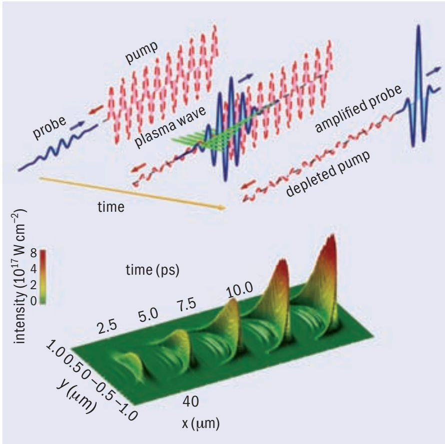
LASERS&ACCELERATORS

Raman amplification could boost plasma-based acceleration

Researchers using the first large-scale particle-in-cell simulations have found that Raman amplification of laser beams in a plasma can produce multi-petawatt peak powers – albeit in a definite parameter window – without the plasma medium being destroyed through instabilities. The control of these instabilities promises big reductions in costs and complexity for producing ultra-intense laser pulses, which in turn would allow greater access to higher intensities for use in inertial laser fusion or in laser-based particle accelerators. The process also scales to short wavelengths allowing, for example, the compression of free-electron laser pulses to durations of an attosecond.

Since the invention of the laser 50 years ago, the drive to produce increasingly intense lasers for investigating physical processes at the intensity frontier has required larger amplifying media. This progress has followed a path similar to development in accelerators as described by the Livingston curve: as one technique saturates another is discovered. At present, conventional amplifying media are based on solid-state lasers, which have already proved successful at reaching powers on the petawatt scale. Such lasers, when focused, can produce intensities of the order of 10^{21} W/cm^2 on target, equivalent to 10^9 atmospheres, the pressure found inside stars. However, the intensity threshold for the breakdown of the optical components in these systems demands metre-scale beams.

A promising new technique uses a much smaller amplifying medium – millimetre-diameter plasmas, which can be 100 000 times smaller than conventional optics, making the system compact and less expensive. Raoul Trines and colleagues of the Central Laser Facility, STFC Rutherford Appleton Laboratory, St Andrews University and the Instituto Superior Técnico, Lisbon, have made the first systematic study of high-power Raman amplification. In this process a long pump pulse and a counter-propagating short probe pulse are sent into a plasma where they couple through a plasma wave and energy transfers from the pump to the probe pulse, resulting in amplification (see figure).



Top: Illustration of the Raman amplification process in which energy transfer occurs between a long pump pulse and a short probe pulse when they meet in plasma. Bottom: An example of successful amplification in the simulation.

Using multidimensional, fully relativistic particle-in-cell simulations the team has discovered how to produce short multi-petawatt laser pulses while controlling instabilities, for example, from forward Raman scattering. They find that although increasing the pump intensity or plasma density can lead to efficiency in the amplification process, it can also increase the instabilities in both the pump and the probe. Nevertheless, they identify a parameter regime in which a 4 TW, 700 μm full-width at half-maximum (FWHM), 25-ps-long laser pulse with 800 nm wavelength can be amplified to 2 PW peak intensity with 35% efficiency, as the lower part of the figure shows.

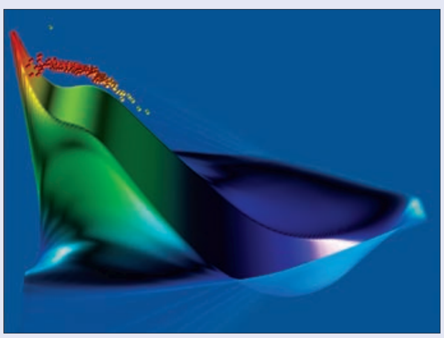
One major application of ultra-high-power laser systems is laser-driven electron acceleration in plasma. Earlier this year, Samuel Martins and colleagues of the Instituto Superior Técnico and University of California Los Angeles, found that electrons can be accelerated to beyond 10 GeV when the driver pulse contains 300 J in 110 fs (2.8 PW peak power). Starting from a kilo-joule pump laser beam with a duration of 100 ps, such a pulse could be produced via Raman amplification in a plasma column only 15 mm long and just a few millimetres in diameter. Producing the same pulse via conventional glass optics would require gratings that are at least one metre across. This is just one of the many applications of high-power lasers that could benefit hugely from the application of the novel technique of Raman amplification.

Further reading

R M G M Trines *et al.* 2010 *Nature Phys.* doi:10.1038/nphys1793.

S Martins *et al.* 2010 *Nature Phys.* **6** 311.

50 years of lasers



To celebrate the 50th anniversary of the first working laser, this issue of *CERN Courier* explores the relationship between lasers and accelerators. Chan Joshi looks at the impact of lasers in research at particle accelerators, from the 1960s up to the present day with schemes to accelerate particles by harnessing the plasma wakefield created by an intense laser pulse (p13) – the topic also of the news story above. Claudio Pellegrini examines the development of free-electron lasers as sources of hard X-rays, in particular at SLAC (p17), and a final article presents the successful story of the FLASH facility at DESY (p21).

FUTURE ACCELERATORS

The global linear collider comes together in Geneva

Members of the global linear-collider community who attended IWLC2010 in Geneva.

The International Workshop on Linear Colliders (IWLC2010) recently brought together many experts involved in research and development for an electron–positron linear collider – the favoured future facility to complement the LHC. Organized by the European Committee for Future Accelerators (ECFA) and hosted by CERN, the meeting took place on 18–22 October and attracted 479 registered participants.

Two complementary technologies are currently being developed for a future linear collider: the International Linear Collider (ILC), based on superconducting RF technology in the tera-electron-volt energy range for colliding beams; and the Compact Linear Collider (CLIC), based on a novel scheme of two-beam acceleration to extend to energies of multi-tera-electron-volts. Taking advantage of a large number of synergies, the two studies are already collaborating closely on a number of technical subjects. These include: beam-delivery systems and machine-detector interfaces; physics and detectors; positron generation; beam dynamics; damping rings; civil engineering and conventional facilities; and cost and schedule.

IWLC2010 merged previously separate workshops on CLIC and ILC for the first time. Covering accelerators as well as detectors and physics, it provided an environment where researchers could exchange ideas, inform their peers about recent achievements and work together on common issues. It also took full advantage of synergies between the two studies, with common working groups to discuss the many shared challenges. The lively discussions, together with the scientific and technical presentations, showed the progress that has been made towards unifying the two study teams into a single linear-collider community.

While the opening and final plenary sessions were held at CERN to facilitate participation and information flow beyond the linear-collider community, the parallel sessions (up to a maximum of 16 simultaneously) were held in the International Conference Centre Geneva. Scheduled activities and satellite meetings started half a day before the workshop formally began and continued throughout. For example, Steinar Stapnes, CERN's Linear Collider studies leader, presented a colloquium, "Towards a future linear collider", as an introduction for CERN staff.

CERN's director-general, Rolf Heuer, introduced the workshop with a presentation on "The LC roadmap" in which he referred to the active role that CERN can play towards defining global linear-collider governance and siting. A plenary session followed that reviewed the physics prospects of linear colliders, the status of the ILC and CLIC accelerators, the concepts for detectors (ILD, SiD and CLIC) and R&D activities for detectors. Another plenary session addressed the potential impact of LHC and Tevatron physics on the linear collider.

Three days were filled with parallel sessions. Some took place as separate accelerator or physics and detector sessions, but many came together in various combinations, with strong interaction between the two communities. In particular, there was a lively discussion session on the scientific imperative to vary the machine energy over a wide range and to scan over energy thresholds, while maintaining adequate luminosity. The progress of the machine designs towards this goal was reviewed and discussed. Excellent progress has been made on both studies towards their next milestones: CLIC will present its Conceptual Design Report for accelerator and detectors in 2011, while the ILC accelerator and the two validated ILC detector concepts – ILD and SiD – will publish a more advanced technical design report and a detailed baseline design, respectively, in 2012.

In particular, the ILC study has achieved its 2010 goal of demonstrating that half of the superconducting accelerating structures produced for the ILC reach the desired acceleration gradient. The successful operation of two advanced test facilities, CESR-TA at Cornell, in the US, and ATF2 at KEK, in Japan, have led to major advances across a range of subjects. The work at CESR-TA has significantly deepened understanding of electron-cloud effects, leading to several promising ways in which they could be mitigated. ATF2 continues to produce important results in many areas of beam instrumentation and beam optics.

As far as CLIC is concerned, the CTF3 test facility, which adresses the major feasibility issues of the novel CLIC technology, is near completion and is being commissioned. There has been important progress on the high-intensity drive-beam generation, which uses complex beam manipulation; on the use of this beam to produce RF power with special power-extraction and transfer structures (PETS); and on the use of this power to accelerate a probe beam, thus demonstrating the feasibility of the two-beam acceleration scheme (*CERN Courier* September 2008 p15). First measurements of the beam quality have shown current stability better than the demanding CLIC requirements. Accelerating structures that include waveguide damping features have achieved performances close to CLIC's target in the first tests at KEK and SLAC. Measurements on a model of the mechanical quadrupole-stabilization system showed good decoupling from ground motion with a residual level consistent with the beam stability specifications.

Regarding the ILC detectors, community-wide detector R&D has led to important advances on high-precision vertex technology, highly granular calorimetry for particle flow, as well as developments in time-projection chambers based on micro-pattern gas detectors. Many of these efforts now proceed together with the CLIC study. For the CLIC detector study, recent simulations of detector performances under CLIC beam conditions have allowed the detector geometries for the CLIC_ILD and CLIC_SiD concepts to be fixed for presentation in the conceptual design report.

In all, this first joint linear-collider workshop was unanimously considered a great success, fostering mutual co-operation on both a regional and a global basis. The next joint workshop is planned to take place in Grenada on 26–30 September 2011.

- For more about IWLC2010, see https://espace.cern.ch/LC2010/default.aspx.

SuperB project reports progress

The SuperB collaboration has completed a series of reports detailing the progress made since publishing the Conceptual Design Report (CDR), in consolidating the physics case and in the design, cost and schedule of the detector and accelerator. The SuperB collider consists of two rings, in which beams of electrons and positrons collide to produce tens of billions of heavy quarks and heavy leptons per year for a sensitive exploration of their decays (B O'Leary *et al.* 2010).

The new detector represents a substantial advance, with improved resolution, radiation hardness and background-rejection capability (Grauges *et al.* 2010). There have been similar advances in the accelerator design compared with the preliminary CDR (Biagini *et al.* 2010). It is now smaller (1250 m circumference), has a fully worked-out lattice, incorporates a polarized electron beam and includes flexibility in reaching its design goal of a luminosity of 10^{36} $cm^{-2}s^{-1}$.

Further reading

M E Biagini *et al.* 2010 arXiv:1009.6178v1 [physics.acc-ph].
E Grauges *et al.* 2010 arXiv:1007.4241 [physics.ins-det].
B O'Leary *et al.* 2010 arXiv:1008.1541 [hep-ex].

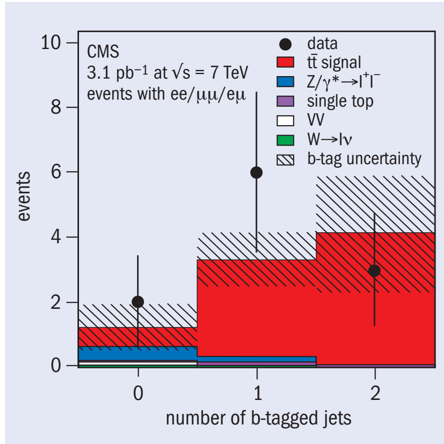
LHC PHYSICS

CMS measures the top cross-section at 7 TeV

The CMS experiment at CERN recently published first measurements of the cross-section for top-antitop pair production at a centre-of-mass energy of 7 TeV. The top quark is the heaviest known fundamental particle, with a mass of about 172 GeV, almost 185 times that of the proton. Until recently the production of top quarks was the privilege of the Tevatron at Fermilab.

Top quarks decay instantly and almost exclusively into a heavy W boson and a bottom quark (b). The b quark then "hadronizes" into a jet of particles, which can often be distinguished from a jet originating from a lighter quark or gluon by the presence of a secondary vertex in the event. The W boson can decay into either two jets or two leptons. The recent CMS analysis relies on the W bosons from both of the top quarks decaying into two leptons, i.e. either to a muon plus a neutrino, or into an electron plus a neutrino. This leads to a signature for top-antitop ($t\bar{t}$) consisting of two b-quark jets, two charged leptons and two neutrinos. The neutrinos will pass through the detector without leaving any trace but their presence can be induced from the missing (transverse) energy in the collision.

Such a signature is very distinct and relatively free of background. The CMS collaboration performed this first analysis on a sample of data taken in the first few months of LHC operation at 7 TeV, corresponding to an integrated luminosity of around 3 pb^{-1}. They identified 11 candidate events and calculated the number of jets per event thought to originate from bottom quarks, as shown in the figure, which also indicates the expectations for signal and background. The latter is indeed very small. The analysis of this event sample yields a top cross section of 194 ± 72 (stat.) ± 24 (syst.) ± 21 (lumi). Within the measurement uncertainties, this value for the cross-section is in good agreement with calculations in higher-order perturbative QCD.



The number of b-tagged jets in events passing all dilepton selection criteria, compared with signal and background predictions. The hatched bands reflect the expected uncertainties on the b-tag efficiency for signal events.

While the top quark is an interesting object to study in itself, it will also play an important role as background in searches for new physics. Therefore an early measurement of its cross-section at this new centre-of-mass energy is an important step towards exploring the unknown.

Further reading

CMS collaboration 2010 arXiv:1010.5994 [hep-ex]. Submitted to *Phys. Lett. B*.

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

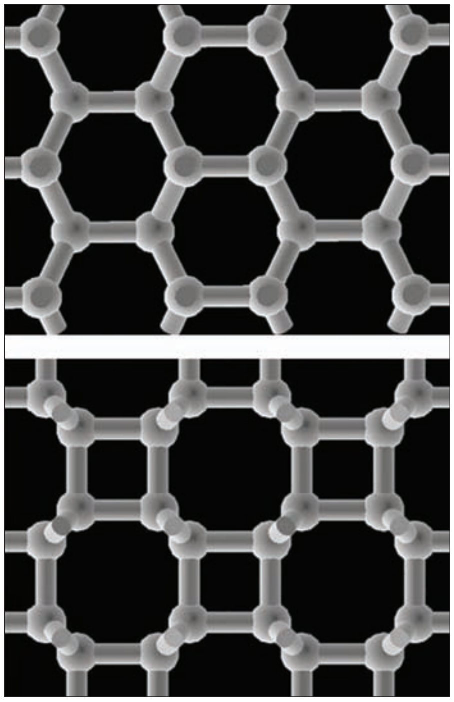
CERN Courier welcomes contributions from the international particle-physics community. These can be written in English or French, and will be published in the same language. If you have a suggestion for an article, please send your proposal to the editor at cern.courier@cern.ch.

Compiled by John Swain, Northeastern University

Researchers look into transparent carbon

Almost everyone knows that carbon can take on more than one form, with diamond and graphite being the most common, and with the fullerenes, carbon nanotubes and this year's Nobel prize-winning graphene close behind. Now, evidence is mounting for the existence of a transparent form of carbon – bct-carbon – with a body-centred tetragonal (bct) structure something between graphite and diamond, first studied in simulations by Koichiro Umemoto and colleagues of the University of Minnesota, Tokyo and Tsukuba.

In separate work, Xiang-Feng Zhou of Nankai University in China and colleagues have made further studies with simulations. While their work is still theoretical, it does explain the experimental observation of a transparent allotrope of carbon formed in the compression of graphite. Remarkably, the material is harder than diamond and actually dents the diamond anvils used to provide the pressure to produce it.



In bct-carbon, rings of four atoms form a 3D network. In the lower image, "short" bonds are orthogonal to the page. The upper perpendicular view (top) shows the vertical structure, where the squares appear edge-on as horizontal bonds.

Further reading

Koichiro Umemoto 2010 *Phys. Rev. Lett.* **104** 125504.
Xiang-Feng Zhou *et al.* 2010 *Physical Review* **B82** 134136.

Experiments detect non-Abelian anyons

The standard elementary particles are either bosons or fermions, depending on whether or not multiparticle wave functions pick up a phase of +1 or −1 on swapping particles. Abelian anyons are quasiparticles that pick up other phases on being swapped, and have long been known to do so.

Now, there is evidence for more complicated non-Abelian statistics for quasiparticles in condensed matter where non-commuting matrices take the place of scalar phases. Perhaps surprisingly, non-Abelian anyons may be easier to detect than Abelian ones because an exchange gives states that do not interfere with the one that existed before exchange (not being equivalent up to a phase).

Robert Willett and colleagues of Bell Laboratories, US, have shown (among other pieces of evidence) exactly this kind of non-interference in Aharanov-Bohm type experiments with quasiparticles of charges $e/2$ and $e/4$ in the quantum Hall effect. The work is generating a great deal of interest because such non-Abelian anyons could form the basis of robust quantum computers.

Further reading

R L Willett *et al.* 2010 *Phys. Rev. B* **82** 205301.

A smoking gun for cigarettes

Lighting a cigarette releases thousands of different molecules, so it might seem unlikely that any single molecule would be a unique marker for tobacco smoke, as opposed to smoke of any other kind. Surprisingly, Juan M Sanchez and colleagues of the University of Girona, Spain, found from samples of air in 56 local cafes and restaurants that the simple molecule 2,5-dimethylfuran can give the game away. This molecule seems to be unique to tobacco smoke and is not found in smoke from cars, cooking or other types of combustion. Looking for this substance is even sensitive enough to detect smoke in the breath of non-smokers who work in smoky environments.

Further reading

M Alonso *et al.* 2010 *Environmental Science and Technology* **44** 8289.

Nonlinear electrophoresis

Electrophoresis is a well known technique for separating molecules or particles based on their electric charge and the drag that they suffer on moving through a liquid carrier-medium. Now, Oleg Lavrentovich and colleagues of Kent State University in Ohio have found a new way to do it: by using liquid crystals as the carrier.

The intrinsic anisotropy of the liquid crystals opens up a range of new phenomena. These include drift velocities that are quadratic in the applied voltage as opposed to linear, which makes it possible to use alternating current and avoid electrolysis. It also offers the possibility to transport both charged and neutral particles, with the necessary asymmetry being provided by the medium itself. In addition to applications in chemical and biological or medical analyses, this also opens up a whole new range of microfluidic applications.

Further reading

O D Lavrentovich *et al.* 2010 *Nature* **467** 947.

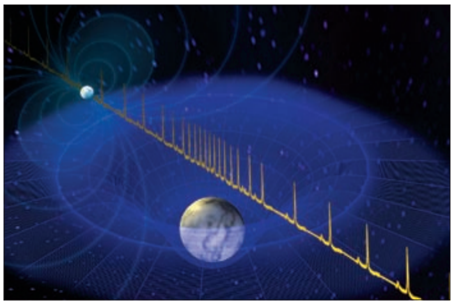
Compiled by Marc Türler, ISDC and Observatory of the University of Geneva

Massive neutron star can't be exotic matter

The most precise determination yet of the mass of a heavy neutron star in a binary system has important implications on its matter content. With a mass twice that of the Sun, the millisecond-pulsar J1614-2230 rules out almost all currently proposed compositions based on hyperon or boson condensates, as well as weakly interacting quarks.

Neutron stars are the densest bodies in the universe. Their density of about 100 000 tonnes per cubic millimetre is comparable to that of atomic nuclei. They form at the heart of massive stars by the collapse of the iron core when nuclear fuel is exhausted. Their formation triggers the explosion of the outer parts of the star that is witnessed as a supernova event (*CERN Courier* November 2008 p11). Pulsars are neutron stars that emit regular pulses of radiation. These "lighthouses of the Milky Way" send a beam of radiation along the direction of their strong magnetic field, which rotates as the neutron star spins.

While the spin period of typical pulsars is around a second, a subclass of them exhibit pulsations on periods down to milliseconds. Such rapidly spinning neutron stars are thought to have been "spun-up" via accretion of matter from a companion star. Their rapid pulses are precise chronometers and allow astronomers to derive the orbital period of the binary star system. What makes the millisecond-pulsar J1614-2230 special is that the companion star is a white dwarf and the orbital motion of the system is seen almost perfectly edge-on from Earth. Like



An artist's impression of pulses from a neutron star (rear) passing near its massive white-dwarf companion in a binary system. (Courtesy: Bill Saxton, NRAO/AUI/NSF.)

neutron stars, white dwarfs are remains of stellar evolution, but with a much lower density (*CERN Courier* October 2009 p10). Their gravitational potential well is, however, deep enough to make a significant imprint on space–time. Hence, the radio pulses from the pulsar passing by the white dwarf on their journey to the Earth will be delayed.

It is this effect of general relativity, identified by Irwin Shapiro in 1964, that was precisely measured to determine the mass of the neutron star in J1614-2230. Paul Demorest of the National Radio Astronomy Observatory (NRAO) in Virginia and colleagues from the US and the Netherlands performed a dense set of radio observations of the system in March 2010 with the NRAO Green Bank Telescope. The data were taken with a new instrument, which corrects interstellar dispersion smearing, and covered the 8.7-day orbital period of the system. These high-accuracy measurements were combined with previous long-term data to characterize the binary system in full. The "Shapiro delay" was detected with extremely high significance, a Markov-chain Monte Carlo approach being used to estimate the errors in the parameters. The derived masses for the white dwarf and the neutron star are 0.500 ± 0.006 and 1.97 ± 0.04 solar masses, respectively. This is by far the most precisely measured neutron star mass to date and allows constraints on the equation of state (EOS) of their nuclear matter.

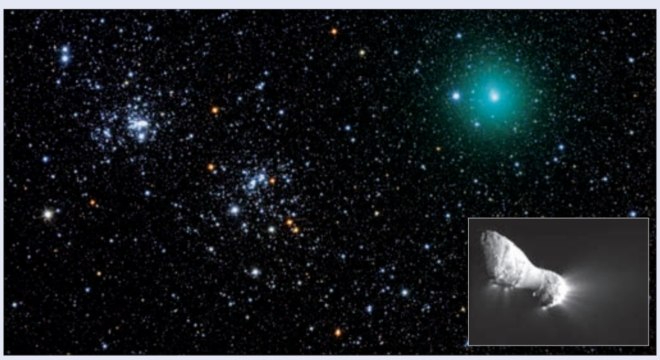
Only a subset of all proposed EOSs are consistent with such a high mass and those are mainly the ones with standard nuclear matter. Most "exotic" hadronic models are too soft at the core of the star to sustain such a high mass. This is particularly the case for hyperons or kaon condensates. Demorest and colleagues note further that condensed quark matter at the heart of the neutron star is not ruled out, but the quarks have to be strongly interacting and are therefore not "free" quarks. This seems to indicate that neutron stars are indeed mainly composed of neutrons, although James Lattimer of the State University of New York at Stony Brook notes that depending on the radius of the star, exotic models could still be viable solutions.

The origin of this unusually heavy neutron star is another mystery. Was it so heavy when it was formed during the supernova explosion, or did it grow through efficient matter transfer from the companion star, or both?

Further reading

P Demorest *et al.* 2010 *Nature* **467** 1081.

Picture of the month



In October, the bright comet Hartley 2 passed in front of the double-star cluster "h and χ Persei", which was catalogued by the Ancient Greek astronomer Hipparchus. The event could be followed with binoculars and is nicely depicted on this image, where the comet is the blue-green glow on the upper-right. The inset image of the nucleus of the comet was captured on 4 November from a distance of only 700 km. This was achieved reusing NASA's Deep Impact spacecraft that impacted comet Tempel 1 in July 2005 (*CERN Courier* October 2005 p11). The peanut-shaped comet appears to be only about 2 km long. (Courtesy Ivan Eder, http://eder.csillagaszat.hu (background)/NASA, JPL-Caltech, UMD, EPOXI Mission (inset).)

CERN COURIER ARCHIVE: 1967

A look back to *CERN Courier* vol. 7, December 1967, compiled by Peggie Rimmer

CERN NEWS

'FOCUS' on computing at CERN

The latest addition to CERN's central computer complex is a CDC 3100 for FOCUS, the "Facility for On-line Computations and Up-dating Services". Its main purpose is to manage data-links to the central computers from smaller computers used on-line in electronics experiments.

The on-line computers carry out preliminary checks and record the data on magnetic tape for full processing later on the central CDCs 6600 and 6400. Some have been connected to the central computers via separate data-links to access this processing directly. Unfortunately, this is an inefficient use of central computer memory and the demand for such links would soon overload the machines.

