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A bright outlook ahead for DESY

Covering current developments in high-energy physics and related fields worldwide

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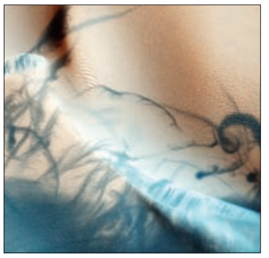
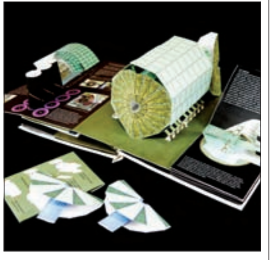
Science takes off at SLAC p6



The beauty of Mars p11



The LHC mysteries unfold p53

Cover: Aerial view of the DESY research centre in the west of Hamburg, the river Elbe in the background. Established in 1959, the laboratory celebrates its 50th anniversary this year (pp15–22). For a more detailed description of the view see the photo on p22. (Courtesy DESY.)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NEWS

LHC NEWS

Protons are back in the LHC

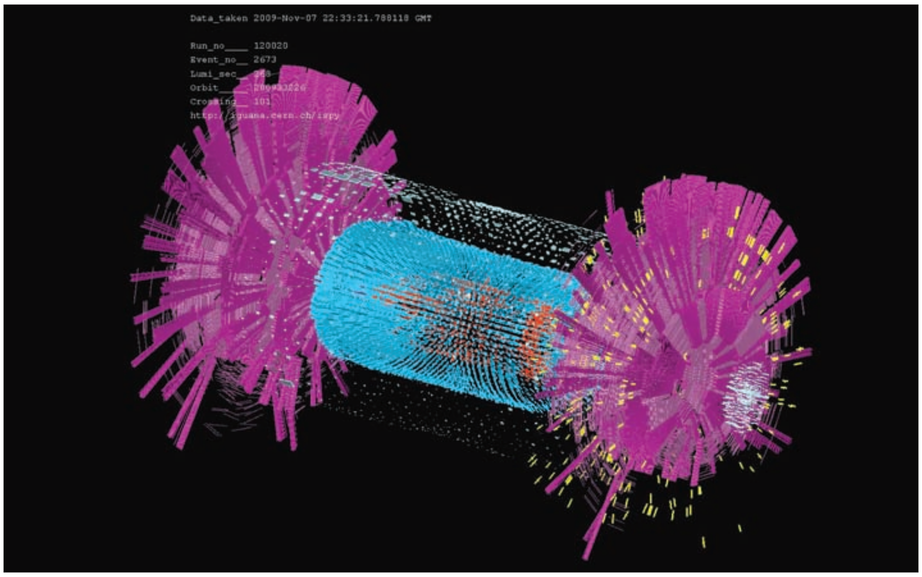
During the last weekend of October, particles once again entered the LHC after the one-year interruption following the incident of September 2008, travelling through one sector in each direction – clockwise and anticlockwise. ALICE and LHCb, the two experiments sitting along the portion of the beam lines in question, were able to observe the effects of beams in the machine. A week later, at around 8 p.m. on 7 November, protons travelling anticlockwise arrived at the doorstep of the CMS experiment, thus completing half of the journey around the LHC.

On 23 October, a first beam of ions entered the clockwise beam pipe of the LHC. Previous tests, on 25–26 September, had involved injecting lead-ion beams through the whole injection chain right up to the threshold of the LHC (*CERN Courier* November 2009 p6). This time, the lead ions entered the LHC just before point 2, where the ALICE experiment is installed, and were dumped before point 3. These tests enabled the machine experts to test the operation of the whole injection chain and an entire sector (sector 1-2) of the LHC.

Several sub-detectors of the ALICE experiment were switched on and saw their first beam. This helped them synchronize with the LHC clock and test the capability of the sub-detectors to measure high particle multiplicities.

During the afternoon on the following day, the first proton beam made its way through the TI8 transfer line up to the anticlockwise beam pipe of the LHC. Protons passed through the LHCb experiment and were dumped just before point 7.

Most of the LHCb sub-detectors were switched off to keep the experiment safe during these delicate operations. Only the beam and background monitors remained switched on, allowing an opportunity for commissioning of the beam-monitoring software. A highlight of the weekend was the switching on of the LHCb magnet, with operators able to measure its effect on the LHC beam and adjust the magnetic compensators around LHCb accordingly to bring the beam back into orbit.



A "beam splash" event in CMS recorded on 7 November, with the beam stopped in collimators to the right, creating close to 1 million muons. Hits in the muon are coloured magenta and yellow, energy deposits on the calorimeters are red blue. The barrel muon detector was on standby and the inner tracking detector remained switched off for reasons of protection.

The first weekend of November saw protons complete their journey anticlockwise through three octants before being dumped in collimators just prior to entry to the cavern of the CMS experiment. The particles produced by the impact of the protons on the tertiary collimators (used to stop the beam) left their tracks in the calorimeters and the muon chambers of the experiment. The more delicate inner detectors remained switched off for protection reasons.

During the same weekend, bunches of protons were also sent in the clockwise direction, passing through the ALICE detector before being dumped at point 3.

Hardware commissioning and magnet-powering tests have also continued in the LHC. By the first week in November, six of the eight sectors had been commissioned up to 2 kA, sufficient to guide a beam at an energy of about 1.2 TeV. Furthermore, the qualification of the new quench-protection system is progressing well, with the measured values complying with the stringent standards.

● CERN publishes regular updates on the LHC in its internal *Bulletin*, available at www.cern.ch/bulletin, as well as on the main site www.cern.ch, via twitter at www.twitter.com/cern and on YouTube at www.youtube.com/cern.

Sommaire

SLAC

Science begins at SLAC's new light source

The first experiments are now under way using the world's most powerful X-ray laser, the Linac Coherent Light Source (LCLS), located at the SLAC National Accelerator Laboratory. With 10 000 million times the brightness of any other man-made X-ray source, the light from the LCLS can resolve detail the size of atoms, enabling the facility to break new ground in research in many fields including physics, structural biology, energy science and chemistry.

The LCLS takes short pulses of electrons accelerated in SLAC's linac and directs them through a 100 m stretch of alternating magnets that force the electrons to slalom back and forth. This motion makes the electrons emit X-rays, which become synchronized as they interact with the electron pulses, thus creating the world's brightest X-ray laser pulse. Each of these laser pulses has 10^{12} X-ray photons in a bunch only 100 fs long.

Commissioning assisted by users is currently under way, with experiments taking place using the Atomic, Molecular and Optical (AMO) science instrument, the first of six instruments planned for the LCLS. In these first experiments, the researchers are using X-rays from the LCLS to gain an in-depth understanding of how the ultrabright beam interacts with matter.

The AMO instrument scientists with the first LCLS users. From left to right: Christoph Bostedt, Steve Southworth, Linda Young, John Bozek, Steve Pratt and Yuelin Li. (Courtesy Brad Plummer, SLAC.)

Early studies are revealing new insights into the fundamentals of atomic physics and have successfully proved the machine's capabilities to control and manipulate the underlying properties of atoms and molecules. Researchers have used the pulses from the LCLS to strip neon atoms completely of all of their electrons. They have also watched for two-photon ionization. This is normally difficult to observe at X-ray facilities, but the extreme brightness of the laser beam at the LCLS makes the study of these events possible.

Future AMO experiments will create stop-action movies of molecules in motion. The quick, short, repetitive X-ray bursts from the LCLS enable experiments to form images as molecules move and interact. By stringing together many such images to make a movie, researchers will be able to watch the molecules of life in action, view chemical bonds forming and breaking in real time and see how materials work on the quantum level.

The LCLS is a testament to SLAC's leadership in accelerator technology. Four decades ago, the laboratory's 3 km-long linear accelerator began to reveal the inner structure of the proton. Now, this same machine has been revitalized for pioneering research at the LCLS. By 2013, all six LCLS scientific instruments will be on-line and operational, providing unprecedented tools for a range of research in material science, medicine, chemistry, energy science, physics, biology and environmental science.

SUPERCONDUCTING MAGNETS

Florida lab is to build high-field 'supermagnet'

The National High Magnetic Field Laboratory at Florida State University has been awarded nearly \$3 million to build a high-temperature superconducting magnet that will break records for magnetic field strength by aiming to reach 32 T. Around 8 km of cable formed from the high-temperature superconductor yttrium barium copper oxide, or YBCO, will go into the construction of the new magnet.

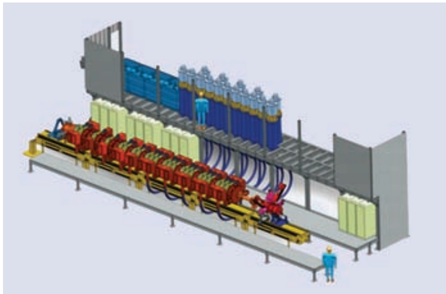
Superconducting magnets are well known in the world of particle accelerators (reaching a field of more than 8 T in the LHC, for example) and in magnetic-resonance imaging in hospitals (with fields of 1–3 T). They are also commonly used in high-field research, where one benefit is that they create more stable fields than do resistive magnets.

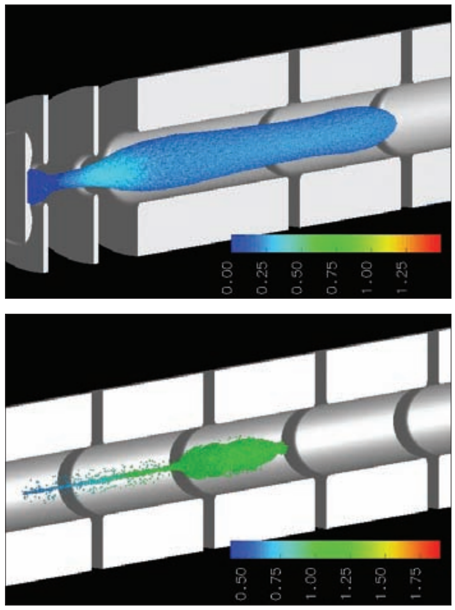
While superconducting magnets use a lot less electricity than their resistive counterparts, they traditionally operate at low temperatures that require costly cryogens. The high-temperature superconductor YBCO produces magnets that are not only cheaper to operate, but ones that do so at magnetic fields above about 23 T, where low-temperature superconducting magnets cease to work.

The construction of the 32 T magnet is funded by a grant of \$2 million from the National Science Foundation and \$1 million from Florida State University. The aim is to develop and demonstrate that technology will allow superconducting magnets to replace the resistive magnets in the National High Magnetic Field Laboratory.

ION BEAMS

NDCX-II project commencing at LBNL





Computer-aided-design picture of NDCX-II (above), and simulation of its ion beam. The ion source and injector are at left; voltage sources (blue) reside on a mezzanine; the induction cells are in yellow-orange; and the drift-compression line and target chamber are at right. Top/bottom right: images (from a 3D simulation video using the Warp code) show the beam at the injector and farther on, undergoing inductive acceleration. (Courtesy NDCX-II Project.)

Construction is beginning on the second-generation Neutralized Drift Compression eXperiment (NDCX-II), a new high-current, modest-kinetic-energy accelerator at Lawrence Berkeley National Laboratory (LBNL). The machine's ion beams will enable studies of the poorly understood "warm dense matter" regime of temperatures around 10 000 K and densities near solid (as in the cores of giant planets). NDCX-II will also allow exploration of important issues in inertial-fusion target physics.

These studies support the ultimate goal of using ion beams to heat deuterium/tritium fuel to ignition in a future inertial fusion power reactor (a role for which accelerators appear well suited). NDCX-II has received $11 million of funding from the American Recovery and Reinvestment Act. Construction began in July with completion of the initial 15-cell configuration anticipated in March 2012.

NDCX-II will accelerate a beam of 30–50 nC of Li^+ ions to 1.5–4 MeV and compress it into a pulse around 1 ns long. The short, high-current pulse is important for applications requiring efficient stopping of ions for rapid heating of a small amount of matter. As with the existing NDCX-I, the new machine uses neutralized drift compression. In this process, the beam's tail is given a higher velocity than its head, so that it shortens while it drifts in a plasma that provides electrons to cancel space–charge forces.

The figure shows the layout of the machine. It will make extensive use of induction cells (accelerating elements) and other parts from the decommissioned Advanced Test Accelerator (ATA) at Lawrence Livermore National Laboratory (LLNL). It will be extensible and reconfigurable. In the configuration that has received the most emphasis, each pulse will deliver Li^+ ions at 3 MeV into a millimetre-diameter spot onto a thin-foil target. Pulse compression to around 1 ns begins in the accelerator and finishes in the drift compression line.

NDCX-II employs novel beam dynamics to achieve unprecedented rapid pulse compression in a short ion accelerator. The 200 kV charged transmission-line pulsed-power voltage sources from ATA, known as "Blumleins", can provide voltage pulses that are not longer than 70 ns. These are shown as blue cylinders in the figure. For them to be usable, it is necessary to reduce the ion bunch duration from its original 500 ns. This shortening is accomplished in an initial stage of non-neutral drift compression, downstream of the injector and the first few induction cells (note the spaces between induction cells at the left end of the figure). Long-pulse voltage generators are used at the front end; Blumleins power the rest of the acceleration.

Extensive particle-in-cell computer simulation studies have enabled an attractive physics design that meets the stringent cost goal. Snapshots from a simulation video are shown in the figure. Studies on a dedicated test stand are examining the ATA hardware and supporting the development of new pulsed solenoids that will provide transverse beam confinement.

Applications of this facility will include studies of warm dense matter using uniform, volumetric ion-heating of thin foil targets, and studies of ion energy coupling into an expanding plasma (such as occurs in an inertial fusion target). NDCX-II will also enable a better understanding of space-charge-dominated ion-beam dynamics and of beam behaviour in plasmas. The machine will complement facilities at GSI in Darmstadt, but will employ lower ion kinetic energies and commensurately shorter stopping ranges in matter.

NDCX-II will contribute to the long-term goal of electric power production via heavy-ion inertial fusion. In inertial fusion, a target containing fusion fuel is heated by energetic driver beams and undergoes a miniature thermonuclear explosion. The largest inertial confinement facility is Livermore's National Ignition Facility (NIF). NIF is expected to establish the fundamental feasibility of fusion ignition on the laboratory scale. Heavy-ion accelerators offer efficient conversion of input power into beam energy, are long-lived, and can use magnetic fields for final focusing onto a target. These attributes make them attractive candidates for a power plant. The beams in such a system will require manipulations similar to those being pioneered on NDCX-II.

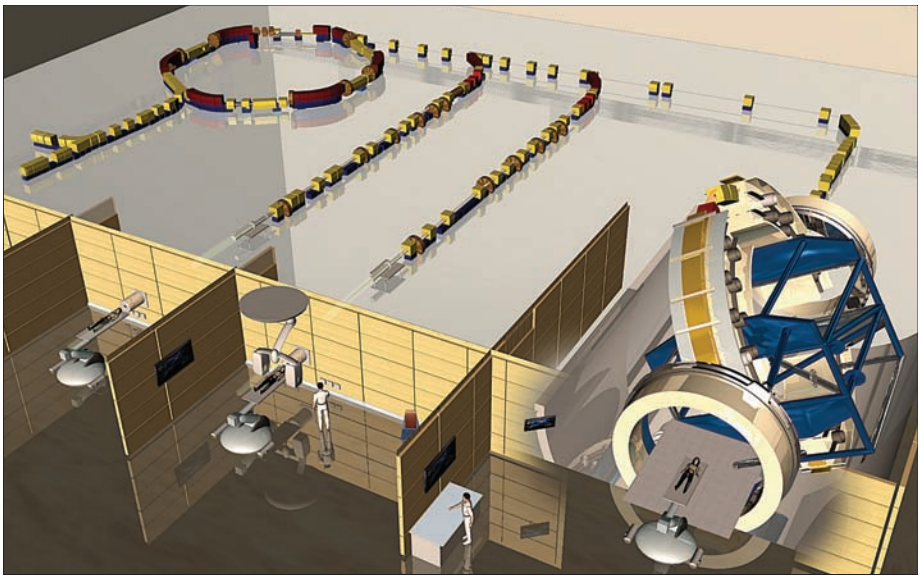
● NDCX-II is sponsored by the US Department of Energy's Office of Fusion Energy Sciences. It is being developed by a collaboration known as the Virtual National Laboratory for Heavy Ion Fusion Science, including LBNL, LLNL and the Princeton Plasma Physics Laboratory.

Further reading

For more information, see http://newscenter.lbl.gov/feature-stories/2009/10/14/warm-dense-matter and references therein. The video can be viewed at http://hifweb.lbl.gov/public/movies/ICAP09.

MEDICAL PHYSICS

Heidelberg Ion Therapy Centre opens



The approximately 5000 m^2 of the HIT accelerator facility at the Heidelberg University Hospital consists of (from left) an ion source in which protons and heavy ions are generated; a synchrotron ring in which the particles are accelerated; and three beam lines, which lead into two horizontal treatment areas, plus a gantry that allows the beam to circle round the patient. (Courtesy HIT.)

The Heidelberg Ion Therapy Centre (HIT) celebrated its opening at the Heidelberg University Hospital on 2 November. Developed with scientists and engineers at GSI in Darmstadt, the novel ion-beam cancer therapy facility is now ready to treat large numbers of patients, some 1300 a year.

HIT uses beams of ions, i.e. positively charged carbon or hydrogen atoms, which penetrate the body and exert their full impact deep within the tissue (*CERN Courier* December 2006 p17). To reach the tumour tissue, the ion beams are accelerated and then steered with such precision that they can irradiate a tumour the size of a tennis ball with millimetre accuracy, point by point. The surrounding healthy tissue remains mostly unaffected, so the method is particularly suited for treating deep-seated tumours that are close to vital or important organs such as the brain stem or the optic nerve.

The new facility has grown out of pioneering work at GSI, which has conducted fundamental research in radiobiology, nuclear physics and accelerator technology for therapeutic uses since 1980. The construction of a pilot ion-therapy project at GSI began in 1993 in a collaboration between GSI, the Heidelberg University Hospital, the Deutsches Krebsforschungszentrum in Heidelberg and the Forschungszentrum Dresden-Rossendorf.

At the same time, plans were made to introduce ion-beam therapy as a regular component of patient care with a new clinical facility at Heidelberg. HIT thus represents a direct transfer of technology from the GSI pilot project, which introduced several innovative techniques. These included: the raster scan method, which allowed tailored tumour irradiation with a carbon-ion beam; an accelerator that permits rapid variation in the energy of the ion beam in order to adjust the penetration depth inside a tumour; a fast control system to steer the ion beam safely inside the patient at millisecond intervals; and monitoring of the irradiation through a positron emission tomography (PET) camera, to make sure the beam hits the tumour.

Since 1997, 440 patients, most of them with tumours at the base of the skull, have been treated with carbon ion beams at the GSI facility. Clinical studies proved the success of the treatment, documenting a cure rate of up to 90%. Ion-beam treatment is now an accepted therapy, with health-insurance providers refunding the costs.

The new treatment centre is operated by the Heidelberg University Hospital, where a special building with a floor space of 60 m × 80 m was constructed to host it. The facility has a 5 m long linear accelerator and a synchrotron with a diameter of 20 m. Three treatment spaces are located adjacent to the accelerators, two of which are a development of technology used at GSI. The third treatment space features a gantry – a rotating ion-beam guidance system – that is a direct advance on the prototype developed at GSI. The gantry allows the ion beam to be aimed at a patient's tumour at any angle, thus greatly enhancing the treatment options.

The ion-beam cancer treatment available at HIT is the first of its kind. Japan is currently the only other country offering ion-beam cancer therapy, but with a less effective irradiation technique. In the scope of a licence agreement between the GSI and Siemens AG, two more facilities modelled on HIT are under construction in Marburg and Kiel.

SCIENCEWATCH

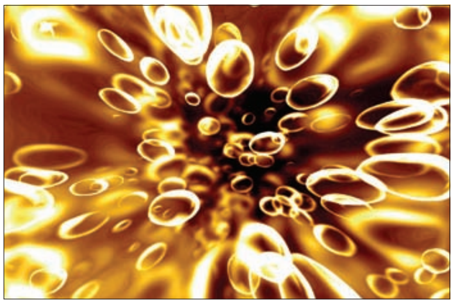
Compiled by John Swain, Northeastern University

Researchers discover how we sense the taste of bubbles

The pleasure that everyone finds in drinking carbonated beverages – especially in the festive season! – is often attributed to mechanical agitation of the tongue caused by the bubbles. However, it is actually an effect caused by the carbon dioxide itself and researchers in the US have identified in the laboratory the fizz-detecting cells and the enzyme that make it all possible.

