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CERN COURIER

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

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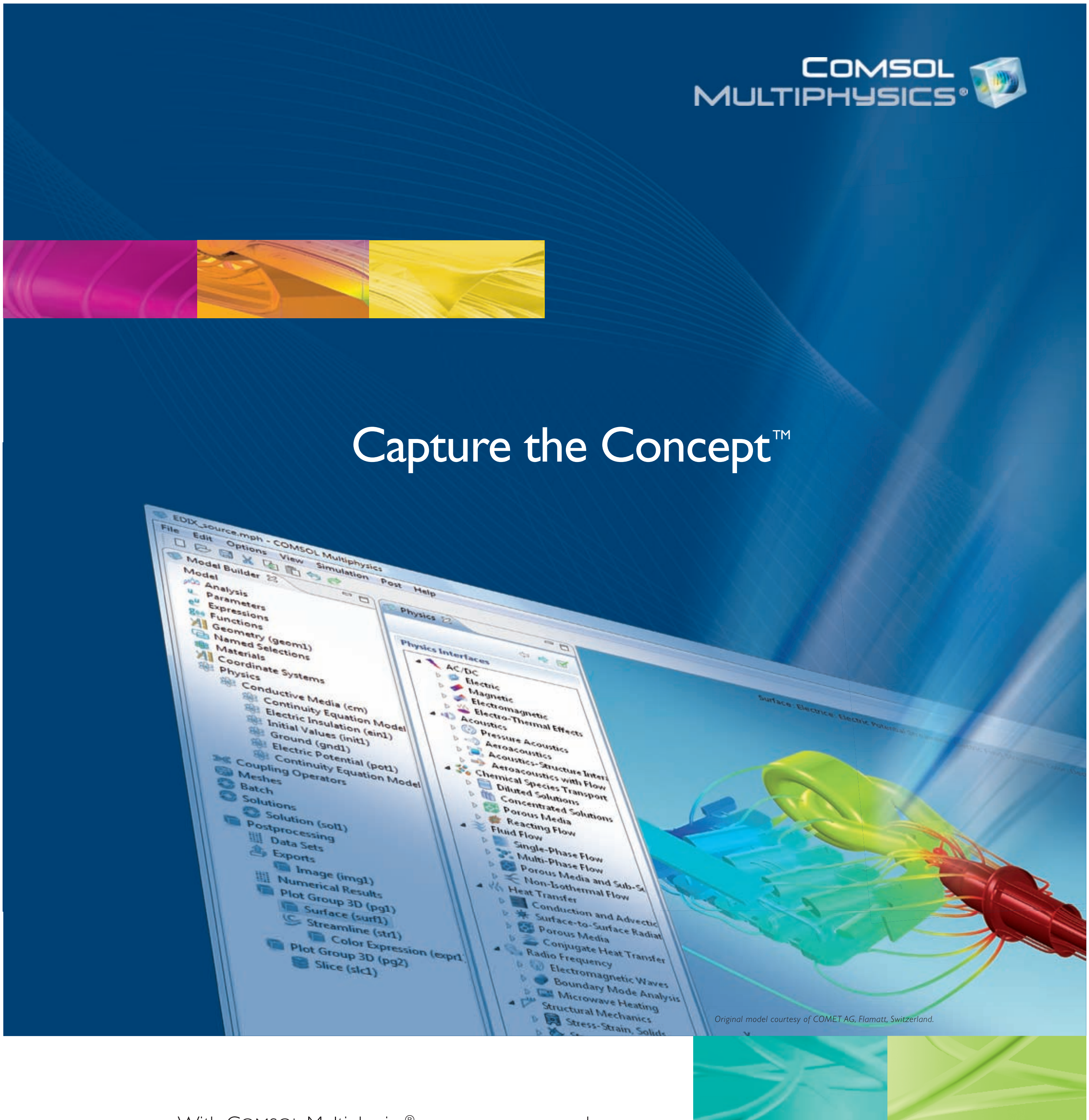
What did ALICE see? p7

A dream comes true p24

Strange exotic atoms p28

Cover: The LHC achieves a record-breaking energy on 30 November as both beams reach 1.18 TeV. The smooth orange curve shows the rise in energy determined by the current in the magnets. The green trace shows the intensity of Beam 2, which drops during the ramp but then remains constant once the energy reaches 1.18 TeV.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CERN

LHC restart impresses Council

At its 153rd session on 18 December, the CERN Council heard that the LHC had ended its first full period of operation two days earlier, following collisions at a total energy of 2.36 TeV – a world record. The LHC circulated its first beams of 2009 on 20 November, ushering in a remarkably rapid beam-commissioning phase (p24). The first collisions were recorded on 23 November, and the world-record beam energy was established on 30 November. Following these milestones, a systematic phase of commissioning led to a period in which the six LHC experiments recorded more than a million collision events, which were distributed for analysis around the world on the LHC Computing Grid.

At the end of this first period of running, the LHC went into standby mode for a short technical stop to allow preparations for higher energy running after a restart scheduled for February. In November teams had commissioned and tested the magnet powering up to 2 kA, which corresponds to a beam energy of 1.18 TeV (*CERN Courier* December 2009 p5). To run at higher energies requires higher currents, placing more exacting demands on the new machine protection systems, which need to be readied for the task. Commissioning work for higher energies has been under way throughout January, together with necessary adaptations to the hardware and software of the protections systems that have come to light during the 2009 run.

"Council is extremely pleased and impressed by the way the LHC, the experiments and the Computing Grid have operated this year," said Council president Torsten Åkesson. "The laboratory set itself an ambitious but realistic programme at its February [2009] planning meeting. The fact that all the objectives set back then have been achieved is a ringing endorsement of the step-by-step approach adopted by CERN management."

Torsten Åkesson (right) symbolically hands over the presidency of CERN Council to Michel Spiro.

Other Council business included the question of geographic enlargement of CERN. Council heard from a working group established in 2008 to examine this question, and accepted a series of guiding principles concerning such an enlargement, with a possible associate status involving balanced benefits and obligations being developed. In parallel, CERN has received five applications for membership over the past 12 months. Council decided to establish a working group to undertake the tasks of technical verification and fact-finding relating to these applications.

At the end of the meeting, Åkesson handed over the Council's presidency to Michel Spiro, director of the National Institute for Nuclear Physics and Particle Physics (IN2P3) at the Department of Nuclear and Particle Physics and of the National Centre for Scientific Research (CNRS) in France. "I am greatly honoured to have been elected president of the CERN Council," said Spiro. "I will be the Council's 20th president, and it is with humility that I take up the mantle of my illustrious predecessors, not least Professor Åkesson, who has made significant progress with the organization over the term of his mandate. With the first results from the LHC eagerly anticipated, the period ahead promises to be a golden era: it is these results that will shape the future of particle physics and of CERN."

Screens show the return of beam to the LHC.

Sommaire

SUPERCONDUCTORS

CERN to be reference lab for ITER's superconductor tests

The fourth meeting of the Steering Committee of the CERN/ITER Collaboration Agreement took place at CERN on 19 November. It marked not only the end of a second year of successful collaboration between ITER and CERN on superconducting magnets and associated technologies but also the establishment of CERN as the ITER reference laboratory for superconducting strand testing for the next five years.

The implementation agreement for 2009 encompassed a variety of topics. These included expertise in stainless steel and welding, high-voltage engineering, the design of high-temperature superconductor current leads, and testing and consultancy in cryogenics and vacuum technology.

The main role of CERN as the ITER reference laboratory will be: to carry out yearly benchmarking of the acceptance test facilities at the six domestic agencies involved in superconducting strand production; to help in the training of the personnel involved in these tests around the world; and to carry out third-party inspection and expertise in case of problems during production. To this end, CERN will use the facilities that were set up for strand qualification for the LHC, but with an important modification: the upgrade of magnetic fields from 10 T to 15 T to properly test samples of niobium-tin (Nb_3Sn) superconductors.

Left to right: Luca Bottura, head of the CERN Superconductor and Devices Section; Neil Mitchell, head of the ITER Magnet Division; Frederick Bordry, head of the CERN Technology Department, Arnaud Devred, head of the ITER Superconductor Systems and Auxiliaries Section; and Lucio Rossi, head of the CERN Magnet, Superconductors and Cryostats Group. They are standing in front of a sample-holder used for measurements of critical currents in strands of Nb_3Sn in the Superconductor Laboratory at CERN.

This programme has considerable synergy with the study for high-gradient quadrupoles in Nb3Sn that CERN is pursuing to prepare new technology for the LHC luminosity upgrade (*CERN Courier* November 2009 p16). Nb3Sn has a superior performance to the niobium-titanium alloy employed in the LHC. However, the brittleness of Nb3Sn and the need for high-temperature heat treatments mean that much R&D is still required. ITER will see the first large-scale use of Nb3Sn: some 400 tonnes of the conductor will be used for the toroidal field coils and the central solenoid.

US niobium-tin superconducting magnet reaches 200 T/m

A focusing magnet based on niobium-tin superconductor, built by members of the US LHC Accelerator Research Program (LARP), has reached the design gradient of 200 T/m. The US group is working on strategies to upgrade the inner triplet quadrupole magnets that perform the final focusing of the particle beams close to the interaction points.

In an upgraded, higher-luminosity LHC the inner triplets will be subjected to still more radiation and heat than the current magnets are designed to withstand. One of the goals of LARP is to develop upgraded magnets using niobium tin (Nb_3Sn), which is superconducting at a higher temperature than the niobium titanium (NbTi) currently used. Nb_3Sn therefore has a greater tolerance for heat and can remain superconducting at a magnetic field more than twice as strong. However, it is brittle and sensitive to pressure and to become a superconductor when cold, it must first be reacted at temperatures of 650–700 °C.

The LARP effort initially centred on a series of short quadrupole models at Fermilab and Berkeley and, in parallel, a 4-m long magnet based on racetrack coils, built at Brookhaven and Berkeley (*CERN Courier* October 2007 p8). The next step involved the combined resources of all three laboratories on the fabrication of a long, large-aperture quadrupole magnet. In 2005 the US Department of Energy (DOE), CERN and LARP set a goal of reaching, before the end of 2009, a gradient of 200 T/m in a 4-m long superconducting quadrupole magnet with a 90 mm bore for housing the beam pipe.

This goal was met on 4 December 2009 by LARP's first "long quadrupole shell" model magnet. The magnet's superconducting coils performed well, as did its mechanical structure, based on a thick aluminium cylinder (shell) that supports the superconducting coils against the large forces generated by high magnetic fields and electrical currents. The magnet's ability to withstand quenches – sudden transitions to normal conductivity with resulting heating – was also excellent.

● LARP is a collaboration of Brookhaven National Laboratory, Fermilab, Lawrence Berkeley National Laboratory and the SLAC National Accelerator Laboratory, founded by the DOE in 2003 to address the challenge of planned upgrades to the LHC's luminosity.

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

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

LIGHT SOURCES

UK's ALICE facility collides beams to make X-rays

Physicists working on an R&D prototype for the next generation of accelerator-based light sources – Accelerators and Lasers in Combined Experiments (ALICE) at the Daresbury Laboratory in the UK – are celebrating after successfully colliding electrons and a powerful laser beam to produce short-pulsed X-rays. This is the first time this has been done in the UK and the first time that the concept of using an accelerator and laser source together has been demonstrated on ALICE.

The Compton Back Scattering project saw a team of scientists from the Cockcroft Institute, the University of Manchester, the Max Born Institute and the Science and Technology Facilities Council (STFC) accelerate bunches of electrons and then collide them head-on with a high-energy, short-pulse multi-terawatt laser photon beam. The technique converts

The ALICE facility at the Daresbury Laboratory. (Courtesy STFC.)

the optical laser light to X-rays, as the electrons transfer energy to the photons.

ALICE is the first accelerator in Europe to operate using energy recovery, where the energy used to create its high-energy beam is captured and reused after each circuit of the accelerator for further acceleration of fresh particles. The recent success comes just one year after the facility first achieved energy recovery (*CERN Courier* January/February 2009 p7).

Ten nations sign up for European XFEL project

On 30 November, representatives from Denmark, Germany, Greece, Hungary, Italy, Poland, Russia, the Slovak Republic, Sweden and Switzerland signed the "Convention concerning the Construction and Operation of a European X-ray Free-Electron Laser Facility". Six language versions each of the Convention and the Final Act now carry the signatures of 11 government representatives, including two from the Federal Republic of Germany. These two documents lay the foundations of the European XFEL project, define the financial contributions of the current partner countries, and confer the responsibility for the construction and operation of the X-ray free-electron laser facility on the nonprofit company European XFEL GmbH.

For internal reasons France and Spain will sign the Convention later and China plans to join within the next six months.

FACILITIES

Extreme light rises in Eastern Europe

A new international player has entered the arena of intense short-pulse coherent light technology, with the latest developments in the Extreme Light Infrastructure (ELI) European project, which was launched in November 2007 in its preparatory phase and involves nearly 40 research and academic institutions from 13 EU member states. At the end of 2009, ELI decided to create a pan-European Extreme Light Facility based at several research sites. The first three sites have been selected and a decision on a fourth site, to deal with "ultrahigh peak power", will be taken in 2012 after validation of the technology.

The field of "extreme light" is opening up a new direction in fundamental and applied research (*CERN Courier* March 2009 p21). It is currently carried out in Europe – mainly in France, Germany, Russia and the UK – as well as in China, Japan, South Korea and the US. With the new initiative, other European countries hosting the three sites for the new facility are set to take a leading role.

The site in Prague, Czech Republic, will focus on providing ultrashort-pulse beams of energetic particles (10 GeV) and radiation (up to a few mega-electron-volts) produced from compact pulsed-laser plasma accelerators with a planned overall laser peak-power reaching 50 PW. In Hungary, a site in Szeged will be dedicated to extremely fast dynamics, taking snap-shots at the attosecond scale (10^{-18} s) of electron dynamics in atoms, molecules, plasmas and solids based on an optical few-femtosecond laser with an average power of several kilowatts.

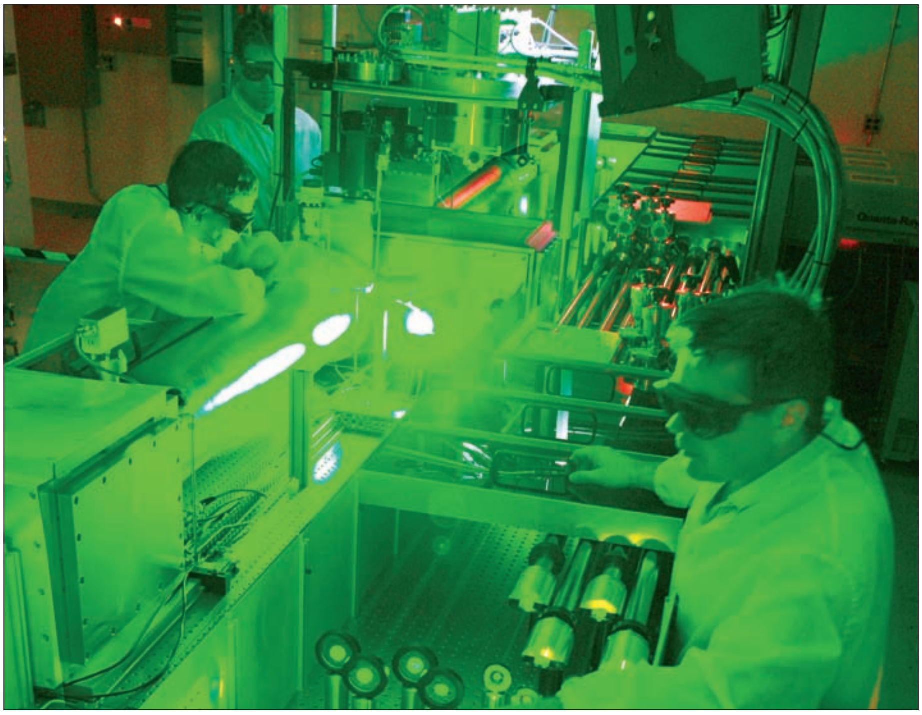
The third site in Magurele, near Bucharest, Romania, will produce radiation and beam particles at energies high enough to address nuclear processes. With this facility a renaissance in the field of nuclear physics is expected. The planned laser peak-power will reach 30 PW. Intense radiation created at ELI could help to clarify the processes limiting the lifetime of nuclear power reactors, offer new avenues to control the lifetime of nuclear waste, fabricate new nuclear pharmaceutical products, and lead to laser-driven hadron therapy, and phase-contrast imaging as a medical diagnostic tool.

Completion of the fourth ELI site will afford new fundamental investigations into particle physics, nuclear physics, acceleration physics and ultrahigh-pressure physics, leading on to applications in astrophysics and cosmology. It will offer new research directions in high-energy physics relating to particle acceleration and the study of the vacuum structure and critical acceleration conditions.

ELI's host countries have been mandated to form a pan-European Research Infrastructure Consortium (ERIC), which will be open to all European countries, and possibly others, willing to contribute to the realization of the project. A unique centralized management will preside over the integrated infrastructure. The host countries are to provide about 15% of the funding, while the EU is contributing the balance under its infrastructure investment programme. A total of €750 million is currently earmarked for the initial three sites.

BERKELEY

BELLA will boost plasma accelerator research



Berkeley researchers (Wim Leemans, left and Csaba Toth, right) assisted by technician Joe Wallig (back) are aligning a high-peak-power laser system, TREX, that is used to power laser plasma accelerators in the giga-electron-volt class. (Courtesy Berkeley Lab.)

Lawrence Berkeley National Laboratory is set to explore further the high-gradient acceleration of electron beams using ultra-short pulse lasers with the construction of a new facility – BELLA, the Berkeley Lab Laser Accelerator. The primary goal is to provide researchers within the laboratory's Laser Optical Systems Integrated Studies (LOASIS) programme with a petawatt-class, ultra-short pulse laser system for experiments aimed at demonstrating a 10 GeV electron beam from a metre-long plasma channel.

A laser plasma accelerator (LPA) of this kind relies on creating an electron-density wave in an ionized medium (i.e., plasma) by displacing the electrons away from the ions with an intense laser pulse. The charge separation results in a strong electric field (up to 10^{10} V/m) that co-propagates with the laser pulse (like a wake behind a boat) and is capable of accelerating electrons to very high energies in a short distance. Electrons pulled out of the background plasma into the wake can then "surf" on it to reach high energies. Typical electric fields generated in an LPA can be more than a 1000 times larger than in conventional RF accelerators, enabling the acceleration of electrons to giga-electron-volt energies in distances of centimetres instead of tens of metres.

BELLA will build on previous results from the LOASIS programme, which is led by Wim Leemans, one of six recipients of the US Department of Energy's Ernest Orlando Lawrence Award for 2009. In 2004, researchers with LOASIS showed that high-quality electron beams with an energy spread of a few per cent could be produced at energies of 100 MeV from a structure only 2 mm long (*CERN Courier* November 2004 p5). Two years later, the team demonstrated that beams of 1 GeV can be produced from a 3 cm-long plasma structure (*CERN Courier* December 2006 p17). One of the key elements of these experiments was the guiding of the laser beams in plasma channels over distances that are long compared with their natural diffraction distance, much as an optical fibre guides a low-power beam.

The aim with the BELLA facility is to scale up these experiments to produce electron beams with energies exceeding 10 GeV in a metre-scale plasma channel. Such devices could form the building blocks of a future-generation linear collider for particle physics, provided that technology is developed to cascade many of these modules and to produce high-quality electron beams with high efficiency. While it could take decades to match the output of the highest-energy RF-based machines, BELLA represents an essential step in investigating how more powerful accelerators of the future might become not only more compact and but much less expensive. Such systems also hold the promise of making possible a table-top accelerator operating in the range of tens of giga-electron-volts, which would be small and cheap enough for universities and hospitals.

The development of a compact linear accelerator with the BELLA project will have also several short-term applications. Among the unique features of LPA-produced electron beams are their duration of a few femtoseconds and their intrinsic synchronization to a conventional laser. A high-quality 10 GeV electron beam could be used to build a soft X-ray free-electron laser, which would be a valuable tool for biologists, chemists, materials scientists and biomedical researchers, allowing them to observe and time-resolve ultrashort (femtosecond) phenomena. A multigiga-electron-volt electron beam could also be used to produce highly collimated, mega-electron-volt photons that could penetrate cargo in a nondestructive way and be highly useful for remote detection of nuclear material. Such high-energy photon beams can be produced by scattering an intense (low-energy photon) laser pulse off the high-energy electron beam.

BELLA will be housed in an existing building at Berkeley. The space will be reconfigured and upgraded to include a clean room, new laser laboratory space and additional shielding. The project is funded largely by the American Recovery and Reinvestment Act (commonly known as economic stimulus funding), which is providing $20 million towards BELLA's construction. The facility will be completed in about three and a half years.