The solution is to use the 3100 as an intermediary, to receive all the on-line computer data-links and manage their access to the central computers via one link. Another advantage of the intermediate computer is that a typewriter console can be added to each on-line computer to allow the physicists to select and modify their programs in the central computers and receive their results printed out by the console.

Arrival of the CDC 3100 at Cointrin airport, destined for the FOCUS development project

COMPILER'S NOTE

CERN's achievement in bringing together people from all corners of the world in a sustained common endeavour is unsurpassed. For more than half a century, the organization has remained almost immune to the vicissitudes of the Cold War, international conflicts and civil strife. Today, CERN's 10 000 users, drawn from 95 countries, represent almost half of the nations on the planet. That these young scientists and engineers regard this motley mix as seemingly normal bodes well for the future as the first decade of the new millennium draws to a close (or was that last December?).

Better than one part in a million

CERN has given considerable attention to the problems of metrology because of the immediate requirement for aligning the intersecting storage rings ISR and the future requirement for aligning the 300 GeV machine, ten times the diameter of the 28 GeV proton synchrotron PS.

An automatic measuring device, the Distinvar, has been developed for rapid and accurate measurements of distances up to 55 m. It was tested in one of the PS tunnels for a thousand measurements over a distance of 50 m and gave a relative precision of better than one part in a million.

The Distinvar uses a calibrated invar wire attached to a special reading head which reads off the difference between the calibrated length and the actual distance between the measured points. In the head, a "balance beam" oscillates between two electrical contacts fixed to a carriage that moves along a precision micrometer screw until the tension in the wire is balanced by a weight. The position of the carriage (and hence the distance to be measured) is then transferred via a potentiometer to be read at the recording station or passed to a computer.

The absolute precision is obtained by calibrating the invar wire before and after a measurement against a 4 m-long invar rule calibrated by the International Bureau of Weights and Measures (Sèvres). Each measurement takes three minutes, is entirely automatic and could be performed by remote control, for example in radioactive areas.

The Distinvar will be used in the alignment of the ISR magnets. Because of its speed and reliability it has not been necessary to allocate time for alignment in the construction programme.

Separators for Serpukhov

CERN is busy studying a radiofrequency particle-separator system [and a fast-ejection system] to be used on the 70 GeV proton synchrotron, which came into operation at the Serpukhov Institute for High Energy physics in October. The designs are at an advanced stage and only minor extensions of the techniques used on the CERN proton synchrotron PS have been necessary to meet the requirements of the higher-energy machine. The spirit of collaboration is excellent and the practical aspects of such an extensive collaboration between two high-energy physics Laboratories are working well.

The purpose of a particle separator is to sift out a particular type of particle at a particular momentum from the spray of particles with a wide momentum range coming from a target bombarded by the accelerated proton beam.

A two-cavity radio-frequency separator, brought into operation at CERN in 1965 by a group led by B W Montague, was already designed for possible extension to three cavities, an idea first put forward by W Schnell. With three cavities it is possible to overcome a limitation of the two-cavity system, namely that the separation of one type of particle from two other types is only possible for very narrow momentum regions.

The proposed design for Serpukhov is based on a new three-cavity system and covers a momentum region from 17 to 36 GeV/*c*. It completed a very successful test run in June when P Bernard, P Lazeyras, H Lengeler and V Vaghin [from Serpukhov] succeeded in separating antiprotons with a momentum of 12 GeV/*c*, about twice as high as previously achieved and about the highest momentum that can be reached with the CERN PS.

● Compiled from texts on pp250–252.

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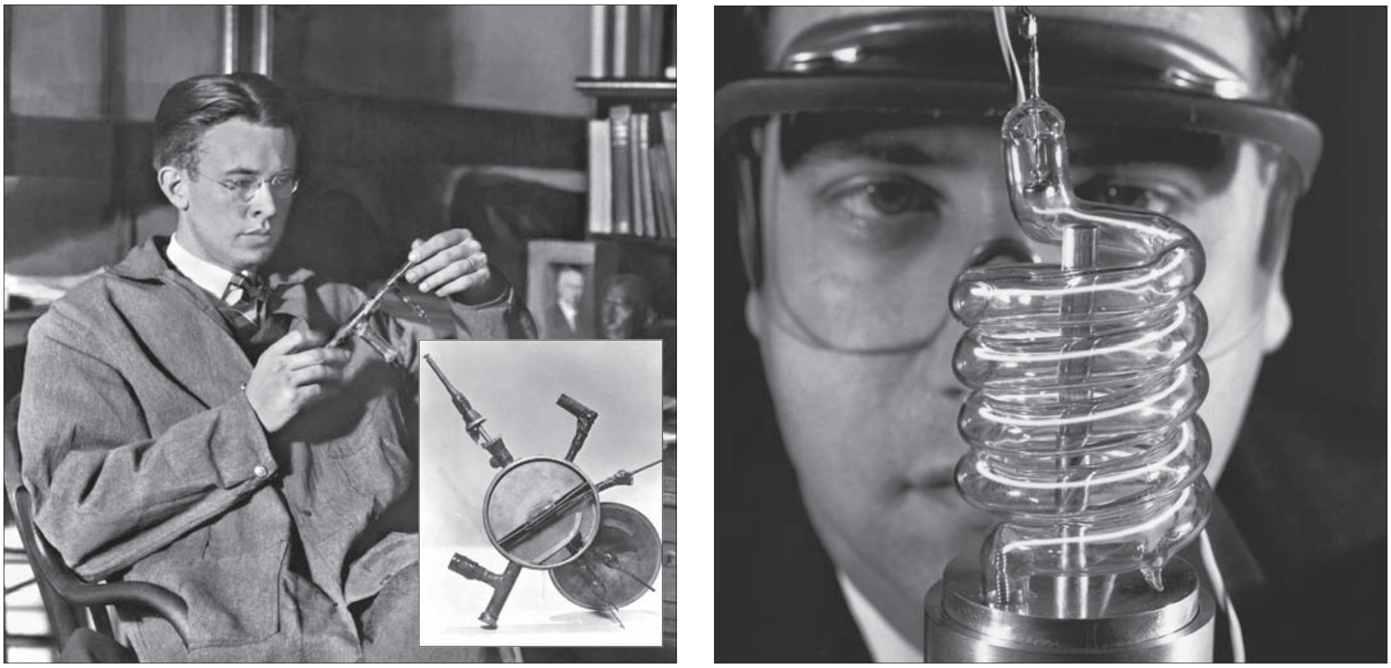

Fig. 1. Left: Ernest Lawrence invented the first circular accelerator in 1930. His cyclotron was 10 cm in diameter and accelerated protons to 80 kV. (Courtesy LBNL.) The first laser was a ruby laser produced by Theodore Maiman in 1960. (Courtesy HRL Laboratories.)

How lasers cast a light on accelerator science

Since their invention, lasers have played important roles in research at particle accelerators. This link is set to continue growing ever closer, as **Chan Joshi** explains.

Particle accelerators, invented during the first half of the 20th century, and lasers, invented during the latter half of the 20th century, are arguably the two most successful tools of scientific discovery ever devised. The first cyclotron, which Ernest Lawrence conceived of in 1930, and the first laser, which Theodore Maiman produced exactly 30 years later, were both palm-size devices (figure 1). Just as the cyclotron was followed by betatrons, synchrotrons and colliders, the ruby laser was followed by other solid-state, liquid, gaseous and semiconductor lasers. Since their inception, both lasers and accelerators have found applications in science, medicine and industry. Today, in contrast to their humble antecedents, the LHC at CERN and the laser of the National Ignition Facility at Lawrence Livermore National Laboratory (LLNL) are indisputably the most complex scientific instruments ever constructed for particle physics and inertial-fusion research, respectively.

The relationship between these two inventions runs deeper than this parallel history. Accelerator-based free-electron lasers (FELs) have over the past three decades been extending the capabilities of coherent light sources (p17). On the flip side, intense, short-pulse lasers are being used to accelerate charged particles at a rate thousands of times greater than is possible using conventional microwave accelerators (*CERN Courier* June 2007 p8). There is little doubt that these two great inventions will continue to be the premier tools of scientific discovery in the foreseeable future.

Laser Compton scattering

Lasers began to play an important role in accelerator-based science not long after their invention. In a head-on collision between photons and electrons the Compton scattered (CS) photons are shifted up in frequency by a double Doppler shift. Within four years of the invention of the laser in 1960, a ruby laser was used to demonstrate Compton scattering of laser photons off a 6 GeV electron beam ▷

at the Cambridge Electron Accelerator (Bemporad *et al.* 1965). This was the first time that photons of a few electron-volts had been frequency up-shifted more than 100 million times to produce gamma-ray photons with energies of more than 100 MeV. Since then, laser CS photons at these energies have been used for nuclear physics. It was not until the late 1990s – when lasers had become sufficiently powerful – that collisions between giga-electron-volt CS photons, off relativistic electrons, and multiple laser photons were able to produce electron–positron pairs in the first demonstration of light-by-light scattering (Burke *et al.* 1997).

These early experiments used head-on collisions between giga-electron-volt electrons and visible laser photons to produce CS photons in the giga-electron-volt range. However, X-ray photons with an energy of a few kilo-electron-volts are needed for many scientific applications, such as to probe structural dynamics in condensed matter. In 1996, using the 50 MeV injector beam of the Advanced Light Source at the Lawrence Berkeley National Laboratory (LBNL), experimenters made a laser pulse collide with the electrons at 90° to produce the first subpicosecond pulses of X-ray photons with a wavelength of 0.04 nm (Schoenlein *et al.* 1996).

Compton scattering can also occur when an electron beam passes through a periodically varying magnetic field, such as in a magnetic wiggler or an undulator. Here, the static magnetic field looks like an electromagnetic wave in the frame of the relativistic electrons: the electrons Compton scatter these photons, which in classical terms is just synchrotron radiation. In an FEL, Compton scattering provides the noise photons (spontaneous emission) that are subsequently amplified by the FEL instability (stimulated emission). The subpicosecond photon-pulse facility (SPPS) at SLAC – a precursor of the Linac Coherent Light Source (LCLS) – showed that sub-100 fs X-ray pulses could be obtained via an undulator-based CS source of photons in the 10 kV range (Cornacchia *et al.* 2001).

It is extremely difficult for an electronic transition to provide laser action at such short wavelengths because the pumping density – required to achieve gain – scales as the frequency of the photons to the fourth power. Therefore, it is likely that above a photon energy of 1 kV, FELs are the only way to generate high-power, coherent radiation. In an FEL, the electron beam must be bunched on the scale of the photon wavelength so that the phases of the emitted photons all add coherently. This places a stringent requirement on the normalized emittance (ε_N) of the electron beam. However, the recent success of the LCLS has shown that accelerators are capable of producing beams of the necessary brightness (I/ε^2_N, where I is peak current) to produce tunable coherent photon beams in the 1–10 kV range (figure 2).

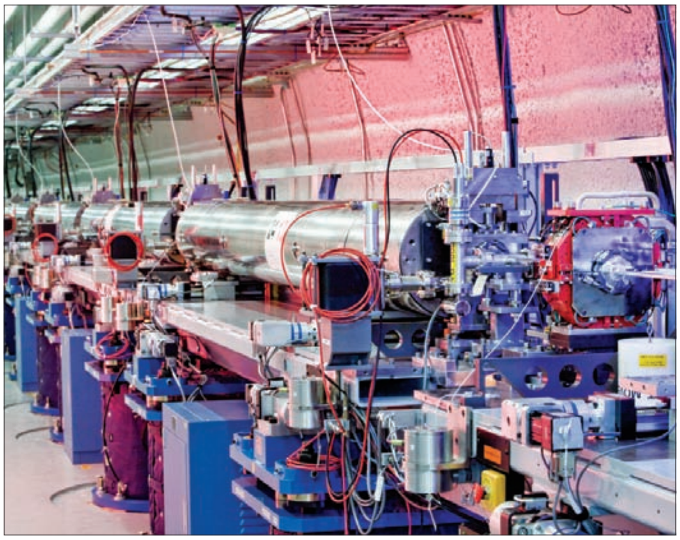

Fig. 2. Inside view of the undulator hall of the LCLS. The world's shortest wavelength laser is based on conventional accelerator technology. (Courtesy Brad Plummer/SLAC.)

Lasers at light sources and accelerators

Synchrotron-radiation facilities such as the European Synchrotron Radiation Facility, France, the Advanced Photon Source, US, and Spring-8, Japan, are now being used by thousands of scientists in virtually every field. The key innovation that led to orders of magnitude increase in the brilliance of the emitted radiation was the introduction of insertion devices, i.e. magnetic wigglers and undulators. Many "pump-probe" experiments on these machines use undulator-produced X-ray photons to pump or induce change/damage in atoms/molecules, electronic and biological samples, together with a time-delayed laser pulse to probe the induced change, or vice versa. These pump-probe experiments on ultrafast phenomena using accelerator-based light sources will continue to push the boundaries of experimental science in the coming years.

How are the high-brightness electron beams needed for X-ray FELs and for future colliders for high-energy particle physics produced? Here, again, lasers have played a critical role. Until the mid-1980s, thermionic cathodes embedded in RF cavities were used to produce electron bunches. It was realized that the emittance of beams from these RF guns could be greatly improved by replacing the thermionic cathode (LaB_6 for instance) by a photocathode (Cu, Mg or alkali cathode). Richard Sheffield and colleagues at Los Alamos National Laboratory carried out pioneering work on the first photo-injector gun with a Cs_3Sb cathode (Sheffield *et al.* 1996). By illuminating the photocathode with a short laser pulse of photons with an energy just greater than the work function of the cathode material and by operating the gun at high gradients, very high currents of electron bunches with emittances less than 1 mm mrad have been produced (Akre *et al.* 2008). For FELs, the short duration combined with low emittance implies a beam of high brightness that can be readily bunched by the FEL instability on the wavelength scale of the emitted radiation. Almost all recent FELs, including FLASH at DESY (p21), the high-gain harmonic-generation (HGHG) FEL at Brookhaven National Laboratory and the LCLS at SLAC, use photo-injector guns as the source of electrons.

Lasers are also routinely used for alignment and diagnostics in particle accelerators. A "laser wire" is a type of beam-profile monitor used to sample nondestructively the transverse profile of intense electron or positron beams that would ordinarily destroy a thin metallic wire. The local density of the beam is sampled through collisions with a tightly focused laser pulse that has a spot size smaller than the particle beam. The relative CS yield provides a measure of the beam profile.

Future linear colliders for particle physics will bring nanometre-sized beams of electrons and positrons into head-on collision, maximizing the luminosity. Conventional techniques for measuring the

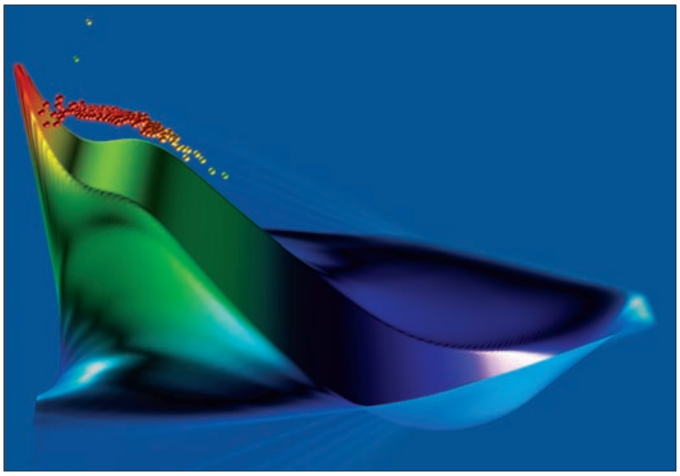

Fig. 3. Computer simulation of electrons (dots) being accelerated by the longitudinal electric field of a wake produced by a laser pulse in plasma. Laser wakefield acceleration has produced the world's highest gradient (100 GeV/m) accelerator. (Courtesy C Huang, Los Alamos National Laboratory, and F Tsung, UCLA.)

size of the beam spot, such as the laser-wire scanning described above, are not suitable for measuring submicron spots. Instead, laser photon CS at 90° has been used as a noninvasive diagnostic technique for measuring ultrasmall beam sizes (Shintake 1992). Two counter-propagating laser beams produce a standing-wave interference pattern. As the focused electron bunch is scanned across this interference pattern (using a weak steering magnet) the gamma-ray yield is modulated and the depth of modulation of the CS gamma-ray flux gives the spot size. This technique has been used at the Final Focus Test Beam Facility at SLAC to measure a 47 GeV beam with a transverse size as small as 60 nm. A modified version of this technique using a propagating beat-wave interference pattern can be used as a bunch-length monitor.

Measurement of the width of highly relativistic electron bunches shorter than 100 fs poses a serious challenge. Fortunately, the transverse electric field of such bunches can itself be used to induce a change in the polarization of a synchronized laser pulse in an electro-optic crystal that is placed in the vicinity of the beam (Cavalieri *et al.* 2005). The duration of the photons that are affected by the polarization change can then be measured to give the pulse width of the electrons.

Accelerating with lasers

Lasers are now being used directly to produce medium-energy (100 MeV–1 GeV) electron beams (Leemans and Esarey 2009). Indeed, laser particle acceleration has grown into a distinct subfield of research since the first Laser Acceleration of Particles Workshop at Los Alamos in 1982. A short but intense laser pulse propagating through plasma can excite a wave in space-charge density, also called a wake, behind the pulse. The longitudinal electric field of this wake can be tens of giga-volts per metre, which is large enough to capture some of the plasma electrons and accelerate them (figure 3). However, the wake propagates at a phase velocity that is equal to the group velocity of the laser pulse in the plasma. Since the group velocity of a photon packet in a medium is always less than the speed of light, the accelerating electrons continuously dephase with respect to the wake. A combination of beam loading and dephasing leads to a quasi-monoenergetic beam of electrons whose energy increases as the plasma density is decreased. The transverse spread of the electrons can be a few microns and the emittance less than 1 mm mrad. Several groups are embarking on research programmes to demonstrate the coherent amplification of undulator radiation, with the eventual goal of demonstrating a tabletop, extreme-ultraviolet FEL based on a laser-wakefield accelerator (LWFA).

Although a laser-based plasma accelerator operating at the energy frontier is at this stage far into the future, the US Department of Energy (DoE) has funded the construction of a research facility called BELLA at LBNL whose goal is to demonstrate a 1 m-scale 10 GeV LWFA that can then be staged multiple times to give high energies (*CERN Courier* January/February 2010 p8).

An alternative approach is to use a laser pulse to produce an accelerating electromagnetic mode directly in a miniature photonic band-gap structure or a slow wave structure in a plasma medium. It is too early to say what the eventual architecture of a high-energy accelerator based on these concepts would look like but the research is fascinating in its own right.

A bright future

In the future we are likely to see even greater merging of lasers and accelerators. Laser CS has been proposed as a method for generating polarized positrons for a future e^+e^- collider using a high-finesse laser cavity in conjunction with an electron storage ring operating at a few giga-electron-volts. In this proposal the electron micro-bunches collide with (the circularly polarized) laser photons circulating in the cavity to produce the CS photons. These polarized multimega-electron-volt photons then collide with a target of high atomic number (Z) to produce a copious number of polarized positrons via pair production (Araki *et al.* 2005).

A CS-based gamma–gamma collider would be a natural second interaction region for any future e^+e^- collider because cross-sections for some reactions are larger for gamma–gamma collisions than for e^+e^- collisions (Telnov 1990). With a proper choice of laser wavelength and intensity, much of the electron energy can be converted into the gamma-ray photon and, with a net yield of about one photon per electron, the final luminosity of a gamma-gamma collider can be comparable to that of an e^+e^- collider (Kim and Sessler 1996). While the peak power (1 TW) and the pulse width (1 ps) required for the laser used in a gamma–gamma collider are easily obtained today, the repetition rate of such lasers is still a couple of orders of magnitude lower than in state-of-the-art lasers. There is reason for optimism, however, because diode-pumped solid-state lasers appear promising for achieving the high average powers needed.

Other possible uses of laser CS photons are for nuclear spectroscopy, where the transition energies are in the multimega-electron-volt range, as mentioned above, and for the detection of hidden fissionable materials via the observation of nuclear resonance fluorescence (NRF). If the line-width of the CS photons can be made to be less than that of nuclear transitions, then such a source could revolutionize nuclear spectroscopy much in the same way that tunable lasers have transformed atomic spectroscopy. An example of an ambitious CS source is MEGa-ray (mono-energetic gamma-ray), now under development at LLNL. It uses a state-of-the-art 250 MeV, X-band accelerator to generate an extremely bright beam of ▷

electrons at an effective repetition rate of 1 kHz, together with a high average power, picosecond laser to generate high fluxes of narrow-bandwidth mega-electron-volt photons for NRF (Gibson *et al.* 2010). A kilo-joule-class nanosecond laser end-station is proposed at the LCLS facility to generate matter of high energy-density that will then be probed by the highly directional X-rays from the FEL.

Laser cooling normally conjures up images of cooling atoms of low thermal energy. However, at a number of places, laser cooling has already been demonstrated on high-energy beams. For example, experiments at GSI, Darmstadt, have used laser cooling on C^{3+} ions at around 1.5 GeV, leading to an unprecedented momentum spread of 10^{-7}. Laser cooling has been proposed as a method for achieving beams of ultra-low emittance for future e^+e^- linear colliders (Telnov 2000).

There is no doubt that lasers will play an ever increasing role in accelerators, and vice versa.

● This work was supported by the US DoE grant number DE-FG02-92ER40727. The author thanks Andy Sessler for his input to this article.

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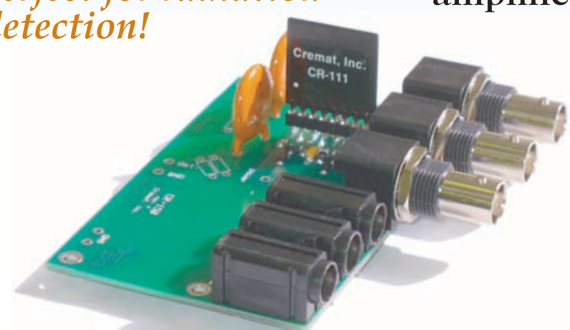
Résumé

Les lasers pour éclairer la science fondée sur les accélérateurs

Depuis leur invention, il y a 50 ans, les lasers jouent un rôle important dans la recherche menée auprès des accélérateurs de particules. Ainsi, la diffusion Compton entre des photons laser et un faisceau d'électrons de haute énergie a été rapidement utilisée pour produire des rayons gamma destiné à des recherches en physique nucléaire. Il est certain que l'apport des lasers va rester très important et se développer. Les lasers pourront à terme non seulement être utilisés pour le diagnostic de faisceau et servir de source de particules, mais aussi permettre d'accélérer des particules, en utilisant le champ de sillage créé par une impulsion laser intense.

Chan Joshi, *University of California Los Angeles.*



Making X-rays: bright times ahead for FELs

Free-electron lasers are now entering the hard X-ray spectral region and opening a new window on matter. Their development and future promise is intimately linked with the physics of particle beams, as Claudio Pellegrini explains.

The successful lasing at the Linac Coherent Light Source (LCLS), which makes use of SLAC's famous linac, is a landmark in the development of coherent electromagnetic radiation sources. It is the first hard X-ray free-electron laser (FEL), operating in the wavelength range 0.12–1.5 nm, with a respective pulse duration of 50 to several femtoseconds and the number of coherent photons per pulse ranging from 10^{13} to 10^{11} (Emma *et al.* 2010). Until recently the best hard X-ray source has been undulator radiation from an electron beam of a few giga-electron-volts in a specially designed storage ring. Now, the LCLS has set a new standard. Its peak X-ray brightness is higher than that of the best synchrotron radiation source by 10 orders of magnitude, as figure 1 shows. Its X-ray beam gives us, for the first time, the capability to explore matter with wavelengths and pulse durations as short as 0.1 nm and 1 fs – the atomic scales of length and time.

With these breakthrough characteristics the X-ray FEL provides a new window on dynamical processes at the atomic and molecular level. Imaging of non-crystalline matter at nanometre and subnanometre scales is also made possible by the coherence properties of the radiation. Taking an atomic-scale motion picture of a chemical process in a time of a few femtoseconds or less, and unravelling the structure and dynamics of complex molecular systems, such as proteins, are among the exciting experiments made possible by this novel source of X-rays. The LCLS – and the other hard X-ray FELs now being built at DESY in Germany and at Spring-8 in Japan – will open a new chapter in the biological and physical sciences, together with other hard X-ray FEL projects being developed in China, Korea and Switzerland.