Jayaram Chandrashekar of the University of California, San Diego, and colleagues used a combination of electrophysiological measurements and genetic manipulation to show that the fizz detectors are in sour-sensing cells in the tongue. They are based on an enzyme, carbonic anhydrase 4, that turns carbon dioxide in water into a bicarbonate ion and a proton.

The enzyme is one of several targeted by acetazolamide, a drug used to protect against altitude sickness. Back in 1988 users had noted that it made fizzy beverages taste flat, thus making drinking champagne at the tops of high mountains a disappointment for anyone taking the drug.



Bubbles taste better thanks to our fizz detectors. (Courtesy Bram Janssens/Dreamstime.com.)

Further reading

J Chandrashekar *et al.* 2009 *Science* **326** 443.

Optical diodes

Photonic crystals are materials with bandgaps, which do not allow certain wavelengths of light to pass. Just as bandgaps in semiconductors forbid electrons to have certain energies, is it possible to construct a photonic analogue of a diode?

Zheng Wang of MIT and colleagues there and at Yale University have done just this. They constructed an array of magneto-optical ferrite rods placed in a magnetic field in such a way that microwaves passing in one direction were not allowed to propagate, while those moving the other way went through unimpeded, with a difference of 50 dB in the two directions.

Apart from the novelty of the physics involved, the work also suggests the possibility of novel optical fibres with hollow cores surrounded by materials of the kind described above. Having no material inside, they could allow very long-range transmission without repeaters.

Further reading

Z Wang *et al.* 2009 *Nature* **461** 772.

More insulating than the vacuum

A hot object radiates heat into the surrounding space so it might be tempting to think that nothing would be less conducting than empty space. Nevertheless, Shanhui Fan of Stanford University and colleagues have found something even less able to conduct heat – and it contains matter.

The idea is simple: a suitable photonic crystal opaque to a band of infrared could actually block more heat flow than pure nothing. At or above room temperature, a stack of 10 silicon layers, each 1 μm thick and separated by 90 μm gaps of vacuum, would have a thermal conductance half that of empty space, with the possibility of countless future applications.

Further reading

W T Lau *et al.* 2009 *Phys. Rev.* **B80** 155135.

Massive neutrinos and CNB timescales

There is plenty of evidence that neutrinos have mass, so what could it reveal about the cosmic neutrino background (CNB) – the neutrino analogue of the cosmic microwave background (CMB)? With massless neutrinos, studies of the CNB would peer farther back in time (to about a second after the Big Bang) than researchers "see" with microwave photons (380 000 years after the Big Bang). Massive neutrinos go slower than the speed of light and, over timescales comparable to the age of the universe, that makes a big difference.

Scott Dodelson of Fermilab and Mika Vesterinen of the University of Manchester have shown that the CNB originates from a distance of 1–10 billion light-years – less than the 40 billion light-years for the origin of the CMB, taking into account the expansion of the universe. This implies that the neutrinos of the CNB come from regions where there is now interesting astronomical data and could, if measurable, provide valuable information about what seeded the formation of distant galaxies and clusters of galaxies.

Further reading

Scott Dodelson and Mika Vesterinen 2009 *Phys. Rev. Lett.* **103** 171301.

Molecular flasks

Chemical reactions often proceed via highly unstable intermediates with lifetimes that are too short for techniques like X-ray crystallography to be usable. Now Takehide Kawamichi and colleagues of the University of Tokyo have found a solution. Their technique uses the tiny spaces in highly porous materials as molecular flasks, which slow the reactions due to steric (space restriction) effects. Cooling to cryogenic temperatures and reheating can effectively start and stop reactions and opens up the possibility of making movies of reactions. Using a reaction between an amine and an aldehyde the team observed the intermediate hemiaminal and determined its structure.

Further reading

T Kawamichi *et al.* 2009 *Nature* **461** 633.

Compiled by Marc Türler, ISDC and Observatory of Geneva University

VERITAS observes the origin of cosmic rays

The detection of very-high energy (VHE, E> 100 GeV) gamma-rays from the starburst galaxy Messier 82 (M82) by the Very Energetic Radiation Imaging Telescope Array System (VERITAS) may help solve a 100-year-old mystery on the origin of cosmic rays. It provides new evidence for cosmic rays being powered by exploding stars and stellar winds.

The sensitivity to VHE gamma-rays of the current generation of Cherenkov telescope arrays has opened a new era in the study of cosmic rays. The gamma-rays are produced by the interaction of cosmic rays – particles that zip through space at nearly the speed of light – with interstellar matter and ambient radiation. As the induced gamma-rays are not deflected by magnetic fields in the galaxy, they have the advantage of pointing back to their production sites.

The detection of VHE gamma-rays from the rim of the supernova remnant RX J1713.7-3946 by the High Energy Stereoscopic System (HESS) was already strong evidence for cosmic-ray acceleration in the shock wave launched by the supernova explosion (*CERN Courier* January/February 2005 p30). Another piece of evidence now comes from VERITAS, the northern hemisphere analogue to HESS. The array of four 12-m Cherenkov telescopes located in Arizona was pointed towards the "Cigar Galaxy" M82 for 137 hours between January 2008 and April 2009. This exceptional observation effort finally paid off with a firm detection (4.8σ) of this galaxy located 12 million light-years away in the direction of the constellation Ursa Major, near the well known Big Dipper or Plough. M82 was a prime target for VERITAS because it was predicted to be the brightest starburst galaxy in terms of gamma-ray emission and was out of reach for HESS, located too far south in Namibia.

Composite image of the starburst galaxy M82 obtained with the Hubble, Spitzer and Chandra space telescopes. X-ray emission by Chandra (blue) and infrared light from Spitzer (red) complement Hubble images of ionized hydrogen emission (orange) and visible light (yellow-green). (Courtesy NASA, ESA, CXC and JPL-Caltech.)

VERITAS observed less than one gamma-ray photon from M82 an hour. With only 91 events, the spectrum of the VHE emission is quite poorly determined. It was, however, found that both the intensity and the photon index ($\Gamma = 2.5 \pm 0.8$) in the 0.9–5 TeV range are consistent with a recent model prediction for M82. In this energy range, the dominant contributors to the VHE gamma-ray emission are supposed to be inverse-Compton scattering from cosmic-ray electrons and the decay of neutral pions originating from the interaction of ions (mostly protons) with atoms in the interstellar medium. The inferred density of cosmic rays in the central core of M82 is about 500 times that on average in the Milky Way. The Hubble telescope revealed that this region of about 1000 light-years in diameter contains hundreds of young, massive star clusters. The wind of the most massive stars and a supernova rate 30 times higher than in our galaxy are supposed to accelerate enough cosmic-ray particles to produce the VHE gamma-ray radiation observed in M82.

Until now, the only sources of VHE gamma-rays detected outside the Milky Way were active galactic nuclei, where the observed radiation is supposed to be emitted by a relativistic jet launched by a super-massive black hole. The detection of the non-active galaxy M82 – as well as that of NGC 253 reported in September by the HESS collaboration – is a new breakthrough for Cherenkov telescope arrays.

Further reading

HESS collaboration, Acero *et al.* 2009 *Sciencexpress*, DOI:10.1126/science.1178826.

VERITAS Collaboration 2009, *Nature*, in press, doi:10.1038/nature08557.

Picture of the month

This is not body art, nor an evocation of the *Star Wars* planet "Tatooin", but a true colour view of sand dunes on Mars. This amazing image was taken by the High Resolution Imaging Science Experiment (HiRISE) camera on NASA's Mars Reconnaissance Orbiter. The region shown is about 1 km across and is located in the centre of a large crater at mid-northern latitude on Mars. The graceful grey swirls are caused by dust devils frequent in deserts on both Earth and Mars. These kind of mini-tornadoes remove locally a thin layer of reddish sand covering the dark grey basaltic ground of the crater. The aligned grey lines in the bottom part of the image are probably caused by sand sliding down the dune face again, revealing the darker colour of the basaltic sand in the crater. (Courtesy NASA/JPL/University of Arizona.)

CERN COURIER ARCHIVE: 1966

A look back to *CERN Courier* vol. 6, December 1966, compiled by Peggie Rimmer

CERN COUNCIL

The science behind the 300 GeV project

A report on the "status of the project for a European 300 GeV proton synchrotron" was presented to the CERN Council at its December meeting. The following extracts are from the sections covering the scientific background to the proposal.

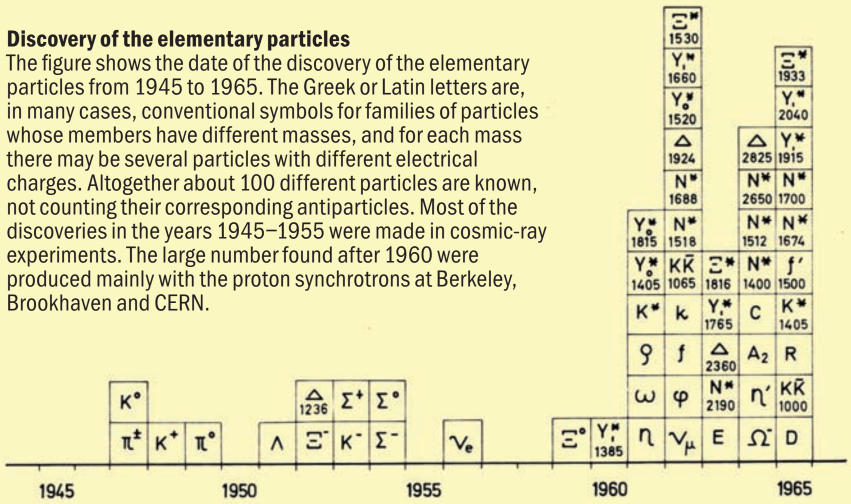
Up to now, the most significant discovery in high-energy physics is that the proton, neutron and electron are not the only basic particles of nature. There are many more – difficult to observe because, when produced, they disintegrate almost immediately. But they are as important as the proton, neutron or electron when one tries to understand the nature of the strong and weak forces.

The first of these new, highly unstable particles were discovered in cosmic rays. The high-energy accelerators constructed in the last 15 years have revealed the existence of close to a hundred more. These have often been called elementary particles – a name that is getting more and more questionable as their properties are better known.

As the list of the known particles grew, their astounding variety at first created bewilderment and discouraged systematic interpretations. Quite remarkably, however, the last five years have brought us to the stage where the very multiplicity of particles has revealed a novel order, characterized by well defined mathematical principles of symmetry (usually denoted by the symbols SU_3 and SU_6). Particles that, at first sight, are completely different from each other have now been recognized as belonging to the same family and as having deep-lying similarities. The proton and neutron cannot be understood separately, they are only two members of a larger family containing perhaps 18 particles. Also, the interpretation of the strong and weak forces is profoundly affected by these new principles of symmetry, which allow single interpretations of experimental facts that would have been wholly unrelated a few years ago. Finally, most physicists now tend to believe that the new symmetries may be the manifestation of a remarkable internal structure of the proton, neutron and many other particles, which were earlier regarded as elementary. If this is true, the proton may contain even more fundamental objects (for which the name of "quark" has been proposed) – a fact that would open up once more completely new viewpoints in physics.

It is in the light of this general development that the significance of the 300 GeV project can best be evaluated. Large-scale improvement and extension programmes have been undertaken to increase the potentialities of the CERN and Brookhaven proton synchrotrons. These will ensure that the advanced positions reached by Europe and the USA can be maintained for some 10 years. But the next step must be prepared now, because projects on this scale take a decade to construct and bring into use. The community of particle physicists agrees that this step consists of building much larger proton synchrotrons – such machines have the advantage of offering simultaneously higher energies and higher beam intensities. Thus, the USSR is approaching completion of a 70 GeV proton synchrotron and the USA is preparing the final decision to build a 200 GeV proton synchrotron. In Europe, both ECFA (the European Committee for Future Accelerators) and the Scientific Policy Committee of CERN have agreed that the 300 GeV proton synchrotron, with its higher energy compensating its longer construction time, would provide our continent with a suitable instrument to take over in the second half of the next decade.

● Compiled from the article on pp231–233.



Discovery of the elementary particles
The figure shows the date of the discovery of the elementary particles from 1945 to 1965. The Greek or Latin letters are, in many cases, conventional symbols for families of particles whose members have different masses, and for each mass there may be several particles with different electrical charges. Altogether about 100 different particles are known, not counting their corresponding antiparticles. Most of the discoveries in the years 1945–1955 were made in cosmic-ray experiments. The large number found after 1960 were produced mainly with the proton synchrotrons at Berkeley, Brookhaven and CERN.

COMPILER'S NOTE

The article quoted a statement by Nobel Laureate Edwin McMillan to the US Joint Committee on Atomic Energy, 1965: "In no case in the past have scientists been disappointed in the results following an increase in available energy."

The 300 GeV Super Proton Synchrotron (SPS), finally built at CERN, made available not only an increase in energy but also an impressive variety of physics. Planned as a 300 GeV proton accelerator, a beam energy of 400 GeV was announced within minutes of turn-on in 1976. In 1981 it was transformed into a proton–antiproton collider, where the W and Z were discovered. In the 1990s it alternated between providing 20 GeV electrons and positrons for the Large Electron–Positron Collider (LEP), and accelerating heavy ions to energies well beyond 100 GeV per nucleon. While the Standard Model was being tested with outstanding precision in LEP collisions, Big Bang matter – the quark-gluon plasma – was being created in fixed-target experiments.

Today the SPS is accelerating protons to 450 GeV on their way to the LHC, designed to reach 7 TeV per beam – another energy increase that will surely not disappoint, whatever the results.

DESY marks 50 years of accelerator research

When DESY was founded in December 1959 as a German national laboratory for high-energy physics, it was far from obvious that it would develop from its modest beginnings into a research centre with an international reputation that now extends beyond particle physics to photon science.

The first five chairmen of the DESY directorate, photographed in 1993. From left: Herwig Schopper (1973–80), Wolfgang Paul (1971–73), Willibald Jentschke (1959–70), Volker Soergel (1981–93) and Bjørn Wiik (1993–99). (Courtesy DESY.)

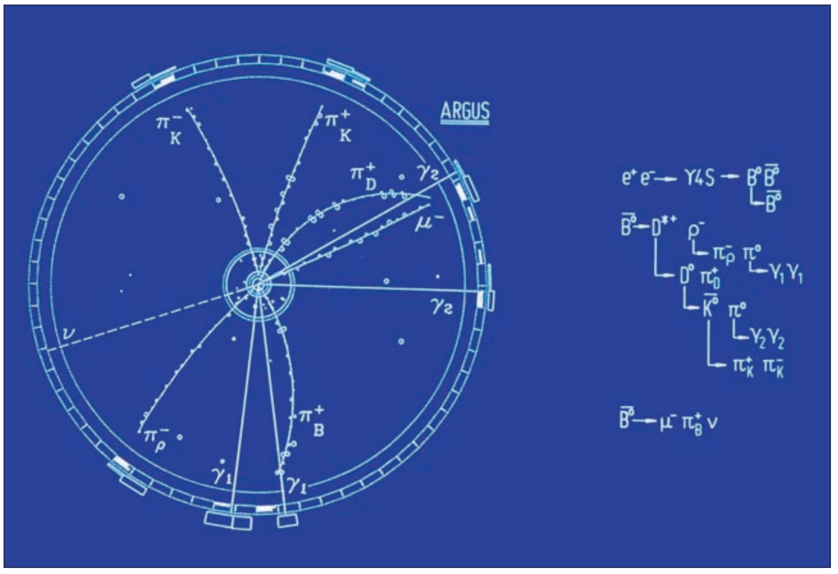
The founding father of DESY, Willibald Jentschke, was a Viennese nuclear physicist who had built a successful career in the US by the time he accepted a professorship at Hamburg University in 1955. He arrived with a plan to build a substantial laboratory for which he managed to secure unprecedented start-up funding worth about €25 million in today's money. Jentschke discussed his ideas with leading German nuclear physicists, including Wolfgang Gentner, Wolfgang Paul and Wilhelm Walcher, at the 1956 Conference on High-Energy Particle Accelerators at CERN. Together they conceived the idea to create a laboratory serving all German universities, thus making good use of Jentschke's "seed money". This would enable German physicists to participate in the emerging field of high-energy physics where similar laboratories were planned or already in existence in other European countries. With the backing of influential personalities such as Werner Heisenberg and the firm support of the authorities of the City of Hamburg, the plan eventually materialized and Jentschke became the first director of the Deutsches Elektronen-Synchrotron, DESY, which came into being in December 1959.

DESY's founders wisely opted for a 6 GeV electron synchrotron – the highest electron energy they could expect to reach with contemporary technology. In this way the machine would be complementary to CERN's proton accelerators, the Synchrocyclotron and the Proton Synchrotron. The DESY synchrotron started operations in 1964. At the time, physics with electron and photon beams was considered a niche activity, but under Jentschke's direction DESY managed to perform new and beautiful measurements of the nucleon form factors and the photoproduction of hadrons. It also earned renown for having "saved QED", with an experiment led by Sam Ting that corrected earlier results from the US on wide-angle electron-pair production.

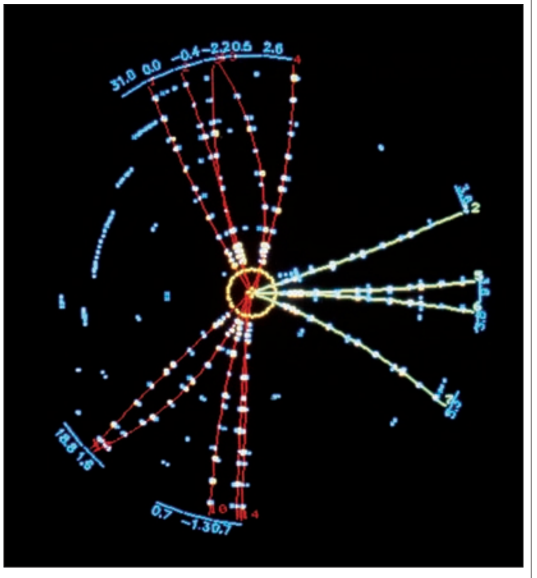
In the early 1960s, the laboratory developed plans to build a large electron–positron storage ring. The motivation was to try something new, but the physics prospects did not appear exciting. Few people at the time took quarks seriously, so the physics community expected hadron production to be dominated by time-like form factors and to decrease dramatically with energy. It was a bold move to base the future of DESY on electron storage rings as the main facility to follow the synchrotron. After controversial discussions, the laboratory nevertheless took the step towards an uncertain future: the construction of DORIS, a two-ring electron–positron collider with 3 GeV beam energy, began in 1969.

Exciting times

Good news followed with the discovery at the storage rings Adone in Frascati and the low-beta bypass of the Cambridge Electron Accelerator in Massachusetts that cross-sections for electron–positron collisions decrease only mildly with increasing energy. This was finally interpreted as evidence for quark–antiquark pair production and went a long way in establishing the quark model. The bad news was that beam instabilities, in particular in two-ring storage machines, were much stronger than expected; moreover, SPEAR, the simpler one-ring machine at Stanford, had started up some years before DORIS. So the J/Ψ and the τ-lepton were found at SPEAR. The experiments at DORIS were nevertheless able to contribute substantially towards charm spectroscopy, for example by discovering the P-wave states of charmonium and finding evidence for leptonic charm decays. The real opportunity for DORIS came later, however, after the discovery of the b quark in 1977. DESY ▷



An event recorded by the ARGUS detector at the DORIS storage ring shows the decay of the Υ(4S) resonance into a pair of B mesons, identified by their decay. This is evidence of B–$\bar{B}$ mixing. (Courtesy DESY.)



A three-jet event, registered at the PETRA storage ring; such events were a direct evidence for the existence of gluons. (Courtesy DESY.)

made a big effort to upgrade DORIS in energy so that B mesons could be pair produced. The experimenters were able to perform a rich programme on the physics of the B particles, culminating in 1987 in the discovery of the mixing of neutral B mesons.

Plans for a bigger ring surrounding the whole DESY site were already under discussion during the construction of DORIS, and the discovery of the J/ψ in November 1974 provided the final impetus. Under the guidance of the director at the time, Herwig Schopper, and an energetic accelerator division leader, Gustav-Adolf Voss, PETRA – an electron–positron collider with an initial centre-of-mass energy of 30 GeV – was completed in 1978, far ahead of schedule and below budget. PETRA was later upgraded to 46 GeV and, for the eight years of its lifetime, was the highest-energy electron–positron collider in the world. The year 1979 saw the first observation of three-jet events at PETRA, leading to the discovery of the gluon and a measurement of its spin. Other important results concerned the comparison of the production of quark and gluon jets with the predictions of QCD perturbation theory to second order, leading to a measurement of the strong coupling constant α_S and the first measurements of electroweak interference in muon- and τ-pair production.