● For more information about BELLA and the LOASIS programme, see http://loasis.lbl.gov/.

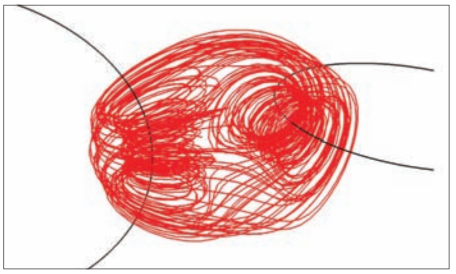
SCIENCEWATCH

Compiled by John Swain, Northeastern University

Simple circuits create chaos

Textbooks usually show magnetic fields as simple loops around current-carrying wires, but what happens with the many convoluted wires that make up electrical circuits? Quite remarkably, Makoto Hosoda of Osaka City University in Japan and colleagues have shown that typical magnetic fields are wildly complicated and, indeed, chaotic. Even two circular current loops at right angles to each other produce elaborately knotted fields, which are chaotic in the sense that, when following the field lines from two nearby points, the researchers find wildly diverging trajectories.

Such complex fields are well known in plasma physics, but finding them in simple circuits has come as something of a surprise. The good news is that it might be that the chaos avoids the build-up of fields that could otherwise disrupt small devices, allowing them to operate stably.



Induced magnetic field lines wrap around perpendicular current loops in a chaotic fashion. (Courtesy Hosoda et al. *2009.)*

Further reading

M Hosoda *et al.* 2009 *Phys. Rev.* **E80** 067202.

Defining amperes

The present definition of the ampere is arbitrary, so it would be good to have a physically meaningful absolute measure for current. Ville Maisi at the Centre for Metrology and Accreditation in Espoo, Finland, and colleagues have managed to gang together 10 single electron transistors to make something like a 10-electron "turnstile", which can produce a precise current of 100 pA.

This is a a factor of 10 higher than previously possible. Scaling to higher currents, to a real current standard in terms of electron charge per second, appears to be within sight.

Further reading

V Maisi *et al.* 2009 *New Journal of Physics* **11** 113057.

GRB observation vindicates relativity

Recent theories of quantum gravity have suggested that the speed of light could vary slightly with the energy of the photons involved, thus violating the Lorentz invariance that underlies the special theory of relativity. Now observations of photons from a gamma-ray burst by the Large Area Telescope (LAT) and the Gamma-ray Burst Monitor (GBM) on the Fermi Gamma-ray Space Telescope have set stringent limits on such effects.

Fermi observed GRB 090510 on 10 May 2009, when it triggered both the LAT and the GBM, and photons detected by the LAT included one with an energy as high as 31 GeV. Given the large distance to GRB 090510 (around 7000 million light-years), this made it possible to search for small variations in the photons' speed by comparing arrival times over a wide energy range starting at around 100 MeV.

A A Abdo and colleagues used the observations to show that linear variations in the speed of light with energy are ruled out at 1.2 times the Planck scale ($E_{Planck} = 10^{19}$ GeV). On the negative side this is a remarkable constraint on quantum gravity theories, while on the positive side it suggests that quadratic effects could be testable in similar observations.

Further reading

A A Abdo *et al.* 2009 *Nature* **462** 331.

Spintronics comes in from the cold

Saroj Dash and colleagues at the University of Twente in the Netherlands have demonstrated the injection and detection of spin in silicon at room temperature, together with its control via a weak magnetic field.

Polarized electrons or holes enter and leave silicon from conducting ferromagnets via tunnelling, retaining spin lifetimes of 140 ps in n-type silicon and 270 ps in p-type silicon, with drift distances large enough to make interesting devices possible. Previous injection and detection of spins in non-magnetic semiconductors has been restricted to n-type materials below 150 K.

Further reading

Saroj P Dash *et al.* 2009 *Nature* **462** 491.

Ion mystery has been solved

Among the many mysteries of water is the origin of the Hofmeister series. This is a 120-year-old list of ions that describes their effects on the structure of water – most notably, how they alter the strength of hydrophobic interactions with proteins. The science behind the series has remained a puzzle since the list was created by Franz Hofmeister when he was studying proteins in Prague in the late 1880s.

Now Yan Levin of the Federal University of Rio Grande do Sul in Brazil and colleagues may have found the key to understanding the series. Their detailed calculations of the polarization of water around various ions and its effect on surface tension provides a list that not only matches experimental measurements of surface tension, but also reproduces the Hofmeister series, making a link between polarization, water–ion–air surface effects and water–ion–protein interactions.

The work has wider implications because it also explains the tendency of highly reactive halogen ions to move to the surfaces of water droplets – an important and until now mysterious phenomenon in atmospheric chemistry.

Further reading

Yan Levin *et al.* 2009 *Phys. Rev. Lett.* **103** 257802.

ASTROWATCH

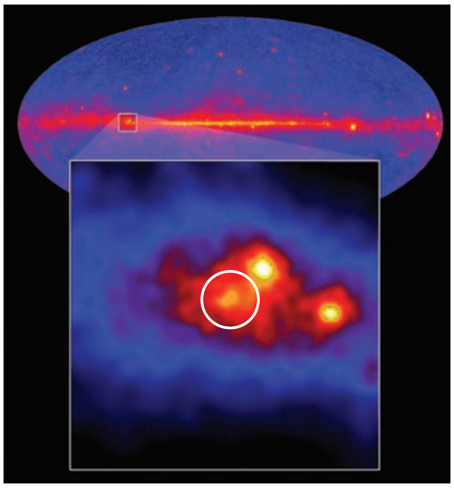
Compiled by Marc Türler, ISDC and Observatory of Geneva University

AGILE and Fermi see a flaring microquasar

The two currently operating high-energy gamma-ray satellites have both detected Cygnus X-3 (Cyg X-3) during episodes of strong radio flaring. These first detections of a genuine microquasar in our galaxy demonstrate that even small-scale relativistic jets are powerful particle accelerators.

Cyg X-3 is a peculiar binary system in our galaxy that might end its life as a gamma-ray burst (*CERN Courier* November 2009 p10). What makes this X-ray binary special is not the compact object that is likely to be a black hole or a neutron star, but the companion object, which is a rare Wolf-Rayet star. Such massive stars are in a late stage of their evolution and are characterized by a strong stellar wind blowing away the outer layers of gas, which are already enriched with heavy elements such as nitrogen, carbon and oxygen.

With a short orbital period of less than 5 hours, the black hole or neutron star of Cyg X-3 is moving very close to the hot surface of the Wolf-Rayet star, and deep inside its wind is blowing at about 1000 km/s. Inhomogeneities in the wind hitting the compact object are likely to be the cause of the extreme variability of Cyg X-3. The chaotic accretion of gas from the wind sometimes leads to the formation of relativistic jets, which have been resolved by radio telescope arrays. This characteristic makes Cyg X-3 a microquasar, in analogy with the powerful jets of quasars, the active hearts of remote galaxies (*CERN Courier* July/August 2006 p10).



Zooming in on Fermi's all-sky map shows the location of the microquasar Cyg X-3 in the Cygnus constellation along the Milky Way. (Courtesy NASA/DOE/Fermi LAT collaboration.)

The Italian Astro-rivelatore Gamma ad Immagini Leggero (AGILE) satellite detected four major gamma-ray flares of Cyg X-3 at photon energies above 100 MeV. As M Tavani and colleagues reported in *Nature*, the flares lasted only a couple of days and were found during a long-term observing campaign of the Cygnus region between mid-2007 and mid-2009. They were all observed at epochs when the hard X-ray flux monitored by NASA's Swift satellite was low. Furthermore, three of the four gamma-ray flares preceded a radio flare by less than 10 days. As the radio flares are known to be emitted by relativistic particles in the jet, this coincidence strongly suggests that the gamma-ray flare is also emitted by the jet or is related to the jet-formation process.

NASA's Fermi satellite was launched in 2008, one year after AGILE, and also detected several flares of Cyg X-3 at energies above 100 MeV. Thanks to the superior sensitivity of its Large Area Telescope (LAT), the Fermi LAT collaboration was able to detect a periodicity in the gamma-ray signal corresponding to the 4.8 hour orbital period of the Cyg X-3 binary system. This detection, reported in *Science*, locates the origin of the flares within the complex gamma-ray emission region surrounding Cyg X-3. The Fermi data also confirm the link found by AGILE between gamma-ray flares and flaring activity observed at radio frequencies.

The corroborating results on Cyg X-3 by the two missions provide the first evidence that a genuine microquasar can emit high-energy gamma rays. This detection has important implications for the jet acceleration mechanism, although the actual emission process, in particular whether the emission comes from electrons or protons, is still the subject of debate.

Further reading

M Tavani *et al.* 2009 *Nature* **462** 620.
The Fermi LAT collaboration 2009 *Science* **326** 1512.

Picture of the month

This is the first image released from the Visible and Infrared Survey Telescope for Astronomy (VISTA) of the European Southern Observatory (ESO). The new 4.1 m telescope is installed at ESO's Paranal Observatory, in the Atacama Desert of northern Chile, next to the Very Large Telescope. VISTA was developed by a consortium of 18 universities in the UK led by Queen Mary, University of London. A 3 tonne infrared camera with a total of 67 million pixels provides wide images covering about 10 times the area of the full Moon. This infrared image shows the Flame Nebula (NGC 2024), a spectacular star-forming cloud of gas and dust in the Orion constellation. This region includes the famous Horsehead Nebula, shown best in the inset visible-light image. (Courtesy ESO/J Emerson/VISTA and Cambridge Astronomical Survey Unit.)

CERN COURIER ARCHIVE: 1967

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

NEWS FROM ABROAD

From first beams to first experiments

The alternating-gradient electron synchrotron, Nina, at the Daresbury Nuclear Physics Laboratory, UK, produced its first high-energy beams on 2 December 1966. The following day, the design energy of 4 GeV was reached and 4.5 GeV was achieved on 5 December. One of Nina's most important design features is that it should be able to accelerate currents in excess of 1 μA and possibly up to 10 μA.

The decision on the site [*now the home of Fermilab*] for the proposed USA 200 GeV accelerator was announced on 16 December. From more than 200 sites, 85 were investigated by the National Academy of Sciences. From a short list of six reached in April 1966, the US Atomic Energy Commission selected Weston, a suburb of Chicago, not far from the Argonne National Laboratory.

On 30 December 1966, the world's first proton synchrotron to contribute to particle physics – the Cosmotron at Brookhaven National Laboratory, USA – was closed down. The machine began operation in 1952 and was capable of a maximum energy of 3 GeV. With the advent of the 33 GeV machine at Brookhaven in 1960, high-energy physics experiments went more and more to the bigger machine.

Experiments began at the end of November 1966, at the Stanford Linear Accelerator Centre, USA, using the 20 GeV linear accelerator, six months ahead of schedule. Electron beams with an energy of 10 GeV were achieved for the first time in May 1966 and since then the energy has been increased to give beams in the energy range 10 to 18 GeV.

Gravity matters

The preliminary results of a highly refined experiment carried out by Stanford University physicists F C Witteborn and W M Fairbank were announced at the end of December. They have succeeded in measuring the effect of gravity on electrons, the lightest of all of the particles.

The difficulty of the experiment does not lie in the lightness of the particle but in the fact that the gravitational force on an electron due to the field of the whole Earth is equalled by the electromagnetic force due to another electron at a distance of about 5 m. Thus, it is necessary to shield the electron as far as possible from all electromagnetic fields, including those from the material in the experiment itself.

Electrons emerged from a cathode at the bottom of a 5 cm-high, vertical copper tube, which shielded the particles from external fields. A large superconducting magnet formed a "magnetic bottle" in the centre of the tube. A few electrons were moving slowly enough for the time they took to spiral up to the top of the tube to be measured with an accuracy of about 2%. The gravitational force could then be determined from these flight times and the electric field required to prevent the electrons from accelerating.

The experimenters now hope to look at the effect of gravity on positrons (anti-electrons). If this proves feasible, it will test the idea, beloved of science fiction writers, that antimatter may fall up, instead of down, in a gravitational field.

● From articles on pp12–13.

COMPILER'S NOTE

The tendency of antimatter to annihilate with matter makes it immensely difficult to study. The gravitational effects of matter on antimatter have still not been conclusively measured, not to mention those of antimatter on antimatter. All effects may be attractive with the same strength as that of matter on matter, but some hypotheses, such as attempts to explain the accelerating expansion of the universe, postulate otherwise.

Meanwhile, science fiction rules OK!

CERN NEWS

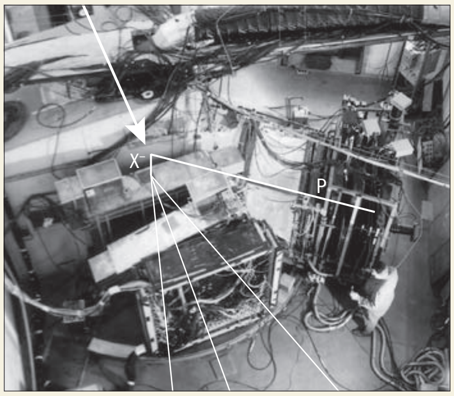
Seven new mesons at the PS

The "missing-mass spectrometer" experiment was concluded at the CERN proton synchrotron in January. About 25 scientists and engineers from 10 European countries, the USA and the USSR participated at various stages in a team led by B Maglic.

Over a period of about a year, the experiment identified seven new heavy mesons.

The basic interaction investigated was $\pi^- + p \rightarrow p + X^-$. Negative pions from the synchrotron, directed onto a hydrogen target, could produce recoil protons and negative mesons of different masses (X^-). Measurements of the momentum and direction of an incoming pion and the recoil proton indicated the meson mass as "missing mass/energy". The novelty of the spectrometer lay in measuring the momentum of recoil protons without the conventional use of a large magnet. The proton detectors were mounted on a turntable that could be moved through angles known with respect to the direction of the incoming pion beam. For each meson that can be produced, there is an angle at which a high percentage of the recoil protons will emerge, the so-called Jacobian peaks.

The squares of the measured meson masses lie neatly on a straight line and it has been pointed out (for example, by Prof. Dalitz at the Berkeley Conference last year) that this fits well with the model of an underlying quark–antiquark system.



Superimposed on a view of the missing mass spectrometer is a typical event – an incoming pion producing a heavy meson (X^-) in a hydrogen target. The intricate experimental array to detect the recoil proton (p) and the decay products of the meson can be seen mounted on the turntable.

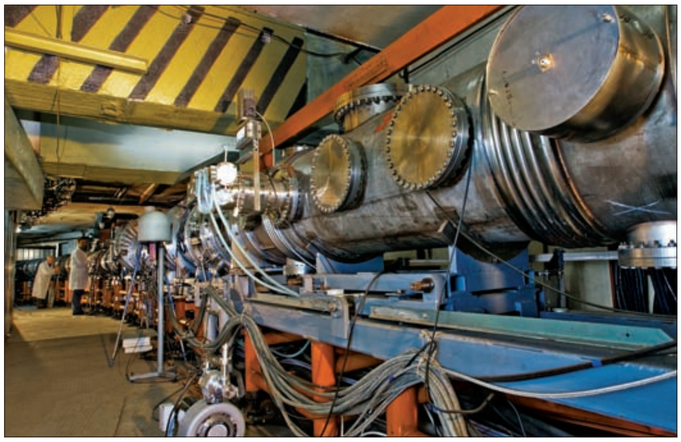
● From article on pp31–32.

NICA targets the mixed phase in hadron matter

A new heavy-ion collider facility at Dubna, based on the Nuclotron accelerator, will provide a microscope on the phase of hadronic matter where quarks and gluons mix with composite particles. **Alexei Sissakian** and **Alexander Sorin** explain.

Dynamic scientific projects with daring research programmes involving high technology can often trigger breakthroughs in innovation and industrial development. A team at the Joint Institute for Nuclear Research (JINR) at Dubna has conceived of one such project: the Nuclotron-based Ion Collider fAcility (NICA), a superconducting accelerator complex for colliding beams of heavy ions in the energy range of 4–11 GeV per nucleon in the centre of mass. It is this kind of project that is vital if Russia is to become a leader in innovation development.

The aim of NICA is to study an intricate and mysterious phenomenon: the mixed phase of quark–gluon matter. Conceived by the research group led by Alexei Sissakian, head of the NICA project, the facility is based on the Nuclotron, the superconducting ion synchrotron that already operates at JINR's Veksler and Baldin Laboratory of High-Energy Physics. This latest project builds on the scientific schools and traditions of the scientists who founded this international centre for research in nuclear physics on Russian territory. The result is a collaboration between physicists at Dubna and other Russian scientific centres: the Institute for Nuclear Research of the Russian Academy of Sciences (RAS); the State Scientific Centre; the Institute for High-Energy Physics (IHEP) in Protvino; the Budker Institute of Nuclear Physics (BINP); the Scientific Research Institute for Nuclear Physics of Moscow State University; and the Institute for Theoretical and Experimental Physics in Moscow.



A view of the Nuclotron, which will form the heart of the NICA project at JINR. It will study mixed-phase quark–gluon matter. (Courtesy JINR.)

New lease of life

The NICA project has been under development since 2006, in close co-operation with leading institutions of the RAS, the Rosatom State Atomic Energy Corporation, the Federal Agency for Science and Innovation, the Federal Agency for Education, Moscow State University and the Russian Scientific Centre "Kurchatov Institute". It will culminate in a unique accelerator complex – a cascade of four accelerators that includes the existing Nuclotron – which should be completed by 2015. Constructed at JINR with much effort and hardship in the period of change in Russia during the 1990s, the Nuclotron has been useful for world science but owing to insufficient financing, this superconducting accelerator has not achieved the planned beam parameters. The capacity of the vacuum and cryogenic equipment that was affordable a decade ago did not allow further energy increases. Today, however, the NICA project is breathing new life into the Nuclotron and has opened up new prospects for high-energy physics.

Studying the properties of nuclear matter is the fundamental task for modern high-energy physicists, with experimental research conducted at an extremely small scale – around a millionth of a nanometre. Achieving this task not only opens new horizons in perceptions of the world and enables researchers to decipher the evolution of the universe, it also lays the foundation for the development of new techniques on the super-small scale.

According to modern ideas, quark–gluon matter has a mixed phase – like boiling water that exists simultaneously with vapour. The mixed phase of hadronic matter should include free quarks and gluons simultaneously with protons and neutrons, inside which quarks are already constrained – or "glued" – by gluons. In the phase diagram of temperature and baryon density, the border between the hadronic state and quark–gluon plasma is not a thin line but a domain the size and shape of which is still difficult to determine. It is here, in what we call "the Dubna meadow", where the mixed phase of hadron matter should exist.

NICA begins with the heavy-ion source, KRION, which propels nuclei into the linear accelerator that will be constructed by ▷

Alexei Sissakian, director of JINR and head of the NICA project, speaks at the round-table meeting in September last year. (Courtesy JINR.)

specialists from IHEP in Protvino. The beam then enters the booster-synchrotron, where particles are accelerated to the required energy. Thirty-four bunches, each consisting of 10 000 million nuclei, are transported into the Nuclotron. Once aligned by the superconducting magnets to form a thin thread approximately 30 cm long, they are split into two colliding beams of 17 bunches, each with its own ring in the 251 m-circumference ion collider.

These two collider rings intersect at two points equipped with detectors. At one collision point, the MultiPurpose Detector (MPD) will detect the existence of the mixed phase and a number of other features in this energy range, such as chiral-symmetry restoration, critical phenomena and the modification of hadron properties in the hot, dense quark–hadron medium. The MPD is designed to spot particles that shoot out from the collision point in every direction. It will be necessary to apply mainly new technological approaches to develop a device with a sufficiently high level of sensitivity. Another detector is planned for the spin programme – the Spin Physics Detector (SPD) – which will be located at the second collision point. Particle polarization is another mystery of the universe, which Dubna's theoreticians hope to unravel through experiments for NICA that have been designed together with specialists from BINP in Novosibirsk, who are pioneers in colliding-beam-accelerator technology.

The upgrade of the Nuclotron in Dubna is fully underway. The vacuum in the ring has been improved and the cryogenic complex – the heart of the superconducting accelerator – has been completely upgraded, as well as the power system. Modern diagnostic equipment is currently being installed and a new ion source is under development. The technical project for the NICA accelerator complex and the project concept are being developed at the same time.

Several groups of high-quality specialists from different JINR laboratories work in the NICA/MPD centre, where they are implementing the project for the new accelerator complex and experimental facilities. These include theoreticians, computer programmers, accelerator technologists, co-ordinators and experimentalists. Alexander Sorin, co-supervisor of the NICA project, is the centre's general leader. Igor Meshkov heads the activities on the development of the accelerator complex and his former student, Grigory Trubnikov, now deputy-chief engineer of JINR, is leading the Nuclotron upgrade. Vladimir Kekelidze, the director of the Laboratory of High-Energy Physics, heads the team designing the MPD.