The soft X-ray region, at wavelengths from a few nanometres to about 50 nm, has also seen a dramatic increase in performance with the equally successful operation of FLASH at DESY (p21). Another soft X-ray FEL, Fermi@Elettra in Trieste, will be completed by the beginning of 2011 and new soft X-ray FELs are being designed at the Lawrence Berkeley National Laboratory and at SLAC, as part of LCLS II, an addition to the existing LCLS.

Another important aspect of FELs has been the successful construction and operation at the Jefferson Laboratory of an FEL with high average power, up to 9–15 kW, at wavelengths ranging from about 1.6 to 6 μm (*CERN Courier* June 2005 p27). A distinctive characteristic of this FEL, critical for high average-power operation, is the use of a recirculating superconducting linac to recover the electron energy after the beam has amplified the FEL radiation (figure 2, p18). A similar approach to reach even higher average power is being used in an extension of the programme sponsored by the US Navy.

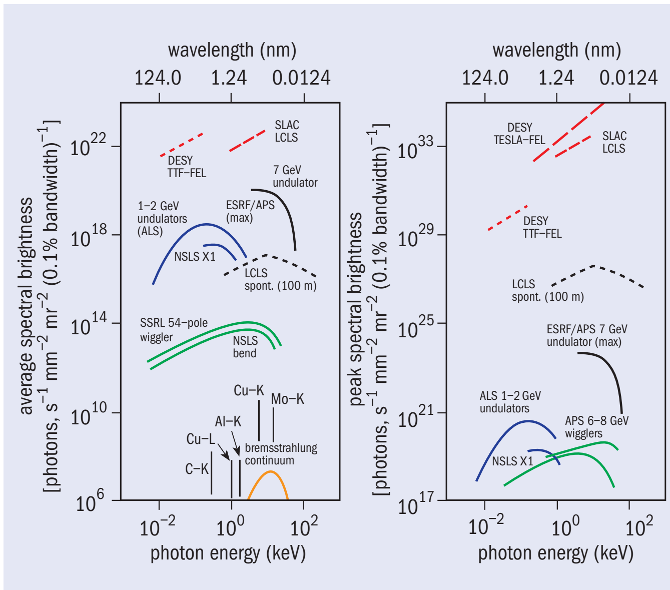


Fig. 1. The peak and average brightness of storage-ring based synchrotron radiation sources and of the X-ray FELs of the LCLS and DESY TELSA-FEL (now the European XFEL). The experimental results for LCLS and the DESY TTF-FEL, now called FLASH, reach or exceed the expected brightness (dashed lines) in these plots from the LCLS conceptual design report, SLAC-Report-593, 2002.

Soft and hard X-ray FELs represent the latest success in the development of FELs, which began a few decades ago. Many FEL oscillators have been in operation since the 1980s, at laboratories around the world, but mainly in the near- to far-infrared region. Scientists have used their unique properties of full tunability from the visible to the far-infrared and high peak power of tens to hundreds of megawatts to explore many areas of physical, chemical and biological sciences. ▷

FEL oscillators operating in the infrared, visible or near ultraviolet part of the electromagnetic spectrum can take advantage of the existence of high-reflectivity mirrors to use an optical cavity and so operate at small gain, as John Madey first proposed (Madey 1971). In this mode of operation the undulator magnet, where the electron beam emits the radiation, can be rather short, although many electron bunches are needed to amplify the radiation in small steps up to the maximum saturation value. For an oscillator system the radiation pulse is nearly Fourier-transform and diffraction limited.

In the X-ray spectral region, research is being done to develop the mirrors and other components, in particular a very high-frequency electron gun, needed for an X-ray oscillator (Kim *et al.* 2008). Mirrors in general have small reflectivity and an optical cavity is complicated and, until now, impractical. The main approach – used for the LCLS, FLASH and most other new X-ray FELs – is not to use an optical cavity, but to operate in the high-gain regime, reaching saturation in a single pass of an electron bunch through a long undulator. The system can start either by amplifying the spontaneous radiation in the undulator within the bandwidth of the FEL gain (a self-amplified spontaneous emission, or SASE, FEL) or by amplifying an external laser signal (a seeded FEL) (Bonifacio *et al.* 1984). A SASE FEL is nearly diffraction limited but is not transform limited, except when a very short electron bunch is used to generate and amplify the radiation (Reiche *et al.* 2008). Seeded FELs can be nearly diffraction and transform limited.

The physics of the high-gain regime is that of a collective instability. Under the effect of an input field, external or self-generated from noise, the longitudinal distribution of the electron beam evolves from a random initial state to one in which the electrons are captured in microbunches separated by one radiation wavelength. In a SASE FEL, such as the LCLS, the collective instability leads to self-organization of the electrons in the equivalent of a 1D relativistic electron crystal propagating through the undulator at a speed near that of light. Because the crystal planes are separated by one radiation wavelength, the electrons emit in phase. As the radiation power grows exponentially, the electron longitudinal distribution changes from disorder to order. The result is that, while in the case of spontaneous radiation the total intensity is proportional to the number of electrons, N_e, in the high-gain case the total intensity is proportional to a power of N_e between 4/3 and 2. The number of electrons in a bunch is typically of the order of 10^9–10^{10}, so the change in intensity can be quite large. The number of coherent photons emitted spontaneously by one electron going through an undulator is approximately given by the fine structure constant, or about 10^{-2}. When a high-gain FEL reaches saturation the number can be as large as 10^3–10^4.

New levels of sophistication

The electron beams for X-ray FELs require a new level of sophistication in their generation, handling and diagnostics. An FEL operating as an oscillator or a single-pass amplifier requires an electron beam with a large six-dimensional phase-space density, becoming larger as the wavelength decreases. However, the scaling is much more favourable than for other kinds of laser, a key reason for the success of FELs in the X-ray spectral region. In the high-gain regime, the six-dimensional density required for the electron beam scales only as the inverse of the square root of the radiation wavelength.

The electron beam for the LCLS is generated by a radio-frequency electron gun before passing down the last kilometre of the 3 km-long SLAC linac (figure 3). This beam has the highest six-dimensional phase-space density ever generated. The density is preserved through the process of beam acceleration and longitudinal compression, minimizing the effect of all of the collective instabilities that can dilute the density of a high-intensity beam. In turn, the high phase-space density is used to allow the self-organization of the beam – the FEL collective instability that leads to lasing. It is interesting to note that much of the beam physics needed to control the instabilities during acceleration and compression has evolved in the study of electron–positron linear colliders.

The main difference between the LCLS at SLAC, the European XFEL and the Spring-8 Compact SASE Source (SCSS), Japan, is in the choice of the linear accelerator to produce the electron beam – an existing S-band room-temperature linac for the LCLS, a superconducting linac for the XFEL and a C-band linac for the SCSS. While the peak intensity and power will be similar for the room-temperature and superconducting systems, a superconducting linac can produce more electrons and more X-rays per second. The wakefields

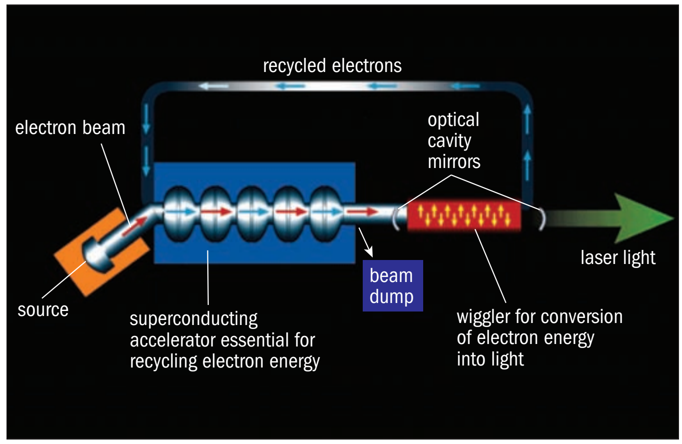


Fig. 2. Schematic of the high average-power infrared FEL at Jefferson Lab, with an energy recirculating linac. (Courtesy Jefferson Lab.)

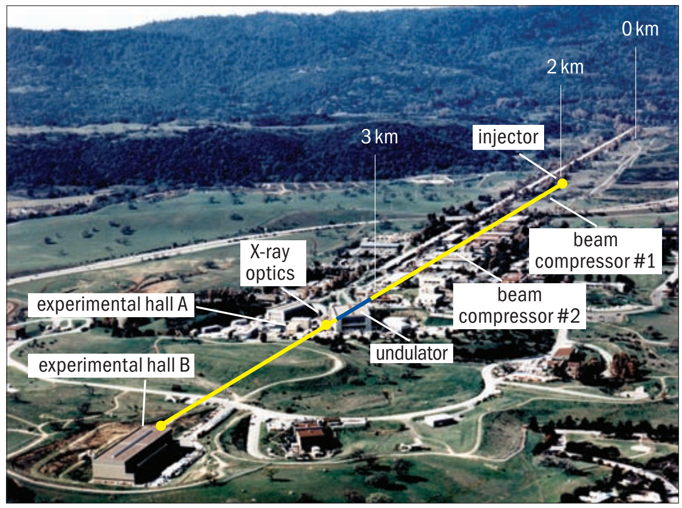


Fig. 3. The position of the LCLS superimposed on a view of the SLAC site, showing how the FEL uses the last 1 km of the 3 km-long SLAC linac together with new elements, including bunch-length compressors and the 130 m long undulator. (Courtesy SLAC.)

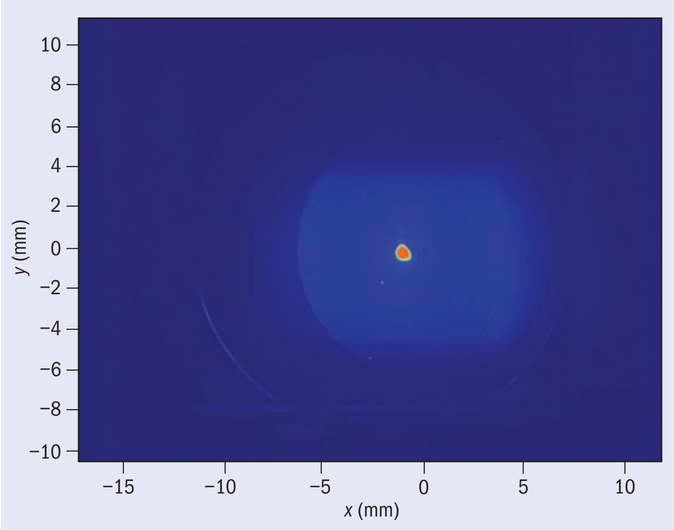
in the two types of linac are also different but in both cases will produce a beam with the required characteristics.

FELs, notwithstanding their larger size, cost and complexity, offer attractive advantages over atomic/molecular lasers: complete and continuous tunability, capability of high average power and a more favourable scaling for gain at short wavelengths. These characteristics, in particular the capability of lasing in the soft and hard X-ray regions, with control of the pulse length from a few to hundreds of femtoseconds, gigawatt peak power and full tunability, are making FELs attractive to an ever wider number of scientists. On the other hand, FELs are large and expensive, justifying their use only when their characteristics are fully utilized and when atomic and molecular lasers are not available to produce radiation with similar characteristics.

With the development of high repetition-rate electron guns and by making use of continuous-wave superconducting linacs, FELs can reach repetition rates of megahertz. Using the extraordinary brightness of electron beams produced by radio-frequency or other novel types of electron sources, together with high-frequency, high-gradient room-temperature linacs, it is possible to reduce the size and cost of the accelerators driving the FELs – a particularly important factor for hard and soft X-ray devices. Ongoing research into short-period undulators, as well as the novel laser/plasma accelerators being developed in many laboratories, might lead in the future to compact, table-top FELs, at a cost and size compatible with a university-scale laboratory.

Such developments in scale hold promise not only for the FELs. The six-dimensional density of the LCLS electron beam is so large that if the beam is further compressed in the transverse direction, it generates on its surface electric fields as high as many tera-electron-volts per metre (Rosenzweig *et al.* 2010). Because of these properties, the electron beam itself could be used for the exploration of atomic physics or for exciting plasma wakefields exceeding 1 TV/m, thus opening the way to a table-top tera-electron-volt accelerator for use in frontier high-energy physics. While the success of short-wavelength FELs owes much to the advances in the physics of particle beams stimulated by work on electron–positron linear colliders, it is now possible to look to a future in which the development of FELs will help to continue the exploration of matter at the subatomic level.

In summary, FELs are being developed to operate in an ever larger spectral region, from hard X-ray to terahertz frequencies, generating pulses with femtosecond to attosecond duration, or pulses with extremely small line width. Longitudinal coherence can be pushed to near the Fourier-transform limit using seeding and other techniques. Such high-power, diffraction- and transform-limited X-ray pulses, with a duration that can be controlled between attoseconds and hundreds of femtoseconds, will lead to new discoveries and new knowledge in many areas of science.



A laser pulse from the LCLS, recorded in SLAC's main control centre. The pinpoint in the middle is the laser light from the LCLS. It is surrounded by a larger halo of dimmer, non-coherent X-rays, resembling more the X-rays produced at a synchrotron light source. (Courtesy SLAC.)

Further reading

For a list of all of the existing FEL oscillators see http://sbfel3.ucsb.edu/www/fel_table.html.
R Bonifacio, C Pellegrini and L Narducci 1984 *Opt. Comm.* **50** 373.
P Emma *et al.* 2010 *Nature Photonics* **4** 641.
K-J Kim, Y Shvyd'ko and S Reiche 2008 *Phys. Rev. Lett.* **100** 244802.
J M J Madey 1971 *J Appl. Phys.* **42** 1906.
S Reiche *et al.* 2008 *Nucl. Instr. and Meth. A* **593** 45.
J B Rosenzweig *et al.* 2010 *Proc. IPAC'10* 4080.

Résumé

Un brillant avenir pour les lasers à électrons libres

Les lasers à électrons libres constituent une application importante des accélérateurs de particules, les faisceaux de particules étant utilisés pour produire des impulsions de lumière intenses et cohérentes. À présent, les sources de lumière cohérentes linéaires du SLAC sont entrées dans la région spectrale des rayons X durs pour la première fois, ouvrant de nouvelles perspectives sur les processus dynamiques au niveau atomique et moléculaire. Leur développement et leurs perspectives sont étroitements liés à la physique des faisceaux de particules. La recherche en cours pourrait conduire à des réductions de dimension, non seulement pour les lasers à électrons libres, mais aussi pour les accélérateurs.

Claudio Pellegrini, *University of California Los Angeles.*

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- Programmable PLL for clock synthesis
- Programmable digital I/Os
- Analog output with majority or linear sum
- FPGA fimware for Digital Pulse Processing
  - Zero Suppression
  - Smart Trigger for pulse detection
  - Trapezoidal Filters for energy calculation
  - Digital Charge Integration
  - Digital CFD for timing information
  - List Mode
  - Particle Identification
  - Possibility of customization
- Software Tools for Windows and Linux

								Form factor / Interfaces / Channels			
								VME	NIM	Desktop	PCI Express
Series	Full scale Range (V)	AMC FPGA[1]	Input Type	Max. Sampling Rate	Bandwidth (MHz)	Resolution (bits)	Memory (MS/ch)	VME64 Opt. link	USB2.0 Opt. link	USB2.0 Opt. link	PCI Express
724	± 1.125 /± 5	EP1C4/ EP1C20	Single Ended Differential	100 MS/s	40	14	0.5/4	8 ch	4 ch	4/2 ch	2 ch
720	± 1	EP1C4	Single Ended Differential	250 MS/s	125	12	1.25/10	8 ch	4 ch	4/2 ch	2 ch
721	± 0.5	EP1C4	Single Ended Differential	500 MS/s	250	8	2	8 ch	-	-	-
731	± 0.5	EP1C4	Single Ended Differential	0.5-1 GS/s	250/500	8	2-4	8-4 ch	-	-	2-1 ch
740	± 1/± 5	EP3C16	Single Ended	65 MS/s	30	12	0.19/1.5	64 ch	32 ch	32 ch	-
751	± 0.5	EP3C16	Single Ended Differential	1-2 GS/s	500	10	1.8-3.6/ 14.4-28.8	8-4 ch	4-2 ch	4-2 ch	-
761	± 0.5	EP3C16	Single Ended Differential	4 GS/s	Tdb	10	7.2/57.6	2 ch	1 ch	1 ch	-
742[2]	± 0.5	EP3C16	Single Ended	5 GS/s	Tbd	12	0.128	32+2 ch	16+1 ch	16+1 ch	-

(1) AMC: ADC & Memory controller FPGA. ALTERA models available: EP1C4: Cyclone (4.000 LEs), EP1C20: Cyclone (20.000 LEs), EP3C16: Cyclone III (16.000 LEs). (2) Switched capacitor.

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Small details Great differences

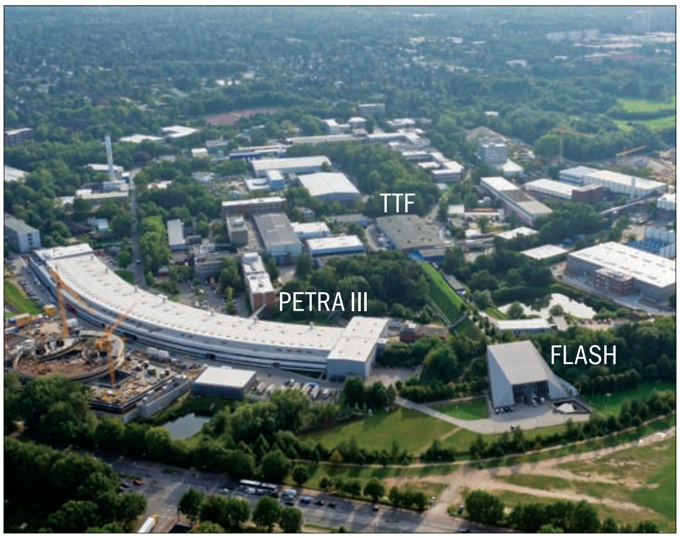
FLASH: the king of VUV and soft X-rays

DESY's experience with accelerators made it a natural home for one of the world's most brilliant radiation sources, where the intense laser pulses allow for fascinating research.

The FLASH free-electron laser at DESY is the first user facility to deliver, over the past five years, short and intense light pulses in the vacuum ultraviolet (VUV) and soft X-ray region. As such, it provides the photon-science community with unprecedented opportunities to explore new territory, ranging from physics via chemistry to biology.

FLASH was initially built as a test facility for the "TESLA Linear Collider with Integrated X-Ray Free-Electron Laser Facility". At the beginning of the 1990s, DESY initiated a vigorous R&D programme towards an e^+e^- linear collider. Because there were indications from the funding agencies in Germany that such a facility should be attractive not just to the particle-physics community, DESY and its international partners developed a conceptual design for a 500 GeV e^+e^- linear collider featuring an integrated X-ray laser facility – the TESLA project.

Based on the good experience with superconducting technology at the hadron–lepton collider HERA at DESY and the need for high luminosity at the linear collider, the challenge to realize the accelerator in superconducting RF technology was taken up by a large international effort, the TESLA collaboration. To achieve the ambitious goal of increasing the accelerating gradient while reducing the cost of the cryomodules, in each case by a factor of five, DESY built a test facility and decided to combine it with a free-electron laser (FEL) in the VUV spectral range.

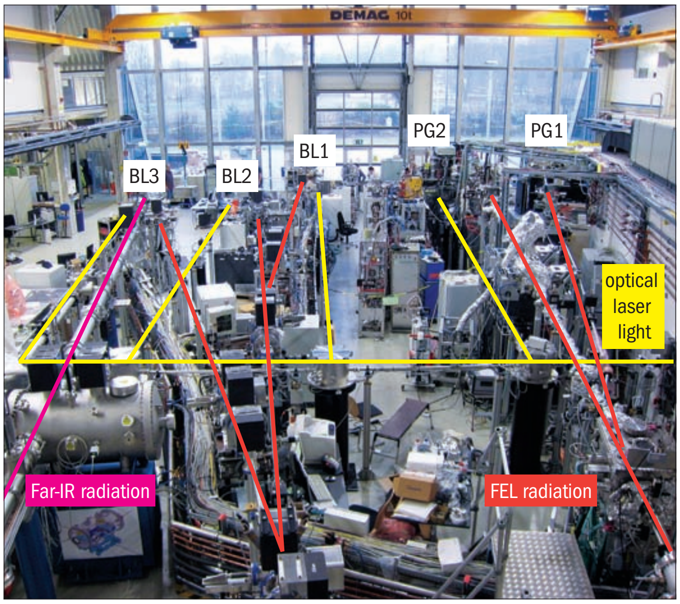


The FLASH facility at DESY in Hamburg. The TESLA Test Facility (TTF) was the starting configuration, to focus on the development and testing of the superconducting linac for the TESLA project, which combined a linear collider with an integrated X-ray FEL facility. From 2003 the TTF was expanded to an FEL user-facility for soft X-rays, which included a new tunnel and a new experimental hall (in the foreground) and is today known as FLASH. (Courtesy DESY.)

Pioneering with the TTF

With excellent results achieved at the TESLA Test Facility (TTF), in March 2001 the collaboration published the technical design report for the TESLA project. In February 2003, the German government decided that the X-ray FEL part of the proposal should be realized in Hamburg as a European project, with Germany paying half of the cost. Construction of the facility, named the European XFEL, started in January 2009 and the first electron beams are expected in 2014 (*CERN Courier* November 2010 p8). As for the TTF, it was expanded and converted to the soft X-ray FEL user facility FLASH, which has been serving the photon-science community at DESY since August 2005.

In its first stage of expansion, the approximately 100 m-long TTF consisted of a low-emittance laser-driven photocathode electron gun, a pre-accelerator, two superconducting accelerator modules, three sections of undulator structures (each 4.5 m long) and various electron- and photon-beam diagnostics. Lasing at saturation at a wavelength of 98 nm was achieved in September 2001, setting a world first and proving the feasibility of FELs using the principle of self-amplified spontaneous emission (SASE) in the VUV range (*CERN Courier* November 2001 p8). Subsequently, tunability between 80–120 nm was demonstrated, as well as a high degree of lateral coherence of the beam. The duration of the gigawatt radiation pulses was estimated to be between 30 and 100 fs, but a ▷



The FLASH experimental area. The FEL beam can be switched to five experimental stations (in the background close to the window) by moving plane mirrors. Similarly, a synchronized optical-laser beam can be transported in vacuum to each of the stations by switching plane mirrors, which are mounted in the four cylindrical vacuum vessels in the foreground. The optical laser is located in a hutch on the right, just outside the picture. (Courtesy DESY.)

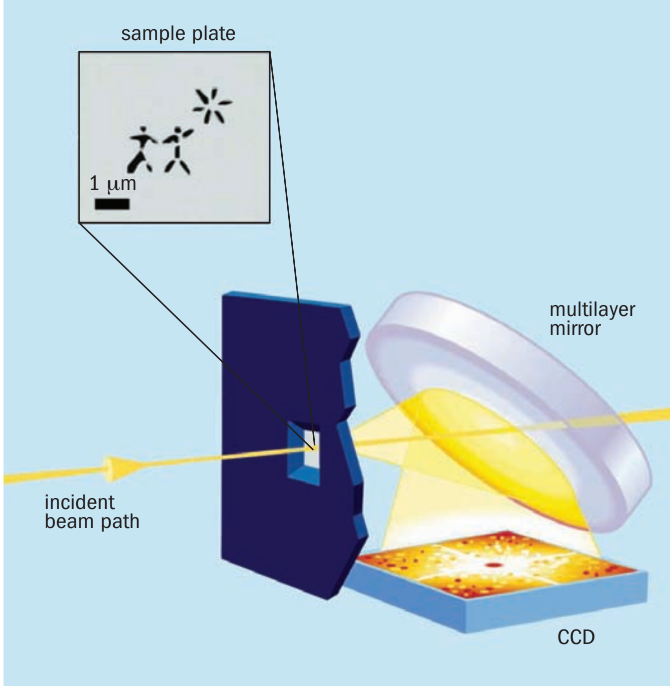


Fig. 1. The FLASH beam is incident from the left. It is focused on a 20 µm spot on the sample, which is a transmissive silicon-nitride membrane, 20 nm thick, with a picture milled through its entire thickness using a focused ion beam (this is enlarged in the inset where the scale bar indicates 1 µm). The direct beam passes through the sample window and exits the camera through a hole in a graded multilayer planar mirror. The mirror reflects only the diffracted light from the nanoscale object onto a CCD detector, which records a continuous diffraction pattern.

tool for the direct measurement of such ultrashort pulses was not available at the time. The peak brilliance of the FEL radiation was around 10^{29} photons/(s mrad^2 mm^2 0.1% bandwidth), i.e. about eight orders of magnitude higher than that available at the best synchrotron radiation storage rings.