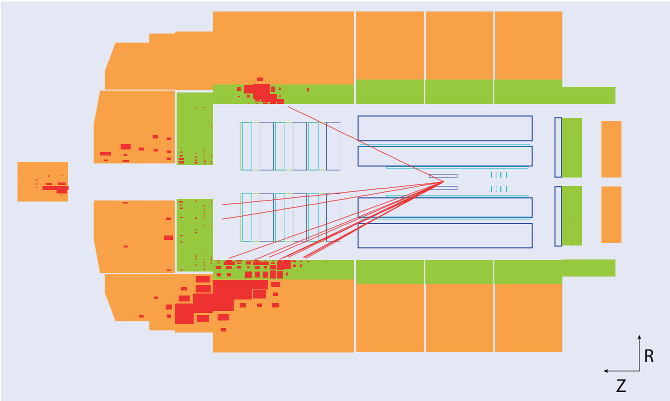
It was an exciting time in which experimenters and theorists worked together closely on the new fields that PETRA had opened up. By the time the experiments were completed in 1986, they had contributed greatly to establishing the Standard Model as a generally accepted theory. With PETRA, DESY had grown into a leading centre for particle physics, reflected by the international nature of its user community, with as many as 50% of the visiting scientists coming from outside Germany.

So what was to come after PETRA? As a guiding principle, complementarity with the programme at CERN had always been central to DESY's strategy. So, when CERN opted for the Large Electron–Positron (LEP) collider, the next big project for DESY became HERA – the world's only electron–proton collider. Bjørn Wiik had been pursuing plans for such a machine for years and these gathered full momentum when Volker Soergel became DESY's director in 1981. Together, Wiik and Soergel succeeded in convincing colleagues and funding agencies in Canada, France, Israel, Italy and the Netherlands to contribute to HERA as a joint project through the provision of machine components to be manufactured by the respective home industries or laboratories. In addition, physicists and technicians from universities and institutes not only in Germany but in many other countries, foremost China and Poland, came to DESY to participate in the construction of the machine. Eventually almost half of the manpower used to build HERA was from outside DESY. This "HERA model" of how to realize a big accelerator facility became an outstanding success. HERA was also unique in being situated underground in a residential area, but it took little more than six years from the start of construction to obtain the first electron–proton collisions at the full centre-of-mass energy of 300 GeV, in 1991. Two big detectors, H1 and ZEUS, started taking data immediately; HERMES and HERA-B followed a few years later.

Further expansion

HERA was operated successfully until 2007. While spectacular "new physics" failed to appear, the experiments revealed the structure of the proton with unprecedented beauty. Their results will define our knowledge of the nucleon for the foreseeable future and will be invaluable for interpreting the data from the LHC experiments (*CERN Courier* January/February 2008 p30 and p34); they also offer some of the most precise tests yet of QCD and of the electroweak interaction.

Wiik succeeded Soergel as DESY's director in 1993 and he soon initiated another vision: TESLA, a linear electron–positron collider of 500 GeV centre-of-mass energy employing superconducting accelerating cavities. It would, at the same time, provide the beam for an X-ray free-electron laser. An international collaboration was formed to develop the project and it had made substantial progress when, in 2003, a decision by the German government forced a drastic change of plan. While the government agreed to the realization of the X-ray free-electron laser part of the project within an international framework, it did not at the time support building the high-energy



A deep inelastic electron–proton scattering event, recorded by the H1 detector at HERA. The proton beam comes from the right, the electron beam from the left. The electron is back-scattered off a quark inside the proton and emerges to the left upwards. The quark is knocked out of the proton and produces a shower at the lower left. (Courtesy H1/DESY.)

A view inside the 6.3 km tunnel of HERA shows the superconducting magnets – used to guide the proton beam – installed above the normally conducting magnets of the electron ring. (Courtesy DESY.)

Measuring station in the experimental hall of the new PETRA III synchrotron radiation source at DESY – one of the most brilliant storage-ring-based X-ray sources in the world. (Courtesy Dominik Reipka, Hamburg.)

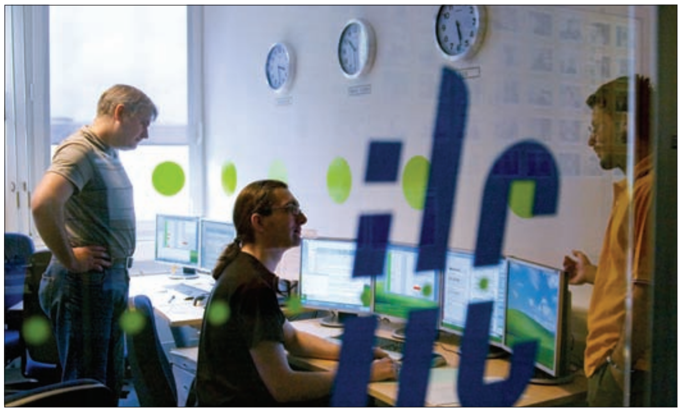
collider in Hamburg and decided to await the course of international developments before recommending a site for the collider. The German government did, however, renew its support for R&D work for a linear collider, which enabled DESY to proceed with this and maintain its involvement in the international co-ordination and decision process. By endorsing the realization of one of the world's most powerful X-ray lasers in the Hamburg area, this decision in effect contributed to strengthening the second "pillar" of DESY's research: photon science.

Photon science – a modern term for research with synchrotron and free-electron laser radiation – was not new to DESY. On the initiative of research director Peter Stähelin, DESY had already built laboratories and instruments for utilizing synchrotron radiation at the original synchrotron and had made them available to a wide community of users in the 1960s. Later, the storage ring DORIS offered a continuous beam with much improved conditions, in particular for X-rays. The quality was enhanced further by insertion devices such as wigglers and undulators. In 1980 DESY created HASYLAB, a big laboratory to provide the growing community of users with all of the facilities they required. The research spanned a wide area, from materials science, physics, chemistry and geology to molecular biology and medical applications. Among the most active users were the European Molecular Biology Laboratory (EMBL) – which operated its own outstation at DESY – and special groups that the Max Planck Society established for applying the synchrotron radiation at DESY to research in structural biology. One prominent Max Planck group was led by Ada Yonath from the Weizmann Institute in Israel, who won the 2009 Nobel Prize in Chemistry for unravelling the structure of the ribosome. Part of this work was done with the help of synchrotron radiation from DORIS.

In 1993, after an upgrade with additional insertion devices, DORIS became entirely dedicated to the generation of synchrotron radiation and, with more than 40 beamlines, became a leading X-ray facility. By 1995 PETRA's performance as a pre-accelerator for HERA was so smooth that this machine could also be used as a source for hard X-rays. The rising demand for such beams led to the rebuilding of PETRA as a dedicated synchrotron-radiation source, once the operation of HERA ceased in 2007. PETRA III was completed in 2009 together with a large new experimental hall (*CERN Courier* September 2008 p19). As one of the most brilliant light sources of its kind, it will be a world-leading facility for research with hard X-rays and provide high intensity for very small probes.

The big challenge for the DESY accelerator experts in the forthcoming years will be the construction of the X-ray free-electron ▷

The 30 m-long undulator of the FLASH free-electron laser at DESY, the only such facility to produce high-intensity, ultrashort radiation pulses in the vacuum ultraviolet and soft X-ray wavelength range down to 6.5 nm. (Courtesy Manfred Schulze-Alex, Hamburg.)



The new CMS and ILC control rooms at DESY allow the operation and data-taking of CMS to be monitored as well as ILC test experiments at CERN and Fermilab to be run remotely from Hamburg. (Courtesy Barbara Warmbein, DESY.)

laser, the European XFEL. Having grown out of the TESLA project, this 3 km-long facility will be equipped with superconducting accelerating cavities and precision undulators. It will allow users to study dynamic processes with atomic-scale resolution in space and time, opening exciting research opportunities. A similar but smaller self-amplifying spontaneous-emission laser, FLASH, has already been operating at DESY for a few years. It generates ultrashort laser pulses of vacuum-ultraviolet and soft X-ray radiation and is in high demand by experimenters because of its unique properties (*CERN Courier* January/February 2007 p8).

With around 2000 users, photon science is now a major activity at DESY. No longer having a high-energy accelerator on site, DESY's particle physicists have turned to the LHC and become partners in the ATLAS and CMS collaborations. This revives a tradition, as in past decades, of DESY physicists participating strongly in experiments at CERN, such as with bubble chambers and muon beams. DESY is also setting up a National Analysis Facility – a computing and analysis platform for LHC experiments. Studies relating to a possible International Linear Collider (ILC), which will make use of superconducting cavities as developed for TESLA, also remain on the agenda. DESY has formed a close relationship with the German universities and institutes that are involved in the LHC or the ILC studies within the national Helmholtz Association alliance, "Physics at the Terascale", which extends to theoretical particle physics and cosmology (*CERN Courier* May 2008 p11). The DESY theory group is also strongly engaged in lattice calculations.

In 1992 the Institute of High-Energy Physics of former East Germany, in Zeuthen near Berlin, became part of DESY. Besides its involvement in high-energy-physics experiments, particle theory and the development of electron guns for free-electron lasers, the institute brought astroparticle physics into DESY's programme. DESY Zeuthen is currently a strong partner in the construction of the 1 km^3 IceCube neutrino telescope at the South Pole, which should soon deliver results (*CERN Courier* March 2008 p9).

In its 50th year, with the prospect of photon sources of unprecedented quality, an active role in particle and astroparticle physics and the involvement of a wide international scientist community, DESY is looking forward to a continuing bright future.

Further reading

For more about the 50 years of DESY, see Erich Lohrmann and Paul Söding *Von schnellen Teilchen und hellem Licht, 50 Jahre Deutsches Elektronen-Synchrotron DESY*, Wiley-VCH Weinheim (2009).

Résumé

DESY : cinquante ans de recherche sur les accélérateurs

DESY, fondé en 1959, est un laboratoire allemand de physique des hautes énergies, devenu un centre de recherche de réputation internationale. Son domaine ne se limite pas à la physique des particules, puisqu'il travaille aussi sur la « science des photons » – des recherches pour lesquelles il utilise des rayonnements produits par les synchrotrons et les lasers à électrons libres. Au fil des années, les recherches en physique des particules sont passées du synchrotron initial de 6 GeV au collisionneur électron–positon PETRA, et enfin au collisionneur électron–proton HERA. Pour l'avenir, le grand défi pour les experts des accélérateurs de DESY sera la construction de l'installation européenne XFEL, un laser à électrons libres à rayons X, de 3 km de long, exploitant la technologie supraconductrice.

Erich Lohrmann *and* **Paul Söding**, *DESY.*

Looking back on DESY: a personal recollection

Albrecht Wagner, former director of DESY, recalls his 35-year relationship with the laboratory, from the early days at DORIS to current work towards a future linear collider.

DESY came to my attention for the first time in 1963 through a poster advertising its new summer student programme. Although I did not go to Hamburg that summer, this triggered my awareness of the laboratory. It took 11 more years before I finally went there, as a member of a group from Heidelberg, to work on the electron–positron storage rings, DORIS and then PETRA. It was 1974, the year of the discovery of the J/Ψ and it was in the midst of the related "November revolution" that DORIS started to provide its first collisions. The contributions that this machine was able to make in the understanding of the properties of the bound states of the charm and anti-charm quarks, as well as in the mass measurement of the τ-lepton, created a very stimulating atmosphere – which became the springboard for the next DESY project, the 2.3 km-circumference storage ring, PETRA.

PETRA, originally proposed as a proton–electron collider, was quickly converted into a positron–electron collider. Approved in 1976, it was built in the record time of two years and eight months, while staying 20% under the original budget. With the PETRA experiments being realized in international co-operation, DESY for the first time became a truly international laboratory and laid the foundation for its future development. The main drivers at DESY at that time were Herwig Schopper, Gustav-Adolf Voss, Erich Lohrmann and the many scientists, engineers and technicians from DESY, Germany and the partners abroad. For DESY, this international flavour was new and stimulating. The scientific programme for PETRA was broad, but interestingly enough did not contain what was to become the machine's major highlight – the discovery of the gluon.

It was while working on JADE, one of the four experiments at PETRA, that I lived through the worst moment of my professional career, when early in 1979 the beams were lost in the middle of the detector, breaking many wires of the "jet" chamber on which I was working. But I also experienced extremely exciting, hard-working and very rewarding moments while trying to establish the true nature of the 3-jet events that proved to be the gluon's signature. The scientific success of PETRA, and with it JADE, was paradoxically the reason for me to leave DESY in around 1980 – to work on the next electron–positron collider, the 27 km LEP at CERN. There I joined the OPAL experiment, the big brother of JADE.

Albrecht Wagner, DESY director from 1999 to 2009, standing in the 6.3 km-long HERA tunnel. (Courtesy Rüdiger Nehmzow, Düsseldorf.)

I was called back to Hamburg, the university and DESY just as the hadron–electron storage ring, HERA, was getting ready to operate in 1991. HERA was built by three great personalities: Volker Soergel, Bjørn Wiik and (again) Gustav-Adolf Voss. This time not only the experiments but also the accelerator had been built through international collaboration, in a very successful way that became known as the "HERA model". Although I had moved from working on an experiment to science management, I kept close contact with the experiments and the physics at HERA. When HERA operations came to a close in 2007, we could look back on an impressive and unique harvest of scientific results, from the structure of the proton to the properties of the fundamental forces. Only one wish had not come true, the discovery of the unforeseen.

New technology

Around 1990, work on linear colliders started around the globe inspired by the continuing success of electron–positron colliders. It had become clear that circular machines would no longer be feasible and that a new concept with many challenges had to be tackled. By the mid-1990s DESY decided to concentrate on superconducting accelerator technology and the TESLA collaboration was formed with many international partners. Combining the world know- ▷

how in this area, the collaboration made major progress in raising acceleration gradients and also solved many other problems. To put the technology to the test under realistic conditions, the collaboration built the TESLA Test Facility (TTF) at DESY, which demonstrated the feasibility of the technology and its reliable operation.

At a major meeting in 2001, the collaboration presented a proposal for a 500 GeV linear collider with an integrated X-ray laser (XFEL), to be realized as an international project at DESY. Two years later, the German government decided to approve the XFEL, together with the conversion of PETRA into a synchrotron light source, and to fund continuing R&D for a linear collider. At the same time the TTF was turned into FLASH, a soft X-ray laser facility for science and a test-bed for future linear-collider work. In the same year the International Committee for Future Accelerators unanimously decided that the technology for the linear collider, now called the International Linear Collider, should be based on superconductivity. Together with its partners from the TESLA Collaboration, DESY thus continues to be one of the main players in the R&D work for the next major project of particle physics.

I have focused mainly on the particle physics aspect of DESY. At the same time, however, the lab has been a pioneer in the generation and use of synchrotron radiation. First experiments started in 1964 and the Hamburg Synchrotron Radiation Laboratory (HASYLAB) was founded in 1977 around DORIS – still the work horse, serving more than 2000 scientists a year. Today, with the new light sources PETRA III and FLASH, and as host for the European XFEL, DESY is building and operating a remarkable suite of new tools for photon science.

As a former director of DESY, I am delighted that the laboratory, despite its age, has remained young, flexible, ambitious and successful on a world scale. I hope for DESY, my former colleagues, and all of the guest scientists, that the same can be said in another 50 years.

Résumé

DESY : Albrecht Wagner se souvient…

Albrecht Wagner, ancien directeur de DESY, évoque ici ses 35 ans de relations avec ce laboratoire. Il y a travaillé pour la première fois en tant que physicien des particules, aux anneaux de stockage électron–positon (installation DORIS). Puis il est passé à l'expérience JADE auprès du collisionneur PETRA. Ensuite, après une dizaine d'années passées à l'expérience OPAL au CERN, il est revenu à DESY en 1991, juste au moment où le collisionneur HERA était sur le point de démarrer. Au cours de son expérience de directeur, il a vu le laboratoire prendre un rôle de premier plan dans la technologie des accélérateurs supraconducteurs, qu'il s'agisse de lasers à électrons libres à rayons X, ou d'un projet de futur collisionneur linéaire international.

Albrecht Wagner, *DESY.*

Insight starts here at DESY

DESY's director, **Helmut Dosch**, takes a look at the bright future in store for the laboratory.

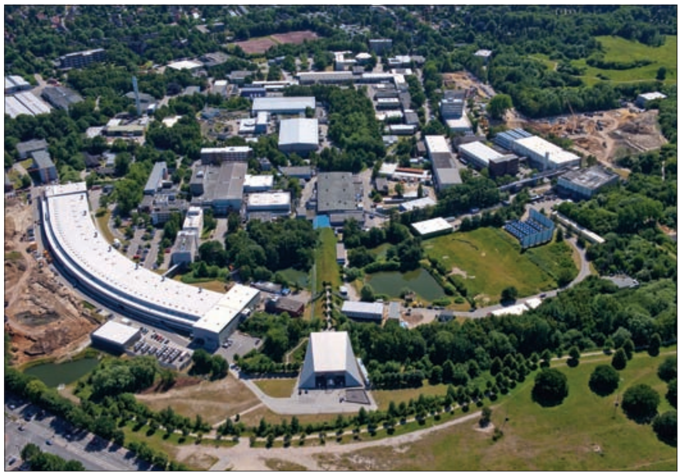
The fundamental questions about the origins and the future of the universe motivated me to choose physics as a course of study when I was 18 years old. My career as a scientist then led me to do research in solid-state physics and finally to investigate solid-state boundaries and nanomaterials using synchrotron radiation and neutrons. As a result, I have more or less closed a circle through my work at DESY. Here, both focuses of my research are united under one roof: particle physics with its fundamental questions, and structural research using cutting-edge light sources – both are fields that provide us with the knowledge base for technological and medical progress.

In an anniversary year, it is time not only to cast a backward glance but also to look forward at a clear objective: working together with all of the people at DESY to strengthen further the lab's world-class international position. Now that HERA has been decommissioned, the focus for our facilities in Hamburg and Zeuthen clearly lies on the new and innovative light sources that are being realized in the Hamburg metropolitan region. "Insight starts here" is the slogan that we have chosen for DESY's research – insight based on top-quality accelerator facilities and an important role as a partner in international projects.

With PETRA III, we have built a synchrotron-radiation source that will outperform all other competitors that use storage-ring technology. As the most brilliant light source of its kind, PETRA III will offer outstanding opportunities for experimentation. It will be of particular benefit to scientists who need strongly focused, very short-wave X-ray radiation to gain high-resolution insights at the atomic level into biological specimens or new high-performance materials. There is a tremendous demand from researchers aiming to develop new materials in the area of nanotechnology or new medicines based on molecular biology. A new interdisciplinary centre for structural systems biology is being set up in the direct vicinity of PETRA III.

This equips us perfectly to deal with the challenges of today and tomorrow. But the DESY tradition is also to keep in mind the challenges of the day after tomorrow – in other words, to build the light sources of the future. With the free-electron lasers, DESY has again assured itself a place in the world's leading ranks when it comes to the development of a new key technology. On the basis of the superconducting TESLA technology, we have created light sources that are entering completely new territory by generating high-intensity, ultrashort, pulsed X-ray radiation with genuine laser properties. With this kind of radiation, scientists can for the first time observe processes in the nano-cosmos in real time.

Helmut Dosch has held the role of DESY director since March 2009. (Courtesy Rüdiger Nehmzow, Düsseldorf.)



Bird's eye view of the DESY research centre in Hamburg. The 260 m-long FLASH free-electron laser with its experimental hall can be seen in the foreground. On the left of it is the large new experimental hall of the PETRA III synchrotron radiation source. The DESY site is encompassed by the 2.3 km PETRA III storage ring. On the upper right side of the picture, near the former HERA refrigeration hall, is the construction site of the injector complex for the European X-ray laser XFEL, a 3.4 km-long free-electron laser facility that will run from the DESY site in a north-western direction towards the town of Schenefeld. The halls of the 300 m-circumference DORIS III storage ring can be seen between the PETRA III experimental hall and the beginning of the FLASH linear accelerator. (Courtesy Reimo Schaaf, Schönwalde.)