The construction of any modern experimental facility is impossible without detailed technical planning, so JINR has sought to involve the best-qualified engineers and designers in the process. Nikolai Topilin has returned to Dubna from CERN – where he was responsible for the development of the front-end calorimetry for the ATLAS experiment at the LHC – as chief designer of the NICA complex. It is a good sign for Dubna that engineering designers are returning, having left for the West when Russian science was in decline. Their high-level abilities have always been – and still are – in demand in western countries, so the fact that physicists and engineers are returning to Dubna shows that JINR has chosen the right way forwards.

The development of an accelerator is always linked with the course of events elsewhere, so the physics programme for such a facility and the concept of its construction elements are dynamically inter-related from the outset of the erection of this large-scale machine. The NICA project's White Book, published in spring 2009, contains the physics basis of the experimental programme at the accelerator complex. It is constantly being replenished with new pages and is open to everyone wanting to contribute to the project (http://theor.jinr.ru/twiki-cgi/view/NICA/WebHome).

Because Dubna is an integral part of the worldwide scientific community, the research and quality of the facilities must be of the highest level for it to attract partners. On 9–12 September 2009, the Laboratory of Theoretical Physics held the fourth round-table discussion on the programme, "Physics at the NICA Collider", with 82 experts in heavy-ion physics from leading nuclear centres in 16 countries (including six JINR member states and four JINR associate members) invited to take part. Representatives from experimental collaborations of leading large facilities for similar research – JINR's friends and scientific rivals – also showed interest in the programme for NICA, including RHIC at Brookhaven in the US, the Super Proton Synchrotron at CERN and the future Facility for Antiproton and Ion Research (FAIR) at GSI in Germany. The delegation from Germany was the largest, with nine experts, including Boris Sharkov, director-designate of FAIR, and Peter Senger, leader of the Compressed Baryonic Matter collaboration at FAIR.

The specifications of the NICA collider formed the main topic of discussion. Experts analysed the main aspects: nuclear-matter research in experiments with relativistic heavy-ion collisions; new states of nuclear matter at high baryonic densities; local P- and CP-violation in hot nuclear matter (the chiral magnetic effect); electromagnetic interactions and restoration of the chiral symmetry; mechanisms of multiparticle production; correlation femtoscopy and fluctuations; and polarization effects and spin physics at the NICA accelerator. Participants also discussed details of the strategy to develop the MPD and the SPD, based on the physics programme. Representatives from institutes in Russia and elsewhere took an active part in developing the programme. Russian scientists working abroad, including those originally from Dubna, proved to be eager supporters of the NICA project – for example, Brookhaven was represented by the leader of the Nuclear Theory Group, Dmitri Kharzeev.

In summary, there have been considerable qualitative evaluations at the level of world scientific expertise of the expediency and feasibility of the NICA project. "We strongly support the implementation of the NICA collider project and we are sure that if the project is completed in time it will make an outstanding contribution to our knowledge about the properties of the superdense matter...The unique opportunity to put the NICA project into action in Dubna must not be missed," reads the joint memorandum on the results of the round-table discussions.

The coming year will see further contributions from Dubna to the scene of heavy ions. A new scientific journal, *Heavy Ion*, will accompany the research in heavy-ion physics at JINR, with the first issue scheduled for this year. On 23–29 August Dubna will take the baton from Brookhaven when it hosts an important international conference on heavy-ion collisions at high energies, the "6th International Workshop on Critical Point and Onset of Deconfinement".

Further reading

For details of the round-table meeting, see http://theor.jinr.ru/meetings/2009/roundtable/. For more about the NICA project, see http://nica.jinr.ru/.

Résumé

NICA vise la phase mixte de la matière hadronique

L'installation NICA (Nuclotron-based Ion Collider fAcility)sera un complexe d'accélérateurs supraconducteurs destiné à faire entrer en collision des faisceaux d'ions lourds dans la gamme d'énergie comprise entre 4 et 11 GeV par nucléon dans le centre de masse. Elle visera à étudier un phénomène complexe et mystérieux : la phase mixte de la matière quark-gluon. Imaginée par le groupe de recherche dirigé par Alexeï Sissakian, qui pilote aujourd'hui le projet, l'installation est fondée sur le Nuclotron, le synchrotron à ions supraconducteur qui est déjà en service au Laboratoire Veksler et Baldin de physique des hautes énergies, à l'Institut unifié de recherches nucléaires de Doubna. L'installation, qui regroupera à terme quatre accélérateurs, devrait être achevée d'ici à 2005.

Alexei Sissakian, *director of JINR, and* **Alexander Sorin**, *deputy director of the Laboratory of Theoretical Physics, JINR.*

The Blois Workshop comes to CERN

EDS '09, the 13th International Conference on Elastic and Diffractive Scattering, took place at CERN last summer and provided an opportunity to look at what new discoveries the LHC might soon bring. **John Dainton** and **Jacques Soffer** summarize the discussions.

Participants at EDS '09 pose for a group photo in front of the body of the Big European Bubble Chamber from the 1970s, which is on permanent display in the Microcosm garden at CERN.

The 13th International Conference on Elastic and Diffractive Scattering – the "Blois Workshop" – dates back to 1985, when the first meeting was held in the picturesque, old French town of Blois, famous for the 14th-century Royal Château de Blois. The conference series continues to focus on progress towards understanding the physics of hadronic interactions at high energy. A major strength of the meetings is the way in which they facilitate detailed discussion between theorists and experimentalists, thereby motivating new ways of formulating theoretical approaches and confronting them with experimental measurements – past, present and future.

More than 100 participants from 18 countries attended the latest meeting in the series, held at CERN on 29 June – 3 July 2009. The relatively informal manner of the 70 talks encouraged discussion. Appropriately, given the imminent start-up of the LHC, the following topics featured prominently: the total proton–proton (pp) cross-section; elastic pp scattering; inelastic diffractive scattering in electron–proton (ep), pp and heavy-ion collisions; central exclusive production; photon-induced processes; forward physics and low-x QCD; and cosmic-ray physics.

Theoretical developments

On the theoretical side, important aspects of soft diffraction were nicely introduced by Alexei Kaidalov of the Institute of Theoretical and Experimental Physics (ITEP) in Moscow, who emphasized factorization effects and unitarization in the framework of Reggeon calculus. Although everyone anticipates that the total pp cross-section will continue to rise with increasing energy – following the pioneering prediction of H Cheng and TT Wu in 1970 – a number of contributions made distinct predictions for its value at LHC energies – typically ranging between 90 mb and 140 mb, with surprising predictions as high as 250 mb. Several other features of elastic scattering at LHC energies were also considered within the framework of different models that were successful at lower energies. André Martin of CERN, with his long-established theoretical rigour, reported on a new limit for the inelastic cross-section.

The central production of various exclusive final states with one or two "leading protons" – Higgs production at the LHC, in particular – was also a source of much debate. This subject challenges different approaches in QCD, notably the "gluon ladder", and how these approaches relate to the long-standing theoretical construct, the Pomeron. Douglas Ross of Southampton University presented an interesting treatment of the Balitsky–Fadin–Kuraev–Lipatov (BFKL) kernel of such a ladder, based on the extraction of the low-x gluon distribution in experiments at the HERA ep collider. The issue of the "rapidity-gap survival probability" as an explanation for substantial factorization-breaking in inelastic diffraction in hadron–hadron collisions (as opposed to ep collisions) continues to challenge theory and is important when developing models for central Higgs production. Mark Strikman of Penn State University presented a notable proposal of a new sum rule.

The workshop devoted a full day to contributions dealing with the physics of QCD at various extremes, such as at the lowest parton fractional momenta (low-x QCD) and at the highest densities achievable, e.g. in heavy-ion collisions. Emil Avsar and Tuomas Lappi of CEA/Saclay and Francesco Hautmann of Oxford University reviewed the physics of gluon saturation and possible modifications of the ▷

standard QCD evolution equations at tiny values of Bjorken-x. A second topic, summarized by Raphael Granier de Cassagnac of the Laboratoire Leprince-Ringuet, Gines Martinez of SUBATECH, and Jean-Yves Ollitrault of Saclay, concerned studies of the collective behaviour of a multiparton system in a hot, dense state such as a quark–gluon plasma. Various other talks covered the latest experimental and theoretical developments in each of these two active research areas of the strong interaction, all with prospects at the LHC very much in mind.

Experimental highlights

Presentations on experimental developments highlighted the challenge of diffractive physics and the way that it relies on a particularly close symbiosis of measurement and theory. The phenomenology of elastic pp scattering, based on long-standing measurements at the Intersecting Storage Rings at CERN and later experiments at CERN and Fermilab, continues within either "classic Regge" or "geometrical" approaches. The latter is now beginning to produce a "transverse" view of the proton's structure, as Richard Luddy of Connecticut University explained. Such understanding will be testable in the near future in deep-exclusive lepton-scattering experiments, for example in COMPASS at CERN where, as Oleg Selyugin of JINR described, such measurements may be interpreted in terms of generalized parton distributions.

As at all meetings since EDS returned to Blois in 1995, there were reports from the experiments at HERA on the status of the deep-inelastic structure of the diffractive interaction, this time by Henri Kowalski of DESY and Alexander Proskuryakov of Moscow State University. The impressive precision of the data reveals beautiful features that demonstrate the quark and gluon components of the t-channel (i.e. the leading) exchange mechanism. Put differently, the data are sensitive to the parton structure of the proton's diffractive interaction. Results on the scale dependence of these leading exchanges, measured at HERA in exclusive meson production, now provide precise data with which QCD theory has to be reconciled, as Pierre Marage of the Université Libre de Bruxelles explained.

The main experimental highlights came, arguably, from the CDF experiment at Fermilab's Tevatron with the measurements of the central exclusive two-photon production ($pp \rightarrow pp\gamma\gamma$) and di-jet production ($pp \rightarrow pp+2$ jets), presented by James Pinfold of Alberta University, Christina Mesropian and Konstantin Goulianos of Rockefeller University and Michael Albrow from Fermilab. Both processes are important as precursors for the exclusive Higgs search at the LHC; the agreement of the predictions, made prior to the measurements, with the data is an important milestone in the preparation for exclusive Higgs hunting – appropriately christened "Higgs with no mess" by the experimentalists concerned.

A session dedicated to ultrahigh-energy cosmic-ray observations underlined their complementarity to collider measurements in view of understanding hadronic interactions, as Jörg Hörandel of Radboud University, Nijmegen, explained. Alessia Tricomi of INFN/Catania University pointed out that, in particular, forward experiments can contribute valuable data to the development of models of air showers.

Other topics at the meeting included photon-induced processes from the BaBar and Belle experiments, with reviews of relevant heavy-ion results from RHIC at Brookhaven and prospects for the LHC. Looking further into the future, Paul Newman of Birmingham University reported on possibilities for ep and electron–ion interactions at an LHeC (*CERN Courier* April 2009 p22).

Given the venue of EDS '09, perhaps the most appropriate session was the one that was concerned with new experiments. Taking advantage of the presence of the unique breadth of expertise present at an EDS meeting, a panel discussion took place between representatives of theory and experiments, moderated by Karsten Eggert of Case Western Reserve University and CERN. It provided the opportunity to exchange ideas about which measurements to carry out first at the LHC, how to create synergies between different experiments and about future upgrade possibilities for the forward proton detectors. Several new ideas for possible measurements at the LHC were proposed and discussed. With its first data, the LHC will already provide new measurements that are crucial to this active field. The meeting ended with a strong sense of anticipation, given the imminent diffractive data at a new energy scale from the first run of the LHC.

Further reading

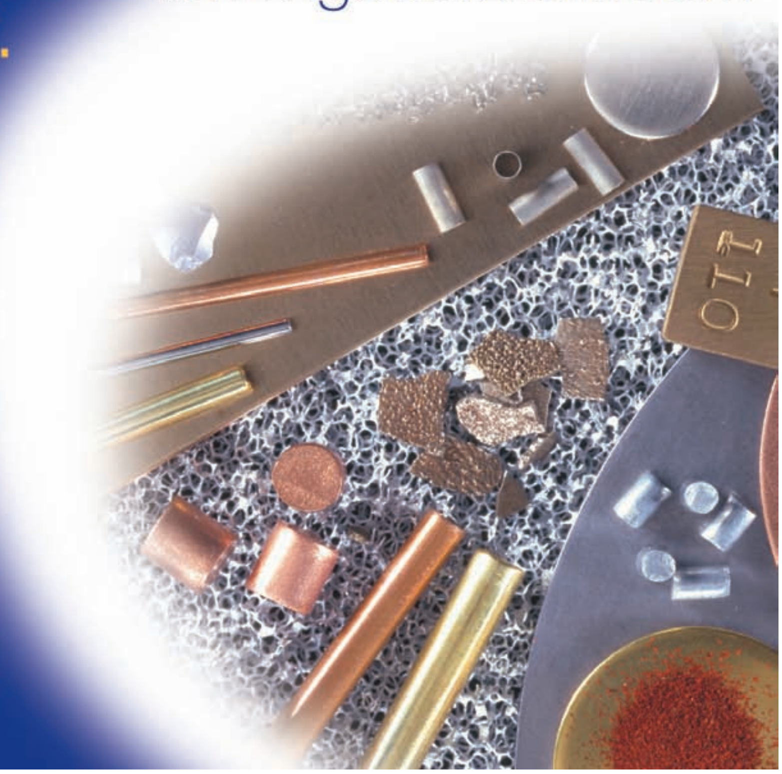
For more information about the conference programme, see www.cern.ch/eds09/.

Résumé

L'atelier de Blois s'installe au CERN

EDS '09, la 13e conférence internationale sur la diffusion élastique et diffractive, a été l'occasion d'examiner ce que le LHC pourrait bientôt nous apporter. Une centaine de personnes de 18 pays ont participé à la réunion, qui s'est tenue au CERN l'été dernier. Environ 70 exposés ont été présentés d'une façon relativement informelle, encourageant ainsi la discussion. À juste titre, étant donné le démarrage imminent du LHC, les débats ont essentiellement porté sur les questions suivantes : la section efficace totale proton–proton (pp) ; la diffusion pp élastique ; la diffusion diffractive inélastique dans les collisions électron–proton (ep), pp et d'ions lourds ; la production centrale et exclusive ; les processus induits par les photons ; la physique aux petits angles et la CDQ à petit x ; et la physique des rayons cosmiques.

John Dainton, *Cockcroft Institute and the University of Liverpool,* **Jacques Soffer**, *Temple University, and the EDS '09 organizing committee.*

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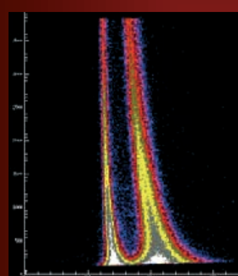
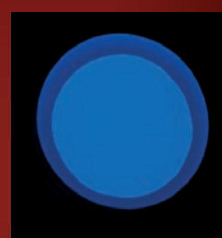




Combined HERA data set scene for the LHC

Combined measurements from H1 and ZEUS address a new paradigm in research and reveal the power of the HERA collider in making predictions for the LHC. **Cristinel Diaconu** and **Tobias Haas** explain.

High-energy physics experiments address fundamental questions using large facilities and complex detectors, which often use innovative detection techniques. It is usual to build and operate more than one such detector at the same accelerator – to confront, compare and eventually merge the measurements. Combining measurements made by similar detectors becomes feasible and ultimately mandatory when these detectors are well understood and tested with many physics analyses. This step was achieved recently by the H1 and ZEUS experiments, which took data at DESY's HERA collider from 1992 until 2007.

HERA was the only electron–proton collider ever built, providing collisions between electrons or positrons of 27.5 GeV and protons of up to 920 GeV to give a centre-of-mass energy of 320 GeV. The data collected at HERA are unique and have led to precise measurements of the proton structure, in particular in the region of low Bjorken-x, below 0.01, where no other measurement exists. At HERA, the point-like electron probes the gluon-fabric of the proton down to scales as small as 1/1000 of the proton's radius. These measurements provide a clean testing ground for the Standard Model. Furthermore, searches for new physics signals at HERA are complementary to searches made at other colliders.

So far, H1 and ZEUS have published individual measurements investigating a plethora of different processes in more than 400 scientific articles. However, for the first time, three joint publications have recently been submitted to the *Journal of High Energy Physics*. These combinations of the H1 and ZEUS data in coherent analyses address a new paradigm in this field of research.

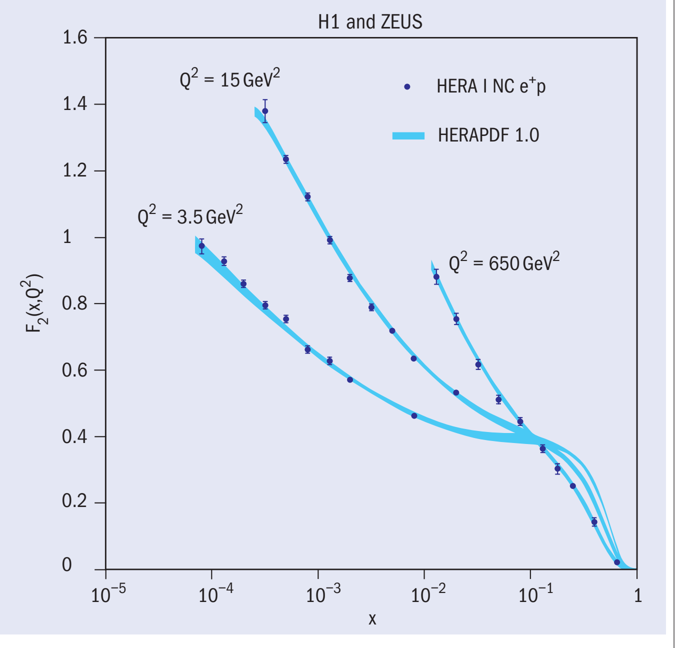


Fig. 1. The combined measurement of the structure function F_2. The precision is improved by more than the naïve expectation, owing to the experiments' cross calibration, and is no longer dominated by the systematic errors. The increase of the structure function at low x, discovered at HERA, is now measured with a precision close to 1%, thereby providing a unique constraint on the gluon content of the proton in a region that is crucial for precision physics at the LHC.

Universal structure functions

Combining data sets improves individual measurements because the amount of information increases. The theory of statistics states that uncertainties diminish by a factor of √2 when the amount of data is doubled. When systematic uncertainties are taken into account, however, the effects are more subtle: there is no gain for errors correlated between the experiments. Typical examples of this kind are theoretical calculations that are needed to extract the experimental results. Uncertainties that are fully uncorrelated (not only between the experiments but also from one measurement point to the next) have a similar behaviour to statistical errors and are reduced by the magical factor of √2. Finally, the most interesting case comes from errors that are correlated within each experiment, but uncorrelated between experiments. One example is the energy scale of the calorimetric measurements: the technologies of the calorimeters in the two experiments are different and they are calibrated using independent procedures. Hence the respective errors are independent between the experiments but are nevertheless correlated from one measurement to the next within each experiment. These uncertainties are reduced by more than the usual factor of √2. This can basically be seen as an effect of a cross-calibrating of the detectors with respect to each other using a large number of independent measurements.