Given the huge increase in brilliance from state-of-the-art third-generation synchrotron sources to FELs, it is crucial for all experiments performed at FELs to understand the interaction of the extremely intense, ultrashort X-ray pulses with matter on the atomic and molecular level. It was therefore natural to perform the first experiments at the TTF on atoms and clusters, the latter being on an intermediate scale between atoms and condensed matter.

Thomas Möller's group studied xenon clusters using 98 nm FEL radiation at power densities up to 7×10^{13} W cm^{-2} (Wabnitz *et al.* 2002). The most striking result revealed in the single-shot time-of-flight mass spectra is the big difference between the spectra measured for xenon atoms and for large clusters. Whereas only single-charged ions are observed after irradiation of isolated atoms, atomic ions with charges up to 8+ are observed when irradiating clusters, although the photon energy of 12.7 eV is only slightly higher than xenon's ionization potential of 12.1 eV. This effect is strongly dependent on the power density of the photon pulses. At a power density of 7×10^{13} W cm^{-2}, each atom in large clusters absorbs up to 400 eV, corresponding to 30 photons during about 100 fs, the duration of the FEL pulse. Möller's team suggests that the clusters are heated up very efficiently by the VUV radiation. Electrons are emitted after acquiring sufficient energy, before the clusters finally disintegrate completely by Coulomb explosion. These first results obtained at the TTF stimulated a broad discussion in the community and a wealth of further experimental and theoretical work.

The operation of the first stage of expansion of the TTF, where emphasis was on the development and test of the superconducting linac for the TESLA project, was concluded in December 2002. In the next phase it was extended to 260 m and converted to a soft X-ray FEL user facility, the commissioning of which started in autumn 2004. The first lasing at a wavelength of 32 nm – another world record – was observed in January 2005. After the official start of user operation in August 2005, the facility was renamed FLASH, for Free-Electron Laser in Hamburg.

The FLASH user facility

Compared with the first expansion stage, the most important changes were the increase in electron energy from about 240 MeV to 700 MeV by adding/replacing cryomodules, installing a second bunch-compressor, increasing the number of undulators from three to six and installing a collimator section to protect the undulator against bremsstrahlung and in case of electron-beam steering accidents. The electron bypass allowed accelerator studies without danger of damaging the undulators. Additionally, an experimental station was installed in the bypass inside the tunnel for damage and other studies using the electron beam. Later, a sixth cryomodule was added and the electron energy increased to around 1 GeV, which enabled lasing at 6.5 nm, first observed in October 2007. The photon beams are delivered to five experimental stations in the FLASH experiment hall.

In 2006/2007, the spectral range of FLASH was also extended

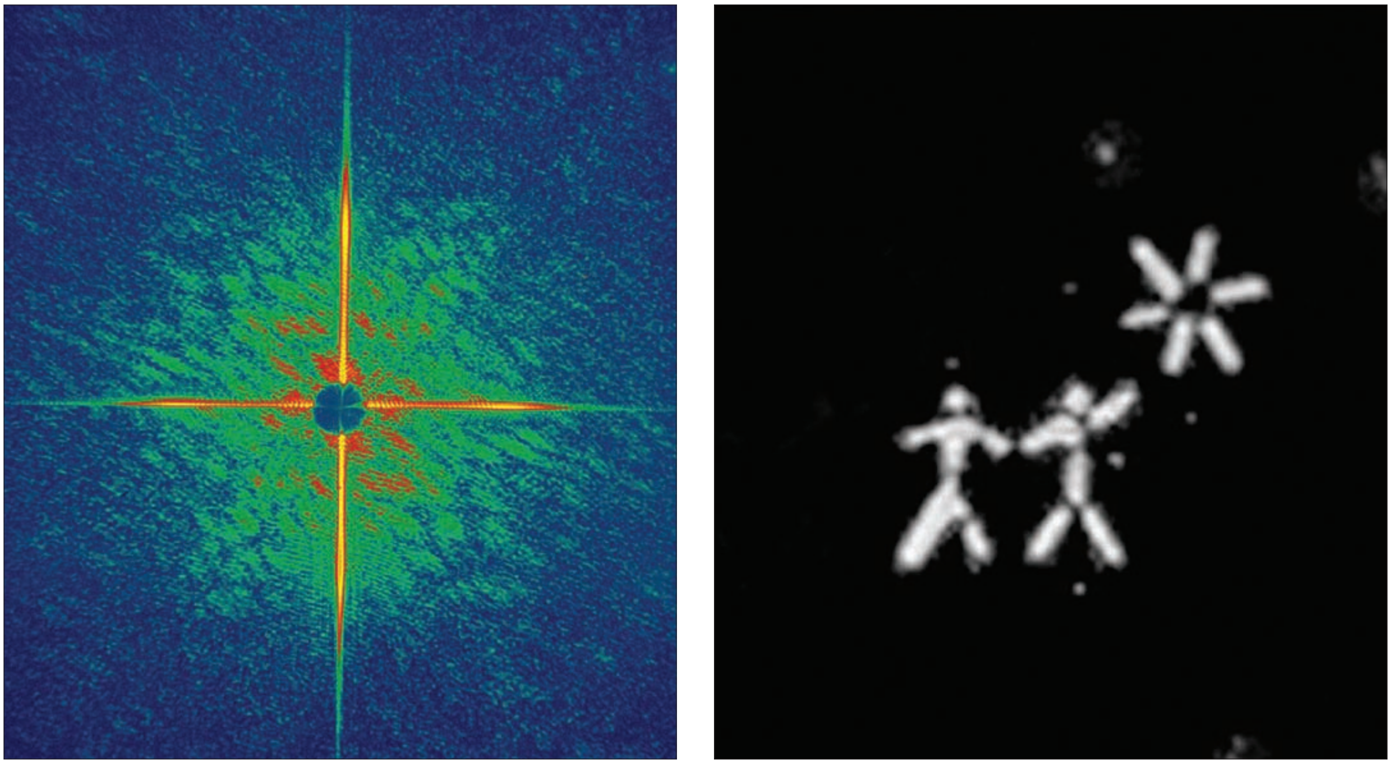


Fig. 2. Left: FLASH X-ray-coherent diffraction pattern recorded for a single $(4 \pm 2) \times 10^{13}$ W cm^{-2}, 25 ± 5 fs pulse. Right: the reconstructed target, which agrees well with the original image that is shown in figure 1. (Courtesy DESY.)

into the far-infrared (IR) by installing a long-period undulator and a new IR beamline. The device produces intense, truly synchronized IR pulses tunable in a broad spectral range, e.g. for two-colour pump-probe experiments. The first experiments at the IR beamline aimed to determine the spatial and temporal properties of individual pulses from FLASH and to unveil their temporal substructure.

During a major upgrade from September 2009 to February 2010, key components of FLASH were replaced or improved. A third-harmonic accelerator module that is now installed creates a much more homogeneous electron distribution in the bunch. Also, the linac was fitted with a seventh cryomodule, boosting the electron energy to 1.2 GeV and the wavelength to 4.45 nm (*CERN Courier* October 2010 p7). At the end of September 2010 the electron energy was pushed to 1.25 GeV and FLASH achieved lasing at 4.12 nm, thus reaching the "water window" in the fundamental harmonic, which opens up exciting new research opportunities for biological studies in particular.

In addition, an external "seeding" experiment called sFLASH has been installed. With sFLASH, the FEL process is seeded by pulses of 38 nm wavelength and 20 fs (FWHM) in duration, which are produced via high-harmonics generation. These pulses are overlaid with the FLASH electron bunches and amplified by being passed through 10 m of undulators. The photon beam is reflected out to an experimental hutch where time-resolved, pump-probe experiments will be pursued. The goal is to run the seeded FEL parasitically to normal FLASH operation by taking only one bunch out of each bunch train.

Recently, the decision was taken within the Helmholtz Association of German Research Centres to construct an extension of FLASH by adding a second undulator beamline and a second experimental hall with up to six experimental stations. The extension will have tunable gap undulators, use various seeding schemes and in a later stage provide polarized FEL radiation.

First experiments with FLASH

FLASH is the world's first FEL user facility in the VUV and soft X-ray spectral range, and many pioneering experiments in a large variety of fields have been performed to date. These include work on atoms, molecules and clusters; matter in extreme conditions, warm dense matter, radiation damage; single-shot, lensless imaging of cells and diffraction from nanoscale crystals; condensed matter spectroscopy and scattering; and photon-beam diagnostics. Today the FLASH website lists 126 publications in refereed journals.

One of the most attractive scientific drivers for X-ray FELs is the single-shot coherent imaging of nanoscale objects. Obtaining enough signal in a single-shot image requires about 10^{12} photons focused on a spot a few micrometres in diameter. However, such high-power densities destroy the sample and the question is whether an experiment can obtain the structural information before the target explodes. Model calculations show that to achieve this goal, the duration of the FEL pulses should be of the order of 10 fs. Henry Chapman and colleagues have performed the proof-of-principle experiment at FLASH using intense (4×10^{13} W cm^{-2}) pulses of around 25 fs duration that contain some 10^{12} photons at 32 nm wavelength (Chapman *et al.* 2006 and *CERN Courier* January/February 2007 p8). Figure 1 shows the experimental set-up. The graded multilayer mirror also acts as a filter for the 32 nm FEL radiation and thus improves the signal-to-noise ratio on the CCD detector. Figure 2 shows the single-shot scattering picture, together with the reconstructed image. The agreement with the transmission ▷

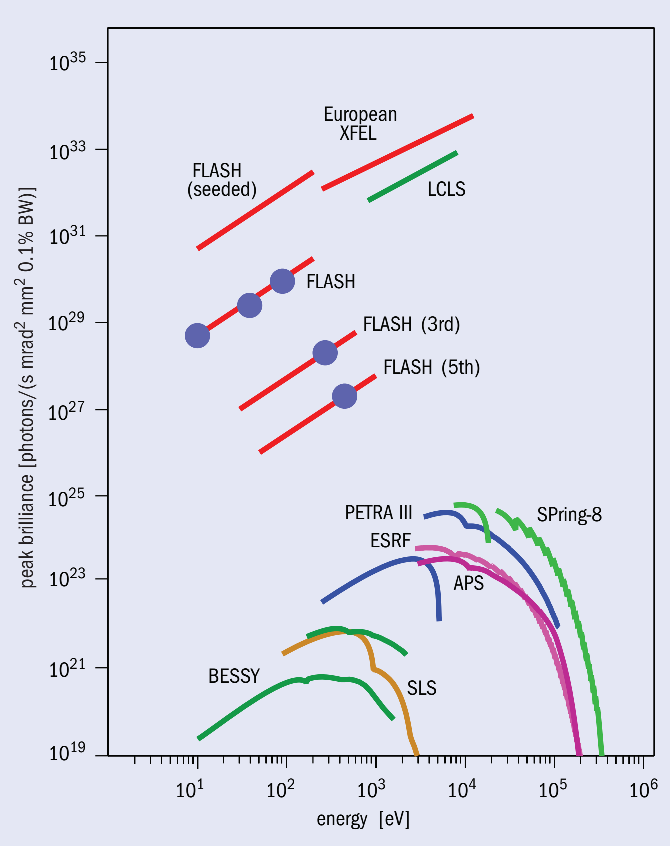


Fig. 3. The spectral peak brilliance calculated for FLASH, the Linac Coherent Light Source at SLAC and the future European XFEL facility, in comparison with the performance of third-generation synchrotron-radiation facilities. Spherical dots show the experimental performance of FLASH at the fundamental at 98 nm, 32 nm and 13.7 nm, and at third and fifth harmonics. The curve "FLASH (seeded)" refers to a proposal for the self-seeding of FLASH.

electron microscopy picture of the target shown in figure 1 is excellent. After transmission of the FLASH pulse, the target heats up to about 60 000 K on picosecond timescales. As a result, the scattering picture taken later with a second FLASH pulse corresponds essentially to a hole in the target.

Figure 3 shows the spectral peak brilliance calculated for FLASH, the Linac Coherent Light Source (LCLS) at SLAC (p17) and the future European XFEL, in comparison with the performance of third-generation synchrotron radiation facilities. Overall, the gain with FELs amounts to approximately nine orders of magnitude. It is interesting to note that the experimental results achieved at FLASH for the fundamental harmonic at 13.7 nm, as well as for the third and fifth harmonics, nicely reproduce the earlier theoretical predictions. The peak brilliance exceeds 10^{30} photons/(s mrad^2 mm^2 0.1% bandwidth) and for an average pulse energy of 40 μJ of the fundamental at 13.7 nm, a power of 0.25 ± 0.1 μJ was measured for the third (4.6 nm) and 10 ± 4 nJ for the fifth (2.75 nm) harmonic. By going to higher-order radiation, the number of photons per pulse is reduced by two to four orders of magnitude. These weaker beams allow, for example, the spectroscopic studies of condensed matter where the full beam intensity would create space charges that mask the ground-state properties of the system under investigation. For example, in combination with a synchronized optical laser, femtosecond time-resolved, core-level photoelectron spectroscopy experiments were performed at FLASH using 118.5 ± 0.2 eV photons from the third harmonic.

FELs such as FLASH have already opened up new vistas in time-resolved science. With the advent of X-ray lasers of even shorter wavelengths with shorter pulses and higher peak powers, such as the LCLS in the US, the SPring-8 XFEL in Japan and the European XFEL in Germany, the photon-science community will finally accomplish the transition from the study of static systems to time-resolved investigations of the dynamics of physical, chemical and biological processes on atomic length and timescales.

Further reading

This article is based on the paper "FLASH: from accelerator test facility to the first single-pass soft X-ray free-electron laser" (Jochen R Schneider 2010 *J. Phys. B: At. Mol. Opt. Phys.* **43** 194001, part of a special issue of *J. Phys. B* on the FLASH facility, see http://iopscience.iop.org/0953-4075/43/19).
For more about FLASH and the science there see https://hasylab.desy.de/e70/e220/index_eng.html.
H N Chapman *et al.* 2006 *Nature Phys.* **2** 839.
H Wabnitz *et al.* 2002 *Nature* **420** 482.

Résumé

FLASH : le roi des ultra-violets extrêmes et des rayons X mous

Le laboratoire DESY, avec son immense expérience en matière d'accélérateurs, est tout désigné pour abriter l'une des sources de rayonnement les plus brillantes au monde, dont les impulsions lasers intenses ouvrent de fascinantes perspectives de recherche. Le laser à électrons libres FLASH, en service depuis cinq ans, est la première installation ouverte à des utilisateurs produisant des impulsions de lumière courtes et intenses dans la région des ultra-violets extrêmes et des rayons X mous. C'est pourquoi il donne aux spécialistes des photons une occasion exceptionnelle d'explorer de nouveaux territoires allant de la physique à la biologie, en passant par la chimie.

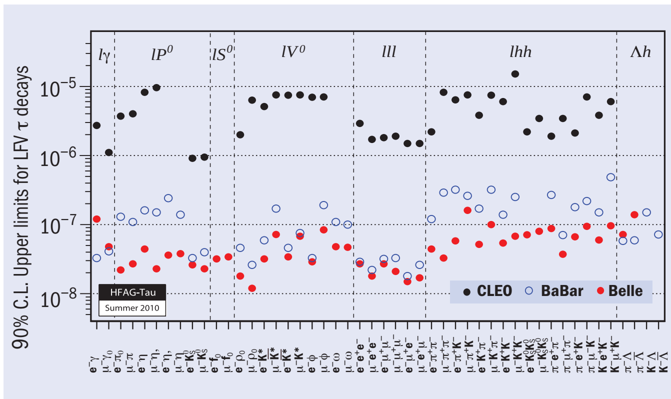
Jochen R Schneider, *DESY, Centre for Free-Electron Laser Science, and* **Ilka Flegel**, *DESY.*

The τ as a laboratory

Recent developments at experiments around the world suggest that the physics of the τ lepton has plenty to offer, as indeed the Tau 2010 workshop revealed.

In the 20 years since the first International Tau Workshop there has been remarkable progress, through work by experiments such as CLEO, BaBar, Belle, those at the Large Electron-Positron collider and the Tevatron, as well as several neutrino experiments, not to mention the work by theorists. The early efforts saw the acceptance of the τ as a standard lepton, a heavy copy of the electron and the muon. But the τ is massive enough to decay into hadrons as well as leptons, so its decays provide a rich laboratory for studies of a large range of physics topics. More recently, the τ has come into use as a tool to search for physics beyond the Standard Model, for example through lepton-flavour violation, charge-parity violation or the production of the τ in decays of possible new particles produced at the Tevatron and the LHC.

Tau 2010, the 11th International Workshop on Tau Lepton Physics, took place at the University of Manchester on 13–19 September. Some 80 delegates from 20 countries participated in a lively meeting that covered many topics in τ physics, including lepton-flavour violation, QCD, the muon-anomalous magnetic moment, τ neutrino physics, τ physics at the Tevatron and the LHC, as well as the outlook for the field. The workshop had a programme of more than 60 talks.



Upper limits at 90% confidence level for 48 lepton-flavour-violating τ decay modes. The data, compiled by the Heavy Flavour Averaging Group, clearly show the recent progress made at the B-factories.

New physics signatures

The τ lepton is important as a potential way to observe the violation of lepton flavour (LFV). Apostolos Pilaftsis of Manchester stressed in his introduction to the LFV session that any observation of it would be an unambiguous signature for physics beyond the Standard Model. While the τ cannot be produced in such copious quantities as the muon, a significant advantage comes from its relatively large mass. The session contained a number of theory contributions and updates on searches for LFV from BaBar and Belle. In his summary of work by the Heavy Flavour Averaging Group, Swagato Banerjee of Victoria showed the recent enormous progress that these B-factory experiments have made in this area (figure 1). Huge improvements on the limits for LFV in τ decays to many possible final states have been made in comparison with those from the CLEO experiment, which had previously been the leader in this area. Further progress is to be expected at Belle II and at the proposed SuperB facility. For LFV in muon decays, the MEG collaboration – searching for muon decays to an electron plus a photon – reported an analysis of its first data, with tantalizing evidence for some possible candidates. Plans for the proposed Mu2e, COMET and PRISM/Prime experiments were also outlined at the workshop.

New physics might also be found in the τ sector through unexpected violations of charge-parity (CPV). This well known phenomenon in K and B physics reflects subtle differences in nature between the behaviour of matter and antimatter. Both the BaBar and Belle experiments have new, complementary results from the decay $\tau \rightarrow \pi K^0 \nu$. A small amount of CPV is expected in this process from the properties of the K^0 system, but neither experiment has found any excess and each has set limits on the strength of any possible CP-violating contributions.

Measurements of the decays of $B \rightarrow \tau\nu$ were presented from both BaBar and Belle, each reporting an excess above the rate expected in the Standard Model. Such an excess could come from mediation of the decay by a virtual charged Higgs particle. However, the excess is small, and more data are needed to confirm its existence.

The mass of the τ is a fundamental parameter in the Standard Model of particle physics, and therefore important to measure in its own right. Also, a precise value for the mass is needed for testing lepton universality, by relating the lepton electroweak couplings and the muon and τ lifetimes. The most precise measurement to date, from the KEDR experiment at the VEPP-4M electron–positron collider in Novosibirsk, was reported at the workshop. The measurement comes from a threshold scan of the τ-pair cross-section using the technique of resonant depolarization to obtain a precise measurement of the beam energy. The new result for the τ mass is 1776.69 GeV with a precision of 0.013%. Plans are in place to improve this further at the BES III experiment in Beijing.

In his introductory talk for the QCD session, Antonio Pich of Valencia stressed the great value of the hadronic decays of the τ as a laboratory for studying QCD. With naive counting of possible fermionic final states, the τ would decay about 60% of the time via ▷

$q\bar{q}\nu$. The hadronic decays make up about 65% of the total – the small difference from 60% arising mainly from QCD effects. It turns out that the non-perturbative contribution to the QCD corrections is small despite the low mass of the τ.

The workshop saw some lively discussion of the various approaches to the calculation of the perturbative terms, with recent developments in contour-improved perturbation theory challenging the approaches based on fixed-order perturbation theory. Despite the theoretical uncertainties, the value of the strong coupling constant, α_s, obtained from the τ decay data remains the most precise experimental measurement and provides a low-energy measurement with a small uncertainty that helps to confirm the running of α_s expected in QCD.

Also in the quark sector, τ decays to strange final states allow for determination of the Cabibbo-Kobayashi-Maskawa matrix element V_{us}. The measurement reported from BaBar, based on the ratio of the rate for $\tau \rightarrow K\nu$ to that for $\tau \rightarrow \pi\nu$, agrees well with results from other methods, while a more inclusive method based on the use of all strange decay modes gives a lower result. This may be a result of missing decay modes and/or problems with the underlying theory. More progress is expected.

Muons and neutrinos

It has been known for some years that the measured value of the muon's anomalous magnetic moment, g-2, deviates from theory by a few standard deviations. The measurement, made by the E821 experiment at Brookhaven, remains one of the few hints for new physics. While electroweak theory and perturbative QCD allow for precise calculations of the principal contributions to the muon g-2, the non-perturbative QCD part from vacuum polarization effects (when a virtual photon fluctuates to a hadronic system) has to be based on experiment.

Andreas Hoeker of CERN introduced the session on this topic, showing how data on τ decays can be used to help with the calculations of the non-perturbative part via the use of conserved vector current to relate the isovector, spin-1 component of the τ decays to the hadronic systems produced in low-energy electron–positron annihilation. A great deal of recent experimental and theoretical progress was reported and while some discrepancies remain to be resolved, the difference between theory and experiment in the value of the muon's anomalous magnetic moment remains at over 3σ. The workshop heard about plans for improved measurements of g-2 at both Fermilab and the Japan Proton Accelerator Research Complex.

William Marciano from Brookhaven introduced the session on neutrino oscillations, noting that there is great potential for major discoveries and surprises in the present and future neutrino experiments. There were reports from the OPERA experiment, including strong evidence for ν_τ appearance, searches for atmospheric ν_τ in SuperKamiokande, the status of the T2K experiment, searches for astrophysical ν_τ in the IceCube detector and latest results from the MINOS experiment.

The session on τ physics at the Tevatron and the LHC produced a particularly lively discussion. Among the highlights were limits on Higgs production from the DØ experiment at the Tevatron, a reconstructed candidate for the decay $W \rightarrow \tau\nu$ in ATLAS and a signal of some 20 events in CMS for the decay $Z \rightarrow \tau\tau$ (figure 2). These were seen as encouraging indications of the thorough work done to develop suitable triggers and algorithms for τ selection at the hadron colliders. Clearly a rich harvest of τ-related physics is yet to come from the Tevatron and, in particular, from the LHC. The last session at the workshop pointed to exciting future potential for much new τ physics from Belle II and the proposed SuperB facility.

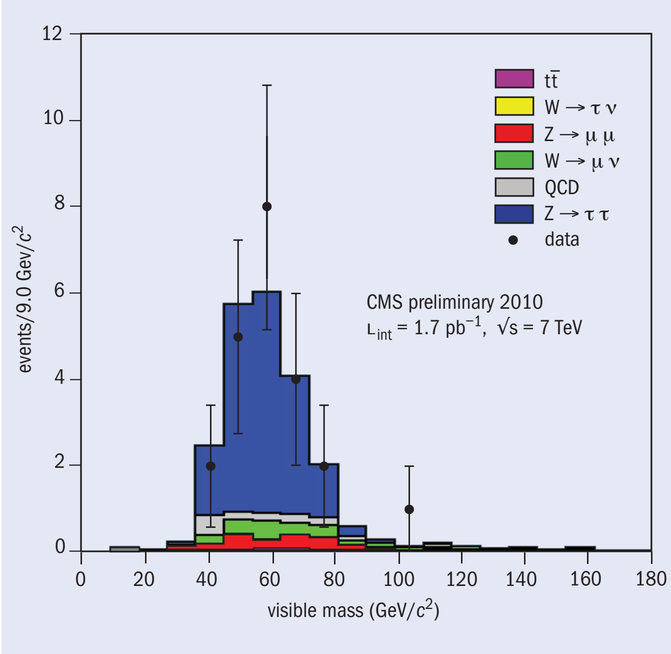


Fig. 2. The signal of some 20 events in CMS for the decay $Z \rightarrow \tau\tau$ at 7 TeV in the centre-of-mass.

Michel Davier of the Laboratoire de l'Accélérateur Linéaire, Orsay, gallantly gave up a visit to Chatsworth House and the Derbyshire Peak District, as well as dinner in the Manchester Museum of Science and Industry, to prepare what was an excellent summary talk of the workshop. The series of Tau Workshops, which Davier in fact initiated in 1990, will now continue into its third decade, with Tau 2012 scheduled to take place in Nagoya, late in 2012.

Further reading

Slides for all the talks are available at www.manchester.ac.uk/tau2010.