They can, for instance, view "live broadcasts" of the formation and dissolution of chemical bonds. That is why there is such a great demand for the FLASH free-electron laser at DESY. The expectations concerning the European X-ray laser, the European XFEL, which is now being built in the Hamburg area, are correspondingly high. DESY is playing a key role regarding this new beacon for science. Among other things, it is building the heart of the facility: the accelerator, which is approximately 2 km long.

International scope

In the fields of high-energy and astroparticle physics, DESY is facing the challenges of the future, which are becoming increasingly global; the era of national accelerator facilities is now a thing of the past. The field is dominated by internationally oriented "world machines" such as the LHC at CERN. So it is quite appropriate that the laboratory already has a long tradition of international co-operation across cultural and political boundaries. At its two locations in Hamburg and Zeuthen, DESY is involved in a number of major facilities that are no longer supported by one country alone, but are implemented as international projects. For example, DESY is participating in the experiments at the LHC and computer centres are being built on the DESY campus to monitor the data-taking and analysis. DESY is also playing a major role in the next future-oriented project in particle physics, the design study for the International Linear Collider.

DESY researchers are also active in astroparticle physics, in projects that include the neutrino telescope IceCube at the South Pole and the development work for a future gamma-ray telescope facility, the Cherenkov Telescope Array. With these two projects, the researchers are taking advantage of the fastest and most reliable messengers from the far reaches of the cosmos – high-energy neutrinos and gamma radiation – to investigate the early stages of the universe.

This broad international orientation is one element of the base that will continue to support DESY in the future. We will go on systematically developing the three main research pillars of DESY: accelerator development, photon science and particle physics. Another important element is the promotion of young scientists, an activity in which DESY engages intensely in co-operation with universities. Our goal is to be a magnet for the best and most creative brains and to co-operate with them in the future to do what we do best: ensuring that insight starts here.

Résumé

DESY face aux défis du futur

Helmut Dosch, directeur de DESY, est aux commandes d'un laboratoire qui évolue rapidement pour s'adapter aux défis du futur. Ici, Helmut Dosch nous explique comment DESY s'est assuré une position de leader mondial dans une nouvelle technologie très importante, avec le développement des lasers à électrons libres. En même temps, DESY fait face aux défis de la physique des particules et de l'astrophysique des particules, deux disciplines de plus en plus mondialisées. Sur ses deux sites de Hambourg et Zeuthen, DESY apporte déjà sa contribution à un certain nombre d'installations d'importance dans le cadre de projets internationaux.

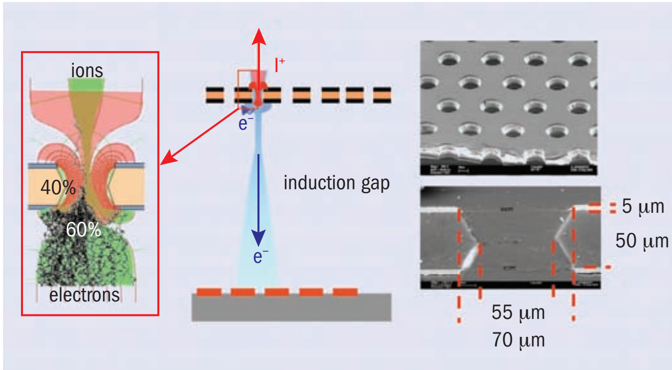
Helmut Dosch, *DESY.*

The continuing rise of micropattern detectors

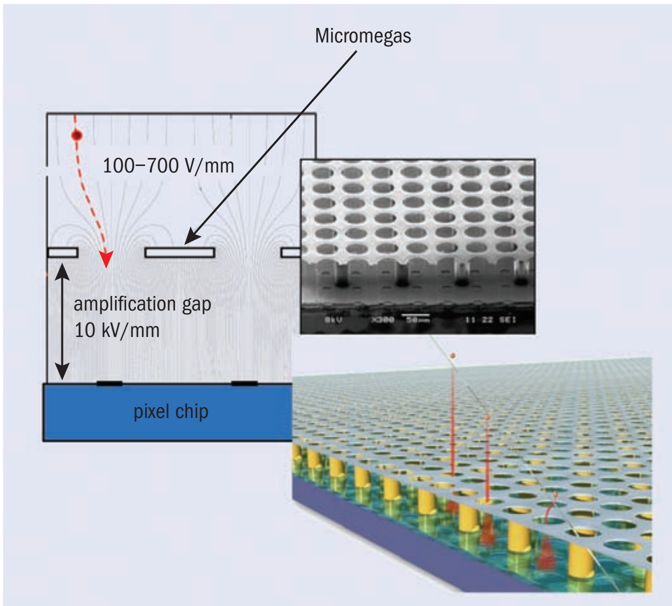
More than 120 physicists, engineers and students attended MPGD 2009, the first International Conference on Micropattern Gaseous Detectors, held on the Greek island of Crete. **Theodoros Geralis** reports.

The invention of micropattern gaseous detectors (MPGDs), in particular the gas electron multiplier (GEM) by Fabio Sauli and the micromesh gaseous structure (Micromegas) by Ioannis Giomataris, has triggered a range of active research and development on a new generation of gaseous detectors (*CERN Courier* June 2006 p37). These technologies, together with other new micropattern detector schemes that have arisen from these initial ideas, are now enabling the development of detectors with unprecedented spatial resolution and high-rate capability, which also have large sensitive areas and exhibit operational stability and increased radiation hardness. Many groups worldwide are developing MPGD devices for future experiments, not only at particle accelerators but also in nuclear and astroparticle physics, as well as for applications such as medical imaging, material science and security inspection.

This range of activity was the subject of the first international conference on MPGDs, which was organized at the Orthodox Academy of Crete, in Kolymbari, Greece, on 12–15 June 2009. The RD51 collaboration, which was established to advance the technological development and application of MPGDs, actively participated in the conference and held its collaboration meeting immediately afterwards on 16–17 June. The Orthodox Academy conference centre offered an ideal environment for the detailed examination of MPGD issues, together with the exchange of ideas and lively discussions that took place in both meetings. Crete is after all where, according to the myths of Daedalus and Talos, technology emerged during the Minoan civilization.



A gas electron multiplier (GEM) detector: schematic (centre) and microscope photographs of a real device from above (top right) and showing the profile of the walls of the holes (lower right), which give the field lines and amplification illustrated on the left.



A Micromegas detector with pixel-chip read-out: schematic (left and bottom right) and a microscope photograph of a real device (top right).

From COMPASS to the ILC

The history of MPGDs is much shorter, but nevertheless it is already rich in results and prospects. In 1999 COMPASS at CERN became the first high-energy physics experiment to use large-area Micromegas and GEM detectors in high-rate hadron beams. Micromegas produced with the new "microbulk" technology have backgrounds of a few 10^{-7} counts/s/keV/cm^2. They might allow big improvements in the research potential of experiments that are searching for rare events (such as CAST, MIMAC and NEXT). Three time-projection chambers (TPCs) developed for the Tokai to Kamioka (T2K) project are using large pixellized Micromegas made using bulk technology to read out data from some 80 000 channels. This promising neutrino oscillation experiment reported impressive technological progress ▷

and results. Meanwhile, GEMs are about to be used in the TOTEM experiment at the LHC (*CERN Courier* September 2009 p19).

Review talks on future accelerators and upgrades, in particular the sLHC and the International Linear Collider (ILC) projects, covered the physics potential and set the requirements for detectors. MPGDs are in a favourable position thanks to their excellent properties. Research and development has already begun on a pixellized tracker (namely GridPix, or the Gas On Slimmed Silicon Pixels [GOSSIP] detector) for the upgrades of the LHC experiments, aiming for a spatial precision of around 20 μm. MPGDs are also good candidates for upgrading end-cap muon detection (with a precision of around 25 μm). Detectors with large surface areas pose a serious problem, however, owing to the huge number of read-out channels. A modified MPGD with controlled charge dispersion on a resistive anode-film laminated above the read-out plane would allow wide pads (about 2.7 mm), thus reducing significantly the number of channels.

GEMs and variations of Micromegas are being designed for digital hadron calorimetry and for TPCs and their read-out electronics at the ILC. The spatial resolution, which is not affected by a magnetic field, is reaching a record 50 μm for this application. The ion feedback suppression offered by the MPGDs is particularly important for operation at high rates. The new development of an integrated Micromegas (INGRID) on top of silicon micropixel anodes offers a novel and challenging read-out solution, and is under study both for a TPC at the ILC and for a vertex detector for ATLAS. Recent results using a triple-GEM structure combined with either Medipix or Timepix read-out electronics were also presented at the conference.

Multiple applications

Moving away from applications in particle physics, the strip-resistive-electrode thick GEM (S-RETGEM) could be used as flame/smoke detectors for the detection of forest fires at distances up to 1 km, compared with a range of about 200 m for commercially available UV-flame detectors. A detector structure inspired by the Micromegas concept, the Parallel Ionization Multiplier (PIM-MPGD), is being developed in collaboration with medical researchers for use in radio-pharmaceutical β-imaging, with a spatial resolution of 30 μm.

X-ray polarimetry for astrophysical applications now has a powerful tool, with intense development work on GEMs and thick GEMs (THGEMs) based on the pure noble gases xenon, argon, and neon. Interesting developments on GEMs and micropixel (μPIC) detectors operating as large-area VUV gas photomultiplier tubes were also presented at the conference. THGEMs are being assessed for applications in ring-imaging Cherenkov detectors and are also being used in a novel nuclear-imaging technique (3γ imaging) for medical purposes.

The construction of MPGDs is now moving away from planar geometry, but not without difficulties. Cylindrical Micromegas, as used in the CLAS12 detector at Jefferson Lab, and the triple-GEM structure developed for the KLOE experiment at Frascati, do not lose their performance compared with planar ones. Spherical GEMs are also being tested to fight parallax effects that pose limitations in many applications.

Rui De Oliveira of CERN presented the excellent research, development and innovation taking place at CERN in close collaboration with the GEM and Micromegas groups. He presented new photolithography and etching techniques that aim to improve several aspects of the performance of MPGDs, e.g. in robustness, homogeneity, sparking and electronics integration. MPGDs are now being manufactured with areas larger than around 0.5 m^2, but further developments are needed for detectors for the sLHC and ILC. Industry has quickly become involved in MPGDs; several companies in Europe, Japan and the US are already manufacturing MPGD elements.

Participants enjoy the pleasant conference setting in the ancient Greek cradle of technology. (Courtesy George Tsipolitis.)

The conference proved the ideal occasion for discussions about the common aspects of all of the variations of MPGDs: field mapping, simulations, gases, electronics etc. All of the groups involved, and the two communities, GEM and Micromegas, came together in a fruitful collaboration. In addition, they were able to sample some of the beauty of Crete, present and past, with two special lectures, one on the history of Crete and the city of Chania, and one on Cretan flora. Participants also enjoyed walking excursions in the gorge of Samaria or visiting the archaeological site of Knossos. The conference dinner featured local delicacies, traditional Greek and Cretan music as well as dancing.

● For more information on the conference and to see the presentations, visit http://candia.inp.demokritos.gr/mpgd2009. The contributions will be submitted for publication in the open-access journal *JINST*, http://jinst.sissa.it.

Résumé

L'irrésistible ascension des détecteurs MPGD

L'invention des détecteurs gazeux à microstructures (MPGD) a ouvert la voie à une nouvelle génération de détecteurs, ayant une très haute définition spatiale et adaptés aux cadences élevées. Leurs autres atouts sont des zones sensibles étendues, une grande stabilité opérationnelle et une résistance aux radiations améliorée. Beaucoup d'équipes dans le monde développent des dispositifs de ce type pour de futures expériences, non seulement dans les accélérateurs de particules, mais aussi pour l'astrophysique des particules, la physique nucléaire, l'imagerie médicale, la science des matériaux et les inspections de sécurité. Ces applications diverses étaient l'objet de la première Conférence internationale sur les MPGD, organisée à l'Académie orthodoxe de Crète, à Kolympari (Grèce).

Theodoros Geralis, *the National Centre for Scientific Research, Demokritos.*

Looking beyond the LHC

Earlier this year more than 100 experimentalists, theorists and machine physicists gathered at a CERN Theory Institute to investigate the impact of early LHC data on the field of particle physics, with particular focus on future accelerators and experiments.

The LHC at CERN is about to start the direct exploration of physics at the tera-electron-volt energy scale. Early ground-breaking discoveries may be possible, with profound implications for our understanding of the fundamental forces and constituents of the universe, and for the future of the field of particle physics as a whole. These first results at the LHC will set the agenda for further possible colliders, which will be needed to study physics at the tera-electron-volt scale in closer detail.

Once the first inverse femtobarns of experimental data from the LHC have been analysed, the worldwide particle-physics community will need to converge on a strategy for shaping the field over the years to come. Given that the size and complexity of possible accelerator experiments will require a long construction time, the decision of when and how to go ahead with a future major facility needs to be undertaken in a timely fashion. Several projects for future colliders are currently being developed and soon it may be necessary to set priorities between these options, informed by whatever the LHC reveals at the tera-electron-volt scale

The CERN Theory Institute "From the LHC to a Future Collider" reviewed the physics goals, capabilities and possible results coming from the LHC and studied how these relate to possible future collider programmes. Participants discussed recent physics developments and the near-term capabilities of the Tevatron, the LHC and other experiments, as well as the most effective ways to prepare for providing scientific input to plans for the future direction of the field. To achieve these goals, the programme of the institute centred on a number of questions. What have we learnt from data collected up to this point? What may we expect to know about the emerging new physics during the initial phase of LHC operation? What do we need to know from the LHC to plan future accelerators? What scientific strategies will be needed to advance from the planned LHC running to a future collider facility? To answer the last two questions, the participants looked at what to expect from the LHC with a specific early luminosity, namely 10 fb^{-1}, for different scenarios for physics at the tera-electron-volt scale and investigated which strategy for future colliders would be appropriate in each of these scenarios. Figure 1 looks further ahead and indicates a possible luminosity profile for the LHC and its sensitivity to new physics scenarios to come.

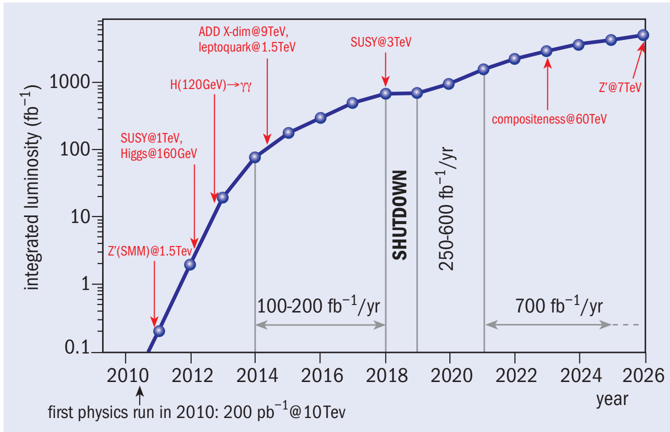


Fig. 1. A hypothetical luminosity profile used for the workshop studies, indicating the available integrated luminosity at the start of each year, assuming the unlikely absence of longer shutdowns in the first years of operation. For this scenario, collisions at a centre-of-mass energy of 10 TeV were assumed for 2010 and at an energy of 14 TeV for the following years; the initial pilot run at 7 TeV was not used. A selection of possible discoveries is indicated along the timeline for illustration.

Present and future

The institute's efforts were organized into four broad working groups on signatures that might appear in the early LHC data. Their key considerations were the scientific benefits of various upgrades of the LHC compared with the feasibility and timing of other possible future colliders. Hence, the programme also included a series of presentations on present and future projects, one on each possible accelerator followed by a talk on the strong physics points. These included the Tevatron at Fermilab, the (s)LHC, the International Linear Collider (ILC), the LHeC, the Compact Linear Collider (CLIC) concept and a muon collider.

Working Group 1, which was charged with studying scenarios for the production of a Higgs boson, assessed the implications of the detection of a state with properties that are compatible with a Higgs boson, whether Standard Model (SM)-like or not. If nature has chosen an SM-like Higgs, then ATLAS and CMS are well placed to discover it with 10 fb^{-1} (assuming $\sqrt{s} = 14$ TeV, otherwise more luminosity may be needed) and measure its mass. However, measuring other characteristics (such as decay width, spin, CP properties, branching ratios, couplings) with an accuracy better than 20–30% would require another facility.

The ILC would provide e^+e^- collisions with an energy of $\sqrt{s} = 500$ GeV (with an upgrade path to $\sqrt{s} = 1$ TeV). It would allow precise measurements of all of the quantum numbers and many couplings of the Higgs boson, in addition to precise determinations of its mass and width – thereby giving an almost complete profile of the particle. CLIC would allow e^+e^- collisions at higher energies, with $\sqrt{s} = 1–3$ TeV, ▷

and if the Higgs boson is relatively light it could give access to more of the rare decay modes. CLIC could also measure the Higgs self-couplings over a large range of the Higgs mass and study directly any resonance up to 2.5 TeV in mass in WW scattering.

Working Group 2 considered scenarios in which the first 10 fb^{-1} of LHC data fail to reveal a state with properties that are compatible with a Higgs boson. It reviewed complementary physics scenarios such as gauge boson self-couplings, longitudinal vector-boson scattering, exotic Higgs scenarios and scenarios with invisible Higgs decays. Two generic scenarios need to be considered in this context: those in which a Higgs exists but is difficult to see and those in which no Higgs exists at all. With higher LHC luminosity – for instance with the sLHC, an upgrade that gives 10 times more luminosity – it should be possible in many scenarios to determine whether or not a Higgs boson exists by improving the sensitivity to the production and decays of Higgs-like particles or vector resonances, for example, or by measuring WW scattering. The ILC would enable precision measurements of even the most difficult-to-see Higgs bosons, as would CLIC. The latter would be also good for producing heavy resonances.

Working Group 3 reviewed missing-energy signatures at the LHC, using supersymmetry as a representative model. The signals studied included events with leptons and jets, with the view of measuring the masses, spins and quantum numbers of any new particles produced. Studies of the LHC capabilities at $\sqrt{s} = 14$ TeV show that with 1 fb^{-1} of LHC luminosity, signals of missing energy with one or more additional leptons would give sensitivity to a large range of supersymmetric mass scales. In all of the missing-energy scenarios studied, early LHC data would provide important input for the technical and theoretical requirements for future linear-collider physics. These include the detector capabilities where, for example, the resolution of mass degeneracies could require exceptionally good energy resolution for jets, running scenarios, required threshold scans and upgrade options – for a $\gamma\gamma$ collider, for instance, and/or an e^+e^- collider operating in "GigaZ" mode at the Z mass. The link with dark matter was also explored in this group.

Working Group 4 studied examples of phenomena that do not involve a missing-energy signature, such as the production of a new Z' boson, other leptonic resonances, the impact of new physics on observables in the flavour sector, gravity signatures at the tera-electron-volt scale and other exotic signatures of new physics. The sLHC luminosity upgrade has the capability to provide additional crucial information on new physics discovered during early LHC running, as well as to increase the search sensitivity. On the other hand, a future linear collider – with its clean environment, known initial state and polarized beams – is unparalleled in terms of its abilities to conduct ultraprecise measurements of new and SM phenomena, provided that the new-physics scale is within reach of the machine. For example, in the case of a Z', high-precision measurements at a future linear collider would provide a mass reach that is more than 10 times higher than the centre-of-mass energy of the linear collider itself. Attention was also given to the possibility of injecting a high-energy electron beam onto the LHC proton beam to provide an electron–proton collider, the LHeC (*CERN Courier* April 2009 p22). Certain phenomena such as the properties of leptoquarks could be studied particularly well with such a collider; for other scenarios, such as new heavy gauge-boson scattering, the LHeC can contribute crucial information on the couplings, which are not accessible with the LHC alone.

Participants at the Theory Institute saw work towards a possible future during a visit to the CLIC test facility, CTF3. (Courtesy Sven Heinemeyer.)

The physics capabilities of the sLHC, the ILC and CLIC are relatively well understood but will need refinement in the light of initial LHC running. In cases where the exploration of new physics might be challenging at the early LHC, synergy with a linear collider could be beneficial. In particular, a staged approach to linear-collider energies could prove promising.

The purpose of this CERN Theory Institute was to provide the particle-physics community with some tools for setting priorities among the future options at the appropriate time. Novel results from the early LHC data will open exciting prospects for particle physics, to be continued by a new major facility. In order to seize this opportunity, the particle-physics community will need to unite behind convincing and scientifically solid motivations for such a facility. The institute provided a framework for discussions now, before the actual LHC results start to come in, on how this could be achieved. In this context, the workshop report was also mentioned and made available to the European Strategy Session of the CERN Council meetings in September 2009. We now look forward to the first multi-tera-electron-volt collisions in the LHC, as well as to the harvest of new physics that these results will provide.