The paper on the measurement of inclusive deep inelastic ▷

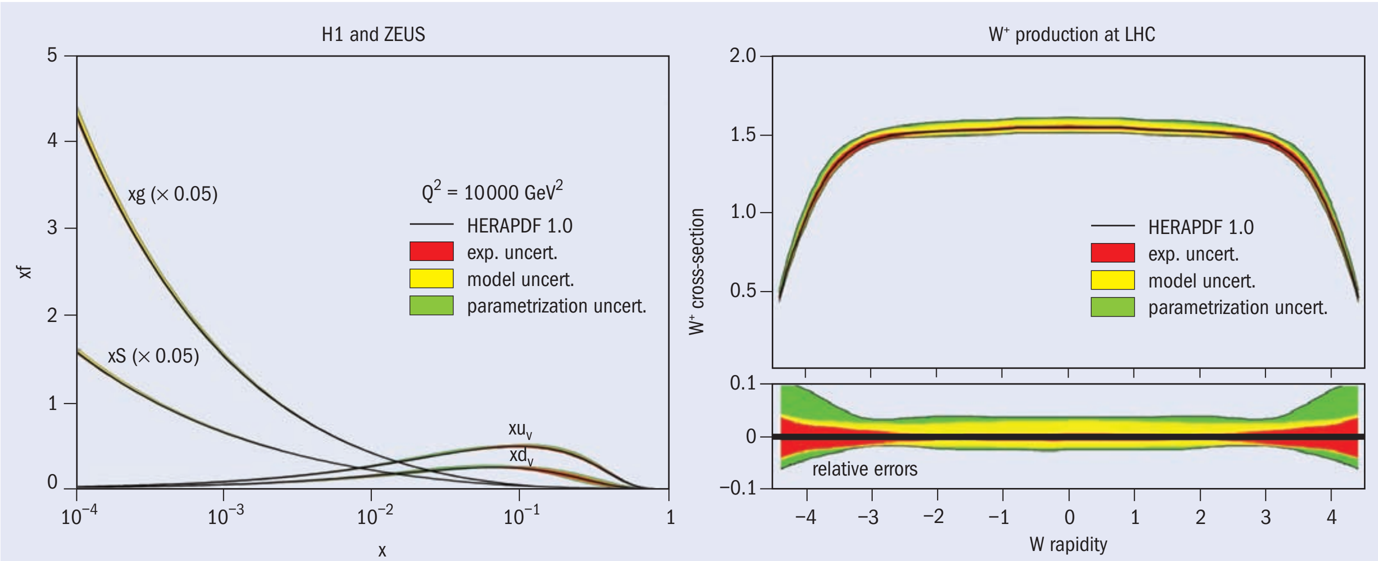


Fig. 2. Left: the proton–parton densities extracted from the combined H1 and ZEUS measurements alone, for virtuality, Q^2=10 000 GeV^2, corresponding to W production at the LHC. The gluon dominates the proton content at low Bjorken-x and is precisely determined from the combined HERA data alone. Right: the impact of the new measurement of the proton structure functions by H1 and ZEUS combined on W production at the LHC. The precision of the prediction is a few percent in the central region, where the experimental uncertainty originating from the data precision is better than 1%. (Figure right, courtesy Amanda Cooper-Sarkar).

scattering cross sections, submitted for publication by the H1 and ZEUS collaborations, contains a combination of more than 1402 individual measurements from 14 publications to obtain 741 cross-section measurements of unprecedented precision. All of the available data on neutral and charged-current interactions taken during the first phase of HERA running from 1992 to 2000 are used. The data cover virtualities, Q^2, of the exchanged bosons from 0.2 GeV^2 up to the highest values reachable at HERA of around 30 000 GeV^2, and values of Bjorken-x as small as 0.2×10^{-6}. These data extend into the electroweak regime from regions where perturbative QCD has never been tested. At small values of Bjorken-x, $x<10^{-2}$, no other measurements exist. In this region the gain from the combination process is impressive: the individual measurements are dominated by systematic errors that become drastically reduced down to as little as 1%. These cross-sections depend on the universal proton-structure functions, F_2, F_3 and F_L, which encapsulate the parton content of the proton. The structure function F_2 dominates over most of the phase space, except at high Q^2, where parity-violating weak effects lead to a non-zero contribution from xF_3, and at large y, where the longitudinal part of the cross-section arising from gluon radiation leads by F_L being sizeable.

Figure 1 (pX) shows parts of the universal structure function, F_2, as a function of the variable x, for various values of the photon virtuality, Q^2. The increase of F_2 towards low x, discovered in the first years of HERA, is confirmed with a precision approaching 1%. As Q^2 grows, F_2 becomes steeper towards low x, reflecting the contributions to the quark component from gluon fluctuations in a $q\bar{q}$ pair. This rise is a fundamental discovery and reveals the role of gluons in binding nuclear matter. It is possible to decompose this structure function into one part that arises from "hard scattering" (so-called coefficient functions) and another non-perturbative part, which reflects the partonic content of the proton. Using the new data, the collaborations have extracted a new set of parton-distribution functions (HERAPDF 1.0), shown on the left in figure 2 for a high photon virtuality, Q^2=10 000 GeV^2. This partonic content is universal and can be used to make predictions for other processes involving protons – for example, cross-sections in proton–proton collisions at the LHC.

One example within the Standard Model is the production of single weak bosons at the LHC. This process can be regarded as a "standard candle" and can even be used to determine luminosity in the collider because the measurement can be done with great accuracy. The precision of the corresponding theoretical predications is dominated by the uncertainties that originate from the knowledge of the proton–parton distributions, which in turn come from the measurements at HERA (figure 2, right).

Ultimately, the H1 and ZEUS measurements provide the standard candle against which any new phenomenon at the LHC in the mass range of up to a few hundred giga-electron-volts will have to be compared. The new physics may well be in this range – in which case a precise knowledge of the production cross-section would be crucial in order to explore the properties of these new particles.

New physics arises in many theoretical extensions of the Standard Model. According to these extensions, a peak in a mass spectrum or a deviation in a certain variable should be observable. However, new physics can also manifest itself beyond the "standard predictions" and show up as spectacular events in regions of phase space where, according to the Standard Model, only few events should be seen. Events with energetic isolated leptons are an example of such a golden channel. Experimentally, they provide a clean signature; theoretically, they benefit from robust predictions.

The experiments at HERA reported the observation of events with isolated leptons (electrons or muons) and missing transverse momentum as early as 10 years ago. In the Standard Model this topology is explained by the production of a W boson, which decays to an energetic charged lepton and a neutrino. The neutrino escapes undetected, leading to "missing" momentum. The observation of

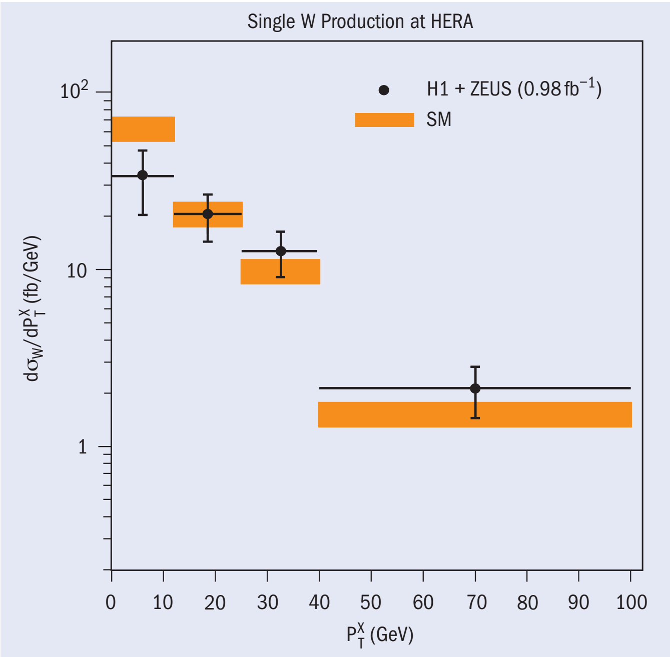


Fig. 3. The cross-section for the production of the W boson at HERA, measured in common by the H1 and ZEUS collaborations.

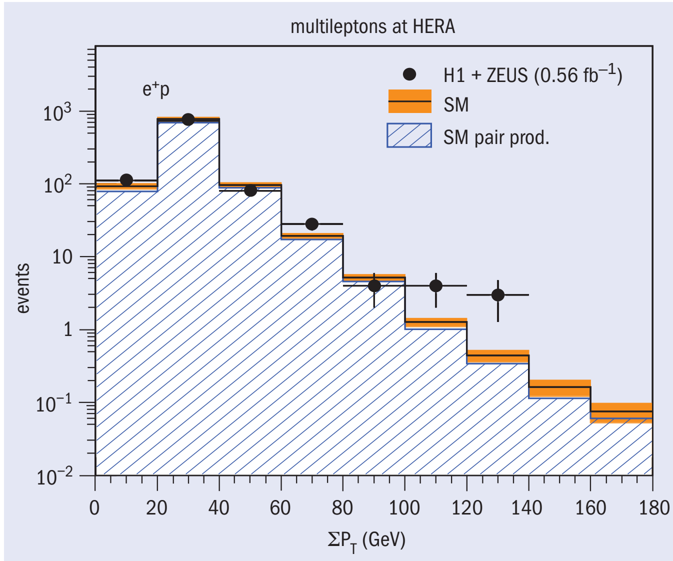


Fig. 4. The distribution of the scalar sum of the leptons measured in multilepton events by the common H1 and ZEUS analysis of e^+p data. Seven events are detected in e^+p collisions as against 1.9 ± 0.2 predicted in the region P_T>100 GeV, while no events are observed in e^-p collisions for a similar expectation.

such a rare process (typically one such event is recorded in 10 million other events) is a challenge and requires the full experimental information of the multilayer/multipurpose H1 and ZEUS detectors. Some of the observed events also contain a prominent hadronic jet – which makes them unlikely as W candidates because any hadronic recoil would typically be produced at low transverse momentum.

H1 observed a discrepancy with the Standard Model amounting to as much as three standard deviations, but with no effect seen in ZEUS. To clarify this point, the collaborations undertook a joint analysis effort. They investigated carefully all of the differences and studied all of the systematic effects. The individual results stand up to this scrutiny. By interpreting the difference as a statistical fluctuation, the two experiments can perform a common analysis. This leads to a decrease in the significance of the observed excess for events with large hadronic transverse momentum to below two standard deviations; it also improves significantly the measurement of the W cross-section (figure 3). Thus, this measurement becomes an important confirmation of the weak sector of the Standard Model in a unique configuration.

The third joint paper deals with events with more than one charged lepton that are dominantly produced by photon–photon collisions, the photons originating from the colliding electrons and protons. In individual analyses, H1 and ZEUS found a few hundred events containing several leptons, both electrons and muons, at high transverse momentum, including some events where the scalar sum of the lepton momenta exceeds 100 GeV. In a combined analysis, seven events are observed in this region in positron–proton collisions for an expected number of 1.9 ± 0.2, while no such event is observed in electron–proton collisions for a similar expectation (figure 4). The observation of the excess in positron–proton collisions is still compatible with the Standard Model and is interpreted as a statistical fluctuation. However, this observation stimulates discussion because it is also possible to attribute the excess to a bilepton resonance, such as a doubly charged Higgs boson, H^{++}, produced in electroweak interactions.

These combined measurements from H1 and ZEUS are the first in a series of legacy results from the unique electron–proton collider, HERA. More than 20 years after the start of the facility and two years after the end of the data-taking, the harvest is in its best phase. This is also good for the LHC.

Further reading

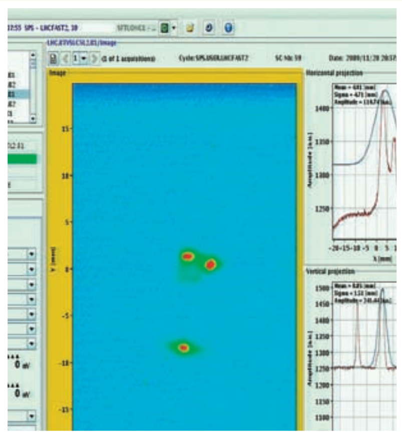
For more about the H1 and ZEUS combined analyses, see www.desy.de/h1zeus/combined_results/index.php and www.desy.de/aktuelles/desy_news/2009/hera_daten/index_ger.html.

Résumé

Des données combinées à HERA : de bonnes prédictions pour le LHC

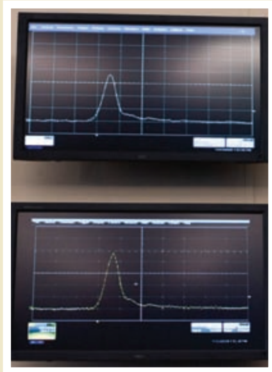
En physique des hautes énergies, il est usuel de construire et d'exploiter plus d'un détecteur complexe auprès du même accélérateur, ce qui permet de confronter, de comparer, et parfois de combiner les mesures. Combiner les mesures devient faisable, et même obligatoire, lorsque les détecteurs sont bien maîtrisés et ont été testés par de nombreuses analyses de physique. Cette étape a été franchie récement par les expériences H1 et ZEUS, qui ont procédé à l'acquisition de données au collisionneur HERA de DESY de 1992 à 2007. Jusqu'à présent, H1 et ZEUS ont publié plus de 400 articles scientifiques sur les mesures prises individuellement, explorant ainsi de très nombreux processus. Maintenant, pour la première fois, trois publications conjointes ont été présentées au Journal of High Energy Physics *révélant la capacité de HERA s'agissant des prédictions pour le LHC.*

Cristinel Diaconu, *CPP Marseille and DESY Hamburg, and* **Tobias Haas**, *DESY Hamburg.*

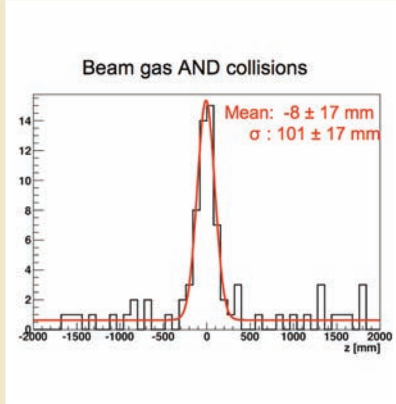


20 November: Telltale dots mark the first orbits of Beam 1.

21 November: This "Mountain range" plot shows how the bunch in Beam 1 remains correctly captured by the RF for turn after turn.



23 November: Screens in the CCC show steady beams, with Beam 1 above, Beam 2 below.



26 November: LHCb reports finding clear collision vertices even with the Vertex Locator (VELO) turned off.

The LHC is back: fou

Between 20 November and 16 December, the LHC not only restarted majestically but went on to deliver a number of "firsts", bringing the year to a close on a high note.

The LHC is back! Applause breaks out in the CCC as dots on the screen indicate that Be two successful circuits of the LHC at 8.40 p.m. on 20 November.

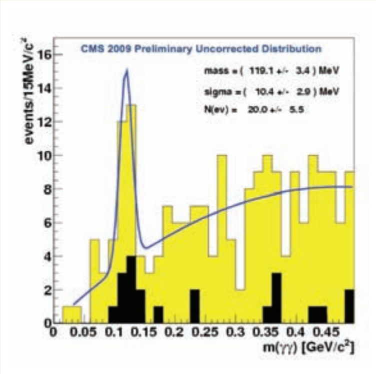
The moment that particle physicists – and many others – around the world had been waiting for finally arrived on 20 November 2009. Bunches of protons circulated once again round CERN's Large Hadron Collider (LHC), a little more than a year after a damaging incident brought commissioning to a standstill in September 2008. As the operators put the machine through its initial paces, the collider passed a number of milestones – from the first collisions in the LHC detectors at 450 GeV per beam to collisions with "squeezed" multibunch beams at the world-record energy of 1.18 TeV. In addition, the collaborations collected sufficient data to calibrate their detectors and assess how well they perform before the real attack on high-energy physics begins later this year.

"It has been remarkable," Steve Myers, CERN's director for accelerators and technology, commented in a presentation to CERN Council and staff on 18 December. "Things have moved so quickly that it has been hard to keep up with the progress." It was also the tip of an iceberg – a pinnacle of highly visible success built on a year of unstinting effort on repairs and consolidation work, painstaking hardware commissioning and the final preparation for operation with beam.

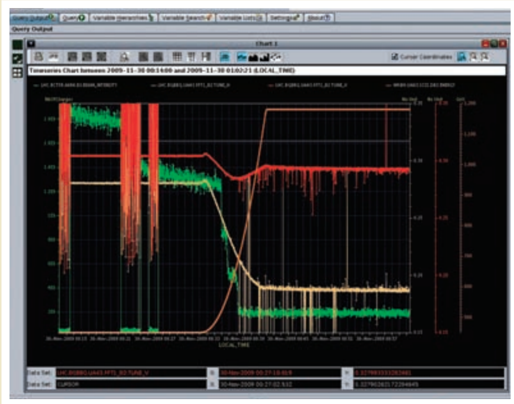
The restart finally got underway with the injection of both beams into the LHC on Friday 20 November and their careful threading round the machine, step by step, as on the famous start-up day in September 2008 (*CERN Courier* November 2008 p26). There was jubilation in the CERN Control Centre as Beam 1 made its first clockwise circuits of the machine at 8.40 p.m. A little over an hour later, it had made several hundred circuits, captured by the RF. It was then the turn of Beam 2, which completed the first anticlockwise circuit at 11.40 p.m. and had also been captured successfully by the RF at a little after midnight.

During the following hours the four experiments were treated to special "splash" events, in which a single beam strikes a collimator nearby. These events produce an avalanche of particles that leave a host of tracks and allow the collaborations to check the relative timing of the detectors, for example.

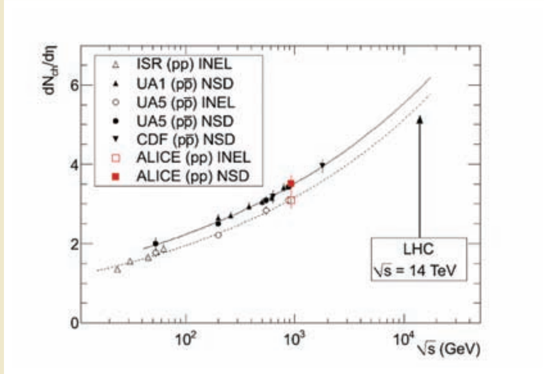
The first day already demonstrated that vital elements of beam instrumentation, such as the beam-position monitors and beam-loss monitors, were working well. Over the following weekend, the operators continued commissioning, in particular on Beam 1, including



26 November: CMS shows a di-photon plot based on data collected in the first collisions only three days earlier, with a clear peak at the mass of the π^0.



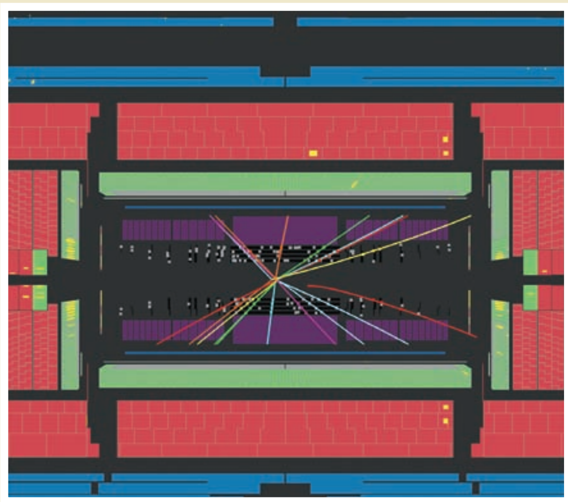
30 November: At 0.44 a.m. both beams reach 1.18 TeV. This screen shows Beam 2 (rising line indicates energy).



1 December: ALICE submits paper for publication with measurement (red) of the pseudorapidity density of charged particles in the central region, based on first collision data.

ur remarkable weeks

Beam 1 has made



The first collision between proton beams recorded by the ATLAS experiment on 23 November.

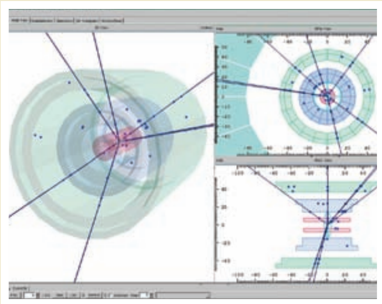
fine-tuning of the RF. This work already led to a good beam lifetime of around 10 hours, as measured from the decay of the beam current. Other key studies included measurements and refinements of the betatron tune (the frequency of transverse oscillations about the nominal orbit) and chromaticity (variations in the tune as a function of the momentum deviation). The tune of the machine immediately showed itself to be remarkably good, a testament to the many years of effort involved in the design and construction of the thousands of magnets that guide the beams round the 27 km ring.

Monday 23 November saw the LHC reach a brand-new milestone when the two beams circulated simultaneously for the first time at 1.25 p.m. – just in time for an announcement at a press conference about the restart that was held at CERN at 2.00 p.m. The operators then adjusted machine parameters to provide the experiments with the first, real beam–beam collisions, each in turn.

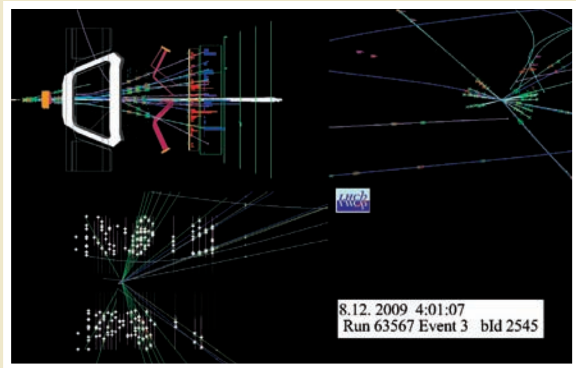
ATLAS was first, with a collision event recorded at around 2.22 p.m. Four hours later it was the turn of ALICE, which immediately saw the trigger rate rise from about 0.001 to 0.1 Hz. Over the next 40 minutes the experiment recorded nearly 300 events. LHCb followed at about 5.45 p.m. This experiment found it less easy to confirm collisions because only the larger and more distant parts of the detector were switched on, but nevertheless the events collected showed indications of good-looking vertices. Soon after 7.00 p.m. the operators tried again for collisions in ATLAS and CMS, this time at a slightly higher intensity and with improved beam steering. CMS bagged its first collision at 7.40 p.m.