Résumé

Le τ, un laboratoire d'idées

Ces dernières années, le τ est devenu un outil de recherche pour la physique au-delà du Modèle standard, et ses perspectives sont prometteuses, comme l'a révélé le 11e atelier international sur la physique du lepton tau. Un atelier Tau 2010 a eu lieu à l'Université de Manchester en septembre. Quelque 80 délégués issus de 20 pays ont participé à cette réunion animée, où de nombreux sujets ont été abordés : violation de saveur du lepton, chromodynamique quantique, physique du neutrino du tau, physique du tau au Tevatron et au LHC, et perspectives de la discipline.

George Lafferty, *University of Manchester.*

Picture this: a photo walk

Five major labs invited amateurs inside to and click away for a new photo competition.

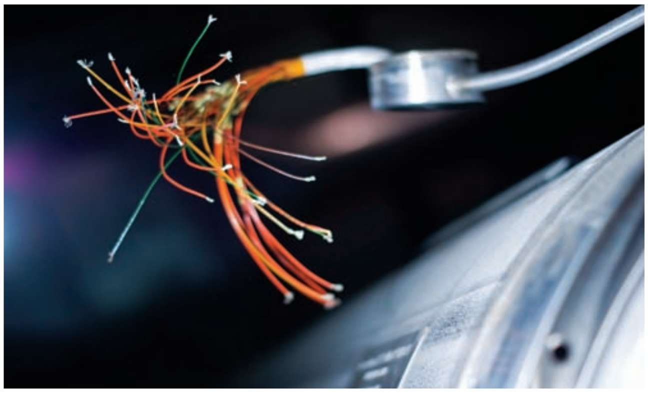
The first Global Particle Physics Photowalk brought more than 200 photographers together at five particle physics laboratories: CERN in Switzerland; DESY in Germany; Fermilab in the US; KEK in Japan; and TRIUMF in Canada. They glimpsed the state of the art in particle and nuclear physics via visits to accelerators, detectors, computing centres and isotope facilities; witnessed scientists at work in control rooms; and saw test facilities for future projects.

Following the event on 7 August, which was organized by the InterAction collaboration of particle-physics laboratories, participants submitted thousands of photographs for local and global competitions. Each laboratory selected the top photographs by jury or by staff vote; the local winners will be exhibited at the laboratories in 2011. The photographs shown here were the finalists for two global competitions: a "people's choice" online vote and a selection chosen by international jury.

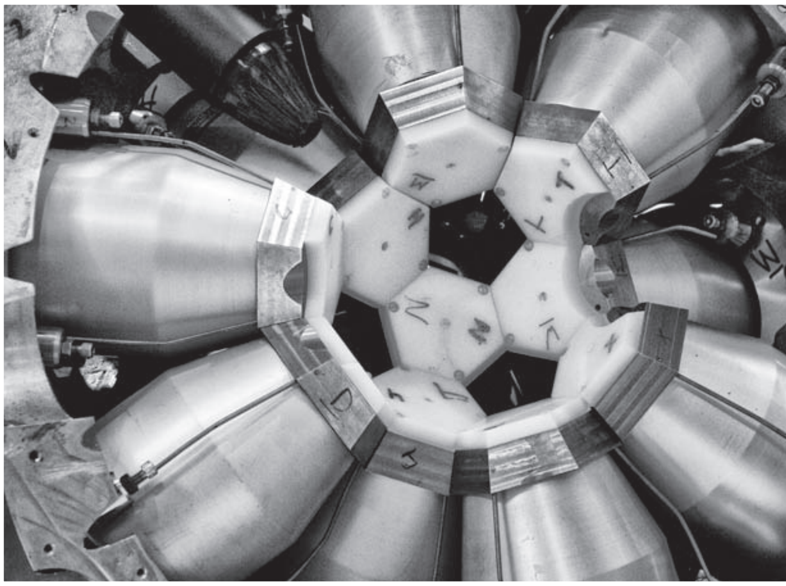
- See all images at www.flickr.com/photos/interactions_photos.

Résumé

Le 7 août, le premier concours Photowalk invitait des photographes à poser leur objectif sur cinq laboratoires de physiques des particules : CERN, DESY, Fermilab, KEK et TRIUMF. Des milliers de photographies ont ensuite été soumises dans le cadre de concours locaux. Les photographies présentées ici sont celles retenues pour la sélection en vue de deux prix décernés au niveau mondial : un prix du public, qui sera déterminé par un vote en ligne, et un prix attribué par un jury international.



Electric cable at CERN *Photographer: Christian Stephani. Laboratory: CERN. This image, placed third in CERN's local competition, shows an electric cable connected to a valve that is designed to avoid pressure damage in a magnet.*



8Pi experiment *Photographer: Mikey Enriquez. Laboratory: TRIUMF. This image of the 8 nuclear-physics experiment won third place in TRIUMF's local competition. The muted b white image of the 8Pi experiment's inner detectors captures the beauty and symmetry ☆1st International jury.*

KEK's Accelerator Test Facility *Photographer: Yuki Hayashi. Laboratory: KEK. This pho of researchers working through the weekend in the Accelerator Test Facility won first pl KEK's local jury and web competition.*

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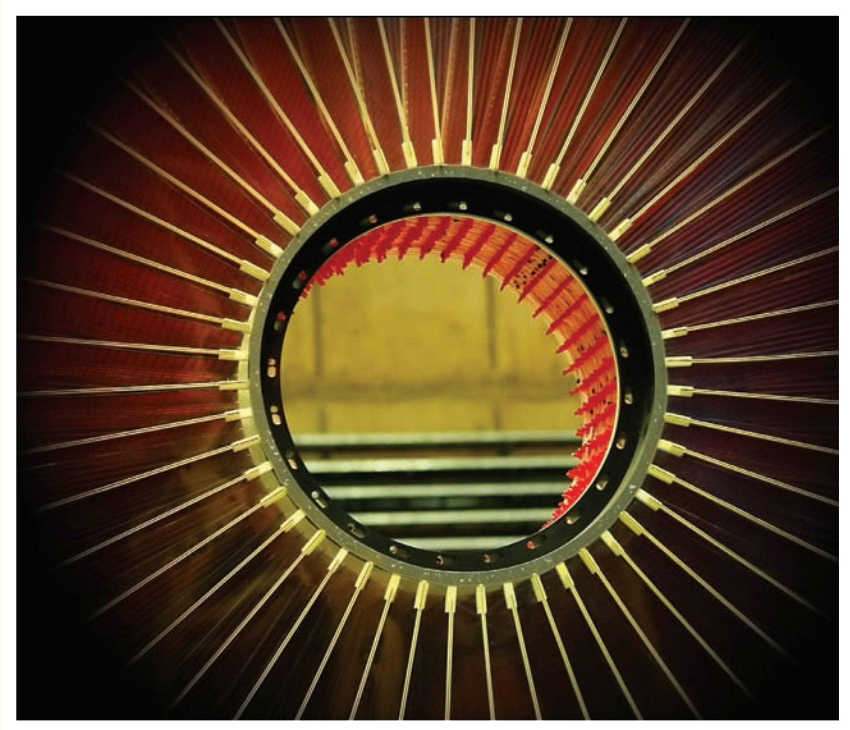

DESY wire chamber *Photographer: Hans-Peter Hildebrandt. Laboratory: DESY. This portrait of a wire chamber won first place in DESY's local competition. This highly symmetrical image of a particle detector fascinated every member of the local DESY jury immediately. The rays leading from the centre, ending in a dark rim, separating the chamber's sectors, and large hole in the middle that allows a blurry view of the things behind, evoke the image of a large eye. The local jury called it "technically flawless and simply fascinating". ☆1st People's choice, ☆2nd International jury.*

The accelerator operator *Photographer: Tony Reynes. Laboratory: Fermilab. This image of an accelerator operator on shift in Fermilab's Main Control Room captured third place in Fermilab's local competition. The Main Control Room is a mission control centre where scientists monitor the laboratory's accelerator complex 24 hours a day, seven days a week. ☆2nd People's choice*

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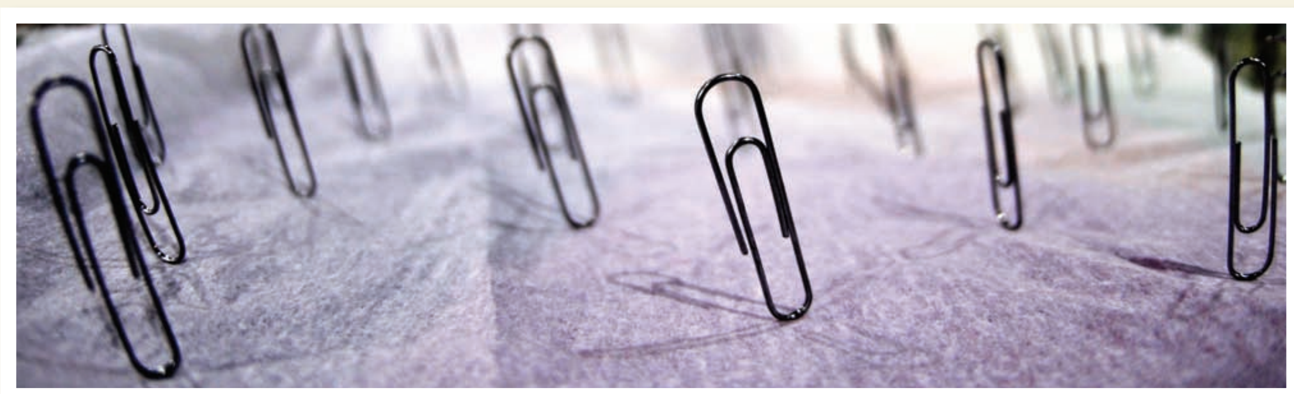
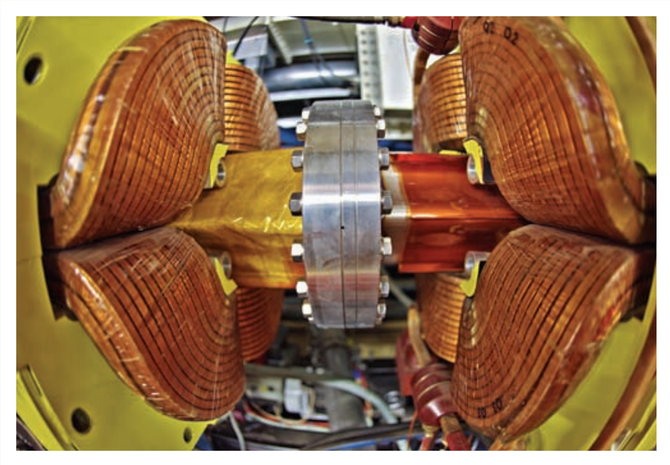


Paperclips atop the world's largest cyclotron *Photographer: Ali Lambert. Laboratory: TRIUMF. This image won first place in TRIUMF's local competition. Above the world's largest cyclotron at TRIUMF, paperclips experience some fringe magnetic field and stand upright, appearing to dance on the table's surface. High-school student Ali Lambert artfully captured this iconic experience of all visitors to TRIUMF.* ▷



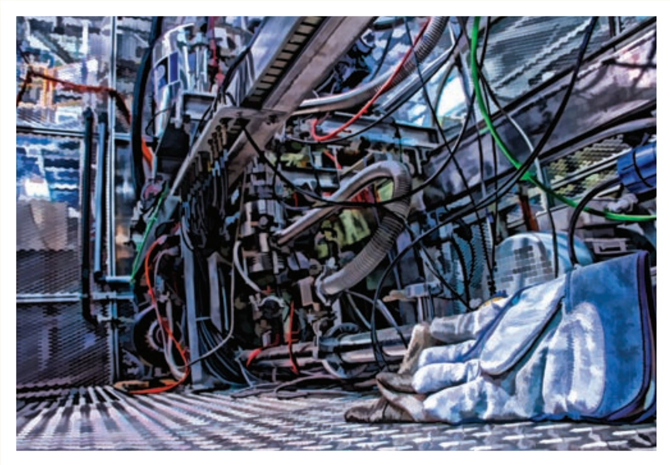
Quadrupole magnets *Photographer: Heiko Roemisch. Laboratory: DESY. This image of two quadrupole magnets won second place in DESY's local competition. The global jury noted the photo's sense of humour and the DESY jury's association with this image was "monstrous force". ☆3rd International jury.*

Test beamline for CERN's Linac4 project *Photographer: Diego Giol. Laboratory: CERN. This won first place in CERN's local competition. Linac4, when completed, will be CERN's newest linear accelerator and the first link in the proton acceleration chain for the LHC.*

Roof of the Meson Laboratory *Photographer: Charles Peterson. Laboratory: Fermilab. This view of the roof inside the Meson Laboratory, one of the buildings in Fermilab's fixed target experimental area, won second place in Fermilab's local competition. Each scalloped section of the roof was intentionally built to be approximately the same size as the tunnel inside the Tevatron.*

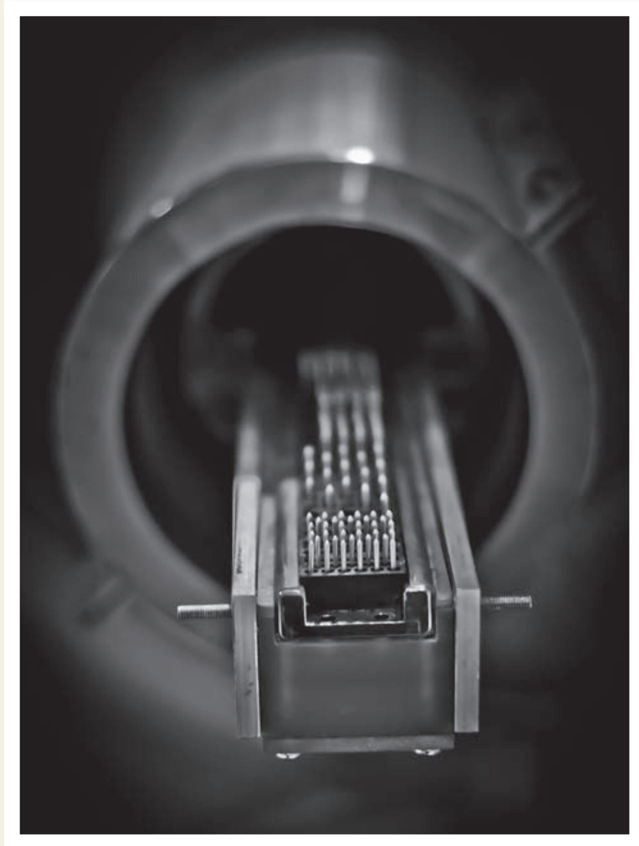
Broken Symmetry *Photographer: Ken Duszynski. Laboratory: Fermilab. This photograph of the Broken Symmetry sculpture at Fermilab's main entrance won first place in the laboratory's local competition. The arch straddles the road and appears perfectly symmetric when viewed directly from below, but has carefully calculated asymmetry from its other views.*

HERA accelerator tunnel *Photographer: Matthias Teschke. Laboratory: DESY. This classic image of HERA's accelerator tunnel captured third place in DESY's local competition. The photographer manages to guide the view around the corner and make the viewer curious about what's behind the bend. The image plays with light and shadow, conveys a sense of space, almost infinity, while at the same time incorporating technicality.*
☆3rd People's choice.



TRIUMF's material-science facility *Photographer: Mikey Enriquez. Laboratory: TRIUMF. This photograph of TRIUMF's material-science facility won second place in TRIUMF's local competition. The seemingly industrial and technical landscape of the facility is softened here by a digitally applied texturing technique.*

Belle Detector *Photographer: Keisuke Mori. Laboratory: KEK. This photograph of the Belle Detector won second place in KEK's local jury and web competition.*



Connection pipe for LHC magnet *Photographer: Diego Giol. Laboratory: CERN. This photograph of a connection pipe from a spare quadrupole magnet for the LHC at CERN won second place in the laboratory's local competition.*

KEK collage *Photographer: Akira Ominato. Laboratory: KEK. This collage of the KEK particle physics laboratory in Tsukuba, Japan, won second place in KEK's local competition.*

Georges Charpak – a true man of science

In a tribute to his long-time friend and colleague, **Ioannis Giomataris** recalls the revolutionary developments in particle detectors that Georges Charpak instigated and looks at some of the other aspects of a long and active enthusiasm for science and society.

Georges Charpak, who died on 29 September, worked at CERN for most of his scientific career (*CERN Courier* November 2010 p6). It was there that he invented and developed the multiwire proportional chamber (MWPC), which led not only to a host of related detector techniques and applications, but also to the ultimate recognition of his contributions – the award of the Nobel Prize in Physics in 1992.

Born in eastern Poland, Georges moved to Paris with his family in 1932 when he was seven. As a teenager he became active in the French resistance to fight against Nazi occupiers and was imprisoned by the French government in 1943, before being transferred to the Nazi concentration camp at Dachau in 1944. He survived because the guards did not realize that their political prisoner was Jewish. After the war he became a French citizen and in 1954 he received his doctorate in nuclear physics from the Collège de France in Paris, where he studied in the laboratory of Nobel laureate Frédéric Joliot-Curie. He devoted his early career to nuclear physics before making the transition to high-energy particle physics.

Members of the g-2 team at CERN in 1961. From the left: F J M Farley, A Zichichi, G Bernadini, T Muller, H Sens and G Charpak.

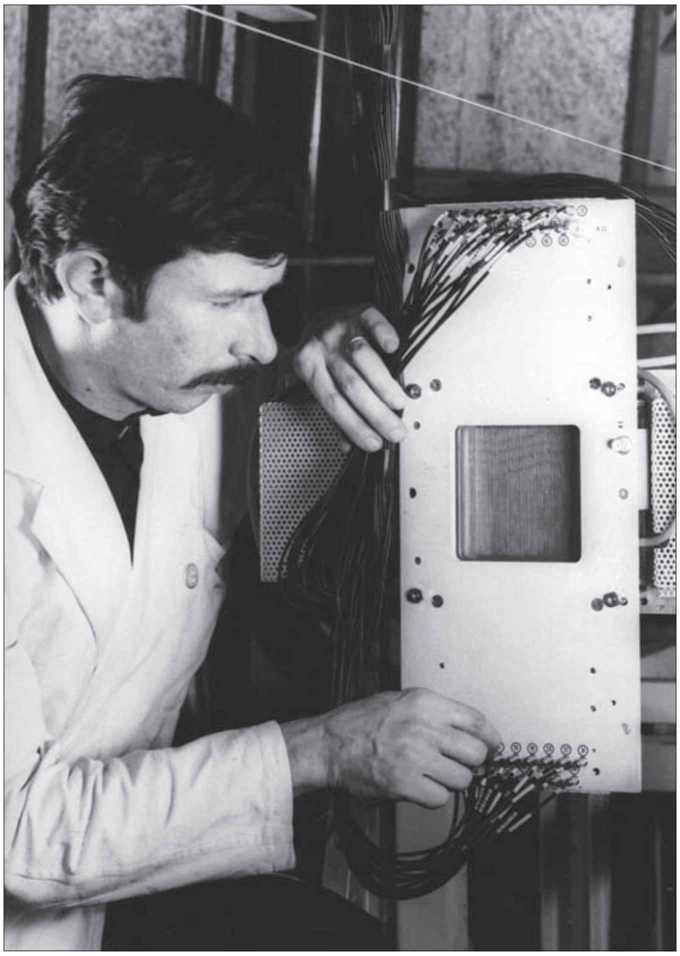
Pioneering times

Georges arrived at CERN in 1959, his first contributions being to the team that in 1961 precisely measured the anomalous magnetic-moment of the muon, predicted by QED (*CERN Courier* December 2005 p12). Testing this prediction to high accuracy is of paramount importance in particle physics because a small deviation from the theoretical value would imply new physics beyond the Standard Model. The pioneering experiment at CERN inspired many physicists in a line of research that continues to this day.

Only a few years later, in 1967–1968, he developed the MWPC, a gas-filled box with a large number of parallel detector wires, each connected to individual amplifiers. Unlike earlier detectors – such as the bubble chamber, which records a few photographs per second – the multiwire chamber could record up to a million tracks a second when linked to a computer. This new technology came at just the right moment as the computer era began to blossom and proper data-acquisition electronics were under intensive development.

With the new detector, particle physics entered a new era. The speed and precision of the multiwire chamber and its offspring – the drift chamber and the time-projection chamber – revolutionized the field. Particle physicists must often sort through many millions of tracks to find one or two examples of the particles they seek, so they need fast detectors. The invention of the MWPC opened the way to operate experiments at much higher particle-collision rates and to test theories predicting the production of rare events and new massive particles. The discoveries of the W and Z bosons at CERN, the charm quark at SLAC and Brookhaven and the top quark at Fermilab would not have been possible without this type of detector, and current research in high-energy physics continues to depend on these devices.

It was an experimental technique that many others had attempted without much success, but the previous experience Georges had ▷



Roger Bouclier working on one of the first MWPCs, which was tested in a beam-line at the Proton Synchrotron in 1968.

Left to right: Georges Charpak, Fabio Sauli and Claude Santiard testing a large MWPC at CERN in 1970.

with similar detectors was a key to his achievement. Working with a cylindrical counter in the Collège de France in 1948, he had realized that signals were produced not by the drifting electrons released by the passage of an ionizing particle but rather by the movement of positive ions, which induce pulses of opposite polarity on the anode-sense wire. The MWPC amplifies the few ionization electrons through electron multiplication near the anode wires. The resulting avalanche produces a signal that can be timed, leading to a variety of high-precision spatial measurement systems. As Georges and his collaborators discovered, the pulses induced in orthogonal cathode strips in a MWPC permit a bi-dimensional read-out. Moreover, determination of the charge centroid provides a better accuracy along the cathode wires (better than 100 μm) than in the other direction, where the accuracy is limited by the spacing of the anode wires. This type of read-out has been used by many experiments and is still in use today at the LHC.

The pitch of the wires limits spatial resolution in the MWPC and the coverage of large areas requires many wires and, therefore, many channels of amplification and read-out. However, Georges and his co-workers found that delayed signals were seen in the MWPC and that the measurement of the time of these signals – the drift time – could provide high-accuracy spatial information. This forms the basis of the operation of the drift chamber, where the wires are much more widely spaced. Drift chambers have been developed by groups worldwide and are used in many experiments because of their economical read-out, high accuracy and the possibility to build detectors with large areas.

The combination of drift-time information with charge-centroid read-out offered the possibility of 3D read-out from a single chamber and in 1974 David Nygren at Berkeley proposed a new evolution of the drift chamber, the time-projection chamber (*CERN Courier* January/February 2004 p40). This has since been widely used by many experiments, in particular ALEPH and DELPHI at CERN's Large Electron–Positron collider and now ALICE at the LHC.

In 1970 Fabio Sauli joined the group at CERN and played an important role in the subsequent developments of the multiwire chamber and the drift chamber. Among these was another promising concept, the multistep avalanche chamber. This was developed in the period 1979–1989 with the aim of reaching even higher counting rates. The basic idea was to split the amplification into two stages and overcome space-charge effects that otherwise counteracted the gain. Here, other distinguished physicists participated in the experimental effort, including Amos Breskin, Stan Majewski, Wotjek Dominic and Vladimir Peskov.

These detectors were subsequently developed further and adapted for detecting UV light to tackle new applications, ranging from fundamental research to medicine, biology and industry. One approach is to use a multistep parallel-plate avalanche chamber coupled to an image intensifier and a CCD to read the UV light emitted during the avalanche. In comparison with photographic emulsions, there is a significant gain in time for data acquisition, with the added advantages of linearity, wider dynamic range in the intensity measurement and a greatly improved signal-to-noise ratio. In collaboration with Tom Ypsilantis and his group, a particular effort was devoted to improving the ring-imaging Cherenkov (RICH) counter, which is used to identify elementary particles. From these investigations, new solid and gas UV photocathodes have been invented and developed.

Georges spent time and effort to push the application of these detectors in medical radiology, where the trend is for digital read-out to replace photographic film so as to improve sensitivity and spatial resolution. The multistep avalanche chambers found impor-

A typical banquet at Georges's laboratory with many colleagues around a table with wine, sausages and cheese he used to bring back from Corsica. From left to right some of his close collaborators: Leszek Ropelewski, D Anderson, Stan Majewski, Anna Peisert, Amos Breskin, Roger Bouclier, Martin Suffert and Vladimir Peskov.

Georges, left, at his house in Cargèse with Alvaro De Rújula (waving) and Ioannis Giomataris (right). (Photos this page courtesy I Giomataris.)

tant applications in β-radiography, which is employed in medical and biological investigations to form "images" of human or animal tissues labelled with β-emitting radionuclides. In 1989 Georges founded a new company, Biospace Instruments, aimed at using this technology for biomedical applications as well as a high-pressure xenon multiwire chamber for low-dose radiography.