- For more about the institute, see http://indico.cern.ch/conferenceDisplay.py?confId=40437. The institute summary is available at http://arxiv.org/abs/0909.3240.

Résumé

Du LHC à un futur collisionneur

Plus de cent physiciens – expérimentateurs, théoriciens ou physiciens des accélérateurs – ont participé à un séminaire au CERN pour étudier l'incidence des premières données du LHC sur la préparation des futurs accélérateurs et expériences. Le but était de donner à la communauté de la physique des particules des outils pour fixer des priorités entre les options. Des résultats inédits dans les premières données du LHC ouvriront des perspectives stimulantes, qui devront être explorées par une nouvelle grande machine. Afin de tirer parti au mieux des possibilités, la communauté de la physique des particules devra s'unir et motiver par des arguments solides la construction d'une telle machine. Le séminaire était l'occasion d'en discuter dès à présent, avant qu'on ne dispose des premiers résultats du LHC.

Albert De Roeck, **John Ellis**, *CERN, and* **Sven Heinemeyer**, *ICFA (CSIC Santander), for the organizers of the CERN Theory Institute.*

The Nobel path to a unif

This year marks significant anniversaries of the three Nobel prizes awarded for work that established electroweak theory, a key element of today's Standard Model. Here we revisit these awards through the pages of the *CERN Courier* archive.

Electromagnetism and the weak force might appear to have little to do with each other. Electromagnetism is our everyday world – it holds atoms together and produces light, while the weak force was for a long time known only for the relatively obscure phenomenon of beta-decay radioactivity.

The successful unification of these two apparently highly dissimilar forces is a significant milestone in the constant quest to describe as much as possible of the world around us from a minimal set of initial ideas.

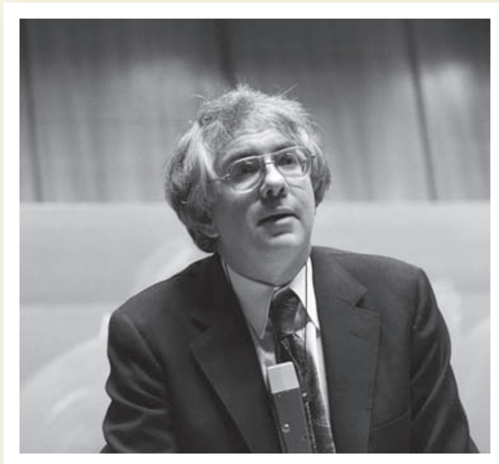
"At first sight there may be little or no similarity between electromagnetic effects and the phenomena associated with weak interactions," wrote Sheldon Glashow in 1960. "Yet remarkable parallels emerge..."

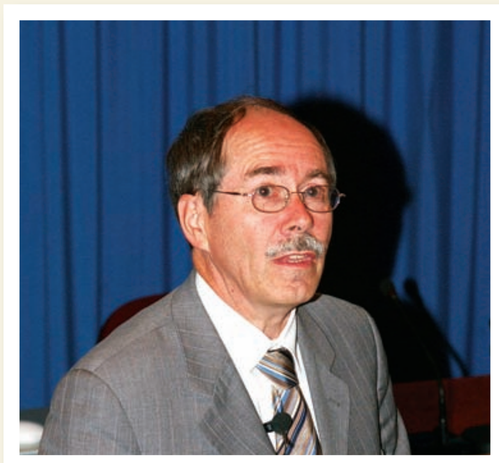
Both kinds of interactions affect leptons and hadrons; both appear to be "vector" interactions brought about by the exchange of particles carrying unit spin and negative parity; both have their own universal coupling constant, which governs the strength of the interactions.

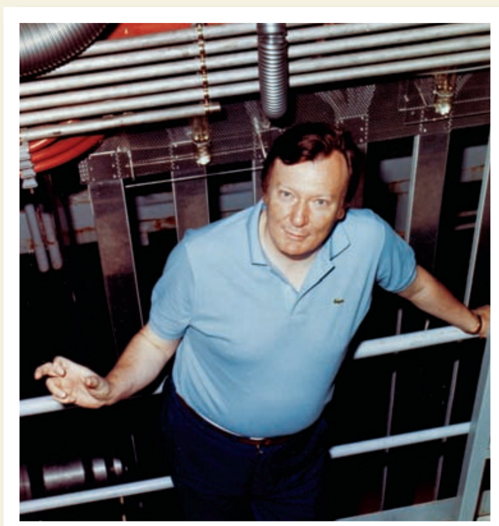
These vital clues led Glashow to propose an ambitious theory that attempted to unify the two forces. However, there was one big difficulty, which Glashow admitted had to be put to one side. While electromagnetic effects were due to the exchange of massless photons (electromagnetic radiation), the carrier of weak interactions had to be fairly heavy for everything to work out right. The initial version of the theory could find no neat way of giving the weak carrier enough mass.

Then came the development of theories using "spontaneous symmetry breaking", where degrees of freedom are removed. An example of such a symmetry breaking is the imposition of traffic rules (drive on the right, overtake on the left) to a road network where in principle anyone could go anywhere. Another example is the formation of crystals in a freezing liquid.

These symmetry-breaking theories at first introduced massless particles which were no use to anybody, but soon the so-called "Higgs mechanism" was discovered, which gives the carrier particles some mass. This was the vital development that enabled Steven Weinberg and Abdus Salam, working independently, to formulate their unified "electroweak" theory. One problem was that nobody knew how to handle calculations in a consistent way...







1979: Sheldon Glashow (top Abdus Salam (above), Intern Theoretical Physics and Imp Weinberg (top right), Harvar Nobel prize for "their contrib unified weak and electromag elementary particles, includ prediction of the weak neutr

1999: Gerardus 't Hooft (left and Martinus Veltman (right shared the Nobel prize for "e structure of electroweak inte

1984: Carlo Rubbia (left) an (right), CERN, shared the No contributions to the large pr discovery of the field particle communicators of weak inte (right) Simon van der Meer is room of the Antiproton Accu where antiprotons were colle method of stochastic coolin Super Proton Synchrotron. C collaboration that built one discovered the W and Z bos their day.

fied electroweak theory

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...It was Gerardus 't Hooft's and Martinus Veltman's work that put this unification on the map, by showing that it was a viable theory that could make predictions possible.

Field theories have a habit of throwing up infinities that at first sight make sensible calculations difficult. This had been a problem with the early forms of quantum electrodynamics and was the despair of a whole generation of physicists. However, its reformulation by Richard Feynman, Julian Schwinger and Sin-Ichiro Tomonaga (Nobel prizewinners in 1965), showed how these infinities could be wiped clean by redefining quantities like electric charge.

Each infinity had a clear origin, a specific Feynman diagram, the skeletal legs of which denote the particles involved. However, the new form of quantum electrodynamics showed that the infinities can be made to disappear by including other Feynman diagrams, so that two infinities cancel each other out. This trick, difficult to accept at first, works very well, and renormalization then became a way of life in field theory. Quantum electrodynamics became a powerful calculator.

For such a field theory to be viable, it has to be "renormalizable". The synthesis of weak interactions and electromagnetism, developed by Glashow, Weinberg and Salam – and incorporating the now famous "Higgs" symmetry-breaking mechanism – at first sight did not appear to be renormalizable. With no assurance that meaningful calculations were possible, physicists attached little importance to the development. It had not yet warranted its "electroweak" unification label.

The model was an example of the then unusual "non-Abelian" theory, in which the end result of two field operations depends on the order in which they are applied. Until then, field theories had always been Abelian, where this order does not matter.

In the summer of 1970, 't Hooft, at the time a student of Veltman in Utrecht, went to a physics meeting on the island of Corsica, where specialists were discussing the latest developments in renormalization theory. 't Hooft asked them how these ideas should be applied to the new non-Abelian theories. The answer was: "If you are a student of Veltman, ask him!" The specialists knew that Veltman understood renormalization better than most other mortals, and had even developed a special computer program – Schoonschip – to evaluate all of the necessary complex field-theory contributions.

At first, 't Hooft's ambition was to develop a renormalized version of non-Abelian gauge theory that would work for the strong interactions that hold subnuclear particles together in the nucleus. However, Veltman believed that the weak interaction, which makes subnuclear particles decay, was a more fertile approach. The result is physics history. The unified picture based on the Higgs mechanism is renormalizable. Physicists sat up and took notice.

One immediate prediction of the newly viable theory was the "neutral current". Normally, the weak interactions involve a shuffling of electric charge, as in nuclear beta decay, where a neutron decays into a proton. With the neutral current, the weak force could also act without switching electric charges. Such a mechanism has to ▷

exist to assure the renormalizability of the new theory. In 1973 the neutral current was discovered in the Gargamelle bubble chamber at CERN and the theory took another step forward.

The next milestone on the electroweak route was the discovery of the W and Z carriers, of the charged and neutral components respectively, of the weak force at CERN's proton–antiproton collider. For this, Carlo Rubbia and Simon van der Meer were awarded the 1984 Nobel Prize for Physics...

...At CERN, the story began in 1968 when Simon van der Meer, inventor of the "magnetic horn" used in producing neutrino beams, had another brainwave. It was not until four years later that the idea (which van der Meer himself described as "far-fetched") was demonstrated at the Intersecting Storage Rings. Tests continued at the ISR, but the idea – "stochastic beam cooling" – remained a curiosity of machine physics.

In the United States, Carlo Rubbia, together with David Cline of Wisconsin and Peter McIntyre, then at Harvard, put forward a bold idea to collide beams of matter and antimatter in existing large machines. At first, the proposal found disfavour, and it was only when Rubbia brought the idea to CERN that he found sympathetic ears.

Stochastic cooling was the key, and experiments soon showed that antimatter beams could be made sufficiently intense for the scheme to work. With unprecedented boldness, CERN, led at the time by Leon Van Hove as research director-general and the late Sir John Adams as executive director-general, gave the green light.

At breathtaking speed, the ambitious project became a magnificently executed scheme for colliding beams of protons and antiprotons in the Super Proton Synchrotron, with the collisions monitored by sophisticated large detectors. The saga was chronicled in the special November 1983 issue of the *CERN Courier*, with articles describing the development of the electroweak theory, the accelerator physics that made the project possible and the big experiments that made the discoveries.

● Extracts from *CERN Courier* December 1979 pp395–397, December 1984 pp419–421 and November 1999 p5.

Résumé

Trois prix Nobel pour une théorie électrofaible unifiée

2009 est l'occasion de commémorer les trois prix Nobel attribués pour des travaux ayant établi la théorie électrofaible, élément essentiel du Modèle standard actuel. D'abord, en 1979, Sheldon Glashow, Abdus Salam et Steven Weinberg étaient récompensés pour leur contribution à l'unification des interactions faible et électromagnétique. En 1984, c'est Carlo Rubbia et Simon van der Meer qui ont été distingués, pour la découverte des particules W et Z. Enfin, en 1999, c'était au tour de Gerardus 't Hooft et Martinus Veltman d'être couronnés, pour leurs travaux élucidant la structure quantique des interactions électrofaibles. Nous reproduisons ici des extraits des articles de l'époque du Courier sur ces récompenses.

Picturing the proton by elastic scattering

The results of 25 years of elastic-scattering experiments with protons and antiprotons suggest a model of the proton with a layered structure that can be tested at the LHC.

High-energy proton–proton (pp) and antiproton–proton ($\bar{p}p$) elastic-scattering measurements have been at the forefront of accelerator research since the early 1970s, when pp elastic scattering was measured at the Intersecting Storage Rings (ISR) at CERN – the world's first proton–proton collider – over a wide range of energy and momentum transfer. This was followed by measurements of pp elastic scattering in a fixed-target experiment at Fermilab, by $\bar{p}p$ elastic-scattering measurements at the Super Proton Synchrotron (SPS) at CERN operating as a $\bar{p}p$ collider and, finally, in the 1990s by $\bar{p}p$ elastic-scattering measurements at Fermilab's Tevatron. Table 1 chronicles this sustained and dedicated experimental effort by physicists, which extended over a quarter of a century as the centre-of-mass energy increased from the giga-electron-volt region to the tera-electron-volt region.

With the first collisions at CERN's LHC on the horizon, pp elastic scattering will come under the spotlight at the experiment known as TOTEM – for TOTal cross-section, Elastic and diffractive scattering Measurement (*CERN Courier* September 2009 p19). The TOTEM collaboration has detailed plans to measure pp elastic scattering at 14 TeV in the centre-of-mass – that is, seven times the centre-of-mass energy at the Tevatron – over a range of momentum transfer, $|t|$ around 0.003–10.0 GeV^2. By contrast, the ATLAS collaboration at the LHC plans to measure pp elastic scattering at 14 TeV in the small momentum-transfer range, $|t|$ around 0.0006–0.1 GeV^2, where the pp Coulomb amplitude and strong interaction amplitude interfere.

A phenomenological investigation of high-energy pp and $\bar{p}p$ elastic scattering commenced in the late 1970s with the goal of quantitatively describing the measured elastic differential cross-sections as the centre-of-mass energy increased and as one proton probed the other at smaller and smaller distances ▷

Table 1

accelerator	$\sqrt{s}$	$\lvert t \rvert$	Reference
CERN ISR (pp)	23–62 GeV	0.8–10 GeV^2	Nagy *et al.* 1979 *Nucl. Phys. B* **150** 221.
Fermilab fixed target (pp)	27.4 GeV	5.5–14.2 GeV^2	Faissler *et al.* 1981 *Phys. Rev. D* **23** 33.
CERN SPS ($\bar{p}p$)	546 GeV	0.03–1.55 GeV^2	Bozzo *et al.* 1984 *Phys. Lett. B* **147** 385; 1985 *ibid.* 155 197.
	630 GeV	0.7–2.2 GeV^2	Bernard *et al.* 1986 *Phys. Lett. B* **171** 142.
	541 GeV	0.00075–0.120 GeV^2	Augier *et al.* 1993 *Phys. Lett. B* **316** 448.
Tevatron ($\bar{p}p$)	1.8 TeV	0.03–0.63 GeV^2	Amos *et al.* 1990 *Phys. Lett. B* **247**, 127 Abe *et al.* 1994 *Phys. Rev. D* **50** 5518.
LHC (pp)	14 TeV	0.003–10.0 GeV^2	TOTEM, Anelli *et al.* 2008 *JINST* **3** S08007.
	14 TeV	0.0006–0.1 GeV^2	ATLAS ALFA 2007 TDR CERN/LHCC.

Table 1. A chronicle of the sustained efforts of research into high-energy pp and $\bar{p}p$ elastic scattering over a quarter of a century.

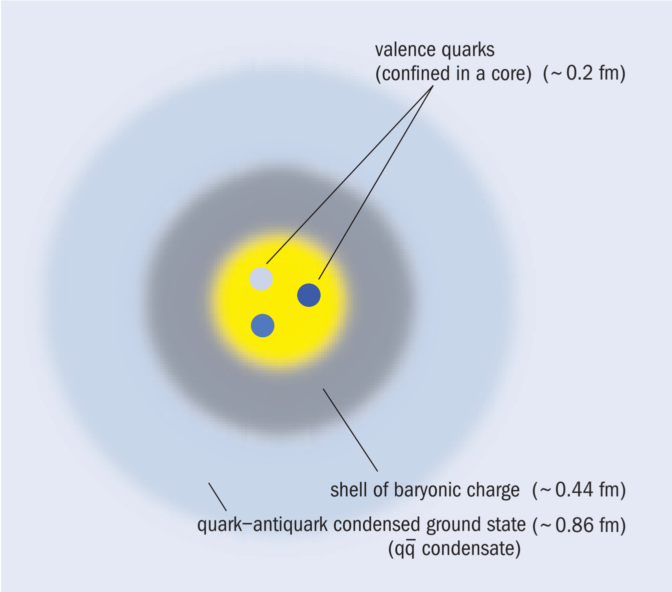

Fig. 1. *Physical picture of the proton from a phenomenological investigation of high-energy pp and p̄p elastic scattering.*

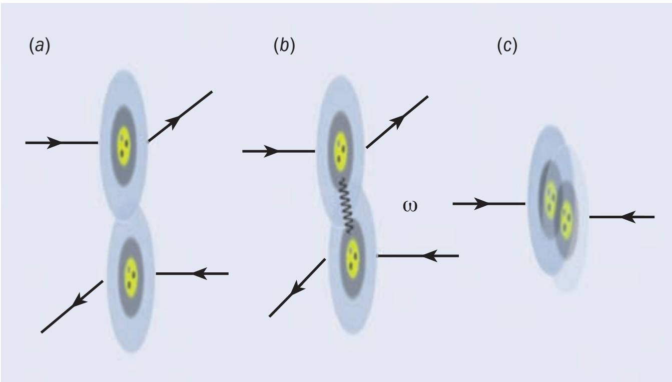

Fig. 2. *Elastic-scattering processes: a) diffraction scattering, b) ω vector–meson exchange, c) short-distance collision (<0.1 fm).*

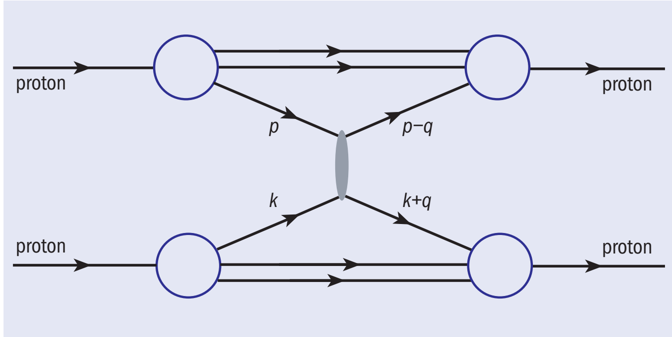

Fig. 3. *Hard collision between a valence quark with 4-momentum p from one proton and a valence quark with 4-momentum k from the other proton; q is the whole momentum transfer ($q=\sqrt{|t|}$).*

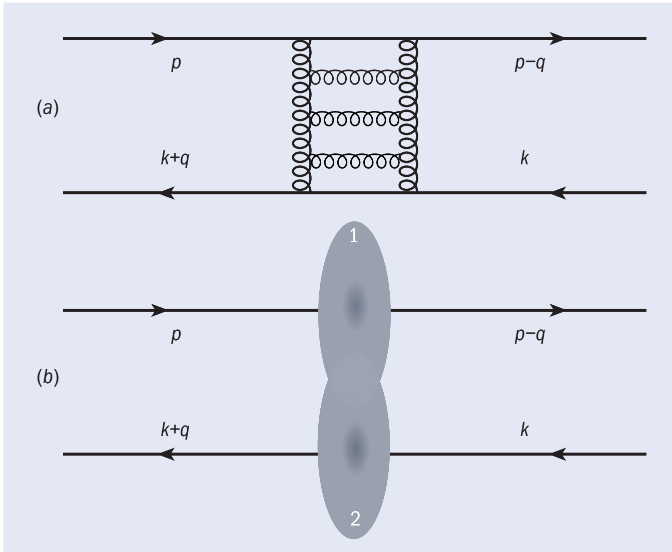

Fig. 4. *QCD processes for valence quark–quark scattering: a) exchange of gluons in the form of ladders, b) low-x gluon cloud of one quark interacting with that of the other.*

with increasing momentum transfer. This three-decade long investigation has led to both a physical picture of the proton and an effective field-theory model that underlies the picture (Islam *et al.* 2009 and 2006).

Three-layer proton

The proton appears to have three regions, as figure 1 indicates: an outer region consisting of a quark–antiquark ($q\bar{q}$) condensed ground state; an inner shell of baryonic charge – where the baryonic charge is geometrical or topological in nature (similar to the "Skyrmion Model" of the nucleon); and a core region of size 0.2 fm, where the valence quarks are confined. The part of the proton structure comprised of a shell of baryonic charge with three valence quarks in a small core has been known as a "chiral bag" model of the nucleon in low-energy studies (Hosaka and Toki 2001). What we are finding from high-energy elastic scattering then is that the proton is a "condensate-enclosed chiral bag".