These first collisions were all obtained with a low-intensity "probe" beam, so called because it allows the operators to probe the limits of safe operation of the LHC with a single bunch per beam of only about 3×10^9 protons. Over the following days, probe beams were used in continued commissioning to ensure that higher intensities could be safely handled and stable conditions could be guaranteed for the experiments over sustained periods. Higher intensities would be needed for the experiments to acquire a meaningful amount of data but nevertheless the first period of collisions provided plenty to report on in presentations to a packed main auditorium at CERN on 26 November, just six days after the restart. There were measurements of timings, tracking, calorimetry, missing energy and plenty more from all four of the big LHC experiments, as well as reconstructions, including π^0 peaks from LHCb and CMS.

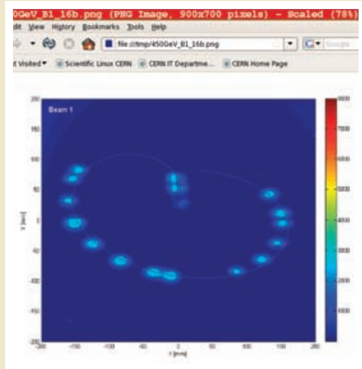
During the first three days the LHC operated as a storage ring and as a collider, but at a beam energy of only 450 GeV – the injection energy from the SPS. An important next step was to begin tests to ramp the current and hence the field in the dipole magnets in synchrony with increasing beam energy (supplied by the RF). On ▷



6 December: With stable beams at 450 GeV per beam and all subdetectors on, ALICE sees the first muon tracks in the spectrometer.



8 December: An event recorded by LHCb during stable beams at 450 GeV shows tracks forming a clean vertex in the VELO.



14 December: Dumping 16 bunches paints a "necklace" at the beam stop.

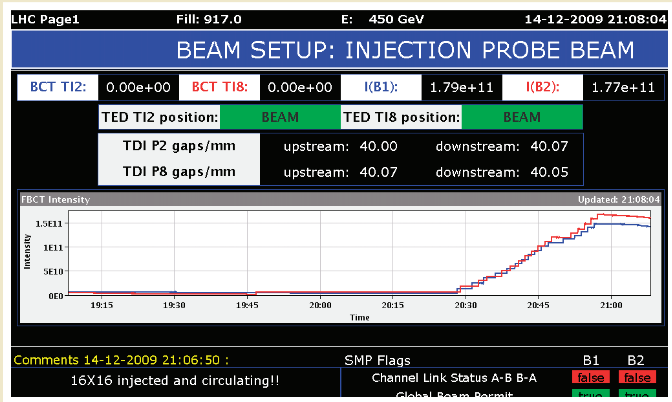
24 November, Beam 1 underwent the first ramp, reaching 560 GeV before it died away after encountering resonances in the betatron oscillations. Nevertheless, the LHC had worked as an accelerator for the first time.

Further commissioning ensued, including energy matching between the SPS and the LHC on 27 November. Two days later, the operators were ready to try the first ramp to a world-record energy and at 9.48 p.m. on 29 November they accelerated Beam 1 from 450 GeV to 1.04 TeV. This exceeded the previous world-record beam energy of 0.98 TeV, which had been held by Fermilab's Tevatron collider since 2001. Within three hours, the LHC had broken its own record, as both beams were successfully accelerated to 1.18 TeV at 0.44 a.m. on 30 November. This was the maximum energy for this first LHC run, corresponding to 2 kA in the dipole magnets – the limit to which the safety systems had been tested before the restart.

Later that same day tests began to study any effects that the solenoid magnets in the experiments might have on the beam orbit, which would need compensatory adjustments. ALICE was the first to ramp the solenoid field, followed by ATLAS and finally the biggest of the three, the "S" in CMS with its full field of 3.8 T. The effects were all small; indeed, changes in the orbit arising from earth tides at the time of the ramp in CMS proved to have a bigger effect than the field of the giant solenoid.

December began with a "first" of a different kind, when the ALICE collaboration, having analysed the 284 events recorded on 23 November, submitted the first paper based on collision data at the LHC for publication in the *European Physical Journal C*. The collaboration analysed the events to measure the pseudorapidity density of charged primary particles in the central region. The results are consistent with previous measurements made at the same centre-of-mass energy a quarter of a century ago, when CERN's SPS ran as a pulsed proton–antiproton collider. The paper was accepted for publication two days later.

From 1 to 6 December the operations team continued with beam commissioning at 450 GeV, in particular with aperture scans to determine the operational space for beam manoeuvres and collimator scans to indicate the best settings for these devices, which are used to "clean" the beam by removing particles forming a halo around the main core. These studies are important for setting the parameters for the safe running of the machine – safe in the sense that the halo particles do not go off course into the LHC magnets or sensitive parts of the experiments.



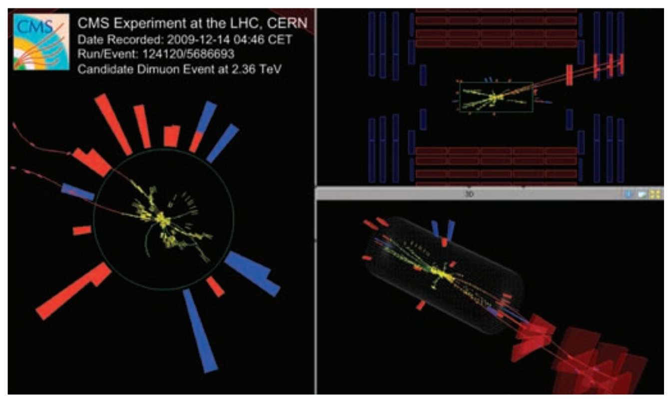
Steps in intensity as the LHC runs with 16 bunches for the first time.

Other studies concern aborting a run safely and depositing the beams in the beam dump near Point 6 on the ring. During normal running, if the beam becomes unstable the beam-loss monitors should sense this and trigger a set of fast pulsed magnets to eject the beams along a tunnel to the beam stop. To avoid dumping all of the energy in a single spot on the dump face – which at full intensity would be around 360 MJ per beam – magnets along the tunnel spread out the beam so that it "paints" a circle when it arrives at the stop.

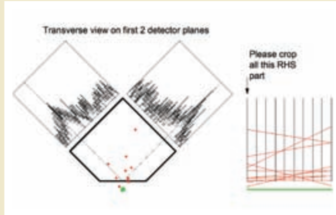
Preliminary investigations of this kind are all undertaken at low intensities with the probe beam. On 5 December the operators took a first small but significant step to higher intensity when they injected two bunches per beam into the LHC. Beam with four bunches each followed in the early hours of 6 December and, at 6.46 a.m., the operators declared the first period of "stable beams" at 450 GeV, with some 10^{10} protons per beam. This meant that the collaborations could switch on all parts of their detectors, including the most sensitive, collecting data at a rate of about 0.5 Hz. Ultimately the LHC will run with 2808 bunches per beam

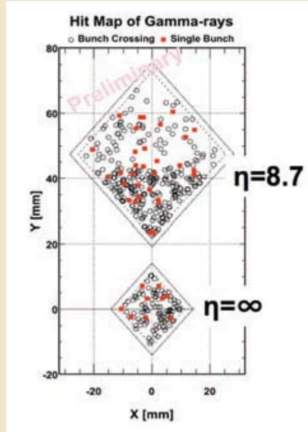
While the operators continued to take steps to increase the intensity – both through more bunches and with more protons per bunch injected from the SPS – stable running at 1.18 TeV also remained an important goal. A test ramp with two bunches per beam on 8 December gave ATLAS the chance to record a first collision at a total energy of 2.36 TeV, although at the time the experiment was in "safe" mode and many parts were turned off.

The continued careful studies with higher intensities led to a first period of stable beams at 450 GeV with higher bunch intensities on

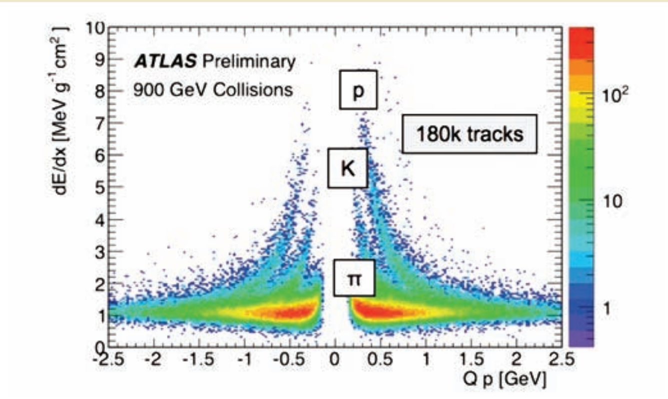


14 December: Collision energy 2.36 TeV; CMS sees a candidate di-muon.





15 December: Silicon detector planes in one of TOTEM's Roman pots reveal the passage of particles close to the main beam orbit (above). 18 December: LHCf shows detection of gamma rays in one arm of the detector (right).



Periods of steady beams with higher intensity allowed the experiments to collect data with all subdetectors on. With sufficient data at a total energy of 900 GeV, the Inner Pixel detector in ATLAS sees the difference between protons, kaons and pions.

11 December, this time with four bunches per beam and 2 × 1010 protons per bunch. This increased the event rates in the experiments to about 10 Hz, some 100 times higher than in the first tests on 23 November. Ultimately, at 9.00 p.m. on 14 December, the LHC began to run with stable beams with 16 bunches, providing some 1.85 × 1011 protons per beam – and trigger rates of around 50 Hz.

The four big experiments were eventually able to observe significant numbers of collisions with all of the subdetectors operational at a beam energy of 450 GeV under stable conditions, accumulating a grand total of 1.6 million events. LHCf, the small experiment that sits in the forward direction close to the ATLAS detector, amassed enough events for the collaboration to begin the first physics. This experiment, which is to study the production of showers of particles similar to those created in cosmic-ray showers, collected some 6000 showers at 900 GeV in the centre of mass.

In addition, progress with ramping on 14 December allowed the experiments to record collisions at a total energy of 2.36 TeV for the first time during a 90-minute period of stable beams, with two bunches per beam. Altogether, the four big experiments recorded some 125 000 events in this new energy region.

With the LHC run scheduled to end on the evening of 16 December for a shutdown for further consolidation work in preparation for running at higher energies, the last two days saw the machine revert to the operators for further commissioning studies. First there were tests on 15 December in which one of the TOTEM experiment's delicate Roman pots was moved closer towards the beam to record the first track in the "edgeless" silicon detectors (*CERN Courier* September 2009 p19).

Finally, in the early hours of 16 December the beam experts were able to test the "squeeze" at the interaction regions. A squeeze involves reducing the beam size at the collision points by reducing ("squeezing") the betatron function, β, which describes the amplitude of the betatron oscillations. With four bunches per beam, the machine ramped once again to 1.18 TeV, a squeeze to 7 m was successfully applied at interaction region 5, where the CMS experiment is located.

After further beam studies, at 6.00 p.m. the operators prepared to dump the beam for the last time in 2009, just as planned. This ended the first, highly successful full commissioning run for the LHC, which is being followed by a technical stop until February. While the LHC remains on stand-by, work continues to implement protection systems to allow high-energy running at up to 3.5 TeV per beam, as well as to make other modifications and repairs in the machine and the experiments. The first four weeks of running had brought plenty of success, auguring well for the future. After some time for celebrations over the festive season, it would be time to prepare for the next step in this great adventure.

Résumé

Le LHC est de retour : quatre semaines remarquables

Le moment que les physiciens des particules du monde entier attendaient est arrivé le 20 novembre 2009. Des paquets de protons ont circulé à nouveau dans le LHC, un peu plus d'un an après l'interruption de la mise en service survenue en 2008. Alors que les opérateurs mettaient la machine à l'épreuve dans les premières étapes de la mise en service des faisceaux, le collisionneur a franchi tous les obstacles, depuis les premières collisions dans les détecteurs à 450 GeV par faisceau jusqu'aux premières collisions de paquets multiples à une énergie record de 1,18 TeV par faisceau. De plus, les collaborations ont recueilli un nombre suffisant de données pour permettre l'évaluation de la performance des détecteurs avant que l'on commence l'exploitation pour la physique au cours de l'année.

Christine Sutton, *CERN.*

The fascinating world of strange exotic atoms

Experts and young researchers from around the world participated in a recent international workshop that focused on puzzles past and present in the study of strange hadronic atoms and nuclei. **Catalina Curceanu** and **Johann Marton** report from Trento.

The field of exotic atoms has a long history and it is currently experiencing a renaissance, from both the experimental and theoretical points of view. On the experimental side, new hadronic beams are either already available, with kaons at the DAΦNE facility at Frascati, or will soon become available with the start-up of the Japan Proton Accelerator Research Complex (J-PARC). New detectors, with improved performance in energy resolution, stability, efficiency, trigger capability etc, are also starting to operate. On the theoretical side the field has advanced significantly through recent developments in chiral effective-field theories and their applications to hadron–nuclear systems. In light of these developments it was appropriate for the international workshop "Hadronic atoms and nuclei – solved puzzles, open problems and future challenges in theory and experiment" to address these topics on 12–16 October 2009, at the European Centre for Theoretical Studies in Nuclear Physics and related areas, ECT*, Trento.

The workshop attracted participants interested in hadronic atoms and nuclei from experiments around the world. (Courtesy C Curceanu.)

Unique methods

So what are hadronic atoms and why is there a growing interest in studying them? An exotic hadronic atom is formed whenever a hadron (pion, kaon, antiproton) from a beam enters a target, is stopped inside and replaces an orbiting electron. Such an exotic atom is usually formed in a highly excited state; a process of de-excitation through the respective atomic levels then follows. The X-ray transitions to the lowest orbits (1s) are affected by the presence of the strong interaction between the nucleus and the hadron, which shifts the 1s level with respect to the value calculated on a purely electromagnetic basis and limits the lifetime (increases the width) of the level. Extracting these quantities via the measurement of the X-ray transitions provides fundamental information on the low-energy hadron–hadron and hadron–nuclear interactions, which is impossible to obtain by any other method. Quantities such as kaon–nucleon scattering lengths, for example, turn out to be directly accessible by measuring the properties of exotic atoms. These are key quantities for dealing in a unique way with important aspects of low-energy QCD in the strangeness sector, such as chiral-symmetry breaking.

The DAΦNE Exotic Atoms Research (DEAR) experiment has measured kaonic hydrogen with unprecedented precision, which led to a lively debate at the workshop on the procedure for extracting the kaon–proton scattering length as well as its compatibility with existing kaon–nucleon scattering data. The SIDDHARTA collaboration, also at DAΦNE, presented the results of an even more precise measurement performed in 2009 on kaonic hydrogen, which will be complemented with an exploratory measurement of kaonic deuterium. The E570 experiment at KEK and SIDDHARTA have both measured kaonic helium and found that there is agreement with theory, thereby solving the "kaonic helium puzzle" – a long-standing discrepancy between measured and theoretical values for the 2p level in ^{4}He. The new E17 experiment planned at J-PARC will in the near future measure the X-ray spectrum of kaonic ^{3}He with the highest precision. With other experiments already in the pipeline at existing and/or future machines at GSI, J-PARC and DAΦNE, the future of hadronic atoms will extend its horizons both in terms of precision as well as in dealing with new types of exotic atoms not previously measured, such as kaonic deuterium or sigmonic atoms (where a sigma replaces an electron).

Another hot topic that was intensively discussed at the workshop concerns the recent studies of K^- mediated bound nuclear systems. Theory originally suggested that the (strongly attractive) isospin I=0 K^-N interaction in few-body nuclear systems can favour the formation of discrete and narrow K^--nuclear bound states with large binding energy (100 MeV or even more). However, recent work suggests that such deeply bound kaonic nuclear states do not exist: antikaon–nuclear systems might be only weakly bound and short-lived. There are different interpretations for the existing experimental results based, for example, on the interaction of negative kaons with two or more nucleons. This topic is related to a new puzzle in the physics of kaon–nucleon interactions: the nature of the $\Lambda(1405)$ – does it have a single- or double-pole structure? There were long discussions about this at the workshop.

New frameworks

All of these topics have important consequences in astrophysics, for example, in the physics of neutron stars. The workshop reviews of experimental results covered experiments at KEK, Brookhaven and Dubna, as well as FINUDA at DAΦNE, the FOPI detector at GSI, OBELIX at the former Low-Energy Antiproton Ring at CERN, and the DISTO detector at the former Saturne laboratory in France. There was also a critical review of current theories and models. Discussions about future perspectives centred on an integrated strategy in which complementary facilities should bring together the various pieces of the overall puzzle. Among these are experiments proposed at J-PARC (E15, E17), GSI (upgrades of the FOPI and HADES detectors) and DAΦNE (AMADEUS), together with the possibility of using antiprotons to create single- and double-strangeness nuclei at CERN, J-PARC or the Facility for Low-energy Antiproton and Ion Research at GSI.

The workshop proved that the field of hadronic atoms and kaonic nuclei is active. While some puzzles, such as those concerning kaonic hydrogen and kaonic helium, are now solved thanks to the newer experiments (E570 at KEK, DEAR and SIDDHARTA at DAΦNE), many problems remain unresolved, or "open". The workshop formulated and targeted important questions that still need experimental results and deeper theoretical understanding. There are many future challenges in both the experimental and theoretical sectors, which were formulated within a single framework for the first time.

There was also a round-table discussion, led by Avraham Gal from the Hebrew University of Jerusalem, that dealt with the search for the K^--nuclear bound state. This proved extremely useful because it established common ground on what information (i.e. experimental results) could bring light to the field in future. This is important because new experiments are about to start, including the upgrades to AMADEUS, E15, HADES and FOPI.

The five-day workshop also included a visit to the Fondazione Bruno Kessler (FBK) centre for scientific and technological research. This gave the opportunity for the FBK to demonstrate its capacity to perform research in the field of frontier detectors for future experiments and to establish contacts with experiments that are potentially interested in such developments. In addition, there were presentations of the EU Seventh Framework Programmes (FP7), with Carlo Guaraldo of LNF-INFN Frascati describing the HadronPhysics2 project. In particular, experimentalists and theoreticians came together in a session dedicated to the LEANNIS Network in HadronPhysics2 FP7 – a network that focuses on low-energy antikaon–nucleon and nucleus interactions – in which topics and perspectives in the field were presented and discussed.

A highlight of the workshop was a visit to the Fondazione Bruno Kessler centre for scientific and technological research. (Courtesy C Curceanu.)

One important success of the workshop was that young people made up around half of the participants and that researchers from many countries took part, including Israel and Iran. This made it an occasion for not only scientific exchanges but for cultural and social ones as well, proving once again that scientists are part of society, with an important role.

Further reading

For full details of the workshop, see www.ect.it/.

Résumé

Le monde fascinant des atomes exotiques

Le domaine des atomes exotiques connaît une renaissance, du point de vue expérimental et théorique. Du côté expérimental, de nouveaux faisceaux hadroniques peuvent être obtenus, ou pourront bientôt être obtenus. De nouveaux détecteurs, ayant une performance améliorée, commencent également à fonctionner. Côté théorie, des avancées significatives ont eu lieu avec des développements récents dans les théories du champ effectif chirales et leur application aux systèmes noyau–hadron. L'atelier international sur le thème « atomes et noyaux hadroniques – énigmes résolues, problèmes en suspens et défis futurs pour la théorie et les expériences » a traité de ces questions du 12 au 16 octobre 2009, au Centre européen pour les études théoriques en physique nucléaire (ECT), à Trente.

Catalina Curceanu, *LNF-INFN Frascati (Roma), and* **Johann Marton**, *SMI-Vienna.*

DESY

PETRA III starts up as a leading light source

On 16 November Germany's federal minister for education and research, Annette Schavan, and DESY's director, Helmut Dosch, took part in firing the starting shot at the inauguration of Hamburg's new synchrotron-radiation source, PETRA III. They were joined by Hamburg senator for science and research, Herlind Gundelach, and Jürgen Mlynek, president of the Helmholtz Association, of which DESY is a member.

PETRA III is the latest reincarnation of the PETRA electron–positron storage ring that ran from 1978 to 1986. As PETRA II it formed part of the injection chain for the HERA electron/positron–proton collider, until HERA shut down in 2007. Now, as PETRA III, it contains a completely new section, with wigglers and undulator magnets to provide the high-brilliance synchrotron radiation (*CERN Courier* September 2008 p19). The new facility demonstrated its potential in October by establishing a beam of a record-low horizontal emittance of 1 nm rad before final commissioning. The wigglers dampen the beam to guarantee the reduction of its transverse size.