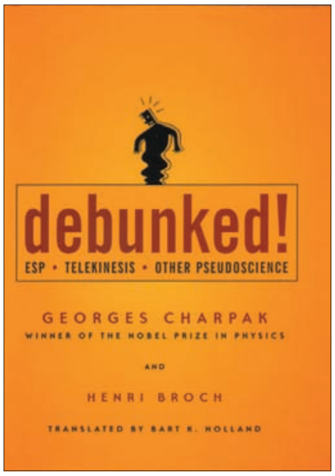
In the 1980s Georges and I began a close collaboration at CERN, developing new detector concepts adapted to solve specific problems in particle physics, including a high-energy gamma telescope with good energy resolution. In 1990 we began working with Leon Lederman on a new device – the "optical trigger" – which was to select particles containing the b quark in real time in high-intensity proton collisions. These particles fly a short distance before decaying and this serves to differentiate the decay products from other particles produced in the target. In a suitably positioned, thin crystal cell, internal reflection enhances the Cherenkov light produced by the decay products – while that from other relativistic particles passes straight through. This provides a way to tag the b-quark particles and enrich the collected sample with good events.

In 1991 we proposed the Hadron Blind Detector, which was then developed by an international collaboration. In this concept, most of the particles produced in proton collisions, which are hadrons, are not seen by the detector, while electrons and high-momentum muons are reconstructed efficiently. This selection criterion filters out unwanted events. The concept was demonstrated in October 1992 at CERN, just before the announcement of the Nobel prize, at a time when Georges and other team members were conducting experiments at night. In these investigations we used a gaseous parallel-plate detector and while optimizing it we demonstrated experimentally the advantage of a narrow amplification gap. This triggered the idea of building a device with an even narrower amplification gap and from that a new detector concept was born: the Micro-Mesh gaseous structure or MicroMegas, which our group at Saclay has developed since 1995. Georges used to say that this detector and some other new concepts belonging to the family of micropattern gaseous detectors (MPGDs) will revolutionize nuclear and particle physics just as his detector did.

Georges spent many weekends and summer holidays at his house in Cargèse, a village established by Greeks at the end of the 18th century in Corsica. His house was located two steps from the Institut d'Etudes Scientifiques de Cargèse. Developed by the physicist Maurice Lévy in the 1960s, the institute became an important summer school for theoretical physics, gathering together some distinguished physicists and many of those involved in the Standard Model, which was under intense development at that time. Georges used to join these lectures during summer and always welcomed the participants at his house nearby for a sip of wine. He invited many physicists to his house to discuss new ideas in physics as well as many other subjects. Among these visitors was Alvaro De Rújula, who with Georges, Sheldon Glashow and Robert Wilson proposed the use of neutrinos produced by a multi-tera-electron-volt proton synchrotron as a tool for geological research: at these energies, the neutrinos are suitable for "tomography" of the Earth because they have a range comparable to its diameter.

A concern for people

Given his experiences during the Second World War as a political prisoner it is perhaps not surprising that later in life Georges became a highly motivated humanitarian campaigner. In particular, he was a founder member of the Yuri Orlov committee, the human-rights group that was set up by a group of accelerator and particle physicists at CERN in 1980. Orlov, a Soviet physicist who had been imprisoned for his support of human rights, soon became a *cause célèbre* in the western scientific world. Shortly afterwards the committee broadened its scope to support Anatoly Shcharansky and Andrei Sakharov – also in the Soviet Union – and many individuals elsewhere from the worlds of science, mathematics and technology who, for political or ideological reasons, were being persecuted or imprisoned by authoritarian régimes of differing political colours. One of Georges' many public actions in this context was at the press conference organized by the Yuri Orlov committee at the United Nations in Geneva in October 1980. Already an eminent figure in science at that time, and well respected for his complete freedom from ideological bias, he was able to contribute much to the influence of this and similar events. The combined efforts of such groups and individual activists eventually bore fruit in the form of favourable outcomes ▷



Georges was keen to share his enthusiasm for science, with books for the general public (left) and his project for schools La Main à la Pâte.

Left to right: Philippe Delmas Georges and Ioannis Giomataris looking at signals from a novel spherical detector (visible on the right) during a recent visit to Saclay. (Courtesy I Giomataris.)

in these three particular cases as well as in others worldwide.

In the mid 1990s Georges returned to Paris and a new life with highly diversified activities began for him. Keen to popularize science, he became widely known to the general public through several books that made physics accessible to as wide an audience as possible. Together with Richard Garwin he wrote *Megawatts and Megatons: A Turning Point in the Nuclear Age* in which they evaluate the benefits of nuclear energy and show how it can provide an assured, economically feasible and environmentally responsible supply of energy that avoids the hazards of weapon proliferation. They make a strong statement in favour of arms control and outline specific strategies for achieving this goal worldwide. In 2004, with Henri Broch, he wrote *Devenez Sorciers, Devenez Savants*, later translated into English, which derided pseudoscience, astrology and other misconceptions (*CERN Courier* March 2005 p48).

Education was also of great importance to Georges. He created La Main à la Pâte, an association to introduce hands-on science education in primary schools in France, an idea that had been first initiated in Chicago by his friend Leon Lederman. From 1996, with the support of the French Academy of Sciences and some of his colleagues, Georges propagated the new idea of teaching science in primary schools. The prestigious Ecole Nationale Superieur des Mines (ENSM) at Saint Etienne created a laboratory in his honour and established the "puRkwa Prize" to reward pedagogical initiatives that help children to acquire the scientific spirit.

Since returning to Paris, part of his scientific activity was connected to the work in my laboratory at Saclay, which he used to visit several times a year. We kept an old oscilloscope especially for him, as he disliked the new digital devices. He co-signed many publications related to our research. One example in 1996 was the new development by CERN and Saclay of a promising way of fabricating the MicroMegas detector, referred to as "bulk" technology, which is now widely used by many experiments and allows the fabrication of large and cost-effective detectors (*CERN Courier* December 2009 p23). Every two years, since 2002, we have organized a conference in Paris on Large TPCs for Low-Energy Detection. The purpose of the meeting is an extensive discussion of present and future projects using a large time-projection chamber (TPC) for low-energy and low-background detection of rare events (low-energy neutrinos, double beta decay, dark matter, solar axions etc.). Georges actively participated in the conference, giving introductory talks that pointed out links between science, education and technology.

Georges was active until the end. He recently published, together with François Vannucci, a new book, which can be considered as his testament, celebrating the physics that he loved. I met him at his home a day before his death and was impressed by the clarity of his mind. He was excited to hear of the new progress in physics and in detector developments conducted by my group. He was himself thinking about a novel radon detector, believing that its industrial success would allow him "to buy new shoes", a phrase he used the day of the award of the Nobel prize 18 years ago.

Georges liked music and especially classic songs. He often invited musicians to his home in Paris and enjoyed the company of artists from the opera and friends at a typical Parisian bistro where they would sing around a piano player. For his last resting place, as he had wished, several musicians played classical music during the ceremony. I will keep in my memory a kind man, a humanist, who was enthusiastic, optimistic and always open to new ideas. I have the feeling, as many other colleagues do, that our second "father" has passed away.

● I would like to thank Fabio Sauli, John Eades and Peter Schmid for their help in the preparation of this tribute.

Résumé

Georges Charpak – un grand homme de science

Georges Charpak, qui s'est éteint le 29 septembre, a mené l'essentiel de sa carrière au CERN. C'est au CERN qu'il a inventé et développé la chambre proportionnelle multifils. Ce détecteur et ses descendants ont ouvert une nouvelle ère dans les expériences de physique des particules et lui ont valu le prix Nobel de physique en 1992. Rendant hommage à son ami et collègue, Ioannis Giomataris rappelle quelques-unes des évolutions marquantes du domaine des détecteurs dont Georges Charpak fut l'initiateur et l'inspirateur, et évoque également le travail important qu'il a accompli en matière d'enseignement des sciences.

Ioannis Giomataris, *CEA-Saclay.*

AWARDS



A selection of 2011 APS prize-winners: (left to right) Yaroslav Derbenev, Gerald Gabrielse and Ian Hinchliffe. (Courtesy Jefferson Lab, Harvard and ATLAS.)

APS announces winners for 2011

The American Physical Society (APS) has announced its awards for 2011, including some major prizes in particle physics and related fields.

With physics at the LHC having started during 2010, it is appropriate that the award that recognizes and encourages outstanding achievement in particle theory – the J J Sakurai Prize for Theoretical Particle Physics for 2011– goes to Ian Hinchliffe of the Lawrence Berkeley National Laboratory (LBNL) and Kenneth Lane of Boston University, together with Estia Eichten and Chris Quigg of Fermilab. The four receive the prize for their "work, separately and collectively, to chart a course of the exploration of TeV-scale physics using multi-TeV hadron colliders". In 1983–1984, Eichten, Hinchliffe, Lane and Quigg wrote "Supercollider physics", a paper that explored the reach of high-energy hadron colliders for the physics of the Standard Model and for potential new physics associated with the electroweak breaking scale of 1 TeV. They have all since worked on various ideas that will be tested at the LHC. Hinchliffe served as ATLAS physics co-ordinator in 2006–2007 and is currently head of LBNL's ATLAS group.

Theoretical physics is also the focus this year of the Hans A Bethe Prize for outstanding work in theory, experiment or observation in the areas of astrophysics, nuclear physics, nuclear astrophysics, or closely related fields. Christopher J Pethick of the Nordic Institute for Theoretical Physics receives the 2011 award "for fundamental contributions to the understanding of nuclear matter at very high densities, the structure of neutron stars, their cooling, and the related neutrino processes and astrophysical phenomena".

The Lars Onsager Prize is another award for theoretical physics, in this case to recognize outstanding research in theoretical statistical physics, including the quantum fluids. The 2011 award goes to Alexander A Belavin of the L D Landau Institute for Theoretical Physics, Alexander B Zamolodchikov of Rutgers University and Alexander M Polyakov of Princeton University for their "outstanding contributions to theoretical physics, and especially for the remarkable ideas that they introduced concerning conformal field theory and soluble models of statistical mechanics in two dimensions".

Experimental physics is rewarded by a number of APS prizes. The W K H Panofsky Prize in Experimental Particle Physics is to recognize and encourage outstanding achievements in the field. The award for 2011 goes to A J Stewart Smith of Princeton University, Laurence Littenberg of Brookhaven National Laboratory and Douglas Bryman of the University of British Columbia. They receive the prize for "leadership in the measurement of kaon decay properties and in particular for the discovery and measurement of $K^+ \rightarrow \pi^+ \nu\nu$".

The Robert R Wilson Prize for Achievement in the Physics of Particle Accelerators is also to recognize and encourage outstanding work in the field. Yaroslav Derbenev of the Thomas Jefferson National Accelerator Facility receives the 2011 prize for "a broad range of seminal contributions and innovations in beam physics, including theory and control of polarization with 'Siberian snakes', electron and ionization cooling, round-to-flat beam transformations, FELs and electron–ion colliders."

In nuclear physics the Tom W Bonner Prize is to recognize and encourage outstanding experimental research in nuclear physics, including the development of a method, technique or device that significantly contributes in a general way to nuclear-physics research. Richard F Casten of Yale University receives the 2011 prize for "providing critical insight into the evolution of nuclear structure with varying proton and neutron numbers and the discovery of a variety of dynamic symmetries in nuclei".

The Julius Edgar Lilienfeld Prize recognizes a most outstanding contribution to physics, by a single individual who also has exceptional skills in lecturing to diverse audiences. The 2011 award goes to Gerald Gabrielse of Harvard University "for novel methods that enable measurement of the electron magnetic moment and fine structure constant to unprecedented precision", as well as his skill in sharing this science with a range of audiences.

Finally, the Prize for a Faculty Member for Research in an Undergraduate Institution goes to Janet Seger of Creighton University. A member of the STAR collaboration at the Relativistic Heavy Ion Collider in Brookhaven, she receives the 2011 award for "significant contributions to the understanding of ultra-peripheral relativistic heavy-ion interactions, skill in involving undergraduates in a large experimental research collaboration and successful mentoring of undergraduates at her institution".

Pomeranchuk prizes for 2009 and 2010

André Martin of CERN and Valentine Zakharov of the Max Planck Institute for Physics, Munich, have been awarded the Pomeranchuk Prize for 2010. They received their awards in a ceremony on 1 October that was tempered by sadness. Both Nicola Cabibbo, laureate of the prize for 2009, and Alexei Kaidalov, chairman of the prize committee, have recently passed away. During the ceremony opened by the new chairman, Alexander Gorsky, the audience rose in memory of these two influential theoreticians. The prize, established by the Institute of Theoretical and Experimental Physics (ITEP) in Moscow, is given in memory of Isaak Pomeranchuk.

Left to right: Boris Ioffe, Valentine Zakharov and André Martin at the ceremony. (Courtesy ITEP.)

Cabibbo was awarded the 2009 prize for his outstanding contribution to elementary particle physics – the realization of the idea of mixing in weak interactions, which paved the way to the Standard Model. Boris Ioffe of ITEP also received the 2009 prize, for his pioneering work on CP violation, the elucidation of the space-time picture in deep-inelastic scattering and for important results in perturbative QCD.

Martin received the 2010 prize for his work on analytic properties of scattering amplitudes that led to the Froissart–Martin bound on the growth of cross-sections with energy, while Zakharov was honoured for work including the establishment of QCD sum rules and the computation of precise β-functions in supersymmetric quantum field theory.

The ceremony for the 2009 prize was postponed until this year at Cabibbo's request but sadly he died before it took place. The diploma was sent to the International Centre for Theoretical Physics in Trieste, where it was delivered to his family at the ceremony for the award of the Dirac Medal – also to Cabibbo – on 8 November.

Mexico honours Giubellino

Paolo Giubellino, the spokesperson-elect of the ALICE collaboration, has been awarded the Medal of the Division of Particles and Fields by the Mexican Physical Society. As the first European to be awarded the medal, he is recognized for his work in the development of high-energy physics in Mexico. He received the medal during a special session of the 5th Workshop on High Energy Physics, held on 27 September – 1 October in Mexico City.

Giubellino has played a significant role in developing closer collaboration between Europe and institutes in Latin America. His contributions and support led to Mexico's involvement in the ALICE experiment at the LHC, as well as in the successful construction of the V0 detector and the cosmic-ray detector, in particular.

Paolo Giubellino with Guillermo Contreras Nuno, the President of the Particles and Fields section of the Mexican Physical Society. (Courtesy Isabel Doninguez/Instituto de Ciencias Nucleares of UNAM.)

Pierpaolo Mastrolia, former CERN fellow, has won the Sofja Kovalevskaja Award, presented by the Alexander von Humboldt Foundation. These awards are given to young scientists, helping them develop research groups at German host institutes.

Pierpaolo will be continuing his research at the Max Planck Institute of Physics, Munich. In his project, he seeks to elaborate the mathematical models and employ them to compute processes that are relevant to the discovery of the Higgs particles.

Studies of nuclei near the drip line win the Flerov prize

Sidney Gales, director of the French heavy-ion accelerator laboratory GANIL, Dominique Guillemaud-Mueller of CNRS/Orsay and Yuri Penionzhkevich of JINR are the recipients of the 2009 Flerov prize. They have been honoured for outstanding results achieved in the study of properties of exotic nuclei near the nucleon drip-line. The prize was awarded during the 108th session of the JINR Scientific Council held in Dubna, on 25–26 September.

The G N Flerov prize was established in 1992, in accordance with the resolution of the 71st session of the JINR Scientific Council, in memory of the eminent physicist Georgy Nikolaevich Flerov (1913–1990). The prize is awarded for contributions in the field of nuclear physics related to Flerov's interests connected with experimental heavy-ion physics, including the synthesis of heavy and exotic nuclei using ion beams of stable and radioactive isotopes, studies of nuclear reactions, accelerator technology and applied research.

From left to right: Mikhail Itkis, acting director of JINR, Semen Gershtein, chair of the prize jury, Yuri Oganessian of the Flerov Laboratory for Nuclear Reactions, Sidney Gales and Yuri Penionzhkevich. (Dominique Guillemaud-Mueller was unable to be present.) (Courtesy JINR.)

OUTREACH

Bonn's Physikshow is a hit at CERN

Towards the end of September, 20 students from the University of Bonn put on three highly successful performances of their *Physikshow* in CERN's Globe of Science and Innovation. The students quickly won over their audience using an array of amazing experiments and zany sketches to illustrate the world of particles, the principle of forces and the evolution of the cosmos.

Physikshow, an award-winning theatrical journey into the world of particles, was first performed in 2002 and has evolved over the years thanks to the input of new students (*CERN Courier* October 2007 p54). The key to its success lies in exploiting the students' originality and spontaneity to convey fundamental physics principles through a stage production using simple, entertaining experiments. To mark their trip to CERN, the troupe put a little extra into the show – sequences on LHC research were inserted and the actors learnt their lines in French. More than 370 pupils from local secondary schools in France and the Cantons of Geneva and Vaud travelled to CERN for the two performances that were especially reserved for schools, with the audience for the public event numbering around 250.

Some of the presenters display letters from the particle alphabet outside the Globe of Science and Innovation, where the performances of Physikshow *took place. (Courtesy Merlin Rossbach.)*

SCHOOLS

Students study accelerator physics in Bulgaria

The CERN Accelerator School (CAS) and the Institute for Nuclear Research and Nuclear Energy (INRNE – Bulgarian Academy of Sciences) jointly organized an introductory course on accelerators, held at the Grand Hotel Varna on the Bulgarian Black Sea coast on 19 September – 1 October. The course was extremely well attended with 109 participants, representing 34 different nationalities and coming from countries as far afield as Australia, Canada and Vietnam.

The intensive programme comprised 39 lectures, three seminars and a poster session, where students could present their own work. There were also four tutorial sessions, with participating students split into three groups, and seven hours allocated for guided and private study. Feedback from the participants was very positive, praising the expertise and enthusiasm of the lecturers as well as the high standard of their lectures. For the first time at CAS, CERN's director-general, Rolf Heuer, visited the school and presented a seminar entitled, "CERN and High Energy Physics – the Grand Picture".

In addition to the academic programme, the visiting students had the opportunity during a one-day excursion to visit the Aladja Monastery, built into the local rock, and to enjoy some time at Cape Kaliakra. There was also an evening visit organized to the Varna Observatory in collaboration with Svejina Dimitrova, head of the Astronomic Observatory and Planetarium in Varna.

● The next CAS course will be the Joint School on Particle Accelerators (CERN–US–Japan and Russia) on "Synchrotron Radiation and Free Electron Lasers". The will take place in Erice on 6–15 April 2011. Also next year is a specialized course on "High Power Hadron Machines" in Bilbao on 24 May – 2 June. For details, see www.cern.ch/schools/.

Students came from as far afield as Australia, Canada and Vietnam to attend the latest CAS introductory school. (Courtesy Deyan Stoev, Varna, Bulgaria.)

CELEBRATION

CERN lays on birthday treat for the Ericsons

A Chinese proverb says that happiness is when friends coming from far away meet and talk to each other. These words could very well be used to sum up the celebration held at CERN in honour of the 80th birthdays of Magda and Torleif Ericson, a couple both in the normal sense of the word and often also in the field of physics.

Torleif Ericson received his PhD in 1959 under the supervision of Ben Mottelson in Copenhagen. He joined CERN's Theory Division in 1960, initially to work at the intersection of nuclear and particle physics at the Synchrocyclotron, and retired in 1995. Magda Ericson received her PhD at Saclay in experimental physics in 1958 and later moved to theoretical physics, mastering various aspects of strong and electroweak interactions in nuclei. In 1966 they co-wrote a classic paper on the optical properties of low-energy pions in nuclei.

During the celebratory event on 17 September, speakers reviewed the depth and breadth of the contributions that Torleif and Magda have made to theoretical physics in general and to nuclear physics in particular. José Bernabeu, Guy Chanfray, Wolfram Wiese, Achim Richter and Anthony Thomas all covered the considerable research that has been stimulated by Ericson–Ericson correlation(s) over the past 50 years.

During each of their final remarks, the guests of honour Magda and Torleif mentioned many names – Viki Weisskopf, John Adams, Giuseppe Cocconi, Leon Van Hove, Jacques Prentki, Maurice Jacob – that told of a period when many essential decisions were taken in shaping the future of CERN, and hence European high-energy physics.

A concert and an informal dinner rounded off the celebrations, which were attended by friends and colleagues from CERN as well as from other European and American institutions.

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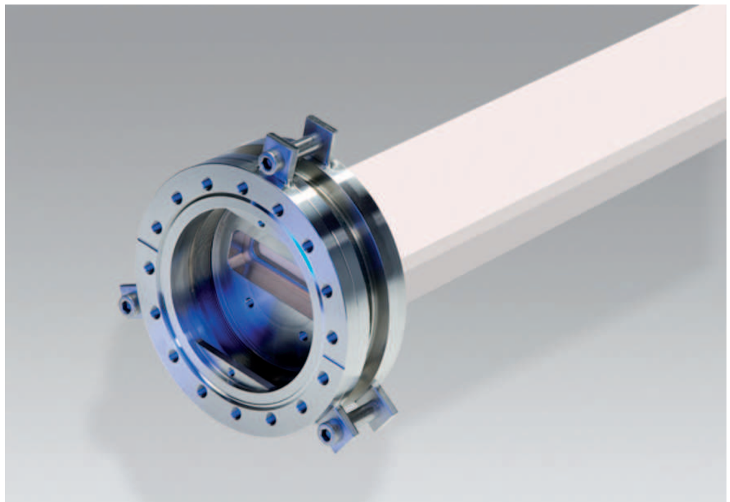

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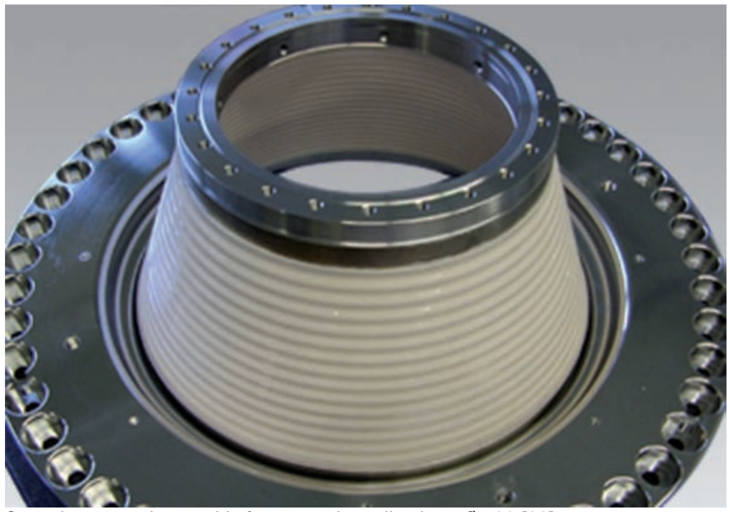

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OUTREACH

ATLAS shows its artistic side

The three-story mural painted on an ATLAS building by American artist Josef Kristofoletti.

On 6 October the ATLAS collaboration officially unveiled a giant mural depicting the ATLAS particle detector on one of the experiment's major surface buildings. Installed in a cavern 100 m underground, the ATLAS detector is no longer open for visits now that the LHC is operating routinely. The mural, painted by American artist Josef Kristofoletti, is three storeys tall yet still one-third the size of the actual detector. It is designed to be the next-best thing to seeing the detector itself.

This is not the first time that Kristofoletti has depicted the ATLAS detector: the giant mural has a smaller relative that was painted for the Redux Contemporary Art festival in South Carolina. That was spotted by members of the collaboration and resulted in the artist being invited to visit the real thing.

Towards the end of October, a different artistic side of the ATLAS collaboration went on display in the UK, with *The Art of ATLAS*, an exhibition at Thinktank, the Birmingham Science Museum. This multimedia installation features a series of short videos that introduce some of the physicists, engineers and technicians who work on the ATLAS experiment, presenting the artists lurking inside them and the imagery they create. The exhibition, which opened on 29 October, will be on display for three months.

NEW PRODUCTS

FLIR Advanced Thermal Solutions Group has released the FLIR SC655, a high-resolution, uncooled infrared camera designed specifically for scientific and research and development applications. The SC655 provides both high frame-rates and full 640 × 480 imagery, enabling capture of more than 300 000 pixels of accurate temperature-measurement data in a single image. The dual-purpose FLIR GF320 camera can be used for thermal inspections at plants. It is fully radiometric, meaning it can detect, measure and visualize temperature. For more details, contact Johan Tegstam, e-mail John.Tegstam@flir.se, or visit www.flir.com.