The proton structure shown in figure 1 leads to three main processes in elastic scattering, illustrated in figure 2. First, in the small $|t|$ region, i.e. in the near forward direction, the outer cloud of $q\bar{q}$ condensate of one proton interacts with that of the other, giving rise to diffraction scattering. This process underlies the observed increase of the total cross-section with energy and the equality of pp and p̄p total cross-sections at high energy. It also leads to diffraction minima, like in optics, which are visible in figure 5. Second, in the intermediate momentum-transfer region, with $|t|$ around 1–4 GeV^2, the topological baryonic charge of one proton probes that of the other via ω vector–meson exchange. This process is analogous to one electric charge probing another via photon exchange. The spin-1 ω acts like a photon because of its coupling with the topological baryonic charge. Third is the process in the large $|t|$ region – where $|t|$ is around 4 GeV^2 or larger. Here one proton probes the other at transverse distances around or less than 1/q, where $q=\sqrt{|t|}$, i.e. at transverse distances of the order of 0.1 fm or less. Elastic scattering in this region originates from the hard collision of a valence quark from one proton with a valence quark from the other proton – a process that can be better visualized in momentum space (figure 3).

We have considered two alternative quantum-chromodynamical processes for the qq-scattering mechanism (represented by the blob in figure 3). One is the exchange of gluons in the form of ladders

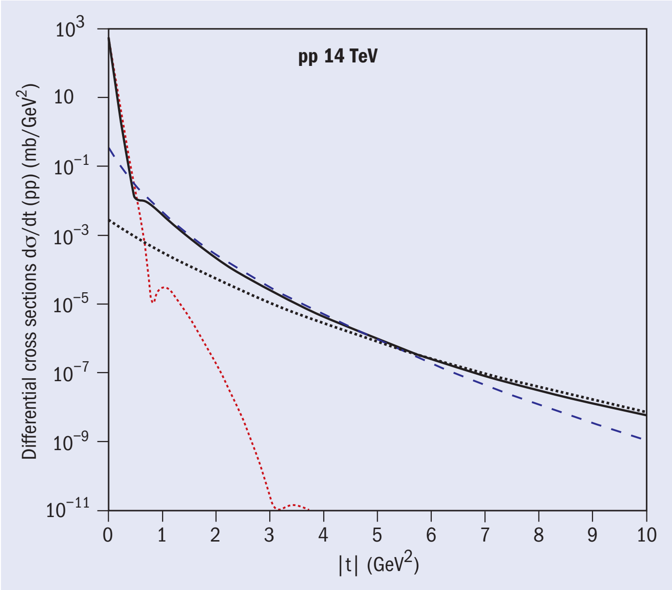

Fig.5. The solid curve shows our predicted differential cross-section at the LHC at 14 TeV (centre-of-mass) from the combination of three processes – diffraction (red dots), ω-exchange (blue dashes), and valence qq scattering from low-x gluon clouds (black dots).

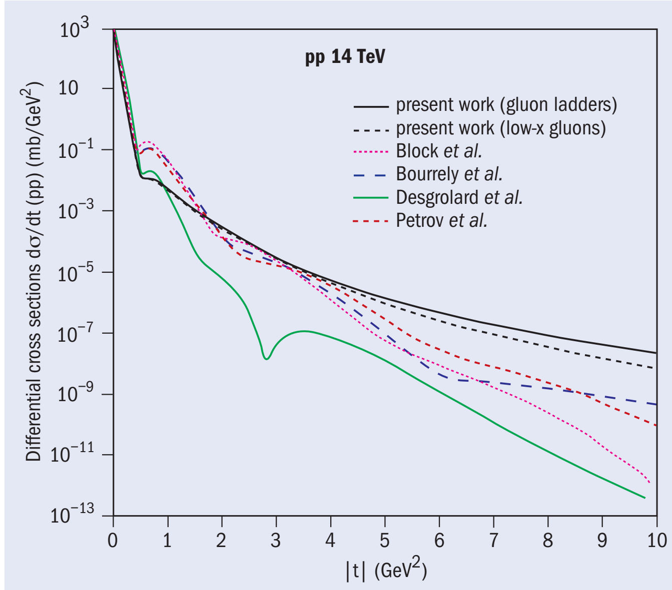

Fig.6. Our predicted differential cross section at the LHC at 14 TeV (centre-of-mass) with qq scattering from gluon ladders (solid curve) and low-x gluon cloud–cloud interaction (dashed curve). Predictions of four other dynamical models are also shown (Islam et al. *2009).*

– called the "BFKL ladder" – as figure 4a shows. The other process we have considered is where the "dense low-x gluon cloud" of one quark interacts strongly with that of the other, as in figure 4b. The low-x gluons accompanying a quark are gluons that carry tiny fractions of the energy and longitudinal momentum of the quark. The finding of the high-density, low-x gluon clouds surrounding quarks is one of the major discoveries at the HERA collider at DESY (*CERN Courier* January/February 2008 p34).

The solid curve in figure 5 shows our predicted elastic differential cross-section at the LHC at a centre-of-mass energy of 14 TeV and in the momentum-transfer region $|t| = 0$–$10\ GeV^2$ arising from the combination of the three processes – diffraction, ω-exchange, and valence quark–quark scattering (from low-x gluon clouds). The figure also indicates separately the differential cross-sections for each of the three processes. It shows that diffraction dominates in the small $|t|$ region ($0 < |t| < 1\ GeV^2$), ω-exchange dominates in the intermediate $|t|$ region ($1 < |t| < 4\ GeV^2$) and valence qq scattering dominates in the large $|t|$ region ($5\ GeV^2 < |t|$).

In figure 6 we compare our predicted differential cross-section at the LHC with the predictions of several prominent dynamical models (Islam *et al.* 2009). A distinctive feature of our prediction is that the differential cross-section falls off smoothly beyond the bump at $|t|$ around $1\ GeV^2$. By contrast, the other models predict visible oscillations. Furthermore, these models lead to much smaller differential cross-sections than ours in the large $|t|$ region, i.e. where $|t|$ is greater than or about $5\ GeV^2$.

If the planned measurement of the elastic differential cross-section by the TOTEM collaboration in the momentum-transfer range of $|t|$ around 0–$10\ GeV^2$ shows quantitative agreement with our prediction, then it will support the underlying picture of the proton as depicted in figure 1. The consequent discovery of the structure of the proton at the LHC at the beginning of the 21st century would be analogous to the discovery of the structure of the atom from "high-energy" α-particle scattering by gold atoms at the beginning of the 20th century.

● The authors wish to thank the members of the TOTEM collaboration for discussions and comments.

Further reading

A Hosaka and H Toki 2001 *Quarks, Baryons and Chiral Symmetry* World Scientific.
M M Islam, J Kašpar, R J Luddy and A V Prokudin 2009 *Proc. 13th Int. Conf. on Elastic and Diffractive Scattering* CERN (29 June – 3 July), to be published. Talk presented by R J Luddy: http://indico.cern.ch/event/41547.
M M Islam, R J Luddy and A V Prokudin 2006 *Int. J. Mod. Phys. A* **21** 1.

Résumé

Représenter le proton par diffusion élastique

Une étude phénoménologique des expériences de diffusion élastique proton–proton et proton–antiproton à hautes énergies, entreprise sur trois décennies, a permis de réaliser une représentation physique du proton et un modèle de théorie des champs effective. Le but était de décrire de façon quantitative les sections efficaces différentielles à mesure que l'énergie dans le centre de masse augmente et que les protons se sondent mutuellement à distance plus réduite avec une augmentation du transfert d'impulsion. Dans l'image résultante, le proton semble avoir trois régions : une région externe constituée d'un état fondamental condensé quark–antiquark, une coquille interne de charge baryonique, et enfin, un noyau où sont confinés les quarks de valence.

Munir Islam *and* **Richard Luddy**, *University of Connecticut,* **Jan Kašpar**, *Academy of Sciences of the Czech Republic and CERN, and* **Alexei Prokudin**, *University of Turin.*

ANNIVERSARY

Jefferson Lab celebrates 25 years

A quarter century after a doubly improbable genesis, the Thomas Jefferson National Accelerator Facility – Jefferson Lab – in Newport News, Virginia, held a 25th anniversary celebration on 29 September, attended by the US Secretary of Energy, Steven Chu.

Until 1996 Jefferson Lab was called CEBAF, for the Continuous Electron Beam Accelerator Facility – the name still used for the five-pass recirculating accelerator that serves experiments in three end-stations and makes Jefferson Lab the US Department of Energy's main facility for electromagnetic nuclear physics.

CEBAF's genesis began following the 1979 conference "Future Possibilities for Electron Accelerators" at the University of Virginia. Within a few years, a plan for a giga-electron-volt-scale electron machine in Virginia had prevailed over proposals from prestigious, long-established sources. By early 1986, in a second surprise, the approved plan had been switched from using conventional accelerator technology to become the first large-scale application of superconducting radiofrequency (SRF) technology.

Discussing a superconducting RF cryomodule, from left to right, are: Hugh Montgomery, Jefferson Lab's director; John Hogan, SRF engineer; Steven Chu, US Secretary of Energy; Andrew Hutton, associate director for accelerators, Jefferson Lab; and Bobby Scott, US congressman. (Courtesy Jefferson Lab.)

The anniversary celebration involved tours, luncheons, journalists and speeches. John Dirk Walecka, the laboratory's original scientific director, offered a combined scientific and historical retrospective on why and how scientific user demand brought CEBAF into being, on what it meant for nuclear physics, and on what it means for science.

Walecka talked of the three electron-scattering experiments at SLAC that had "formed the physics base for CEBAF" and emphasized the inception and evolution of quantum chromodynamics – QCD, the field theory of quarks and gluons. "The challenge and opportunity for CEBAF at the outset," he said, "was to use electron scattering to study just how the traditional picture of the nucleus, involving static potentials, and eventually mesons, evolves with increasing resolution into the quark picture and QCD. In addition, parity-violation experiments could access the weak neutral current."

He also spoke of "disarray" in nuclear physics in the US in the 1960s and 1970s, and praised the evolution of the US Nuclear Science Advisory Committee as a focus and mechanism for long-range planning, as illustrated in part by CEBAF itself. "One cannot overstate the impact it has had to have the entire community argue and set priorities internally, and then stand united in their defence," he said.

Walecka closed his speech with lines from Victor Weisskopf, his thesis adviser, who later served as CERN's director-general. "The dynamics of nuclear matter are probably much more essential to the life of the universe than are terrestrial atomic and molecular physics," the quoted passage began, while ending: "After billions of years of benign radiation from the solar furnace, thinking beings evolved who investigate the processes that may lie nearer to the heart of the universe than the daily world in which we live."

Walecka's retrospective established a context for the other speeches, which included wide-ranging remarks by Chu as well as a scientific overview of Jefferson Lab's evolving research programme by Berthold Schoch of the University of Bonn. Chu's comments included support for basic research and attention to energy and anthropogenic global warming. Schoch's speech included an emphasis on the importance of CEBAF's upgrade to 12 GeV, now in progress (*CERN Courier* April 2009 p15).

Incremental improvements in SRF performance have raised CEBAF's pre-upgrade energy from the originally specified 4 GeV to the 6 GeV now routinely delivered. The origins and success of Jefferson Lab's efforts in this growing field did not escape Chu's notice. He said he especially wanted to thank CEBAF's original director Hermann Grunder and his colleague (and successor) Christoph Leemann because he had "read of the early history and essentially this eleventh-hour decision to go to superconducting". He called the decision "spectacular" and attributed to it "the fact that Jefferson Lab is the leader in superconducting accelerator cavity technology".

AWARDS

Euroscience prize goes to CERN team

CERN has received an award for its efforts in communicating the events surrounding the first beam in the LHC to the media and the public. James Gillies, head of the Communication Group, received the AlphaGalileo Research Public Relations Award on behalf of his team on 14 October during the Euroscience Media Award Ceremony in Hannover.

The team worked hard both before and after the remarkable "first-beam event", in which the protons circulated for the first time round the LHC under the eyes of the world, as regular live action from the CERN Control Centre was broadcast by many TV channels from 9 a.m. to 6 p.m. (*CERN Courier* October 2008 p7). Although common practice for the launch of space vehicles, for example, this was a "first" in the world of particle physics.

The CERN Communication Group also works with communication professionals in all of the CERN member states and major physics labs around the world, through the European Particle Physics Communication Network and the InterAction collaboration. "Without them," says Gillies, "the impact would have been much smaller."

This is the first presentation of the AlphaGalileo Research Public Relations Award, which is worth €5000 and includes a "golden" statue of Galileo Galilei.

The team at CERN will be using the award to give a young communication professional the chance to join the team as an intern throughout the LHC-restart period.

CERN's James Gillies, right, together with Carl-Johan Sundberg, vice-president of Euroscience. (Courtesy Euroscience Foundation.)

APS announces 2010 winners

The American Physical Society (APS) has announced many of its awards for 2010, naming recipients in particle physics and related fields, who are rewarded for their contributions not only to experimental and theoretical physics but also to public service and human rights.

Six physicists share the 2010 J J Sakurai Prize for outstanding achievement in particle theory: Robert Brout and François Englert of the Université Libre de Bruxelles; Gerald Guralnik of Brown University; Carl Hagen of the University of Rochester; Peter Higgs of Edinburgh University; and Tom Kibble of Imperial College, London. They are rewarded "for elucidation of the properties of spontaneous symmetry breaking in four-dimensional relativistic gauge theory and of the mechanism for the consistent generation of vector-boson masses". Their work (done independently by Brout and Englert; Guralink, Hagen and Kibble; and Higgs) was key to the development of electroweak theory and ultimately today's Standard Model of particle physics (*CERN Courier* January/February 2008 p17).

Experimental verification of the mechanism for generating masses is one of the key goals of current research in particle physics, for example, at Fermilab's Tevatron, which has been at the high-energy frontier for 20 years. In recognition of this, Fermilab's John Peoples receives the Robert R Wilson Prize for Achievement in the Physics of Particle Accelerators "for critical and enduring efforts in making the Tevatron Collider the outstanding high-energy-physics accelerator of the last two decades".

The Tevatron should soon be joined by the LHC in probing within and beyond the Standard Model, but over the past decade the best evidence for new physics has come from solar neutrinos. Eugene Beier of the University of Pennsylvania has worked with neutrino experiments for the past 30 years, at Brookhaven, at the Kamiokande II experiment and at the Sudbury Neutrino Observatory. He receives the W K H Panofsky Prize in Experimental Particle Physics for his "major contributions to studies of neutrino interactions, especially studies of solar neutrinos demonstrating unequivocally the existence of neutrino flavour oscillations".

In nuclear physics, the Tom W Bonner Prize aims to encourage outstanding experimental research, including the development of a method, technique or device that significantly contributes to the research in a general way. Steven Pieper and Robert Wiringa of Argonne National Laboratory are rewarded with the 2010 prize for their "development of quantitative, ab initio calculations of the properties of nuclei from A=6–12, including deep physical insight into the nature of nuclear forces and the application of state-of-the-art computational physics".

The APS awards also go beyond purely recognizing research. The Edward A Bouchet Award is "to promote the participation of under-represented minorities in physics by identifying and recognizing a distinguished minority physicist who has made significant contributions to physics research". The 2010 award goes to a particle physicist, Femilab's Herman White, "for his contributions to KTeV experiments and the establishment of a new kind of interaction distinguishing matter from antimatter, as well as his outstanding public service and mentorship roles".

Last, but by no means least, the Andrei Sakharov Prize is named "in recognition of the courageous and effective work of Andrei Sakharov on behalf of human rights, to the detriment of his own scientific career and despite the loss of his own personal freedom". Joseph Birman of the City College of New York at the City University of New York, Morris (Moishe) Pripstein of the National Science Foundation and Herman Winick of SLAC receive the 2010 Sakharov Prize "for tireless and effective personal leadership in defence of human rights of scientists throughout the world". Pripstein is well known as a particle physicist from the Lawrence Berkeley National Laboratory and also as a co-founder of the human-rights group "Scientists for Sakharov, Orlov and Sharansky (SOS)". Herman Winick, who has made many contributions to synchrotron-radiation sources and research, was instrumental in initiating SESAME, the UNESCO-sponsored international centre for Synchrotron light for Experimental Science and Applications in the Middle East.

SCHOOLS

Change at the top for CERN physics schools

After directing the CERN physics schools since 1993, Egil Lillestøl has handed over to Nick Ellis. At the same time, Hélène Haller has taken over from Danielle Métral as the schools' administrator.

The CERN physics schools for young experimentalists date back to the 1960s and as early as 1971 collaboration with the JINR in Dubna led to the Joint CERN–JINR schools, which reached beyond CERN's member states every two years. Then, in 1993, CERN and JINR agreed to organize the schools jointly every year, in the form of the European School for High-Energy Physics. Egil Lillestøl has not only run this school successfully since then but has also created the CERN Latin-American School of High-Energy Physics, beginning in 2001. Danielle Métral has been responsible for the schools' administration since 2001, both for the European and for the Latin-American schools. Now the team is handing the reins over to Nick Ellis as the new schools' director and to Hélène Haller as the incoming schools' administrator.

From left to right: Nick Ellis, Hélène Haller, Danielle Métral and Egil Lillestøl.

Many well known particle physicists have passed through the schools – not least CERN's current director-general, Rolf Heuer. At a celebration on 13 October to mark the handover, he warmly thanked Lillestøl for all of his work, noting that in its present incarnation the European school has contributed to the successful integration of more nations at CERN. JINR director Alexei Sissakian, who has been involved with every joint school from 1971, also thanked the teams and proposed a toast to "a good transformation of the directorate of the school and to the preservation of its traditions, wishing all the best to Nick and Hélène".

CELEBRATION

Novozhilov celebrates 85th birthday in St Petersburg

Yuri Novozhilov, a leading Russian scientist and the head of the theoretical physics department of the V A Fock Institute of Physics of St Petersburg State University, celebrated his 85th birthday in November.

A pupil of Vladimir Fock, the founder of the St Petersburg school of theoretical physics, Novozhilov has been leader of the school for decades and is known around the world for his work as a theorist. His main scientific interests are quantum-field theory, in particular the functional approach, bosonization in meson physics using chiral and conformal anomalies, induced gravity, as well as chiral solitons and the chiral parametrization of gluons.

Science and teaching are unseparable for Novozhilov. In 1961, under the guidance of Fock, he established the chair of high-energy physics and elementary particles in what is now St Petersburg State University. This chair

Yuri Novozhilov, physicist and teacher. (Courtesy St Petersburg State University.)

actively supervises the continued education of new generations of students. He has also been active in organizing the annual "V Fock Schools" in St Petersburg for theoretical physics students, which are popular in the republics of the former Soviet Union and are sponsored by UNESCO.

The existence of the St Petersburg team that since 1992 has participated in the preparations of the ALICE experiment for the LHC is also a result of Novozhilov's vision. He actively supports the development of new ideas and it was he who encouraged the organization of a new field of experimental physics in the theory department more than two decades ago.

For more than eight years (1973–1981) he was associated with UNESCO, as director in the department of scientific and technological development, which was responsible for the UNESCO–CERN collaboration and supported the Abdus Salam International Centre for Theoretical Physics in Trieste. In this context he represented UNESCO on several occasions on the CERN Council.

ECFA

RECFA meets in Moscow and Dubna

A meeting of a subpanel of the European Committee for Future Accelerators (ECFA) held on 9–10 October provided the opportunity for an update on the status and prospects for high-energy physics in Russia. Restricted ECFA (RECFA), a subpanel that acts as a communication channel between each participating country and the ECFA Plenary panel, held open sessions at both the Russian Academy of Sciences (RAS) in Moscow and at JINR in Dubna. A closed session was also held on the morning of the second day.

Participants at the RECFA meeting at JINR, Dubna, on 10 October. (Courtesy JINR.)

At the open meeting held in Moscow RECFA learnt about the current status of particle physics in Russia from Victor Matveev, director of the RAS Institute for Nuclear Research. Alexander Skrinsky, director of the Budker Institute of Nuclear Physics in Novosibirsk (BINP), described the participation of Russian scientific centres in the design and construction of the LHC at CERN and the future super-LHC. Alexei Sissakian, director of JINR, reviewed the status and development of high-energy physics at JINR, focusing in particular on the institute's new advanced project – the Nuclotron-based Ion Collider fAcility (NICA) to accelerate heavy ions for studies of nuclear matter at high temperature and density.

Further reports described the status and upgrades of the accelerator complex of the Institute of High Energy Physics at Protvino, the status and development of co-operation in the Facility for Antiproton and Ion Research in Germany, research in particle physics at BINP, and the involvement of Russian scientific centres in the physics programmes at B-factories. Grigori Shirkov informed the participants about the efforts of JINR and Russia in the design of the International Linear Collider. Representatives of other Russian research centres spoke about research in particle physics for space studies in Russia; Russian projects in cosmic-ray studies; research in particle physics at the RAS Lebedev Physics Institute; the participation of Russian specialists in the development of detectors and in physics at the LHC; the project of a high-flux research reactor, PIK, at the RAS Konstantinov Petersburg Nuclear Physics Institute; and the development of the computing Grid in Russia.