PETRA III will open up new opportunities, especially in the field of structural biology, for example in the research of protein structures. The award of the 2009 Nobel Prize in Chemistry shows the importance of this field of research: one of the laureates was Ada Yonath, who from 1986 to 2004 decoded the structure of ribosomes at PETRA III's predecessor at DESY, DORIS III.

The modernization of PETRA and the construction of the new experimental hall for PETRA III were funded jointly by the German government and the Free and Hanseatic City of Hamburg with €233 million, nearly €150 million of which came from special funds. Following the rule for Helmholtz Association facilities, Hamburg has contributed 10% and the federal government 90% of the total. Within the framework of collective research, the federal ministry of education and research provided an additional €12.2 million for experiments in the current funding period to give scientists from German universities the opportunity for optimal exploitation of PETRA III for their research projects.

From left to right: Jürgen Mlynek, president of the Helmholtz Association; Herlind Gundelach, Hamburg's science senator; Annette Schavan, federal minister for education and research; and DESY director Helmut Dosch. Together, they pushed the start button at the inauguration of PETRA III. (Courtesy DESY.)

APPOINTMENT

Sharkov named as FAIR director designate

Boris Sharkov has been selected to be the scientific director of the future Facility for Antiproton and Ion Research (FAIR). He has also become the new leader of the FAIR Joint Core Team at GSI, taking over from Horst Wenninger on 1 September 2009. The team's goal is to create FAIR GmbH as soon as possible in 2010 and start construction of the new accelerator complex in Darmstadt.

Born in Moscow in 1950, Sharkov received his PhD for physics at the Moscow Engineering Physics Institute (MEPhI) in 1978. He has worked with CERN and GSI for many years and has been responsible for the collaboration between these institutes and the Russian Alikhanov Institute for Theoretical and Experimental Physics (ITEP-Moscow) and later also with the Institut de Physique Nucléaire d'Orsay. He was one of ITEP's directors for several years. Under his leadership the ITEP proton synchrotron was upgraded to the proton-heavy-ion accelerator complex, ITEP-TWAC.

Sharkov was a member of the GSI Experiment Commission from 2002 until 2007 and has been full professor at MEPhI since 2005. He has also been the Russian representative in the FAIR Scientific and Technical Issues Working Group since 2005 and director of the FAIR Russia Research Centre in Moscow since 2007.

Boris Sharkov is to be the scientific director of FAIR. (Courtesy GSI/Gaby Otto.)

SCHOOL

CERN Accelerator School goes to Darmstadt

Participants at the CERN Accelerator School in Darmstadt. (Courtesy Sabrina Appel, TU Darmstadt.)

The CERN Accelerator School (CAS), GSI and the Technische Universität Darmstadt (TU Darmstadt) jointly organized an intermediate-level course on "General Accelerator Physics" at the TU Darmstadt on 27 September – 9 October 2009.

The course followed established practice, with lectures on core topics in the mornings and specialized courses in the afternoons. The latter provided "hands-on" education and experience in three areas: RF measurement techniques; beam instrumentation and diagnostics; and optics design and correction. These proved to be highly successful, with participants choosing one course and following the topic throughout the school. Guided studies, tutorials, seminars and a poster session completed the programme. Participants appreciated a visit to GSI and the project for the future Facility for Antiproton and Ion Research (FAIR), as well as an optional visit to the superconducting linac, DALINAC, in Darmstadt. The school also included an excursion by boat on the river Rhine from Mainz to Bacharach.

The school was very successful, attracting 67 participants representing 21 nationalities. Feedback from the participants was extremely positive, and praised the expertise and enthusiasm of the lecturers as well as the high standard and excellent quality of their lectures.

● The next CAS General Accelerator Physics course will be an introductory course and will take place in Varna, Bulgaria on 19 September – 1 October 2010. Information will soon be available on the CAS website, at www.cern.ch/schools/CAS.

AWARDS

The Nishina Memorial Prize is awarded for strings and gamma rays

Hiroshi Ooguri of the California Institute of Technology and the Institute for the Physics and Mathematics of the Universe (IPMU), and Hirokazu Tamura of Tohoku University have won the Nishina Memorial Prize for 2009. The prize is awarded to young physicists for their achievements in the field of atomic and sub-atomic physics by the Nishina Memorial Foundation, established in 1955 to commemorate Yoshi Nishina. Ooguri receives his share for the study of topological string theory, while Tamura is rewarded for his work on hypernuclear gamma-ray spectroscopy.

Nishina originated the study of nuclear physics in Japan and trained many young Japanese scientists in the field.

VISITS

William Brinkman, director of the Office of Science in the US Department of Energy, centre left, visited CERN on 13 November. He toured the test hall for the LHC's superconducting magnets with (from left to right): **Felicitas Pauss**, CERN co-ordinator for external relations; **John Ellis**, CERN adviser for non-member states; **Jim Strait** from Fermilab and **Lucio Rossi**, deputy head of CERN's Technology Department. He also visited the CMS control room and the computing centre.

The Bulgarian minister of economy, energy and tourism, **Traicho Traikkov**, right, visited CERN on 1 December. He was welcomed by **Rolf Heuer**, CERN's director-general and toured the test hall for the LHC's supercomputing magnets and the ATLAS visitors' centre.

CONFERENCE

Transylvania hosts extreme light

The first International Conference on Light at Extreme Intensities (LEI '09) took place in Brasov, Romania, on 16–21 October 2009, just as the news broke of a multicountry (Czech Republic, Hungary and Romania) commitment to spend €735 million on building up a new European infrastructure in this field of research by 2015. The meeting was organized by Dan Dumitras of the National Institute for Laser, Plasma and Radiation Physics (INFLPR), Bucharest, on behalf of the National Authority for Scientific Research, Romania, and the international consortium, the Extreme Light Infrastructure (ELI). It took place at the Transylvania University of Brasov and was chaired by Gérard Mourou from the Ecole Nationale Supérieure de Techniques Avancées and Ecole Polytechnique, who is also the co-ordinator of ELI.

Participants at LEI '09 in Brasov, Romania. (Courtesy Doru Dutu, INFLPR, Bucharest.)

LEI '09 addressed the new physics opportunities offered by high-intensity relativistic laser technology. Around 150 experts from Europe, the US, Russia, Japan and Korea traded petawatt intensities for ultrarelativistic particle beams; single-cycle femtosecond light-pulses for problems of radiation reactions in electromagnetic theory; and multi-kilojoule pulse energies for cracks in the QED vacuum structure. From attosecond photography to Mach's principle, the breadth of the scientific opportunities continues to amaze (*CERN Courier* March 2009 p21).

JINR

Dubna's member states agree on new plan in Astana

A regular session of the Committee of Plenipotentiaries of the governments of JINR member states took place in Astana, the capital of Kazakhstan, on 19–21 November 2009. This was the first time in the 54-year history of JINR that a regular session of this committee has met in one of the member states. Astana is the location of the interdisciplinary scientific research complex of the L Gumilev Eurasian National University, which was established with the participation of JINR.

At the meeting, JINR's director Alexei Sissakian presented a report on the results of the previous seven-year plan and the main features of a new seven-year programme for JINR's development. He highlighted as major achievements the start-up of the Intense Resonance Neutron Source, the synthesis of new long-lived superheavy elements, the development of the DRIBs cyclotron complex for heavy ions, the upgrading of the research reactor IBR-2M and the superconducting heavy-ion accelerator Nucoltron-M, which is to become the basis for the new superconducting collider NICA (p13). The institute also attained significant results in its network and computing infrastructure.

Speaking about the specific features of the new seven-year plan, Sissakian pointed out that the main purpose of the strategic development of JINR is to take leading positions in three basic research directions. In high-energy heavy-ion physics, the highest priority belongs to the NICA/MPD project – one of JINR's large-scale projects – and to the involvement in external experiments and partnership programmes. These consist of 15 projects in collaboration with CERN, including three ambitious projects at the LHC, and collaborations with national laboratories in the US and Germany. These partnership programmes also imply the involvement of these other centres in JINR's "home" projects in Dubna.

In low-energy heavy-ion physics, the important development stage deals with the project of the accelerator complex for radioactive beams, DRIBs-III. JINR expects to obtain a number of fundamental results in this area. Finally, IBR-2M, the pulsed reactor for fast neutrons with mean capacity of 2 MW, is the basic facility for research at JINR in neutron nuclear physics and condensed-matter physics using nuclear physics methods.

JINR's theorists are active in all three directions and there are educational programmes to promote science to young people. The institute also pays great attention to projects to upgrade the JINR network and computing infrastructure.

The session concluded with a discussion of the new seven-year plan for JINR's development and the financial plan for 2010. The committee approved the plan and agreed the budget for 2010.

ACCELERATORS

CLIC study workshop focuses on feasibility

The annual workshop for the Compact Linear Collider (CLIC) study was held at CERN on 12–16 October 2009. The study is preparing a conceptual design report (CDR), for the end of 2010, for an electron–positron linear collider in the multi-tera-electron-volt collision-energy range (*CERN Courier* September 2008 p15). Such a machine is complementary to that under study for the International Linear Collider (ILC) in the tera-electron-volt energy range, and would allow further exploration of the physics that might be revealed by the LHC. The CLIC accelerator study is a global collaboration with 34 participating institutes from around the world. Daniel Schulte chaired the workshop, which attracted more than 250 participants from 62 institutes in 21 countries.

Participants at the annual workshop of the CLIC study pose outside CERN's main building.

After a welcome by CERN's director-general, Rolf Heuer, the leaders of the CLIC study (Jean-Pierre Delahaye), of the ILC Global Design Effort (Barry Barish) and of the newly formed Linear Collider Detector project (Lucie Linssen) gave an overview of the progress and plans, which were followed by more detailed presentations. The workshop continued in working groups focusing on physics and detector issues as well as on accelerator issues that might arise at CLIC. The closing session presented the conclusions of the working groups, followed by a summary of the workshop by Ken Peach, the newly elected chair of the CLIC Collaboration Board.

In preparing the CDR, the CLIC study has identified a number of feasibility issues that must be addressed to establish that the concept is viable, and has launched R&D to address them. These issues include the novel scheme of the two-beam acceleration, the production of high-intensity drive beam, the generation of a large amount of RF power at high frequency, the development of RF structures with high accelerating fields and of components that are vital to achieving high target luminosity. In addition, the detectors have to be adapted to the specific CLIC technology and the large beam-induced background that is inherently present at high electron–positron collision energies.

The status of the R&D on feasibility issues was consequently the focus of the workshop. Among the highlights presented was the recent demonstration of the full drive-beam generation scheme in the CLIC test facility (CTF3). Progress was also reported in many other critical areas, such as in the understanding of the structure of RF breakdown – one of the main gradient limitations – and in emittance preservation.

The workshop benefited from the participation of a number of ILC experts. The CLIC and ILC studies are collaborating closely on technical issues with strong synergies, in preparation for the best possible facility adapted to the demands of physics based on discoveries at the LHC. This collaboration has already proved to be extremely beneficial for both studies and is still improving. Hence, the studies decided to unite their workshops later this year in the context of an ECFA Linear Collider Workshop covering CLIC and ILC accelerators and detectors to be held at CERN tentatively in September or October 2010.

LETTER

Natural logic

I would like to comment on Antonino Zichichi's "Viewpoint" on Intelligent Design (*CERN Courier* October 2009 p42).

Most scientists will not agree with the statement: "If a fundamental logic (of nature) exists then the author of this logic must exist too." Good science is, and can be, done by people of many different world views and/or religious beliefs. No one can claim that the present scientific knowledge "proves" his or her view with the implication that it "disproves" all the others.

Zichichi claims a "fundamental formal logic of nature" that "matter has to obey". According to the *Oxford Dictionary of English* the term "logic" signifies "reasoning according to strict principles of validity". I cannot see nature to reason in any way. Possibly the claim makes sense if it means a "formal structure of nature". Whether life and reason are part of such a formal structure is not proven. However, by an act of faith one can believe that the entire structure, formal or not, has been "intelligently designed" and logically implemented by a supreme being. Or not.

So far, physics has contributed little to explain life and reason and it is unlikely that any reductionist approach will ever contribute much. On the other hand, and contrary to Zichichi's statement, the theory of evolution, to which Darwin contributed so much, is the best scientific theory we have for all of biology. Not to grant it the qualification "scientific" is shortsighted.
Peter Schmid, Salzburg.

OBITUARIES

Pavel Rehak 1945–2009

Pavel Rehak, pioneer of new concepts in semiconductor particle detectors. (Courtesy Margareta Rehak.)

Pavel Rehak passed away on 4 November 2009, after a brief illness. He pioneered far-reaching new concepts in detectors and influenced many individuals and groups around the world.

Pavel obtained a first doctorate in natural sciences at the University of Prague in 1969. He left what was then Czechoslovakia shortly after and from 1969 until 1972 stayed at the Scuola Normale Superiore of Pisa, where he obtained his second doctoral degree, with Italo Mannelli as his thesis adviser. After a year at the University of Karlsruhe, Pavel went to CERN in 1973 to work with W J Willis on experiments at the Intersecting Storage Rings as a research associate at Yale University. These experiments led, among other results, to the discovery of direct photon production in hadron interactions. In 1976 he became employed by Brookhaven National Laboratory and after moving there he put most of his effort into the development of innovative particle and photon detectors and their read-out electronics, while continuing to participate in physics experiments.

Although maintaining a prodigious output in other areas, Pavel's main interest since 1982 has been in semiconductor detectors. In October 1983 he and Emilio Gatti conceived of the idea of the silicon drift detector during one of Gatti's annual, month-long visits to Brookhaven. Their idea went against conventional thinking. All detector experts, when asked if a semiconductor position-sensitive detector based on electron drift over long distances (analogous to the well developed gaseous drift detectors) could work, answered in the negative: "How could you move electrons along a 100 μm thick sheet of silicon over several centimetres without losing them?"

The crucial step suggested by Pavel and Emilio was to realize that a large, very thin sheet of silicon (e.g. of n type with p^+ doping on each face) can be depleted of free carriers (electrons in this case) from a tiny n^+ contact (an anode about 100 μm in diameter) anywhere at the edge of the sheet. The remaining fixed positive charges create a parabolic potential distribution, with a maximum in the median plane of the sheet. Electrons created by an ionizing particle gather at this potential maximum and can be drifted along the sheet by applying an electric field in the desired drift direction to strip electrodes formed on the surfaces of the silicon sheet. From this basic concept, various geometrical configurations emerged. A large cylindrical drift detector 10 cm in diameter, with radial drift to read-out anodes around the periphery was developed for an experiment at CERN. A large drift-detector system has since been built for the STAR experiment at RHIC at Brookhaven, and the detector technology is one of those included in the ALICE experiment at the LHC.

The concept of depletion of large areas and charge collection over long distances by a small anode has made possible other types of devices. One is the fully depleted charge-coupled device, which has been developed as an efficient X-ray detector for astrophysics experiments at the Max-Planck Institute in Munich and is one of the principal detectors on the X-ray Multi Mirror Mission. Another application is in silicon detectors for X-ray spectrometry, now widespread in industry for trace-element analysis.

Pavel had a deep interest in physics, but most of his work was motivated by his belief that detector developments are among the main forces responsible for progress in physics and other natural sciences. He was truly a renaissance physicist, in that he could delve deeply into various areas of physics. For the past decade he worked on developing new concepts for X-ray detectors for use with synchrotron radiation. During this time his collaboration with younger colleagues flourished, providing inspiration and leaving a deep imprint on everyone who worked with him. He was also a fellow of both the Institute of Electrical and Electronics Engineers and the American Physical Society.

Pavel led an active life. A competitive swimmer in his youth, he pursued this activity with his characteristic tenacity to the end. He was also an avid cyclist and was always eager to take friends sailing. Having participated in the events of 1968 in Central Europe, he closely followed international politics. He maintained fluency in seven languages and had an appreciation for fine arts. Most of all he was generous, honest and caring.

Pavel will be deeply missed by his colleagues and remembered for all that he did and who he was. He is survived by his wife, Margareta, his daughter, Ludmila, and his son Pavel Ludwig.
Veljko Radeka, Brookhaven National Laboratory.

Vladimir Teplyakov 1925–2009

Vladimir Alexandrovich Teplyakov, one of the leading scientists of the Institute for High Energy Physics (IHEP) in Protvino and a well known accelerator physicist, passed away on 10 December 2009.

Teplyakov was born on 6 November 1925 in Tambov in Russia. After being drafted into the Red Army and taking part in the battles of the Second World War, he graduated from the Polytechnic Institute and, in the 1950s, started his career at the Moscow-based Institute for Chemical Physics of the National Academy of Sciences. There he was involved in feasibility studies for a high-current proton linear accelerator to be used for applied purposes in the context of an electronuclear programme. His scientific interests were focused on issues of beam dynamics, the design of accelerating structures and high-power RF engineering.

In 1966 Teplyakov moved to IHEP where he was in charge of commissioning and running a 100 MeV Alvarez drift-tube linac, the I-100. Under his supervision, this machine served smoothly for 20 years as an injector to IHEP's 70 GeV proton synchrotron, the U-70, which was the world's largest machine of this kind at the time of its starting up.

Vladimir Teplyakov. (Courtesy IHEP.)

Teplyakov and Ilya Kapchinsky of the Institute for Theoretical and Experimental Physics Moscow made a major breakthrough in the field when they put forward the concept of the radio-frequency quadrupole (RFQ) linear accelerator in 1969. This development is widely recognized as an important contribution to linac engineering. To mark the invention, Teplyakov and Kapchinsky were awarded both the Lenin Prize of the former USSR and the US Particle Accelerator School Prize for Achievement in Accelerator Physics and Technology in 1988.

Over the following years, Teplyakov contributed greatly to extending RFQ focusing to higher beam energies by developing various RFQ drift-tube structures and RF cavities to drive them. These efforts were not in vain, and in 1985 URAL-30 – the world's only 30 MeV linear accelerator based wholly on the RFQ – was commissioned and put into operation. It is still being employed as an injector to the fast-cycling 1.5 GeV booster synchrotron in the upgraded injector chain of IHEP's U-70 proton synchrotron.

In 2006 Teplyakov received the Achievement Prize of the European Physical Society Accelerator Group, "for the invention of RFQ in collaboration with I M Kapchinsky. RFQ revolutionized the technique for accelerating low-energy ion beams".

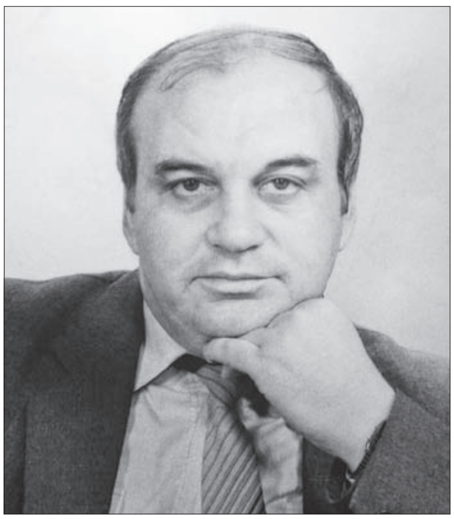
We share our sorrow with his relatives and convey our deepest condolences.

His colleagues and friends.

Tsvetan Dimitrov Vylov 1941–2009

Tsvetan Dimitrov Vylov passed away on 13 December, after a severe and abrupt illness.

A Bulgarian, Vylov spent all of his scientific career at JINR in Dubna where he started work in 1968 as a junior researcher, having graduated from the physics department of Leningrad State University. He participated in and later led research in a range of scientific methods in the precision spectrometry of nuclear radiation at the JINR Laboratory of Nuclear Problems. The methods and spectrometers that he developed were used for fundamental studies of the properties of light nuclei (such as deuteron binding energy, proton and electron mass) and of processes of radioactive decay of rare-earth nuclides and actinoids. The results of



Tsevtan Dimitrov Vylov. (Courtesy JINR.)

these studies were published as an atlas of radioactive-nuclide radiation spectra.

Vylov was the founder of a new line of research at JINR, namely, non-accelerator neutrino physics, and was one of the main organizers of the Non Accelerator Nuclear Physics (NANP) international collaboration. Under his guidance, experiments were conducted on neutrino helicity measurements, the role of the natural width and shape of electron lines in measurements of the antineutrino mass, and to investigate the potential for measuring neutrino mass from the electron capture of certain nuclei. He also initiated experimental studies to search for double neutrinoless beta-decay with an unconventional telescope of high-purity semiconductor germanium detectors. In recent years, he participated in research with reactor antineutrinos and in the development of the new-generation SuperNEMO facility for the studies of double neutrinoless beta-decay with record sensitivity.

From 1984 Vylov led a big international team in the JINR department of nuclear spectroscopy and from 1988 he was director of the Laboratory of Nuclear Problems. He served as vice-director of JINR from 1992 to 2005. He paid much attention to widening and strengthening the co-operation of the institute with scientific centres in JINR member states and other countries. His numerous students successfully work today in various scientific research centres around the world.