Future Technology Devices International Limited has announced the TTL-232RG family of USB-to-TTL serial UART converter cables, which build upon the existing family of cables by offering new versions to support an extended variety of voltage I/O levels. The cables feature a USB-to-serial-converter PCB encapsulated within a standard type-A USB connector with a wire-ended asynchronous UART output. For more details, contact Erika Dichtl, e-mail marketing@ftdichip.com or see www.ftdichip.com.

Maxon Motor has introduced the next generation of EPOS – easy-to-use positioning systems. Several variants of the EPOS2 24/2 positioning controller permit the use of various brushed DC motors with encoder or brushless EC motors with Hall sensors and encoder up to 48 W. The variety of operating modes, such as position, velocity and current mode, means that they can be used flexibly in automation technology, tool building and in mechatronic drive systems. For more details, visit www.maxonmotor.ch.

Narda Safety Test Solutions has extended the frequency range of its Area Monitors AMB-8057 up to 7 GHz, so that they can capture the electromagnetic radiation emanating from WiMax, WiFi, WLAN and other wireless services, and from industrial controllers. The probe makes a linear measurement of the electric field in the range 100 kHz to 7 GHz. A separate version allows selective capture of the field components emanating from mobile phone services at 900 MHz. For more details, e-mail support@narda-sts.de or see www.narda-sts.com.

PI has introduced a 2-axis digital controller for ultrasonic high-stability piezo motor stages, such as those used on the latest generation microscopes. The C-867 piezo motor controller is designed for closed-loop micropositioning systems equipped with piezo linear motor drives. It can be operated from a host PC either via a USB port or an RS-232 interface. For more details, e-mail info@pi-usa.us or visit www.pi-usa.us.

OBITUARIES

Jiří Niederle 1939–2010

Jiří Niederle, a prominent theoretical physicist who was professor at Charles University in Prague, a member of the CERN Council since 1992 and president of the Czech Committee for Co-operation with CERN, passed away on 22 August after a year of illness.

Jiří Niederle was well known for his contributions to particle physics and mathematical physics. He concentrated on theories unifying fundamental particle interactions, conformal theory and gauge formulations of gravitation. In mathematical physics, he solved problems in the field of the representations of Lie algebras, superalgebras and groups, integrable non-linear systems and the theory of contractions and deformations.

His activities extended beyond his contributions to theoretical physics, however, to the problems connected with the radical reconstruction of international co-operation and organization of science after the collapse of the communist regime in a number of European countries in November 1989. Such reconstruction was unavoidable in all of the scientific institutions in these countries. In the Czech Republic, this enormous challenge fell to Jiří, who was appointed president of the Council for International Co-operation of the Academy of Sciences for 12 years in the periods 1990–1997 and 2001–2005, being re-elected twice. Thanks to his initiative and efforts the Academy of Sciences has again become part of the global community of scientific organizations, despite the previous years of artificial isolation.

Jiří Niederle. (Courtesy his personal archives.)

Jiří was not only world renowned as an experienced lecturer for university and post-graduate students but also on popular science, including broadcast and televised popular science programmes. He covered topics such as abstract theoretical physics and subjects describing the construction and work of CERN's big machines, the Large Electron–Positron collider and the LHC. He gave much of himself to his outreach activities; this was particularly important in his home country, which is well known for its high level of industry. In these efforts he was continually mediating, encouraging and supporting contacts between Czech industry and CERN.

Science cannot manage without administration, but it may sometimes happen that more attention is given to administration than to science. It was our experience that Jiří always exerted all of his force, effort and authority to reaching the result that defended the interests of science.

Jiří will be severely missed not only as an excellent physicist, professor, international scientist and organizer of science, but also as a close friend and gentleman. His passing is a great loss for all of us as well as the for the worldwide mathematical and particle-physics community.

His colleagues and friends.

● For more about Jiří Niederle, see the article published in honour of his 70th birthday (*CERN Courier* June 2010 p28).

Jean Meyer 1925–2010

Jean Meyer, who was head of the Service d'expérimentation par les chambres à bulles (SECB) in the department for particle physics at Saclay, passed away on 23 September.

Jean Meyer was born in the territory of Danzig (now Gdańsk) in 1925. Confronted by the rise of Nazism, he fled and immigrated into France towards the end of the 1930s. As the Nazi threat extended, he fled again to Portugal from where he embarked for Brazil. Despite the factory work that was necessary to ensure his survival, he started to learn physics when he was 15 years old and this was to become his passion. In Brazil, he pursued his studies at the university of São Paulo, where he met several great physicists, among them Gleb Wataghin and Beppo Occhialini, one of the discoverers of the pion in 1947, as well as the theorist David Bohm.

On returning to France, Meyer joined the Atomic Energy Commission (CEA), in Saclay. There, in 1958, he designed the first bubble chambers, as the French groups did not yet have any experience in this field, and he quickly became the head of the service for bubble-chamber experiments (SECB). He then left for CERN, where he was offered a permanent position, and became a member of the committee for the construction of the Big European Bubble Chamber. He participated in kaon physics and the checking of SU(3) symmetry with a series of experiments on kaon-nucleon scattering with, in particular, Roland Barloutaud, Antoine Lévêque and P Granet. He also participated in committees for the future of particle physics together with Murray Gell-Mann.

At the request of the Brazilian government, Meyer went back to Brazil in the middle of the 1970s, and created the Wataghin Institute in São Paulo, where he became director, before becoming director of the Brazilian national centre for scientific research.

Meyer returned to France in 1980 and was again employed by the CEA, managing the SECB once more in 1982. In 1984 he became head of the Laboratoire de Physique Nucléaire et de Hautes Energies (LPNHE) (now the Laboratoire Leprince-Ringuet) at the École polytechnique. He made a big reorganization of the laboratory, introducing topics such as plasma acceleration – an activity that continues there successfully today. He remained director until 1990.

Retirement did not mark the end of Meyer's activities, as he took care of extending recruitment at the École polytechnique throughout Europe, his network of relations enabling him to welcome young foreign students. Together with Guy Aubert, director of the Ecole Normale Supérieure (ENS) of Lyon, and Bernard Bigot, director of studies, Meyer continued the "Europeanization" of the ENS, knowing how to attract brilliant European students in collaboration with many European universities.

In recent years, Alzheimer's disease overshadowed the end of his life, and distanced him more and more from the memories of his friends. However, his dynamism and kindness remain in the thoughts of all those who knew him.

His colleagues and friends.

Jean Meyer. (Courtesy Albert FITOUSSI, Jocanal France Services (Paris).)

Joaquim Prades Hernández 1963–2010

Joaquim (Ximo) Prades passed away on 31 August in Granada, after a long battle with cancer that he conducted in his characteristic quiet and optimistic fashion. He maintained his excellent scientific activity until the very end.

Ximo was born in Castelló de la Plana, Spain, on 3 February 1963. He received his degree in physics in 1986 at the University of Valencia, where he continued his studies, obtaining a doctorate in 1991. As a postdoctoral researcher he worked in the Centre de Physique Théorique in Marseille (1991-1993), Nordita and the Niels Bohr Institute in Copenhagen (1993-1995) and Valencia (1996), before becoming an associate professor at the University of Granada in 1997.

He worked in many international and national collaborations, often visiting Valencia, Lund University and CERN, where he recently spent a sabbatical year. An active participant in the European research training networks Eurodaphne, Euridice and Flavianet, he was also the leader of the project "Flavour Physics and QCD" of the Spanish National Programme for Particle Physics.

Ximo Prades. (Courtesy his friends.)

Ximo made notable contributions to particle physics through some 50 publications in journals, as well as many workshop reports and conference proceedings. He began his career working on the kaon bag parameter (B_K), using hadronic duality, and on light-Higgs physics. His scientific research was focused on the interplay of QCD in electroweak processes, most of his work being in non-leptonic matrix elements and determinations of Standard Model parameters. His contributions on the muon anomalous magnetic moment, the $\Delta I=1/2$ rule and CP-violation in the kaon system were particularly relevant, together with the determination of the mass of the strange quark and the Cabibbo angle from the hadronic spectral functions measured in τ decays. Ximo also contributed to the physics of rare kaon decays and many other aspects of hadronic physics.

We are deeply saddened by this tragic loss of a young life. Ximo was an exceptional person, both at the human and professional levels. We will miss him greatly, but his memory will always remain with all of us who had the privilege of interacting and working with him.

We offer our condolences to his wife, Blanca Biel, and family.

Johan Bijnens, Fernando Cornet, Elvira Gámiz and Antonio Pich for his many friends and collaborators.

VISITS

Minister of education, science and technology for the Republic of Korea, **Lee Ju-Ho**, centre left, visited the ALICE surface exhibit at CERN on 22 September with **Jurgen Schukfraft**, ALICE spokesperson, far right, and **In-Kwon Yoo**, Korean contact physicist for the ALICE experiment and professor at Pusan University, centre right. The Korean party also toured the CMS control centre.

Georg Schütte, centre, German state secretary, federal ministry of education and research, toured the LHC superconducting magnet test hall on 23 September. He was accompanied by **Susanne-Corinna Langer-Greipl**, left, a member of the CERN finance committee and a member of the German federal ministry of education and research, and **Rüdiger Schmidt**, right, deputy head of CERN's machine protection and electrical integrity group. The minister also saw the ATLAS visitor centre and met German scientists working at CERN.

On 23 October, UNESCO's director-general, **Irina Bokova**, centre, was welcomed to CERN by the director-general, **Rolf Heuer**, here demonstrating a gift of CERN's special temperature-sensitive coffee mug that illustrates the history of the universe, and **Sergio Bertolucci**, the director for research and scientific computing, left. During her visit she toured the LHC superconducting magnet test hall, the ATLAS visitor centre, and the *Universe of Particles* exhibition.

In a rather more unusual visit, a delegation from Singapore came to CERN on 18 October. The visitors are involved in planning a vast Underground Science City housing R&D laboratories and IT data centres. They came to learn from civil engineers and safety experts about how CERN plans and constructs its underground facilities. They visited the CMS site at Cessy, including the above-ground control room and the Underground Service Cavern.

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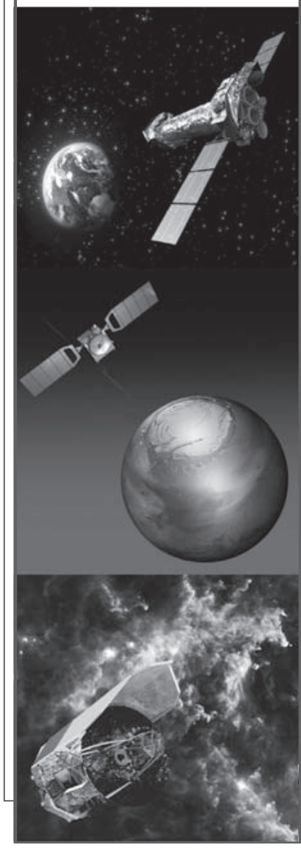

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The deadline for receiving applications and supporting documents is 30th November 2010.

Postdoctoral positions for young theoreticians (Academic year 2011-2012)

The current research areas of the ICTP CMSP Section include strongly correlated electron systems, disordered and mesoscopic systems, ab-initio electronic structure studies, quantum liquids and solids, surface physics, friction, theoretical nanoscience, statistical physics and related interdisciplinary areas, including glassy systems, soft matter, theory of computation, physics of adaptive systems and biophysics.

A limited number of post-doctoral positions for young CM&SP theoreticians will be available starting Fall 2011. Appointments will be made for two years, with the possibility of renewal for one more year. More information and on-line application are available at:
http://www.ictp.it/pages/research/cmsp.html

The deadline for receiving applications and supporting documents is 10th January 2011.

Max-Planck-Institut
für Physik
(Werner-Heisenberg-Institut)

ATLAS Postdoctoral Positions
Based in Munich

The Max Planck Institute for Physics is engaged in fundamental research in particle and astroparticle physics from both experimental and theoretical perspectives. One main research activity is the participation in the ATLAS experiment at the Large Hadron Collider (LHC) at CERN. The institute has contributed to the design, construction and commissioning of the Semiconductor Tracker, the Hadronic Endcap Calorimeter, the Muon Spectrometer, and maintains a 50% share in the federated Munich Tier-2/-3 computing centre for ATLAS.

ATLAS data analysis and optimisation of detector performance

We invite applications for a postdoctoral position in experimental particle physics within our ATLAS Group. The group is engaged in a research program for tests of the standard model of particle physics. It searches for the Higgs boson, for supersymmetric particles and is involved in trigger, detector and electronics development for future upgrades of the ATLAS detector. The successful candidate is expected to play a leading role in the ATLAS data analysis focusing on detector performance studies, measurement of standard model processes and Higgs boson searches. The candidate should also contribute significantly to the improvement of the ATLAS muon trigger and to the development of gaseous precision tracking detectors for the upgrade of the ATLAS Muon Spectrometer. For questions concerning this position please contact Dr. sc. Sandra Kortner (sandra@mpp.mpg.de)

Data analysis and supervision of ATLAS Tier -2/-3 computing centre

We also invite applications for a postdoctoral position to take over responsibility for the smooth operation and further development of our ATLAS Tier -2/-3 computing centre in Munich. The candidate should also contribute to the ATLAS data analysis focusing – among other topics – on measurements of standard model processes. For questions concerning this position please contact Stefan Kluth, PhD (skluth@mpp.mpg.de).

Candidates for these two positions must hold a PhD in particle physics or related fields. Salary and benefits are according to the German public service pay scale (TVöD Bund). The contracts are initially limited to three years with the possibility of extension within the frame of the German Wissenschaftszeitvertragsgesetz. The Max Planck Society is an equal opportunity employer. Interested applicants should send an application letter including curriculum vitae, list of publications and a statement of research interests and arrange for three letters of recommendation to arrive **no later than 15 January, 2011** at the following address:

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)
Frau A. Schielke
Föhringer Ring 6, 80805 München, Germany
E-mail: schielke@mpp.mpg.de

MAX-PLANCK-GESELLSCHAFT

Associate Scientists In Accelerator Physics

The Fermilab Accelerator Physics Center (APC) is seeking strong candidates for two Associate Scientist positions. The Center is responsible for coordinating and/or providing support for all accelerator R&D at Fermilab including activities aimed at improvements to the existing complex, next-generation accelerator facilities, and advanced accelerator R&D for the long-term future. One Associate Scientist will be assigned within the R&D towards muon collider and neutrino factory R&D program, the other to beam physics support of Project X and ILC. The appointments are for an initial term of three years and can be renewed for an additional three years upon the completion of a successful review after the first two years. These positions can lead to a subsequent scientific appointment without term and offer an annual salary fully competitive with university assistant professorships.

Associate Scientists have the opportunity to participate in the full range of activities of the APC including mathematical modeling of new and existing accelerator facilities, design, commissioning and operation of beam facilities, performance and analysis of beam physics experiments, design of new accelerator components, and research on new concepts and methods of beam acceleration.

The successful candidate must have a Ph.D. in Physics and at least 3 years of postdoctoral experience in the physics of accelerators and beams.

Applications and requests for information should be addressed to Dr. Vladimir Shiltsev, Director of APC, via shiltsev@fnal.gov. Applications should include a curriculum vitae, publication list, and three letters of reference and should be received by December 24, 2010.

Fermilab

Fermilab is an Equal Opportunity Employer M/F/D/V

SIGMAPHI
MAGNETS AND BEAM TRANSPORT

Sigmaphi, a **world specialist** in magnetic systems for particle accelerators is looking for 4 engineers to assist with development and research.

Engineer – Superconducting magnets
Work out all mechanical and cryogenic calculations.
Trained in mechanical engineering, 5 years experience at the mechanical study office, knowledge of Ansys.

Sales Engineer
Analyse specifications and prepare price proposals. Trained as an engineer, varied knowledge (magnetics, mechanical and cryogenic) rigorous, autonomous, with an ability to build relationships.

Assistant Engineer to the Production Manager
Prepare the product launches, develop methods. Trained in mechanical engineering, 5 years experience in manufacturing.

Design Engineer
Create drawings for our products. Bachelor degree. A few years knowledge and experience of Solidworks is necessary.

A good level of English is required for all these positions.

Based in Vannes, France.

For further information and to apply, please contact
Mr Lancelot, contact@sigmaphi.fr

Associate Scientist

As a member of the Magnet Systems Department of the Technical Division, the successful candidate will conduct R&D in support of Fermilab's superconducting magnet program, which includes: solenoids for a muon conversion experiment (Mu2e), magnets for new high intensity proton accelerator (Project X), collider ring dipoles and quadrupoles for future accelerators, muon cooling solenoids for muon collider R&D, and beam line magnets for the Long Baseline Neutrino Experiment (LBNE), as well as magnet support for the Fermilab accelerator complex now in operation.

Summary of Responsibilities
- Under the guidance of senior scientists, conduct R&D in support of the Fermilab state-of-the-art superconducting magnet program with emphasis on the magnetic, thermal, mechanical and quench design, test and measurement, and analysis of results.
- Develop research interests that are aligned with Fermilab's magnet program.
- Propose and execute R&D activities in the area of accelerator physics and accelerator technology related to the overall mission of the Laboratory.
- Participate in relevant conferences, workshops and meetings.
- Publish research results in referenced journals.

Minimum Qualifications Requirements
- Demonstrated ability to carry out independent research and/or project leadership
- Ph.D. in experimental physics or closely related field
- 2+ years of post-doctorate experience
- Good oral and written communication skills

Preferred Qualifications Requirements
- Practical experience with magnet design, analysis, fabrication, test, or measurement techniques is desirable.
- Working knowledge of modeling tools for magnetic, mechanical and thermal analysis is desirable.
- Experience in applied superconducting technology is desirable.

Applicant should include curriculum vitae and a publication list. Applications and requests for information should be sent to Victor Yarba at yarba@fnal.gov.

Fermilab

Fermilab is an Equal Opportunity Employer M/F/D/V

Durham University

DEPARTMENT OF PHYSICS

LECTURER / READER

£36,715 – £52,346 per annum (Grade 8/9)

Applications are invited for three permanent positions at lecturer or up to reader level, tenable within the Department of Physics, in association with the Institute for Particle Physics Phenomenology (IPPP). The successful applicants will have expertise in particle physics phenomenology. For two of the posts (Ref: 0512) preference will be given to candidates working in the areas of Beyond the Standard Model and Higgs physics, the third position (Ref: 0514) is in any area of particle physics phenomenology.

Post-holders will be expected to make a substantial contribution to the research activities of the IPPP and to undertake teaching and administrative duties in the Department of Physics. The post is at grade 8 to 9, with an initial salary in the range £36,715 - £52,346 (Spine point 37 - 49). Post-holders at Grade 9 would be more experienced with a record of leadership and vision in particle Physics research over several years.

Closing date: 6 December 2010 **Ref: 0512 & 0514**

Further details of the post and an application form are available on our website (https://www.dur.ac.uk/jobs) or telephone 0191 334 6499; fax 0191 334 6504

MICHIGAN STATE UNIVERSITY

FACULTY POSITIONS IN ACCELERATOR PHYSICS AND ENGINEERING

Michigan State University (MSU) invites applications for two vacant faculty positions at NSCL in the area of Accelerator Science. Faculty are expected to develop and lead world-class research programs, teach, supervise student research projects, and participate in the design and implementation of the Facility for Rare Isotope Beams (FRIB). Each position can be filled at the assistant, associate, or full professor level, with a competitive salary.

NSCL and FRIB offer challenges and opportunities in a variety of state-of-the-art accelerator and particle beam systems, including:

- beam dynamics, electromagnetic calculations and accelerator design
- superconducting RF R&D and system design
- high-performance ECR ion source development
- beam instrumentation, diagnostics, and controls
- innovative concepts in particle beams and accelerators
- electrical, mechanical and cryogenic engineering

Special attention will be given to candidates whose research relates to superconducting accelerator technology.

As the forefront facility in the United States for rare isotope science, NSCL and FRIB have over 400 employees, including 35 faculty members in nuclear and accelerator science. Approximately 150 graduate and undergraduate MSU students are involved in research projects. Learn more about NSCL and FRIB at **www.nscl.msu.edu** and **www.frib.msu.edu**; information about NSCL faculty appointments can be found at **www.hr.msu.edu/documents/facacadhandbooks/NSCLFacPos.htm**

Applicants should send a letter of application, a résumé, including a list of publications, and the names and addresses of at least three references to **Prof. Michael Syphers, NSCL, Michigan State University, East Lansing, MI 48824-1321 or jobs@nscl.msu.edu**.

MSU is committed to achieving excellence through cultural diversity. The university actively encourages applications and/or nominations of women, persons of color, veterans and persons with disabilities. MSU is an affirmative action/equal opportunity employer.

NSCL FRIB

UNIVERSITY OF Cincinnati

Postdoctoral Fellow — Belle and Belle II

The experimental particle physics group invites applications for a Postdoctoral Fellow position with the Belle and Belle II experiments. We seek a recent Ph.D. physicist to join us in development and construction of the "Imaging Time-of-Propagation" (iTOP) hadron ID device for Belle II as well as exploitation of Belle's tremendous data sample in the Upsilon energy region, especially in B_s studies at the $\Upsilon(5S)$.

Details on applying may be found at http://homepages.uc.edu/physics/facultyStaff/jobs.html.
We will begin reviewing applications immediately and continue until the position is filled.

The University of Cincinnati is an equal opportunity/affirmative action employer. Women, people of color, people with disabilities and veterans are encouraged to apply.

KEK,

High Energy Accelerator, Research Organization, Japan

KEK was established in 1997 in a reorganization of the Institute of Nuclear Study, University of Tokyo (established in 1955), the National Laboratory for High Energy Physics (established in 1971), and the Meson Science Laboratory of the University of Tokyo (established in 1988).

KEK seeks sutiably qualified candidates for the following positions at the Accelerator Laboratory:

Assistant Professor (Job No. ACCL 1019)
Number of Job Opening: looking for a few capable people
Term A: No term limit until the age of 63, Term B: 4 years
Start of the term: April 1, 2011.
Application deadline (to reach KEK): December 27, 2010
The successful candidate will belong to the Accelerator Laboratory, and is expected to engage in design, development, construction, and improvement of the SuperKEKB rings and injector. The candidate is also expected to engage in the operation, improvement, and maintenance of related accelerators as well as in R&D work on accelerator technologies for future projects that KEK is promoting.

Assistant Professor Job No. ACCL 1020
Number of Job Opening: looking for a few capable people
Term: No term limit until the age of 63
Start of the term: April 1, 2011.
Application deadline (to reach KEK): December 27, 2010
The KEK Accelerator Laboratory is responsible for the operation and upgrade of JPARC, SuperKEKB, Photon Factory accelerators (PF and PFAR), and the ElectronPositron Linac, including R&D of the relevant accelerator technologies. It is also promoting a wide range of accelerator research including future projects such as linear colliders and Energy Recovery Linacs (ERL) as well as accelerator theory. The successful candidates will be involved in either one of those accelerator projects and be expected to engage in not only R&D work but also operation and maintenance work for the corresponding accelerators.

Postdoctoral Fellow Job No. ACCL 1021
Number of Job Opening: looking for a few capable people
Term A: Postdoctoral Fellow for 1 year might be annually renewed (maximum 2 years).
Start of the term: Successful candidate is expected to take the position as soon as possible.
Application deadline (to reach KEK): December 27, 2010
The Accelerator Laboratory of KEK is responsible for operation and improvement of the JPARC proton accelerators, SuperKEKB, Photon Factory accelerators (PF and PFAR), and the electronpositron injector Linac and promoting R&D of relevant accelerator technologies. It is also promoting extensive research on accelerator technologies for future projects such as the KEKB Upgrade, next generation light sources and linear colliders, as well as accelerator theory and so forth.
The successful candidates will be involved in either one of those accelerator projects and be expected to engage in the accelerator R&D work. We are looking for highly motivated young researchers.

Qualification: applicant must have a Ph. D. obtained, as of the deadline for application, or is sure to get Ph. D. prior to starting the job at KEK.
Your past field of research does not have to be the same as the field of work you are expected to do here.

* Applicants may apply for positions A or B, or for both. Please be sure to prioritize when applying for both positions, i.e. indicating your first choice.