The evening session on 10 October took place in Dubna where the JINR directorate initiated a detailed discussion on NICA, the institute's new project. NICA, with its multipurpose detector (MPD), is at the core of the strategy for research in high-energy physics at JINR in the second decade of the 21st century. Experiments at the new accelerator will be aimed at precision studies of the phase transitions of strongly interacting matter that occur at very high temperatures and densities. The research will facilitate deeper understanding of the processes that took place in the early universe at the moment just after the Big Bang. From the JINR side, the meeting involved JINR's director, Sissakian; vice-director R Lednický; chief scientific secretary N Russakovich, chief engineer G Shirkov; director of the Laboratory of High Energy Physics (LHEP) at JINR, V Kekelidze; the NICA-MPD project leaders A Sorin, I Meshkov and G Trubnikov; and adviser to the JINR director, G Kozlov. In addition, G Trubnikov gave a review of the NICA-MPD project.

RECFA members took an active part in discussions about the new project and expressed their interest in several scientific-technical and organizational proposals, including wide international co-operation. Foreign participants of the joint RECFA–JINR meeting were also able to visit the NICA complex at LHEP, where the large-scale project is implemented at an existing accelerator, the Nuclotron.

ANNOUNCEMENT

JINR seeks candidates for Flerov prize

Applications are invited for the G N Flerov Prize for outstanding research in nuclear physics to be awarded by JINR in 2010, the year of the 70th anniversary of the discovery of spontaneous fission by Georgy Nikolaevich Flerov and Konstantin Petrzhak. The prize, established in 1992 in memory of the eminent physicist Flerov (1913–1990), rewards contributions to nuclear physics related to his interests. These covered experimental heavy-ion physics, including the synthesis of heavy and exotic nuclei using ion beams of stable and radioactive isotopes, studies of fusion, fission, nuclear-reaction mechanisms, accelerator technology and applied research.

The prize will be awarded in March 2010. The contest is for individual participants only. Applications, including a CV, an abstract of research and copies of major contributions, should be sent before 1 February 2010 to: Sergey I Sidorchuk, Scientific Secretary of the Flerov Laboratory of Nuclear Reactions, Joliot Curie str. 6, 141980, Dubna, Moscow Region, Russia; or by e-mail to sid@nrmail.jinr.ru. For further details, visit the website at http://flerovlab.jinr.ru/flnr/.

APPOINTMENT

Seryi is to take the helm at the John Adams Institute

Andrei Seryi will be the next director of the UK's John Adams Institute for Accelerator Science (JAI). He takes over from Ken Peach, who became director of the institute for five years in May 2005.

Seryi is currently leading the work on the Facilities for Accelerator Science and Experimental Test Beams (FACET) at the SLAC National Accelerator Laboratory and is leading the Beam Delivery System for the proposed International Linear Collider. He is also deputy spokesperson for the Accelerator Test Facility collaboration based in Japan. He will take up his post in August 2010 and will divide his time between the University of Oxford and Royal Holloway University of London, who jointly host the JAI. He will also hold a fellowship at Wolfson College Oxford.

The JAI is funded by the UK's Science and Technology Facilities Council (STFC). The institute was created in October 2004 with the aid of a grant from the then Particle Physics and Astronomy Research Council, now merged into the STFC.

Seryi will take over as head of the John Adams Institute in August 2010. (Courtesy Diana Rogers.)

FUNDING

UK research receives a boost

Research into accelerator science and technology in the UK has received a boost with the announcement of nearly £20 million of funding by the Science and Technology Facilities Council (STFC) to the Cockcroft and John Adams Institutes. The funding, which will benefit particle-, nuclear-, atomic- and molecular-physics research, has been awarded to the two institutes to enable them to continue building on the UK's strong research base in accelerator R&D and academic expertise.

The grants will see the Cockcroft Institute of Accelerator Science and Technology awarded £16.4 million to run to 2017 and the John Adams Institute for Accelerator Science awarded a £3.4 million grant to run to 2012. The announcement of funding to the two institutes follows a review of both of them earlier this year by a panel of international experts. Both grants will be backdated to April 2009.

The Cockcroft and John Adams Institutes were created to place academics, scientists and engineers at the forefront of developing the next generation of particle accelerators to meet physicists' demands for higher energy and higher-intensity particle beams for fundamental research. Both institutes participate in the research and development towards future global particle-physics projects based on linear-collider technology and for the study of neutrinos. They are also involved in activities for next-generation light sources as well as in emerging activities for high-current proton accelerators for various sciences and applications using hadron and electron–hadron colliders, neutrons and muons. At the same time, the institutes are also enabling strong links to be built between the research community and hi-tech industry to ensure that the UK can get the maximum benefit from its science.

The Cockcroft Institute is based at the Daresbury Science and Innovation Campus and is a partnership between the STFC Daresbury Laboratory and the universities of Lancaster, Liverpool and Manchester, with support from the Northwest Regional Development Agency. The John Adams Institute is a collaboration between the universities of Oxford and Royal Holloway, London, and has facilities on both sites.

COLLABORATION

UK donates tech components to SESAME

One of the legacies of the world's first dedicated synchrotron light source will be to enable scientific collaboration in the Middle East following the donation of decommissioned components by the Science and Technology Facilities Council (STFC) to the Synchrotron light for Experimental Science and Applications in the Middle East (SESAME). The components, originally from the Synchrotron Radiation Source in Daresbury, will be used to construct experimental beamlines for research into materials and life sciences.

The SESAME project has brought together the governments and scientists of Bahrain, Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, the Palestinian Territories and Turkey, with representatives from another 11 countries (including the UK and Germany, which donated its BESSY I machine) participating as observers to provide help and advice. SESAME is the region's first major international research centre, built in Jordan under the umbrella of UNESCO.

VISITS

Brazilian minister of science, **Sergio Rezende**, centre, visited CERN on 28 September. He toured the cavern of the CMS experiment with spokesperson, **Jim Virdee**, left, and **John Ellis**, right, adviser to the director-general. He also visited the test facility for the Compact Linear Collider Study and met with CERN's director-general, Rolf Heuer, as well as Brazilian scientists working at CERN.

Reinhard Klang of the Austrian Federal Ministry for Science and Research (left), **Klaus Schneeberger**, Chairman EBG MedAustron Board (centre right), and **Hannes Weninger** of the Austrian Parliament, came to CERN on 14 October to participate in the board meeting of EBG MedAustron. Before the meeting they toured the CMS experiment, with spokesperson, **Jim Virdee**, and visited the CERN Control Centre and Linac3. MedAustron is a centre for ion-therapy and research planned for Wiener Neustadt in Austria, with co-operation from CERN.

On 2 November, **Ian Taylor**, chairman of the UK's Parliamentary and Scientific Committee, (centre), visited CERN. Like other recent visitors, he toured CMS with spokesperson **Jim Virdee** (left) and technical co-ordinator **Austin Ball**. After lunch he visited the CERN Control Centre, where he met the head of the Beams Department, Paul Collier, and British colleagues, together with John Ellis and Steve Myers, CERN's director of accelerators and technology.

Twenty-seven engineers involved in the Facility for Antiproton and Ion Research (FAIR), to be built at the heavy-ion research centre GSI near Darmstadt, spent three days at CERN on 14–16 October on a visit organized by Horst Wenninger (front row, second from left). The main goal was to allow the German engineers to meet their CERN counterparts, but the timing meant that it was also possible to include a tour of the ALICE experiment prior to the restart of the LHC.

NEW PRODUCTS

The Numerical Algorithms Group (NAG) has announced the NAG Mark 22 Release Toolbox for Matlab. It allows access to 1415 rigorously tested numerical routines, providing easy migration of prototype code developed in the Matlab environment to final production code in advanced programming languages, such as C or Fortran, while still using the same robust algorithms. This release also includes more than a dozen quickly accessible Matlab-based examples of advanced programming for optimization problems, simulations, time-series analysis and other functions. For more details, e-mail Katie.Ohare@nag.co.uk; or see www.nag.com.

EMCO has introduced new ultra-low power (ULP) series DC–DC converters, which provide output voltages from 0–500 VDC, while consuming less than 2 mW of power. The output voltage is regulated, programmable, and can deliver up to 4 W of power on demand at >85% efficiency. Designed with "green" applications in mind, the ULP series features a shutdown pin that drops current consumption below 10 μA. Standard input voltage range is 5.4–7.4 V. For further details, tel +1 800 546 3680; email sales@emcohighvoltage.com; or visit www.emcohighvoltage.com.

OBITUARIES

Klaus Goebel 1926–2009

Klaus Goebel, an early leading figure in radiation protection at CERN, passed away on 1 October 2009.

Klaus came to CERN in 1956 together with Wolfgang Gentner for whom he had worked as an assistant from 1954 to 1955, after gaining a diploma in economics and a doctorate in physics at the University of Freiburg, Germany.

During these early years at CERN, Klaus measured isotope concentrations in meteorites and, as leader of the Spallation Research Group, he used the Synchrocyclotron (SC) to measure isotope production by protons. This interest in trace measurements carried over into his work in CERN's Health Physics Group, which he joined in 1962. He took over successively the radiation-protection work at the SC and the Proton Synchrotron and become deputy group leader. In the years 1969–70 he spent a sabbatical as a health physicist at the Lawrence Radiation Laboratory.

Klaus Goebel (left) with Anthony Sullivan, during Radioprotection Study Days, held at CERN in 1981.

When Klaus came back to CERN the preparatory work for the construction of the Super Proton Synchrotron (SPS) was under way. In 1971 John Adams called on him as leader of the Radiation Group to design the SPS Radiation-Protection System. It was the first computer-controlled on-line radiation detection and alarm system employed inside the accelerator tunnel (radiation-damage protection), in experimental areas (radiation protection of people) and for the site (environmental protection).

With the completion of the SPS in 1976 Klaus took over the responsibility for radiation safety for the whole of CERN, changing the name of the relevant group from Health Physics to Radiation Protection. Increasing awareness of radiation risks called for frequent reviews of procedures and for the availability of full information, both inside and outside the laboratory – in particular during the planning of the Large Electron–Positron Collider.

Public awareness of radiation issues grew tremendously following the Chernobyl accident in 1986. In view of his contributions in the field of radiation protection, Klaus was elected president of the Fachverband für Strahlenschutz (The Swiss-German Radiation-Protection Society) in 1988 during the critical period following the accident. While working at CERN his expertise in radiation-protection matters was frequently requested elsewhere, for example, for the spallation neutron source project in Karlsruhe and for the radiation-protection system for the JET fusion project in Culham, UK.

When Klaus retired in June 1991 he continued to be active in his field, in particular in various activities within the Ettore Majorana Foundation and Centre for Scientific Culture Erice, where he also acted as director of the International School of Radiation Damage and Protection from 1994 to 2005.

Klaus leaves his wife Elfriede and two children, to whom we convey our condolences.

His colleagues and friends.

Faheem Hussain 1942–2009

A flamboyant character and a theoretical physicist who was quickly at ease in different languages and cultures, Faheem Hussain made his best contributions to science in, and for, international settings.

As an Indian Muslim born before partition in 1947, he was not a native Pakistani. His family moved there, where he grew up and became a keen sportsman. After initial studies at the University of the Punjab in Lahore, he earned his doctorate in 1966 from Imperial College, London, with Paul Matthews and Abdus Salam. It was there

Faheem Hussain. (Courtesy Sara Monticone.)

that he helped make the first predictions of Salam's U(6,6) symmetry theory. Although this failed as a template for particle physics, Hussain's doctoral work earned him a research associateship at the Enrico Fermi Institute, Chicago, from 1966 to 1968.

He returned to Pakistan in 1968, where he joined Quaid-i-Azam University, Islamabad, and soon influenced a new generation of bright, young physicists. In the years 1975–1977 he served as chairman of the physics department, becoming full professor in 1985.

While in the US, the Vietnam war had kindled his deep sense of social justice. Once stirred, this empathy stayed with him: he and his American wife, Jane Steinfels, became immersed in Pakistan's socio-political issues, fearlessly helping victims of authoritarianism.

Unable to make any dent in its iron regimes, Hussain left Pakistan in 1989 and joined the Johannes-Gutenberg University, Mainz. There, with Juergen Koerner, George Thompson and others, he calculated relativistic-wave functions for hadrons and used Salam's formalism to develop a variant of the effective heavy-quark theory. The Mainz group went on to make valuable contributions to the study of heavy baryon decays.

In 1990 Hussain became a senior staff scientist at Salam's International Centre for Theoretical Physics (ICTP), Trieste, developing its high-energy-physics diploma programme. He then took over ICTP's Office of External Activities, assisting young physicists and mathematicians in developing countries. He retired from ICTP in 2004 and moved back to Pakistan, initially at the National Centre of Physics in Islamabad, and later Lahore's University of Management Studies, where he helped to establish a science faculty.

Alongside his administrative roles, he remained active in theoretical physics, working on superstrings, extra dimensions and non-commutative geometry. His experience also made him well qualified to write about science and technology in emerging societies. Hussain's gentleness and modesty always made him popular. Plagued by ill health in his short retirement, he returned for treatment to Trieste, where he married Sara, who he had met earlier at ICTP. He died on 29 September.

Above all, Hussain was socially concerned, continually striving to help the underprivileged, and unafraid to battle against dark forces of oppression wherever he saw them. His exuberance and spirit will be missed by the international science community and by his widespread friends and family.

His friends.

LETTERS

Remembering Jan Nassalski

I was greatly saddened when I heard that Jan Nassalski had died suddenly, and I agree with all of the positive things said about him in the obituary published in *CERN Courier* (October 2009 p32). But one episode in his career was omitted.

For about a year in the early 1970s he was a visitor at University College London (UCL) where he worked with us on the analysis of film from our heavy-liquid bubble chamber at the NIMROD accelerator of the Rutherford Laboratory. Because of passport restrictions from the Polish Communist government, he was unable to stay in London long enough to do a PhD at UCL. Instead, he copied all of his data onto paper tape, took it with him when he returned to Warsaw, completed his analysis there and submitted it successfully in 1973 for a Warsaw PhD under the supervision of Prof. P Zielinski. The work he did in collaboration with UCL, CERN, Tufts University and Brussels was to search for a possible resonant enhancement in the invariant-mass distribution of pairs of Λ hyperons produced when 2.1 GeV/*c* K^- mesons interacted with nuclei. His thesis title was "Analysis of two Λ^0 production in high energy K^- interactions with heavy nuclei in a freon–propane bubble chamber".

For a while we believed we had seen such an enhancement in events with an identified K^+ in the final state, confirming the production of two units of negative strangeness (P Bellière *et al.* 1972 *Phys. Lett.* **39B** 671), but when we later scanned the same film for dilambda events with a K^0 among the final-state baryons (another possible signature for production of strangeness –2) there was no significant enhancement (G Wilquet *et al.* 1975 *Phys. Lett.* **57B** p97). Jan was therefore involved in one of the first failures to observe and prove the existence of a dibaryon resonance, and he helped us all to learn how capricious samples with small statistics can be.

Jan worked harder and more thoroughly than any other graduate student I have known, even missing the departmental Christmas party to complete the preparation of the data tape that he took back to Warsaw.

David Miller, University College London.

The NuTev anomaly

NuTeV would like to respond to the article "NuTeV anomaly supports new effect in bound nucleons" (*CERN Courier* September 2009 p9) . The article asserts that, after the new effects are considered, "the NuTeV data turn out to be in excellent agreement with the Standard Model". NuTeV does not believe this claim is justified.

First, we want to clarify a point that may be misinterpreted in reading the article. The NuTeV result is not based on free-nucleon parton distributions but on structure functions measured in our iron target. Thus, a separate EMC correction is not needed in the NuTeV analysis.

Second, the authors of the work described have made a specific numerical choice for asymmetries in the momentum distribution of the strange v antistrange sea that is different and only consistent at the 5% level with our published measurements.

Finally, after the NuTeV publication, the K_{e3} branching ratio changed and that change has not been included in this update. The electron-neutrinos from K_{e3} decay will cause a small change in the measured neutral current rate, and hence the result.

The NuTeV collaboration plans to update the result with an improved-structure function analysis, an internal measurement of the strange-sea asymmetry and the shift in the K_{e3} branching ratio. Before these are completed, it is premature to draw conclusions that NuTeV supports the model to the stated accuracy.

NuTeV measured the ratios of cross-sections in both neutrinos and antineutrinos. We found a shift in neutrinos and essentially none in antineutrinos. New models, including this one, must explain both ratios and the weak mixing angle result simultaneously.

The model presented is intriguing (arXiv:0908.3198v1). We believe it deserves further research but such a post-diction does not justify the claims made in the article.

Robert Bernstein for NuTeV.

CORRECTION

The affiliation of Igor Ivanov, winner of the Bogoliubov Prize for young scientists (*CERN Courier* November 20009 p41), should have been given as "the University of Liege, Belgium, and the RAS Institute of Mathematics". Apologies to all concerned.

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STARTING DATE: August 1, 2010 or as agreed.

Applications, including curriculum vitae, a list of publications, a short research plan and the names of 4 people who may be contacted, should be sent before **January 31, 2010**, to the Dean of the Faculty of Sciences, 30 Quai Ernest-Ansermet, CH-1211 Geneva 4, Switzerland, or by e-mail in one single file to Laure.Sollero@unige.ch, where further information concerning the job description and working conditions may be obtained.

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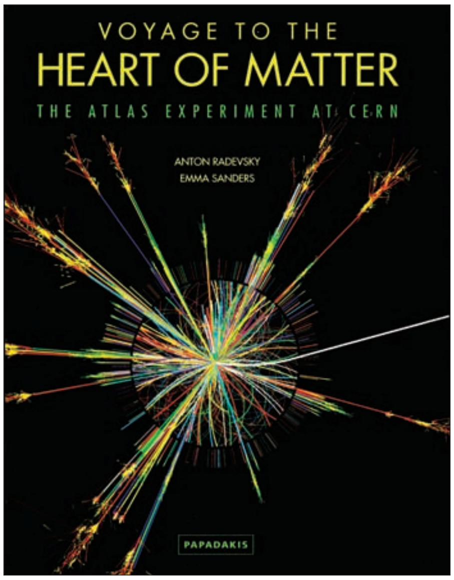
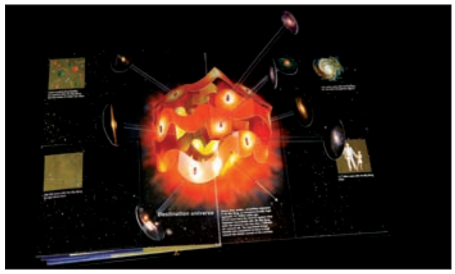
BOOKSHELF

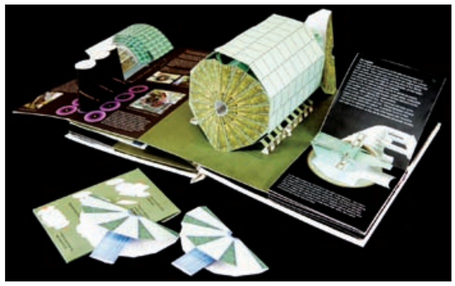
Festive Bookshelf

The year at CERN has been dominated by preparations to restart the LHC and embark on explorations of the high-energy frontier. At the same time, the LHC machine has entered popular consciousness, with worldwide coverage in everything from science magazines to prime-time television.

To help answer the inevitable questions from family and friends, this edition of Bookshelf looks at two books that are aimed at explaining experiments at the LHC to a broader audience, as well as other books that could be considered as presents in this festive season.







Voyage to the Heart of Matter: the ATLAS Experiment at CERN by Anton Radevsky and Emma Sanders, Papadakis. Hardback ISBN 9781906506063, £20.

You would never guess from the title that *Voyage to the Heart of Matter* is a pop-up book about the Large Hadron Collider. And that is a shame because it is an extraordinary work of paper engineering that deserves to stand out on the soon-to-be crowded shelf of popular books about the LHC.

Written by pop-up-book author Anton Radevsky and manager of CERN's Microcosm exhibition Emma Sanders, *Voyage* is only eight pages long yet each turn of the page reveals a pop-up spread that will have you gasping with joy. Most of the corners open up to reveal yet more 3D delights, including delicate reproductions of the ATLAS tracking detectors and a miniature control room, complete with physicists. Others reveal movable elements showing how matter and antimatter annihilate or how showers of particles develop in a calorimeter.