With Vylov's passing we have lost a profoundly educated physicist who had an acute sense of responsibility and immense commitment. We will remember his rare amiability and winning personality that brought him the highest renown among his colleagues and friends.

JINR directorate.

MEETINGS

The **7th International Workshop on Heavy Quarkonium** 2010 will take place at Fermilab on 18–21 May. Working groups will cover spectroscopy, decays, production, Standard Model measurements, quarkonium in media and physics beyond the Standard Model. For more details, see http://conferences.fnal.gov/QWG2010/ or contact Cynthia Sazama, Conference Office, Fermilab; fax +1 630-840-8589; or e-mail sazama@fnal.gov.

The **5th CERN–Fermilab Hadron Collider Physics Summer School** will take place at Fermilab on 16–27 August. The target audience for the school is young postdocs and advanced graduate students with a strong interest in hadron-collider physics. Theorists and experimentalists alike are encouraged to apply. Applications and references should be received no later than 14 February. For more information, contact Cynthia Sazama, fax +1 630 840 4102; e-mail sazama@fnal.gov.see; or see http://projects.fnal.gov/hcpss/hcpss10/.

NEW PRODUCTS

BNC has developed a new front-end utility, PB-5 WinControl, which controls up to 8 of its PB-5 NIM Pulser pulse generators at the same time to synchronize or test multiple systems. Written with a simple GUI, the status of multiple units may be viewed in the same application window. The software is compatible with user scripts. For more details, e-mail robert.corsetti@berkeleynucleonics.com or see www.berkeleynucleonics.com/.

HiTek Power has added an RS232 controlled model to the XRG70 series of high-voltage power supplies for high-performance X-ray applications. The XRG70-703 RS232 has an output range of 0–70 kV at 0–1 mA and a maximum power output of 70 W. The unit incorporates a 5.5 VDC, 3.5 A grounded-filament power supply. The RS232 interface offers a variety of functions. For more details, contact Michelle Quiggan, tel: +44 1903 712400, or e-mail: sales.uk@hitekpower.com or see www.hitekpower.com.

MKS Instruments Inc has introduced web-enabled residual gas analysers with Ethernet connectivity for remote access, Microvision 2 and e-Vision 2. The enhanced technology allows web-based access for faster data acquisition with a wider dynamic measurement range. With improved I/O capacities, the systems feature improved stability, accuracy and speed, enabling more accurate alarm decisions with fewer false positives. For more details, tel: +1 978 645 5538; or see www.mksinst.com.

SmartQuantum has launched an ultra-low-noise infrared single photon detector, covering the wavelength region 900–1700 nm. The SQLightSensor includes a Geiger-mode InGaAs avalanche photodiode and a thermoelectricity cooler that ensure detection efficiency up to 25%, a very low dark count (5×10^{-6} per ns gate), a high-speed trigger up to 10 MHz and low jitter. For more details, contact Jerome Prieur, e-mail: photonics@smartquantum.com or see www.smartquantum.com.

Southern Scientific has designed and built the Radhound, a general-purpose digital radiation monitor. For use with Geiger and scintillation probes, the compact instrument provides measurements of alpha, beta and gamma contamination. It has a digital LCD display with backlight and optional RS232 or IR ports for external communication. Other features include configurable alarm levels and a source-finding facility and rechargeable lithium battery with 12 hours of operation. The primarily standalone unit can also be built into other systems. For more details, see www.ssl.gb.com.

XP Power has released the HPU1K5 1500 W AC/DC power-supply series aimed at bulk power applications within a compact enclosure. Three models with single outputs cover output voltages of +12, +24 or +48 VDC, with input range of 85-264 VAC. Output power is up to 1500 W with high line-input. XP Power also produces the LCL range of low-cost AC/DC power supplies, with 150, 300 and 500 W models and outputs of +12, +13.5, +15, +24, +27 or +48 VDC. For more details, contact Steve Head, e-mail shead@xppower.com; or see www.xppower.com.

RECRUITMENT

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KTH
VETENSKAP OCH KONST

ROYAL INSTITUTE OF TECHNOLOGY

KTH, School of Engineering Sciences, Department of Physics, announces two tenure track positions as assistant professor:

Experimental Astroparticle Physics

Observations of astrophysical compact objects with the Fermi Gamma-ray Space Telescope; development of instrumentation for observations of polarized cosmic X-rays.

Experimental Particle Physics

Studies of hadron-hadron collisions at the LHC with the ATLAS experiment.

For more information see www.physics.kth.se

The International Relativistic Astrophysics PhD (IRAP PhD) selected by the European Commission as an Erasmus Mundus Joint Doctorate

This PhD programme has a duration of 3 years and is developed within a consortium:

- UNIVERSITE DE NICE - SOPHIA ANTIPOLIS, France (Coordinating institution)
- SHANGHAI ASTRONOMICAL OBSERVATORY, China
- FREE UNIVERSITY OF BERLIN, Germany
- AEI - POTSDAM, Germany
- TARTU OBSERVATORY, Estonia
- STOCKHOLM UNIVERSTIY, Sweden
- UNIVERSITY OF FERRARA, Italy
- UNIVERSITY OF ROME - LA SAPIENZA, Italy
- BRAZILIAN CENTRE FOR PHYSICS RESEARCH, Brazil
- OBSERVATORY OF THE CÔTE D'AZUR, France
- INDIAN CENTRE FOR SPACE PHYSICS, India
- INTERNATIONAL CENTER FOR RELATIVISTIC ASTROPHYSICS NETWORK, Italy
- UNIVERSITY OF SAVOIE, France

Applications are now solicited for the course starting in September 2010.

Deadline for Application: February 28, 2010
We invite applications from top-ranked students that either hold or are expected to obtain before August 2010 a Master Degree in Theoretical Physics, Astronomy, Astrophysics, Mathematics or closely related fields. A certified good knowledge of the English language is required.

10 Erasmus Mundus Doctorate Fellowships will be made available by the European Commission, with a monthly stipend of 2800 euros plus a travel allowance.

The selection of students is primarily based on excellence.

Full information about the IRAP PhD programme, the application form, current poster, and detailed instructions on how to apply can be found on the web-site:
http://www.irap-phd.org/

Contact for enquiries is: **chardonnet@lapp.in2p3.fr** (Prof. Pascal Chardonnet)

Prof. Remo Ruffini, Director of IRAP PhD, University of Roma La Sapienza & ICRANet

ICRANet

TU berlin — DESY

The Technical University Berlin, Faculty II, Institute for Optics and Atomic Physics and the Deutsches Elektronen-Synchrotron DESY (DESY) want to fill in as joint appointment a professorship (W3) for

Accelerator Physics for Novel Light Sources

Reference number: II-864

Besides taking an adequate share in teaching physics courses at the university the position includes the coordination of accelerator physics research and development at DESY in Zeuthen, near Berlin, as a leading scientist.

DESY, a member of the Hermann von Helmholtz-Association, develops, constructs and operates accelerator facilities for research in basic natural science available to researchers worldwide. The research programme spans from particle physics to the physics of condensed matter and to molecular biology. DESY plays a central role in the accelerator construction for the European X-ray Laser XFEL. Some important R&D work for this project and for the existing FEL FLASH is being pursued at Zeuthen.

The Technical University Berlin and DESY are looking for an internationally recognized scientist, who will play a major role in the development of accelerator physics and technology with emphasis on Free Electron Lasers. Close cooperation with the Helmholtz-Zentrum Berlin and the Max-Born-Institute is aimed for. Further information can be obtained from Dr. U. Gensch (ulrich.gensch@desy.de), Dr. R. Brinkmann (reinhard.brinkmann@desy.de) or Prof. T. Möller (thomas.moeller@physik.TU-Berlin.de).

Conditions for the position are lecturing qualifications (Habilitation) or equivalent scientific achievements obtained in industry or research centres as well as educational aptitude. Experience in raising external funds is being expected. Compliance with the requirements of the profession according to § 100 BerlHG are assumed (information will be given on request).

The Technical University is an equal opportunity employer. Women, therefore, are particularly encouraged to apply. Applications of disabled persons will be preferred in cases of equal qualification.

Applications should be send before 28 February 2010 to the president of the **Technical University Berlin, Außenstelle Physik, Sekr. EW 2-1, Hardenbergstraße 36, 10623 Berlin, Germany.**

BROOKHAVEN NATIONAL LABORATORY

The Physics Department at **Brookhaven National Laboratory** seeks to fill an **Associate Physicist** position. This position requires a Ph.D. in high-energy nuclear physics or high-energy physics. Candidates should have a proven track record on design, fabrication, assembly and operations of detectors, as well as having demonstrated the capacity for doing independent research in high-energy nuclear physics or high-energy physics for a minimum five years after receipt of Ph.D. Experience with data-acquisition systems is highly desirable.

The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory is the world's only machine capable of colliding high-energy beams of polarized protons, and is a unique tool for exploring the puzzle of the proton's 'missing' spin. Members of the RHIC spin group are playing key roles in detector development and analysis of the polarized proton-proton data in both the PHENIX and STAR collaborations at RHIC. The other major involvement of the RHIC spin group is in the RHIC polarimeters, which provide the measurement of the polarization of the proton beams at RHIC.

The successful candidate will be asked to take a leadership role in the RHIC polarimetry effort by coordinating the upgrade of the RHIC carbon polarimeters as well as the online and offline data analysis. As a member of the group, the successful candidate will be able to choose one of the collaborations and work on analysis of the polarized proton-proton data. In the future, the eRHIC program will give the opportunity to advance and to develop new technologies for hadron and electron polarimetry.

For further details on this position, please contact E.C. Aschenauer (elke@bnl.gov). Under the direction of E. Aschenauer, Physics Department.
Please go to http://www.bnl.gov/hr/careers/ and click on Search Job List to apply for this position. Please apply to Job ID # 15114.

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

POSITION AS LINAC DESIGN AND RF MEASUREMENTS EXPERT

A.D.A.M. SA (www.adam-geneva.com) is a Swiss Company located in Geneva which core business is the development of Linear Accelerators for Medicine.

JOB DESCRIPTION

A.D.A.M. is looking for an additional design expert for Radio Frequency accelerating structures and measurements to work in a project of an innovative linac for protontherapy. The successful candidate will join a team of physicists, engineers, designers and technicians, working on the R&D and industrialization of the accelerator.

Applicants should meet the following requirements: have a degree in Physics or Engineering, Master level, be familiar with 3D electromagnetic field simulation codes (Microwave Studio, ANSOFT HFSS or equivalent) and have experience in designing and measuring linear accelerating structures.

Good knowledge of beam dynamics is a plus. Working language is English.

TERM OF APPOINTMENT

The position foresees three months of probationary period, which may lead to a full-time position as ADAM staff.

SALARY

Gross annual salary would be not less than CHF80,000 depending on education, experience, and seniority of the candidate.

APPLICATIONS

Application deadline is February 1, 2010. Early consideration of outstanding applications are possible. The starting date: According to availability of the appointee.

The applications should be sent electronically to **info@adam-geneva.com**

The application should include a curriculum vitae, a letter stating your interest on the activity, a list of publications, the names of at least three references that can be contacted by ADAM.

Associate Scientist – Fermi National Accelerator Lab

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

Summary of Responsibilities

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

Minimum Qualifications Requirements

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

Preferred Qualifications Requirements

- Practical experience with accelerator magnet design, analysis, fabrication and test.
- Working knowledge of finite element modeling tools for magnetic, mechanical and thermal analysis is highly desirable.
- Experience in applied superconducting technology is desirable.

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

Fermilab

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TECHNISCHE UNIVERSITÄT DARMSTADT

The Institute of Nuclear Physics in the Department of Physics at the Technische Universität Darmstadt invites applications for a

Full University Professorship in Theoretical Nuclear Astrophysics (W3)

(Code. Nr. 440)

to be filled by October 1st, 2010

The professorship will be part of the Helmholtz International Center for the Facility for Antiproton and Ion Research (HIC for FAIR) funded by the Hessian Excellence Initiative LOEWE.

Applicants should have an outstanding research record of international stature at the interface between theoretical nuclear structure and nuclear astrophysics, ideally, with focus on nucleosynthesis processes, stellar evolution, explosive events, or compact objects. The successful candidate is expected to complement and strengthen the research activities of the local research groups at the GSI Helmholtzzentrum für Schwerionenforschung and at the Institute of Nuclear Physics at the Technische Universität Darmstadt. Furthermore, major contributions to the research program of HIC for FAIR and of the research center "Nuclear and Radiation Physics" at the Technische Universität Darmstadt are expected, particularly with regard to the international Facility for Antiproton and Ion Research (FAIR). Synergies with the research activities within the DFG Collaborative Research Center 634 "Nuclear Structure, Nuclear Astrophysics and Fundamental Experiments at Low Momentum Transfer at the Superconducting Darmstadt Accelerator (S-DALINAC)" are welcome.

The successful appointee will teach theoretical physics in its full breadth and will take part in academic administration. The appointee should complement and extend the research profile of the Department of Physics and of the GSI Helmholtzzentrum and strengthen the Department through external fundraising. Willingness to participate in interdisciplinary cooperations with the scientists within HIC for FAIR is expected.

The position will be either permanent or non-permanent with a remuneration package de-pending on experience and qualifications, in accordance with the German "W-Besoldung". Non-permanent contracts can be made permanent following positive evaluation. The regula-tions for employment are specified under §§ 70 and 71 HHG (Hessisches Hochschulgesetz).

Candidates who already hold a civil servant status (Beamtenverhältnis) can be reappointed under the same status. After an initial period of HIC for FAIR funding, the funding of this professorship will be provided by GSI.

The Technische Universität Darmstadt intends to increase the number of female faculty members and encourages female candidates to apply. In case of equal qualifications severely disabled applicants will be given preference.

Two copies of the application including the usual documents (curriculum vitae, list of publications, two-page research concept, teaching record, administration and external fundraising record) should be sent under the above stated code number to the Dean of the Department of Physics, TU Darmstadt, Hochschulstraße 12, 64289 Darmstadt, Germany by **February 10th, 2010**. For questions regarding the position, please contact Professor Dr. Robert Roth, Institute of Nuclear Physics (++49 (0)6151-16 2072, robert.roth@physik.tu-darmstadt.de).

Max-Planck-Institut for Nuclear Physics
Heidelberg
Germany

Postdoctoral position (m/f)
Experimental Dark Matter Physics

The Max-Planck-Institut for Nuclear Physics (MPIK) in Heidelberg invites applications for a post-doctoral position in the field of dark matter search.

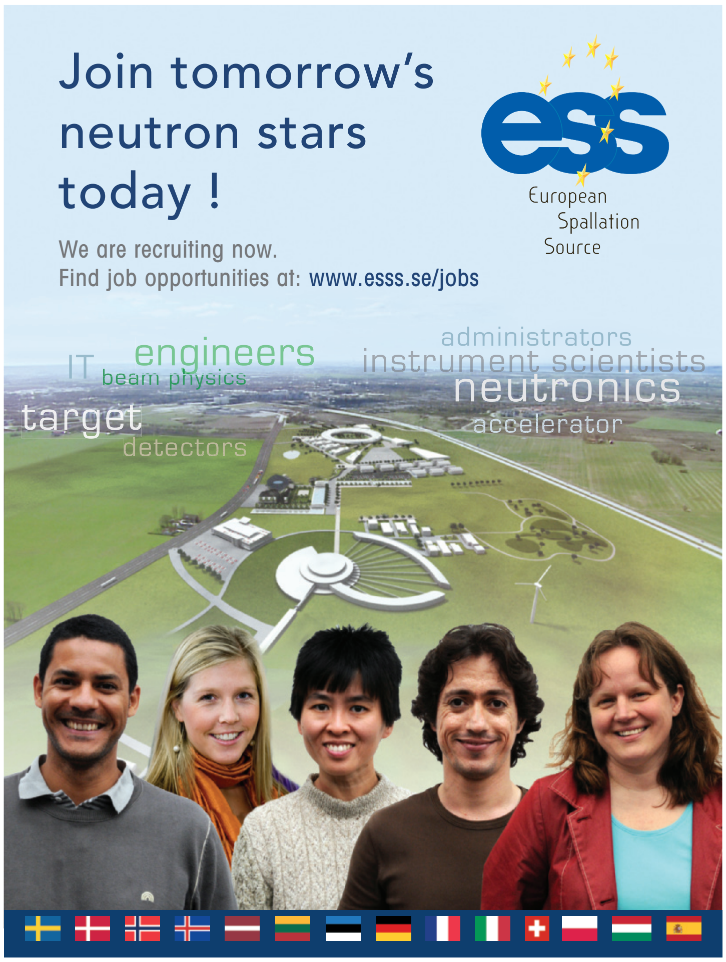
MPIK is involved in the XENON experiment which aims in the direct detection of dark matter using a liquid xenon detector. In addition, it participates in the DARWIN project, part of the ASPERA road-map, which coordinates the European R&D effort in this field towards a ton to multi-ton scale noble liquid dark matter search facility. At MPIK, which is also involved in the neutrino experiments Borexino, Double Chooz and Gerda, there is a long-standing expertise in ultra-low background physics with various technologies to detect radioactive trace impurities with unrivaled sensitivity.

The successful candidate will participate in the relevant activities of the group in XENON and DARWIN. He/She will have the opportunity to contribute to the full spectrum of activities from data analysis of the running XENON-100 experiment to R&D activities for the quick realization of a ton-scale experiment. He/She is particularly encouraged to contribute to the development of new and more sensitive ultra-low background detection techniques, as they are crucial for the success of such experiments. The candidate must have a Ph.D. in experimental particle or nuclear physics. Candidates having previous experience in direct dark matter detection or in the handling of liquefied gases are particularly encouraged to apply.

The position is initially for three years (or up to 5 years, depending on qualification) starting as soon as possible. Applications should include a CV (resume), a statement of research interests, a publication list and arrive until **February 15, 2010 (ref. # 01/2010)**. Two or three letters of reference should also be provided. Applications and letters should preferentially be uploaded to the online application system under
http://www.mpi-hd.mpg.de/~lindner/xenon/

or directly sent by email or postal mail to:
Prof. Dr. Manfred Lindner
Max-Planck-Institut fuer Kernphysik
Saupfercheckweg 1
69117 Heidelberg, Germany

Tel.: +49-6221-516-800, Sec. -801, Fax -802
Email: lindner@mpi-hd.mpg.de
http://www.mpi-hd.mpg.de/lin/



Research Associates

The Accelerator Physics Center (APC) is seeking strong candidates for Research Associate positions. Fermilab's APC is responsible for coordinating and/or providing support for all accelerator R&D at Fermilab including activities aimed at improvements to the existing complex, next-generation accelerator facilities, and advanced accelerator R&D for the long-term future. Main areas of the APC research are Muon Collider and Neutrino Factory R&D; High Intensity Neutrino Source; Beam Physics in Project-X, ILC and at the LHC; Theory and Simulations; Advanced Accelerator R&D. Appointments are typically for three years with one year renewals possible thereafter.

Postdoctoral research associates may participate in the full range activities of the Fermilab Accelerator Physics Center including mathematical modeling of new and existing accelerator facilities, design, commissioning and operation of beam facilities, performance and analysis of beam physics experiments, design of new accelerator components, and research on new concepts and methods of beam acceleration.

Principal Responsibilities
- Participate on scientific teams to carry out research on the relations between space, time, matter, and energy in the areas of detectors and electronics, accelerator technology, computing techniques, ES&H documentation, and/or other technical procedures and functions related to the mission of the Laboratory
- Apply established scientific methods and technology to well-defined, moderately difficult projects to achieve Laboratory goals
- Select and make minor adaptations to procedures and accepted practices
- Participate in Laboratory and University collaborations
- Develop, present, defend, and complete paper on research projects

Demonstrated ability to carry out independent research and Ph.D. in Physics or relevant subject are required. Preference will be given to applicants seeking their first long-term postdoctoral appointment, but applicants with previous postdoctoral experience will also be considered.

Applications and requests for information should be addressed to Dr. Vladimir Shiltsev shiltsev@fnal.gov. Applications should include a curriculum vitae, publication list, research statement, and three letters of reference.

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RECRUITMENT COMPUTING JOBS

We are looking for a

Project Coordinator Grid

About Us
SWITCH is operating the Swiss education network with innovative IT services for Universities in Switzerland. In addition, SWITCH is operating the domain name registration for domains ending in ".ch" and „.li". Our offices are located in downtown Zurich, and the company has 90 employees.

The Job
SWITCH is participating together with Swiss Universities in a EU-funded project that coordinates a Grid infrastructure across Europe („European Grid Initiative" – EGI). SWITCH is acting as the leading institution for Switzerland within this project, for which we have an open position for a project coordinator. The job description comprises besides the coordination of the Swiss participants, the reporting towards the overall project as well as participation in technical work. The latter consist of software development as well as operating grid services.