Method of Selection: applicant is required to come to KEK for an interview. However, we would consider a TV conference to be the interview if the applicant is required to travel a very long distance. (mostly for people abroad.)
Please submit: 1) Curriculum vitae (Please write the job number(s) you are applying for, and the possible date you would be able to start the job at the Accelerator Laboratory. Please write your birth date as well.) 2) Research experience, 3) Research plan at ACCL if employed, 4) Publication list, 5) Reprints of major publication (fewer than 6) and 6) Recommendation letter(s) which must be addressed to Prof. Katsunobu Oide, Director, ACCL in care of Personnel Affairs Unit 1 of KEK).
When you apply for more than one job openings in KEK, your application should be a complete set for each application.
In case cancelling applications after on our procedure starting, we could not send your documents back.
For more information: please contact:
Prior to application, the inquiry should be made to the Director of ACCL, Prof. Katsunobu Oide, Tel: +81 298645314, Fax: +81 298643182
email katsunobu.oide@kek.jp
Applications to be mailed to: Personnel Affairs Unit 1, KEK 11 Oho, Tsukuba, Ibaraki 3050801, Japan
(We accept recommendation or reference letter(s) by email as well: jinji1@ml.post.kek.jp

For further information: **http://www.kek.jp/intra-e/jobs/index.html**

KEK is an equal opportunity, affirmative action employer and encourages applications from women.

Postdoctoral Research Associate position in Physics

The Physics Department at Brookhaven National Laboratory seeks to fill a Postdoctoral Research Associate position in Physics.

Requires a Ph.D. in physics with emphasis on experimental particle or nuclear physics. The candidate will participate in the activities of the group including the design of the Long Baseline Neutrino Experiment at DUSEL in South Dakota, the commissioning and running of the Daya Bay reactor neutrino experiment in China, and related detector R&D.

Travel to DUSEL, Fermilab and/or China should be expected. The candidate will work within the Electronic Detector Group and will have broad associations with other groups in the laboratory and throughout the world to carry out his/her function. The Electronic Detector Group in the Physics Department currently has twelve physicists at various career levels with major current responsibilities in neutrino physics and a long history of research in fundamental particle physics. Under the direction of S. Kettell, Physics Department.

Please go to **http://www.bnl.gov/hr/careers** and click on "Search Job List" to apply for this position. Please apply to Job ID # 15553.

BNL policy states that Research Associate appointments may be made to those who have received their doctoral degrees within the past five years.

Brookhaven National Laboratory is an equal opportunity employer committed to building and maintaining a diverse workforce.

NATIONAL TAIWAN UNIVERSITY

Leung Center for Cosmology and Particle Astrophysics

Distinguished Junior Fellowship

The Leung Center for Cosmology and Particle Astrophysics (LeCosPA) of National Taiwan University is pleased to announce the availability of several Post-Doctoral or Assistant Fellow positions in theoretical and experimental cosmology and particle astrophysics, depending on the seniority and qualification of the candidate. Candidates with exceeding qualification will be further offered as LeCosPA Distinguished Junior Fellows with competitive salary.

LeCosPA was founded in 2007 with the aspiration of contributing to cosmology and particle astrophysics in Asia and the world. Its theoretical studies include dark energy, dark matter, large-scale structure, cosmic neutrinos, and quantum gravity. The experimental projects range from CMB detection in Hawaii, GZK-neutrino detection in Antarctica, infrared telescope in Tibet, and satellite GRB telescope.

These positions are available on August 1, 2011. Interested applicant should email his/her application with curriculum vitae, research statement, publication list and three letters of recommendation before December 10, 2010 to
Ms. Ting-Yi Wu **tyw@phys.ntu.edu.tw**
For more information about LeCosPA, please visit its website at
http://lecospa.ntu.edu.tw/
Three letters of recommendation should be addressed to
Prof. Pisin Chen, Director
Leung Center for Cosmology and Particle Astrophysics
National Taiwan University

Festive Bookshelf

At the end of a successful first year of physics at the LHC, it is time for many of us to spend some time with friends and family, probably after a few hectic hours searching for presents in this festive season. To help with the shopping, this edition of Bookshelf includes some books that aim to take particle physics and related areas of science to a wider audience, together with one or two that you could add to your own wish list.

Massive: The Hunt for the God Particle by Ian Sample, Virgin Books. Hardback ISBN 9781905264957, £18.99. Paperback ISBN 9780753522110, £13.99.

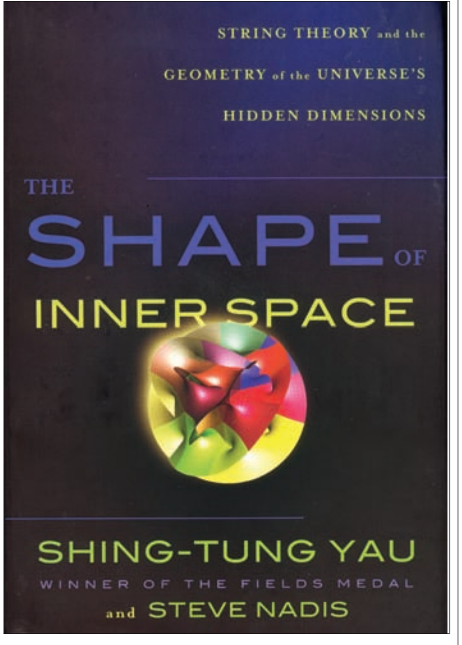
CERN Courier readers don't need to be told that the search for the Higgs boson consumes a considerable fraction of resources in modern particle physics. I am certain that many of you have been asked by family, friends and neighbours for an explanation of what the fuss is all about.

Ian Sample's *Massive* is a marvellous book and well worth reading by both researchers and the layman. In it, Sample describes the history and the personalities behind the search for the Higgs boson. He dispels the common simplifying myth that a single lone genius named Peter Higgs was the sole theoretical mind behind the idea. Instead, Sample gives appropriate credit to the many theorists who made equally critical intellectual contributions.

The author also guides us through history, stopping at points of interest along the way, from the prediction of and the discovery of the W and Z bosons, to the debacle that was the Superconducting Super Collider, to today's exciting efforts at both the Tevatron and the LHC. Along the journey, he relates entertaining anecdotes that he gleaned from interviews with many researchers central to the effort to search for the Higgs over the past several decades. I know personally many of the people whose names appear throughout the book, and I can attest that Sample has accurately conveyed their voices without the distortions that one often observes when reading a report in the media.

Sample's book does have an intentional weakness. He has clearly chosen to focus on the history and personalities involved in the saga of the Higgs boson and to gloss over many technical physics details. A reader who wants to understand more about quarks and leptons and the forces that tie them together will find many other books that do a much better job with these and similar concepts. The book contains only as much physics as is necessary to tie together the human narrative and these two topics are melded together into a seamless and pleasant read.

I did find one physics error in the book. While describing the search for the Higgs boson at the LHC, Sample writes about the decay modes for Higgs bosons with both low and high mass. For the high mass, he states that the expectation is to see four leptons, while at low mass he mentions only the two-photon decay mode. He gives the false impression that this is the dominant mode, rather than simply the one that is popular at the LHC owing to the lower backgrounds. This regrettable error will offend only the purists and does not detract from what I think is an excellent book. I strongly recommend it.
Don Lincoln, Fermilab.



The Shape of Inner Space: String Theory and the Geometry of the Universe's Hidden Dimensions by Shing-Tung Yau and Steve Nadis, Basic Books. Hardback ISBN 9780465020232, $30.

Geometry is the architecture of space, explains Shing-Tung Yau at the start of this book. For most of history, this architecture used the rigid straight lines inherited from Pythagoras, Euclid and other Ancient Greeks. Then, René Descartes, Carl Friedrich Gauss and Bernhard Riemann in turn showed how it could become more flexible.

Whichever way it was constructed, geometry remained largely abstract until almost 100 years ago, when Albert Einstein's theory of general relativity showed how matter influences the space around it. Ever since this pioneer synthesis, mathematicians have been exploring the possibilities of geometry for physics, and vice versa. One early milestone was the attempt by Theodor Kaluza and Oskar Klein to extend space from four to five dimensions. Although their attempt to extract new physics failed, it has never stopped physicists and mathematicians from exploring the potential of multidimensional spaces.

In the same way that Einstein's work revolutionized the theory of gravity, so in the closing years of the 20th century string theory emerged as a new way of viewing elementary particles and their various interactions. Unlike Brian Greene's *The Elegant Universe*, this book is not an introduction to the physics fundamentals of string theory. Instead, it is more concerned with the mathematics that string theory uses.

In 1950, a geometer named Eugenio Calabi launched a bold new conjecture. More than a quarter of a century later, this conjecture was proved by Shing-Tung Yau, and the geometry has since been known as Calabi-Yau manifolds. The two names have become so closely associated that Yau wryly points out how many people assume that his first name is Calabi!

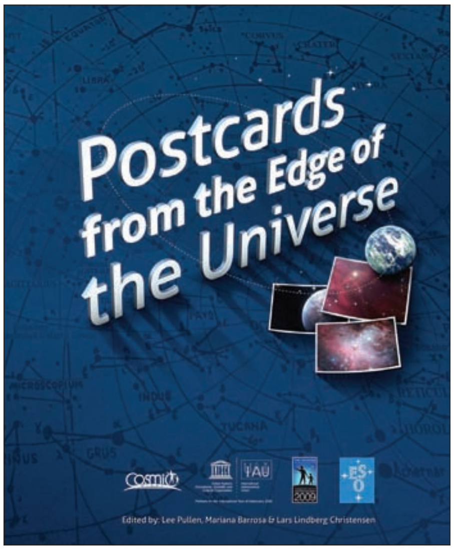
Following a description of such arcane mathematics is difficult, the proof even more so. However, it is dutifully done, in a way redolent of Simon Singh's *Fermat's Last Theorem*, which commendably made mathematics understandable without using equations. Some of Yau's explanations are difficult to follow but a glossary of mathematical terms at the end of the book is a great help. The remainder of the book explains the potential of Calabi-Yau geometry as a framework for string theories – a subject that seems to have taken a place alongside rocket science as a perceived pinnacle of intellectual ingenuity.

While books with two co-authors are not unusual, this one is: one author writes a narrative in the first person, the other uses the third person. Nevertheless it works. For anyone interested in string theory it is a good book for understanding what has been achieved so far, and by whom (however, some notable contributions are missing). It is also a timely reminder of the latent power and elegance of mathematics. Calabi-Yau manifolds could help revolutionize our understanding of the world around us in the same way that Riemannian geometry did. However, while many great minds have chipped away at the problem, the ultimate latter-day Einstein has yet to emerge.
Gordon Fraser, Divonne-les-Bains.

Postcards from the Edge of the Universe
by Lee Pullen, Mariana Barrosa and Lars Christensen (ed.), ESO. Hardback ISBN 9783923524648. €9.90. Free PDF version available from www.postcardsfromuniverse.org.

I'm a sucker for beautiful astronomy books and this one ticks all of the right boxes, right from the table of contents, which shows an artist's view of the Earth stretching out into deep space. It is a good visualization of the depth and breadth of the science covered by the book.

This is no ordinary astronomy photo book. It is a compilation of articles by the *Cosmic Diary* bloggers who told their story throughout the International Year of Astronomy, 2009.



As an anthology of front-line astronomy, it will soon date but it will have lasting value as a snapshot of the different researchers – first-person accounts that personalize the science and give a picture of the reality of life in research. The biographies serve to underline the truly international dimension of the research. Indeed, I am impressed by the variety of the bloggers, spanning five continents, which is no mean feat.

The array of subjects is also impressive – from a fascinating account of meteorites to the recipe for making stars. However, as the links between particle physics and astronomy become stronger, I would have liked to have read something about neutrinos or on gravitational waves, rather than a third description of how to detect exoplanets.

It is perhaps inevitable that the book's biggest strength – its diversity – also gives rise to some weaknesses. This includes a mixed bag of writing styles and a few rather acronym-heavy, dry accounts. And the English does not always flow comfortably. But the approach of only light-handed editing is an attractive one because it allows the writers' personalities to show through. The vast majority of the contributions are written in a chatty, friendly style and take the reader on a visual voyage of discovery.

If I chose to study physics, it was partly because I stumbled on a book in my school library about the mysteries surrounding the superluminal jets emanating from the quasar 3C273. Wow, I thought. I want to know more… I can quite imagine *Postcards* providing the same inspiration.

Buy it for your teenagers now!
Emma Sanders, CERN.

Hubble: A Journey Through Space and Time
by Edward Weiler, Abrams. Hardback ISBN 9780810989979, £19.95 ($29.95).

The publisher and NASA have joined forces to celebrate the 20th anniversary of the Hubble Space Telescope with the release of this inspirational "coffee-table" book. It not only pieces together the story of the telescope itself and the remarkable fruits of its labour, but also gives much prominence to the unparalleled teamwork by the men and women in conceiving, building, launching and operating Hubble – not to mention including detailed information and photographs from various NASA servicing missions.

Being the most celebrated celestial observer since Galileo assembled his first optical instruments, Hubble has without a doubt revolutionized astronomy and produced many of the most significant space photographs of our time.

In this "journey", notable scientists describe the meaning and significance of the top-20 Hubble images and mission astronauts write about their experiences servicing it on various shuttle missions. The book includes a description of how the telescope works before presenting the wondrous world of our solar system, the stars and interstellar clouds. A later chapter explores the outer galaxies and Hubble's quest to document them.

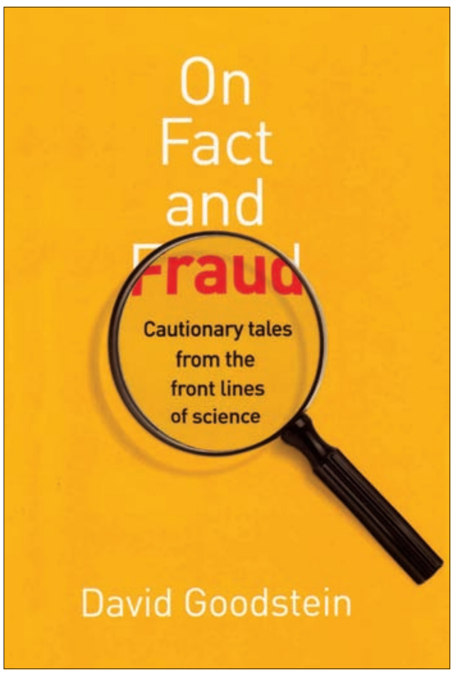
This book makes an ideal gift for readers young and old with an interest in science,

space and astronomy. Younger readers will marvel at more than 100 classic photographs – many of them full page – and older ones will relish the accompanying text and captions.
Jesse Karjalainen, Bristol.

On Fact and Fraud: Cautionary Tales from the Front Lines of Science by David Goodstein, Princeton University Press. Hardback ISBN 9780691139661, £15.95 ($22.95). E-book ISBN 9781400834570, $22.95.

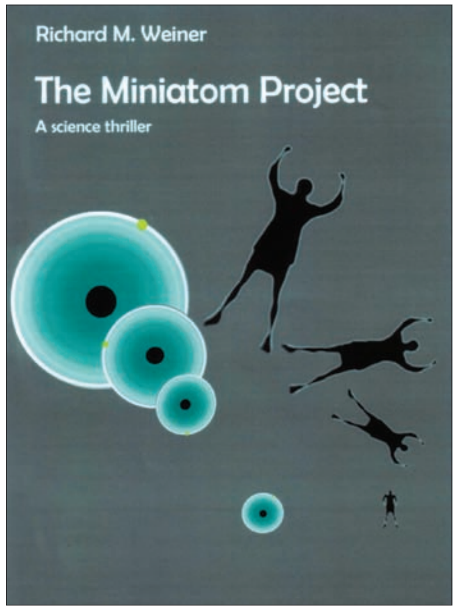
Now that we can easily access scientific papers without leaving our offices, thanks to the availability of electronic versions of the most important journals, many of us at CERN rarely visit the library. Yet there are many other good reasons to stop by, among them the recently created bookshop, which houses a diverse collection of interesting books. This is where I first saw this book, in which David Goodstein shares his knowledge and reflections on scientific misconduct, including first-hand reports on some of the allegations that he studied as Caltech's vice provost.

Throughout the book, Goodstein presents several cases with considerable detail, such that the reader is invited to judge whether scientific misconduct happened or not. The opening case describes Robert Millikan's determination of the electron's charge, based on measurements of 58 oil droplets, and addresses the allegation that this was a subset of all observations, selected because they were in line with the experimenter's convictions. The verdict, "not guilty", is supported by 22 informative pages, offering the reader a tour of the difficulties of the experiment – in the context of 1912 – including an explanation of why viscosity played a more important role than gravity or electricity in understanding the movement of the oil drops. I particularly enjoyed seeing four pages from the original notebooks where the measurements were written down. Rather than "manipulating" his data, Millikan carefully selected high-quality observations to obtain an accurate measurement: his result agrees with the modern value within its quoted 0.2% uncertainty.



The book also contains a highly entertaining report of the "strange and complex case of cold fusion", following the saga from March 1989 to recent days. Here there is also no evidence of scientific fraud, defined by the author as "faking or fabricating data or plagiarism". Martin Fleischmann and Stanley Pons should not have announced their "discovery" as they did (in a press conference) and when they did (too early, fearing to be scooped by someone else). Nuclear fusion on a tabletop would really be too good to be true and many physicists and electrochemists promptly dismissed those claims after finding that they could not reproduce the results in their own labs; but "self-delusion, misperceptions, unrealistic expectations and flawed experimentation are not instances of scientific fraud". Real fraud, in physics, is illustrated by the putative discovery of element 118 by Victor Ninov (Lawrence Berkeley National Laboratory) and by the "remarkable" breakthroughs of Jan Hendrik Schön (Bell Labs) in the field of organic semiconductors. Caltech's own problems of research misconduct are illustrated with two cases in biology.

The first chapter is particularly worth reading, reminding us of the main ideas of Francis Bacon and Karl Popper regarding the scientific method, although I prefer the elegant summary provided by Bo Anderson back in 1984: "Nature never tells you when you are right but only when you are wrong; therefore, you have only learned something when you disagree with the data." Also, Richard Feynman argued that scientists should carefully report everything they are aware of that could invalidate their measurements or models. Goodstein shows that these laudable



ideas are not really suitable in the real world, to ensure rapid and robust scientific progress. Based on his own experience, he argues that bad theories and the experiments that prove them wrong are "quickly and quietly forgotten". Who has ever received a Nobel prize for showing that a model disagreed with data? After listing "fifteen seemingly plausible ethical principles for science", he systematically reveals their insufficiencies as guidelines to sound scientific conduct and replaces them with a more pragmatic "user's manual" on how to pursue a successful and honest career in science.

I would have liked to have seen more examples of scientific fraud, including cases of fabricated data in biology and medicine, but it is understandable that Goodstein prefers to address cases he knows well. Although a little "Caltech-centric", this is an interesting and easy-to-read book, suitable for relaxing with at the end of the year.
Carlos Lourenço, CERN.

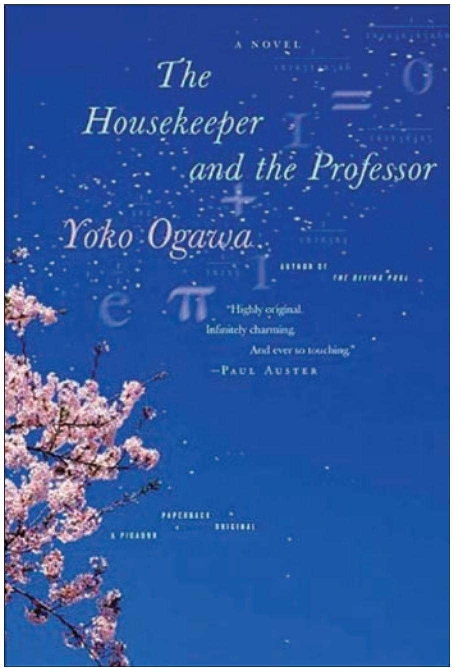
The Miniatom Project: A Science Thriller by Richard M Weiner, CreateSpace. Paperback ISBN 9781451501728, $9.99.

Still looking for Christmas presents? Maybe one for your auntie who still doesn't understand what you find so fascinating about physics? You may have already tried buying her popular science books, but they are sitting on a shelf, unread? Well, here is a book with an interesting basic idea: a novel about a scientist, a young genius with well developed mad streaks, a dramatic death in a computing centre, capable and less capable police forces from various countries, privately funded research organizations, CERN (as we do and don't know it) and a theory. What if one could change the constants of nature? What if, for example, the charge of the electron could be modified in a way that it would have an influence on the size of atoms? Do smaller atoms mean smaller people, and would that solve the world's energy crisis?

Richard Weiner, author and professor of theoretical physics, based at Marburg University in Germany and the University of Paris-Sud, France, thought that this idea was worth exploring – at least in fiction. His first "science thriller", published in 2006 in German and in 2010 in English, first kills scientist Trevor McCallum and then traces his steps from geeky childhood via troubled adolescence to genial research and his last moments before he dies of an improbable surge in computational power. Sounds like good holiday reading?

Well, unfortunately your auntie might not be too impressed because *The Miniatom Project* does not really hold what it promises. While the precept is certainly original and the idea to use it in a novel to engage the non-scientist is laudable, the plot is very constructed, dialogues and characterizations clunky and the tone at times verges on being patronizing. Inconsistencies about CERN and thinly disguised CERN personalities (an attempt at a *roman à clef*?) will not trouble your auntie that much, but the translation is likely to grate with her. CERN certainly is fertile soil for art and fiction of all kinds but *The Miniatom Project* could have done with more editing before going to print.

Barbara Warmbein, DESY.



The Housekeeper and the Professor
by Yoko Ogawa, translated by Stephen Snyder, Vintage Books. Paperback ISBN 9780099521341, £7.99. E-book ISBN 9781409076667, £8.16.

I first came to know the housekeeper, her son and the memory-impaired professor through their roles in an in-flight movie *en route* from Tokyo to Frankfurt. The filmmaking is beautiful and the acting sublime, but the real surprise is the subject matter. This is a story about "Euler's identity", and it carries it off brilliantly, leaving behind a true appreciation of the beauty of numbers. I stepped off the plane wondering if Hollywood could ever do such a thing, and so was happy to discover that at least the novel on which the film was based has an English translation, now available in paperback.

The Housekeeper and the Professor tells the story of a mathematician whose short-term memory following an accident is limited to 80 minutes. He makes his way through the day thanks to Post-it notes, but each morning is a new beginning. It's a story of platonic affection, shared between the professor, his housekeeper and her 10-year-old son and as such is reminiscent of Helene Hanff's *84 Charing Cross Road*. Where it diverges, however, is in its core theme. Rather than through a shared love of books, the protagonists' relationship blossoms by way of mathematics.

Maths is perhaps the most difficult of sciences to popularize. Even Marcus du Sautoy, mathematician and Professor of Public Understanding of Science at Oxford, struggles to convey the beauty of numbers in his engaging BBC documentary, *The Story of Maths*. But where du Sautoy bravely tackles the full story, Ogawa focuses on just one of mathematics' most remarkable equations, $e^{i\pi}+1=0$, gently preparing the reader to understand why this deceptively simple collection of symbols is so extraordinary.

The key to Ogawa's success is the pace of the story, dictated by the fact that the professor begins every day anew. Each morning starts with the same basic conversation, pointing out the significance of a particular number. "What's your shoe size?" asks the professor, for example. "24," comes the reply and the professor goes on to explain that this is the factorial of four. As the conversation develops, we learn that the housekeeper's phone number is the total number of primes between one and 100 million, and a little more maths appears with each conversation.

The square root symbol makes its first appearance as early as the first page – "Root" is what the professor calls the housekeeper's boy. "With this one little sign, we can come to know an infinite range of numbers, even those we can't see," he explains. And sure enough, the square root of –1 makes its introduction two pages later. For e and π, we have to wait until much later.

The maths is never overwhelming, each step being carefully introduced for the benefit of the housekeeper and Root. A shared passion for baseball proves fertile ground for mathematical conversation. We learn, for example, that Babe Ruth's 1935 record of 714 home runs multiplied by its successor (715 set by Hank Aaron in 1974) is equal to the product of the first seven primes and that the sum of the prime factors of 714 and 715 is the same. Because consecutive numbers with this property are rare – there are only 26 such pairs up to 20 000 – they're known as Ruth-Aaron pairs. Mathematics like this weaves its way through the story so that by the time Euler's identity is unveiled, the shock of finding a square root on the first page has been replaced by the pleasure of playing with numbers. Euler's identity is the breathtaking icing on the cake.

The Housekeeper and the Professor is a beautifully told and ultimately touching tale. But perhaps its greatest achievement is that it leaves the reader with a sense of awe at the beauty of numbers.

Yoko Ogawa has published more than 20 works of fiction and non-fiction and won every major Japanese literary prize, says her biography on the Macmillan Publishing website. Two of her novels and a collection of short stories are now available in English. Her non-fiction collaboration with mathematician Masahiko Fujiwara has not yet been translated. Personally, I can't wait.

James Gillies, CERN.