Voyage exploits all three dimensions to wonderful effect. A glorious pop-up universe charts cosmic evolution from the first microsecond, chock-full of quarks and leptons, to the galaxies of present day. Readers are even given the chance to unfurl the ATLAS detector and install the inner detectors and muon chambers.

What is so charming about *Voyage* is the level of detail in the illustrations. You are guaranteed to spot something new each time you read it: the tiny human standing next to ATLAS; the trigger room; and event displays on the physicists' computer screens.

Voyage does have its flaws, though. For instance, some of the pop-up structures need a helping hand as you open and close the pages. A more serious problem is that the authors know too much about ATLAS and haven't simplified the words enough for ordinary readers. This is all the more apparent because of the book's layout: the words need to be read in order yet the book has so many flaps that there is no clear order. The various detector components would benefit from being labelled too. (One of the pop-up structures remains a mystery to me.)

On balance, the book's charms outweigh its faults. It is somehow fitting that its complex paper engineering reflects the engineering achievements of ATLAS and the LHC. *Voyage* is an enchanting book.

Valerie Jamieson, deputy features editor, New Scientist.

Collider: The Search for the World's Smallest Particles by Paul Halpern, Wiley. Hardback ISBN 9780470286203, €24.90 (£18.99, $27.95).

As well as opening a new era of fundamental physics research, the LHC is also making its mark on science publishing. There are already several books on the LHC – soon there will be more. Paul Halpern of Philadelphia's University of the Sciences is a prolific author and has produced a book aimed at the North American market.

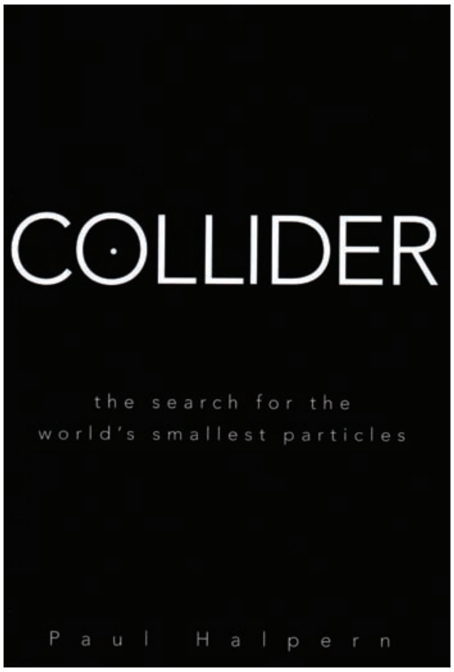
After a tourist's introduction to CERN, *Collider* charts the history of the quest to discover and explain the structure of matter. Any book on particle physics has to shoulder this burden. Thus, in a book about 21st-century science, the first illustration is a portrait of Ernest Rutherford.

Unification, as a means to understand as much as possible from a minimal subset of axioms, is a central theme in physics. Halpern points out the aptness of CERN having its home in Switzerland. Just as the country successfully unifies different languages, religions and geographies, so can it be with physics: with imagination and insight, what superficially seems to be highly disparate, in fact reveals deep parallels.

As well as this theoretical understanding, Halpern also traces the history of the particle accelerators that probe the depths of the atomic nucleus and the detectors needed to capture and record their outcomes. After the Second World War, this science became very much a US speciality, with CERN trying to play catch-up as best it could.

With colliding-beam machines providing an additional stage for this research, it was Carlo Rubbia who helped propose the idea of a proton–antiproton collider. However, Fermilab in the US was committed to equipping its ring tunnel with superconducting magnets, so Rubbia knocked on CERN's door instead.

There, prescient minds saw the value of the scheme. In 1983 came the landmark discovery of the W and Z particles – the carriers of the unified electroweak force (p30). With this collider, Europe had not



only caught up but overtook the US, where it was a blow to national scientific prestige. As Halpern writes: "Like baseball, accelerator physics had become an American pastime, so it was like losing the World Series to Switzerland."

Piqued, the US mobilized for the mother of all colliders, its Superconducting Supercollider (SSC). Halpern recalls the SSC era and points out how the machine, primarily a US venture, was handicapped by its limited international horizon.

After the sudden cancellation of the SSC, the less ambitious LHC collider was alone on the world stage and CERN, itself an international organization, knew how to manage such ventures. The SSC had been a green-field site: CERN had the advantage of an existing tunnel, built to house its electron–positron collider, LEP. More credit should be given to the CERN pioneers who had presciently stressed right at the start that this tunnel should be made wide enough to accommodate big magnets for a later, more ambitious machine. Thanks to such foresight, the LHC could fit inside CERN's existing subterranean real estate.

In 2008 the commissioning of the LHC was overshadowed by a puerile phobia: black holes from the machine would swallow the planet. Halpern creditably blows away such absurdity. It often appears as though the human race is not happy unless it has something to worry about. In 2009 the panic about purported black holes at the LHC seems to have become obscured by other worries.

Collider is timely, instructive and comprehensive. However, its transatlantic view of Europe sometimes gets a little out of focus. With a population of 7600, the thriving French town of Ferney-Voltaire near CERN is not "little touched by modernity". This "village" gives France the novelty of separate access to Geneva airport, and its proximity to the international scene in neighbouring Geneva has played a key role in the development of French secondary-school education. On a more important historical note, Isidor Rabi may have suggested the idea of what eventually became CERN, but he did not create it.

Gordon Fraser, Divonne-les-Bains.

Nothing: A Very Short Introduction

by Frank Close, OUP. Paperback ISBN 9780199225866, £7.99 ($11.95).

In 2003, a travel writer called Bill Bryson caught the imagination of many with a popular-science book called *A Short History of Nearly Everything*. This was in many ways the perfect antidote to Stephen Hawking's intellectually dazzling bestseller *A Brief History of Time*, which left many readers without a physics background perplexed. Reading Frank Close's book *Nothing – A Very Short Introduction*, I am reminded of both Bryson and Hawking at once.

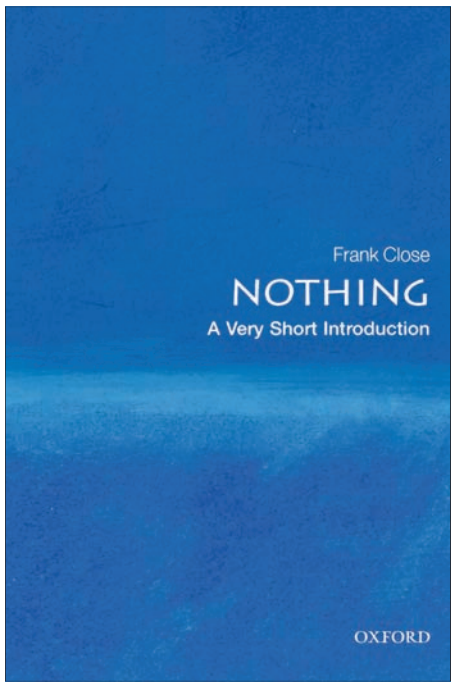
Do not be fooled by the title. Like Bryson, Close covers nearly everything – or at least nearly everything in the history of physics – as he attempts to grapple with the philosophical meaning of nothing through the ages, and how physicists' concept of a pure vacuum has today become cluttered with virtual particles. And like Hawking, he succeeds in being succinct: under 150 pages in this highly portable volume (Bryson's weighty tome, at nearly 500 pages, was short only in name).

In terms of approachability for the uninitiated, Close lies somewhere between Bryson and Hawking. Bryson's advantage in exposing scientific concepts was that, until he started writing the book, he didn't understand many of those concepts himself. So he erred on the side of simplicity. Close succeeds most of the time in keeping the science simple and finding useful analogies for difficult concepts. Fields that permeate the vacuum are introduced through an analogy with weather maps, which chart atmospheric-pressure variations, for example.

But like many an expert who has spent his life steeped in science – Close is professor of physics at Oxford University – he sometimes overlooks the implicit knowledge he carries. After an admirable introduction to zero-point energy in terms of a perpetually trembling quantum pendulum, for example, he goes on to introduce the Casimir effect by stating that, "The Void is a quantum sea of zero-point waves, with all possible wavelengths, from those that are smaller even than the atomic scale up to those whose size is truly cosmic." It is precisely at such conceptually challenging junctures that the attention of the uninitiated may begin to wander.

That said, the book never dwells too long on any one topic to become tedious. Rather, it romps along through a list of some of the most exciting physics breakthroughs of the past century. And all of these, in Close's carefully woven story, have something to do with nothing. Black holes, the cosmic microwave background, the Higgs boson are all there, with a respectful nod to CERN where Close headed the communication and public education activities between 1997 and 2000.

When it comes to filling Christmas stockings, Close's book would be a good choice for a teenager with a burgeoning interest in physics. It has a healthy balance of clear exposure of known facts and tantalizing

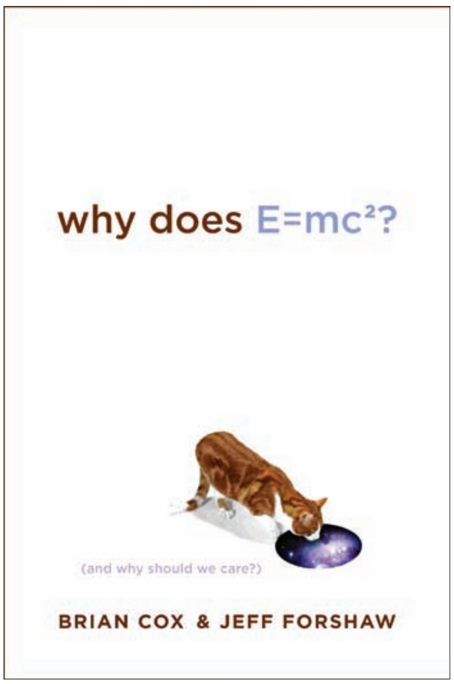


glimpses of the complexity of science at its cutting edge, plus occasional reminders that if the reader really want to understand this stuff, mastering mathematics is essential. Besides, its handy format will squeeze easily into even the smallest of stockings.
François Grey, Tsinghua University, Beijing.

Why Does E=mc2? (And Why Should We Care?) by Brian Cox and Jeff Forshaw, Perseus Books. Hardback ISBN 9780306817588, £12.99 ($24.00).

A century after Albert Einstein published his theory of relativity, and more than half a century after his death, the public imagination is still stirred by all things Einstein. Any writer of physics for non-scientists knows that Einstein is the goose that keeps laying the golden eggs. Just as a comedian knows that a punch to the crotch will always make 'em laugh, a physicist knows that Einstein will make 'em think. Brian Cox and Jeff Forshaw are recent additions to the "World of Einstein" popularizations and their book *Why Does E=mc^2? (and why should we care?)* does a respectable job of bringing the reader into that world. More importantly, it is also a laudable attempt at leading the readers to more modern connections.

The first half of the book explains special relativity in detail and with clarity. The more casual reader might be put off by the long chapters and the long paragraphs, with



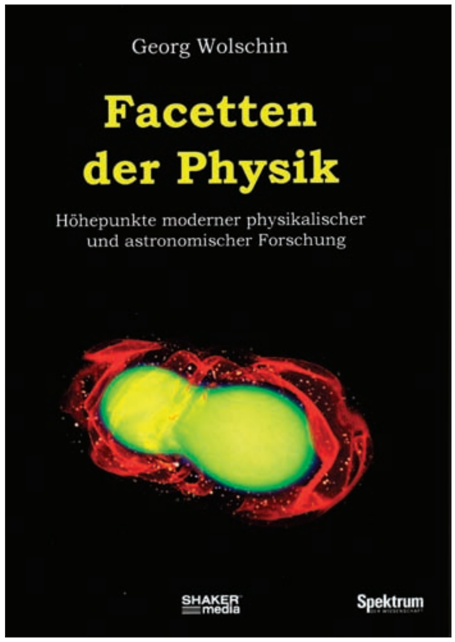
sometimes difficult transitions between concepts, but the elements needed to understand are there for the determined reader. I especially liked the discussion on how to think about invariant lengths in space–time. It is unfortunate, however, that more care was not taken in the figures. Some appear more akin to what is found in a physics-journal article than is suitable in a book about popular science. Nevertheless, that minor point does not damage the discussion much.

The second half of the book discusses more modern developments, with interesting descriptions of pulsars, black holes, nuclear fusion, the Higgs mechanism and more. The connection to E=mc^2 is rather stretched in places, but I did not mind. At times the discussion here becomes quite complex. For example, the Standard Model Lagrangian equation is given in chapter 7, accompanied by pages of explanation that I am afraid may go over the heads of many readers. And again, the figures are complex, including the one-loop QED diagram of e^-e^- scattering. This could be viewed as a plus, however, in that the authors are not shying away from trying to explain more advanced material than is normally attempted in popular books. Furthermore, the basic points that the authors wish the reader to be sure to get are explained patiently, and the anecdotes are entertaining.

Given the strengths of this book, and the level at which it is pitched, I would feel most comfortable recommending it to, for example, determined and precocious teenagers who are already studying physics, but who want to get an introduction to relativity and modern ideas more quickly than the school curriculum allows. The book should hold their interest, and be beneficial to them when they study it again in a more rigorous context.
James Wells, CERN.

Facetten der Physik: Höhepunkte Moderner Physikalischer und Astronomischer Forschung by Georg Wolschin, Shaker Media. Hardback ISBN 9783868580600, €39.90.

The 20th century was marked by many revolutionary advances in fundamental physics, from the microscopic world of particle physics to the cosmological scales of general relativity – topics presented and discussed in a multitude of books, many of them for a general audience. The most recent experimental observations, however,



are not yet included in those "text books" and the general public can only learn about them through articles published in scientific magazines.

Wolschin's book presents a collection of individual articles published between 1998 and 2009 on the highlights of experimental research in modern physics and astronomy. The 45 contributions, decorated with many colourful figures, images and computer simulations, were originally published in the magazines *Spektrum der Wissenschaft*, *Bild der Wissenschaft* and *Sterne und Weltraum*. For the book edition, each original article (5–10 pages long) is complemented by a short paragraph reflecting the latest progress in the corresponding topic. In general, the author succeeds quite well in explaining at a relatively simple level the many complex phenomena addressed, targeting the readers of popular-science magazines.

While astronomy and astrophysics provide the centre of gravity of this compilation, many other research topics are addressed, including practically all branches of high-energy physics, as well as cancer therapy with ion beams, quantum entanglement, etc. The reader can, for instance, learn about WMAP's measurement of the temperature fluctuations in the cosmic background radiation and how their spectral analysis probes the age and geometry of the universe. Or about ESA's recently launched Planck satellite, which will perform improved measurements and further test the cosmological models.

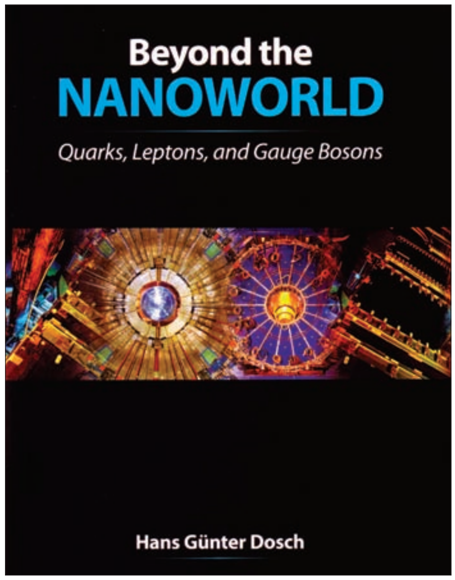
Triggered by the world year of physics (2005) and sprinkled with interviews with well known physicists, several articles discuss Einstein's ideas and their experimental testing. One of these tests involves the search for gravitational waves. In other articles, Wolschin describes the Laser Interferometer Space Antenna (LISA), a sophisticated and highly sensitive triangular laser-interferometer system that will be based on three satellites placed 5 million kilometres apart. The observation that neutrinos are not massless (one of the most interesting experimental results of recent years) also merits considerable attention in the book, requesting an "extension of the Standard Model of particle physics".

The format of the book is somewhat puzzling, with the articles ordered chronologically, starting with the most recent. After reading the latest article on neutrino physics, the other three seem repetitive. The book would have benefited from organizing the articles by topic and merging the ones with similar contents.

Hermine K Wöhri, Laboratório de Instrumentação e Física Experimental de Partículas, Lisbon.

Books received

Beyond the Nanoworld: Quarks, Leptons and Gauge Bosons by Hans Günter Dosch, A K Peters. Hardback ISBN 9781568813455, $39.



Elementary particles are a long, long way beyond the "nanoworld" of molecules, being firmly embedded in the "femtoworld". This primer on particle physics takes the reader on the journey from the first discoveries of subatomic structure to today's Standard Model, following both experimental and theoretical developments. It tries to avoid mathematics, but doesn't shy away from difficult concepts; readers are spared equations, but they need patience. It was originally written in German as *Jenseits der Nanowelt*, where it challenges Harald Fritzsch's classic *Quarks, Urstoff Unser Welt*. The English version covers similar ground to Frank Close's *The New Cosmic Onion*.

Recounting fond memories of when DESY first began

Pedro Waloschek recalls the times that gave birth to DESY and today's Standard Model.

Do you remember? If you are old enough you certainly will. I refer to the sixth decade of last century, when the research centres CERN and DESY were created. About that time I tried to explain to my sister Jutta (an artist who always considered logarithms as some species of worms) our understanding of the structure of matter. I started with the usual story about all visible matter being made of molecules which in turn are composed of atoms. And all atoms are made of very small particles called protons, neutrons and electrons. I even tried to explain some details on nuclear, electromagnetic and gravitational forces; three basic particles and three forces, an elegant and simple scheme. I left out solar energy and radioactivity.

But Jutta was not happy. In the early 1950s she came with us to the Andes mountains to expose nuclear emulsions in which we searched for cosmic mesons and hyperons. Jutta was also an attentive observer during the many evenings that I spent with Gianni Puppi in the ancient building of the Physics Institute of Bologna, scanning bubble-chamber pictures provided from the US by Jack Steinberger. We were looking for so called Λ and θ particles, trying to learn about their spin and some difficult-to-understand parity violation. So Jutta knew that there were many more particles and effects in existence, which I could not explain to her.

And, at a certain point, we particle physicists did not like the situation either. Our initial excitement with the discovery of exotic particles did not last long. We were not pleased with the several hundred particles and excited states (most of them unstable) that had been found but which did not fit into our traditional scheme of the structure of stable matter. There was no good reason for them to exist. It seemed at a certain moment quite useless to continue adding more and more particles to this "particle zoo" as it was condescendingly called. We were just making a kind of "particle spectroscopy" with no visible goal in mind.

Jutta's Standard Model of particle physics. (Courtesy Jutta Waloschek.)

In addition, at that time we had already been forced to abandon our beloved organization in small university groups, each one proud of their individual discoveries. Now, it was often the case that several of these groups had to join forces to reach significant results. One extreme example was a collaboration of about a hundred physicists on a single project to expose an enormous emulsion stack in the higher atmosphere and subsequently to undertake its inspection. Results were published with more than a hundred authors on a single paper, a kind of horror vision for individualists. It was the beginning of the international globalization of research, initiated (as are so many other issues) by particle physicists.

But none of this helped us understand the particle zoo. There was general agreement that new ways should be found, perhaps by the systematic study of reactions at higher energies. It was in this period that the European research centre CERN was created in 1954. Other local accelerator projects were started in a number of countries too, some of which were designed as a complement to the planned proton accelerator at CERN. A group of German physicists were dreaming about an electron machine, and this led to the foundation of DESY in Hamburg exactly 50 years ago.

However, life for electron-accelerator enthusiasts was not easy. While most particle physicists agreed about building proton machines, several did not accept the idea of working with electrons. I remember serious claims that everything related to electrons and electric charges could be accurately calculated within the framework of quantum electrodynamics. Consequently nothing new could be learnt from experimenting with electrons. Fortunately this was wrong!

The results of the following 50 years of global research are well known. Single papers are now often signed by more than a thousand authors and our understanding of the inner structure of matter has improved by a factor of thousand. The existence of most of the particles of our zoo can be understood and their inner structure has been explained (including our protons and neutrons). Quarks and leptons as basic particles and several fundamental forces with their exchange quanta form an elegant scheme called the "Standard Model of particle physics". There are still some problems to solve, but I did try again to explain the basics to my sister Jutta. She illustrated her feelings after our last discussion.

Pedro Waloschek, a physicist at DESY from 1968 until retiring in 1994, was the CERN Courier*'s correspondent for the laboratory for many years. He is author and editor of several books, including the autobiography of accelerator pioneer Rolf Wideröe.*