Your Profile
You hold a higher degree in computer science or a related field and have in-depth knowledge of internet technologies, web services, object-oriented programming, PKI and software engineering.
Experience in grid computing is highly desirable; participation in EU funded projects is a definite plus. You have gained experiences in project management and you enjoy working in an international environment in the area between research, implementation and operation. As an open personality with good communicative skills you value the collaboration with your customers. You are fluent in English and have the ability to express yourself in German.

We Offer
Competitive employment conditions, very good social benefits, flexible working hours as well as your continuing education are important to us.

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SWITCH, Human Resources, Gudrun Reheis, P.O. Box, 8021 Zürich, Tel. 044 253 98 22, personal@switch.ch

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Phone +41 44 268 15 15, www.switch.ch

BROOKHAVEN
NATIONAL LABORATORY

The Physics Department at Brookhaven National Laboratory seeks a Linux/Solaris System Administrator. This position requires a masters degree with a minimum of 3 years of experience or a bachelors degree with a minimum of 5 years of relevant experience, preferably in computer science or related discipline. Demonstrated experience in administering Linux-based clusters, Solaris, ZFS, Java and distributed systems is required. Working knowledge of shell scripting, Perl/Python, cfengine or similar tools for cluster administration, virtualization (vmware or xen) software, web-based languages and MySQL is essential. Familiarity with monitoring tools such as Nagios, Ganglia and Cacti is desirable. The ability to work in a team-like environment (often under pressure and project deadlines) is essential.

The Linux/Solaris System Administrator will provide system level administration and support to a large scale storage cluster and contribute to the efforts by the General Computing Environment (GCE) team to support the RACF operations. In this role they will be responsible for hardware/software deployment, configuration management, user support and troubleshooting.

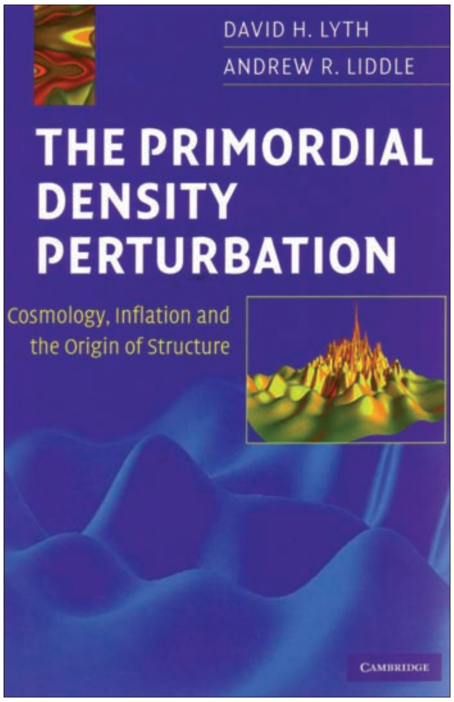
Yearly compensation is in the range of $66k - $80k U.S. dollars (plus health, retirement and other benefits), depending on qualifications and experience.

Please go to http://www.bnl.gov/hr/careers and click on Search Job List to apply for this position. Please apply to Job ID # 15122.

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

BOOKSHELF

The Primordial Density Perturbation: Cosmology, Inflation and the Origin of Structure by David Lyth and Andrew Liddle, Cambridge University Press. Hardback ISBN 9780521828499, £40 ($75). E-book ISBN 9780511536922, $60.



In the early 1990s, the discovery of minute inhomogeneities in the temperature of the cosmic microwave background (CMB) marked the beginning of an observational endeavour that continues today thanks to dedicated satellite missions, such as the Wilkinson Microwave Anisotropy Probe and Planck. Current observations seem to suggest that the CMB anisotropies and polarization stem from inhomogeneities of the spatial curvature, which are related via general relativity to the fluctuations of the energy density. The latter fluctuations are often called, in the jargon, density perturbations. This monograph by David Lyth and Andrew Liddle unveils the different facets of the interplay between density inhomogeneities, quantum field theory and observational astrophysics. It follows (and partly overlaps with) *Cosmological Inflation and Large-Scale Structure,* written less than nine years ago by the same pair of authors.

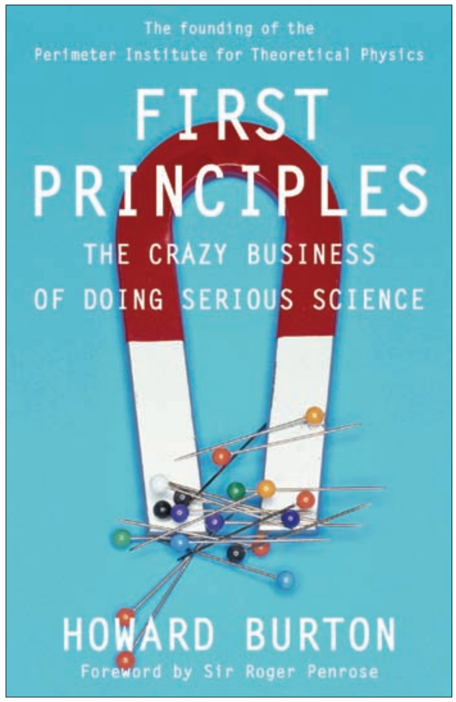
The Primordial Density Perturbation is organized into three parts. The first and second parts provide a swift reminder of concepts connected to relativity (both special and general) and the Standard Cosmological paradigm (sometimes dubbed the ΛCDM model where Λ stands for the dark-energy component and CDM is the acronym for cold dark matter). The third part of the book, titled "Field Theory", collects all of those aspects of quantum-field theory that are germane to the evolution and normalization of cosmological perturbations. The section's main focus is organized around the description of space–time geometry in its most relativistic regime, i.e. when the typical wavelengths of the fluctuations in the spatial curvature are comparable with the Hubble radius, whose size is a million times larger than the extension of a typical spiral galaxy, such as the Milky Way.

Despite the excellent effort made by the authors, it seems necessary – especially for students and novices – to keep other dedicated books about quantum field theory on hand as well as books about cosmology (appropriately quoted through the 29 chapters of the text), such as the monumental *Cosmology* by Steven Weinberg (Oxford University Press 2008, *CERN Courier* May 2009 p43) and the reference treatise of the early 1990s *Principles of Physical Cosmology* by Jim Peebles (Princeton University Press 1993).

The rich literature that is flourishing these days on the mutual interplay between the microphysics probed by particle accelerators and the macrophysics scrutinized by astrophysics and cosmology suggests an increasing interest in these themes among a community that ranges from undergraduate students to skilled practitioners of the field. The different treatises are in agreement on one aspect: the unknown territory to be charted by the LHC will influence not only the forthcoming path of particle physics but also the development of cosmology and high-energy astrophysics during the next two decades.

Massimo Giovannini, CERN and INFN (Milan-Bicocca).

First Principles, The Crazy Business of Doing Serious Science by Howard Burton, Key Porter Books. Paperback ISBN 9781554701759, $24.95.



Science, usually an also-ran in the major funding stakes, is nevertheless occasionally surprised by generous benefactors. Just before the Wall Street crash in 1929, the Bloomberger family sold their department store to Macy's of New York and altruistically invested the proceeds in what would become the Institute for Advanced Study (IAS), Princeton. This was not to be a university, and its research would not be dictated or contracted. With mathematical science high on its agenda, early members included Albert Einstein, John von Neumann and Kurt Gödel.

The IAS soon became a template for other research centres, both in the US and abroad. One of these was Israel's Weizmann Institute, whose initial benefactors were the Sieff family, from another retailer, Britain's Marks and Spencer. Another was India's Tata Institute, supported by the mighty eponymous industrial combine. More recently came the foundation established by the Norwegian-American innovator Fred Kavli.

Another fresh venture is the Perimeter Institute (PI) for Theoretical Physics in Waterloo, Ontario, established in 1999 by Mike Lazaridis, co-founder of Research in Motion, the developers of the ubiquitous BlackBerry handsets. Lazaridis thrust an unsuspecting Howard Burton into the role of PI's first executive director, with the job of getting the new institute up and running. This book is Burton's memoirs of those heady days.

After labouring towards a PhD in theoretical physics, and with financial organizations snapping up numerate scientists, in 1999 Burton started looking for a job. The covering letter for his CV concluded with the line: "Please help save me from a lucrative career on Wall Street." One CV went to Research in Motion. To Burton's surprise a prompt and enthusiastic reply came from Lazaridis, who had an idea at the back of his mind and was looking for help to make it crystallize. Burton vividly conveys the difficulties of trying to sound enthusiastic in an interview for a job he didn't even begin to understand.

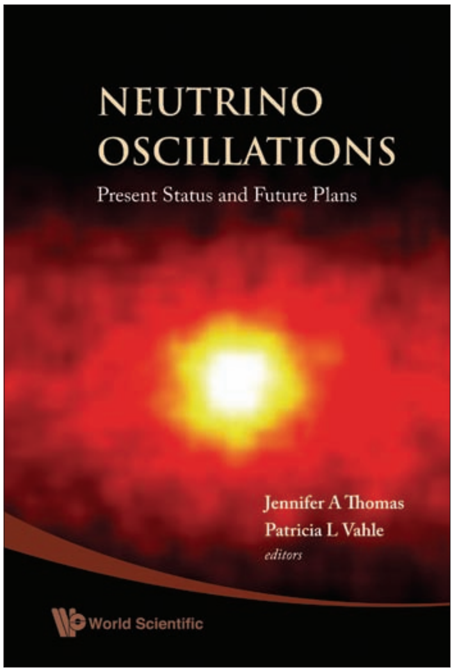
Nevertheless, he was hired. To clarify his own ideas, he went far and wide to explore possibilities and seek out recruits. One early candidate was Roger Penrose at Oxford, whose foreword to the book is characteristically stimulating and enigmatic by turns. There is a hilarious anecdote about trying to make a telephone call from Penrose's office. Another amusing episode comes when Burton goes to ask his former teacher at Guelph University to join the board of the new institute. On arrival, Burton is wrong-footed by being offered a postdoc position, which he immediately has to turn down and instead make his counter-offer to an even more surprised former teacher.

Soon, Burton was seeking other recruits and looking for suitable premises. With the first physicists in residence, attention turned towards establishing a working environment. Burton's initial confusion was now inherited by scientists unused to Lazaridis' work style. Burton's chapter, "The trouble with physicists", illustrates the culture shock when the brash commercial world meets the passive serenity of academia. Commendably, outreach was soon identified as a major objective at PI, with a successful series of public lectures and other events.

The book's "crazy" subtitle and the offbeat cover illustration could be misleading: at first glance it is easy to assume that the book is eccentric. However, its informal style masks serious issues. PI aims to redress the balance in a world dominated – culturally, intellectually, technologically and economically – by scientific research, but which is nevertheless largely uncaring and unappreciative of the importance of science.

Because PI is an institute for theoretical physics, theorists especially will enjoy the book, and many well known figures flit across the pages. There is no official collective noun for theoretical physicists, but Burton's acknowledgements include a list of about 200 of them, which surely qualifies for one ("galaxy", "group", "resonance"?).

Gordon Fraser is editor of The New Physics for the 21st Century*, recently reissued by Cambridge University Press in paperback.*



Neutrino Oscillations. Present Status and Future Plans by Jennifer A Thomas and Patricia L Vahle (eds.), World Scientific. Hardback ISBN 9789812771964, £40 ($69). E-book ISBN 9789812771971, $90.

This book is a collection of review articles related to neutrino oscillations. There is an introductory article presenting most of the basic theory, which is followed by seven articles about past or running experiments and concluded by five articles on future neutrino experiments (that is, at the time of writing; OPERA is now taking data). Each experimental article is written by a member of the respective collaboration. Somewhat pressed for time (and by the editor of *CERN Courier*) I thought I could "wing" this review by just reading the first article as well as two experimental chapters. However, I soon found myself engrossed in the book and hopped around from article to article, following my curiosity. This was quite enjoyable and also very informative.

The book is pleasantly concise at 265 pages and yet very accessible. It thus offers a good overview of the current status of the experimental field. It was naturally necessary that a choice be made of which experiments to discuss. Thus, famous experiments such as the Homestake chlorine experiment as well as GALLEX and SAGE are only mentioned in the preface. The editors' goal is clearly not to compile a comprehensive coverage of the history but instead the main points on which our experimental understanding of neutrino oscillations rests today. Consequently the tritium experiments on neutrino mass are not discussed at all. However, some room is given to the unresolved questions regarding the LSND and MiniBooNE experiments. There is also no discussion of the wide-ranging theoretical models.

The editors make no statement as to the intended readership; I would think this is for active particle physicists. Younger graduate students might get a feel for the subject but would need to look up many of the original references or consult a textbook for an understanding of the arguments. In this context, it would have been helpful if the experimental chapters had explicitly referenced the relevant formulae of the theory chapter. Fortunately the book does contain an index to guide the reader.

Herbert Dreiner, University of Bonn.

Strong Interactions of Hadrons at High Energies. Gribov Lectures on Theoretical Physics by Vladimir Gribov, prepared by Y Dokshitzer and J Nyiri, Cambridge University Press. Hardback ISBN 9780521856096, £80 ($144). E-book ISBN 9780511451454, $128.

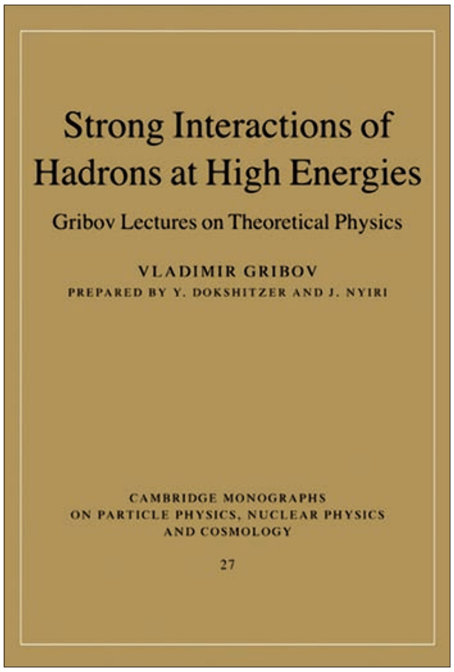
This is a peculiar book in that it was published in 2009 but collects together the lectures on strong interaction theory that Vladimir Gribov gave in the 1970s – as rescued by Y Dokshitzer and J Nyiri from the written notes of some of the best of Gribov's students.

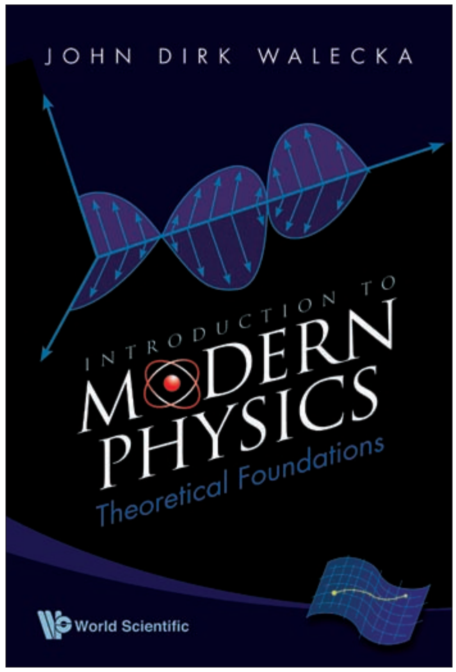
As the book explicitly declares and is evident from the content, the material has not been "modernized". It thus essentially presents the strong interactions before QCD, which is only marginally mentioned in the book (the last chapter barely touches it). Even within this restricted realm, some important "old" topics, such as broken chiral invariance and soft pion physics, are not discussed. (Perhaps the qualification in the title "at high energies" is meant to justify this omission).

What the book does treat in detail is the

S matrix approach, unitarity, analyticity and dispersion relations. It covers Regge theory in depth, starting from the basic non-relativistic theory up to Reggeon exchange and Reggeon field theory. This part is still interesting in that the precise relationship with QCD has not yet been derived, and the presentation is lucid and brilliant.

In conclusion the book is a tribute to the late Vladimir Gribov and provides the reader with the possibility of gaining an insight into his personal style and profound knowledge of the subject. However, the book does not offer a modern perspective on the current theory of the strong interactions.
Guido Altarelli, CERN.





Introduction to Modern Physics: Theoretical Foundations by John Dirk Walecka, World Scientific. Hardback ISBN 9789812812247, £54 ($93). Paperback ISBN 9789812812254, £40 ($69).

Like other books by John Dirk Walecka, this introduction to modern physics is a well written textbook. A first glance of the table of contents is impressive: each chapter covers subjects that could correspond to a full course. The first chapter, a summary of Newton's mechanics, statistical physics and electrodynamics, is followed by an overview of the problems that, at the end of the 19th century, motivated the formulation of quantum mechanics (chapter 4) and special relativity (chapter 8). Chapters 5–7 cover atomic and subatomic physics, while the base for high-energy physics is introduced in chapters 9 (relativistic quantum mechanics) and 12 (quantum fields). Chapter 10 is about general relativity and chapter 11 covers quantum fluids and superconductivity.

Although making some cuts is unavoidable, the author has been able to provide an almost full overview of all of the fundamentals while avoiding the risk of making only a qualitative introduction. He introduces the basic mathematical tools necessary to make the text as quantitative as possible for the typical student undertaking such a course on modern physics. To keep the size and complexity of the treatment under control, Walecka decided to delegate part of the theoretical developments to the guided exercises. This is not in contrast with his statement in the preface that he hates the phrase "it can be shown", as many of the exercises are, in practice, guided proofs of important results.

The only aspect that I can criticize is the poor quality of illustrations, which are far from the high standard of the text. However, this should not discourage readers because the illustrations are clear enough to disclose all of the information that they contain. To balance this negative aspect, I should mention the existence of several appendices, which provide an overview of useful mathematics and extra developments. This is fundamental because the typical reader may not have a deep mathematical background and it also makes the book easier for people who read it to review the basics of 20th-century physics.
Diego Casadei, New York University and CERN.

Books Received

Proceedings of the Conference in Honor of C N Yang's 85th Birthday: Statistical Physics, High Energy, Condensed Matter and Mathematical Physics edited by M-L Ge, C H Oh and K K Phua, World Scientific. Hardback ISBN 9789812794178, £99 ($122).

The Conference on Statistical Physics, High Energy, Condensed Matter and Mathematical Physics was held in honour of Chen-Ning Yang's 85th birthday in Singapore in October – November 2007. The conference paid tribute to the breadth and depth of Yang's achievements in physics and science education since he received the Nobel Prize in Physics 50 years ago. This notable birthday volume is a collection of the presentations made at the conference by many eminent scientists who had worked closely with him or who have been influenced to some extent by his work. The areas covered are: high energies and field theories; statistical physics, condensed matter and biophysics; quantum physics; and other topics, including personal recollections from colleagues and students.

Experimental Neutron Scattering by B T M Wilis and C J Carlile, Oxford University Press. Hardback ISBN 9780198519706, £45 ($90).

The first systematic experiments in neutron scattering were carried out in the late 1940s using fission reactors built for the nuclear-power programme. Crystallographers were among the first to exploit the new technique but were soon followed by condensed-matter physicists and chemists and, most recently, engineers and biologists. The aim of this book is to provide a broad survey of the experimental activities of all of these users. It should appeal to newcomers to the field of neutron scattering, who may be intimidated by the bewildering array of instruments at central facilities (such as at the Institut Laue Langevin in France, the ISIS facility in the UK and PSI in Switzerland), and who may be uncertain as to which instrument to use.

Highlights of half a century

A symposium at CERN provided an informal but fascinating history of half a century in particle physics, with personal recollections giving a real "inside story".

Some of the galaxy of speakers, left to right: Rolf Heuer, Leon Lederman, Lyn Evans, Jerome Friedman, Burton Richter, Gerardus 't Hooft, Sheldon Glashow, Martinus Veltman and David Gross.

When CERN's LHC came back to life on 20 November 2009, it was almost exactly 50 years since the first beam circulated in the Proton Synchrotron (PS). In the intervening years, theorists and experimentalists discovered and developed all of the elements of today's Standard Model of particles and forces. Key players from these five remarkable decades, including 13 Nobel laureates, came together for the symposium, "From the PS to the LHC: 50 years of Nobel Memories in High-Energy Physics", held at CERN on 3–4 December. Like a family reunion that offers glimpses into old photo albums, the occasion brought past glories to life, in particular for the younger members of the audience.

The first afternoon focused on CERN, from the PS to the LHC. Günther Plass highlighted the many ways in which the PS has evolved and improved, right up to the present as this remarkable machine remains a key link in the injection chain for the LHC. Jack Steinberger, who received the Nobel prize in 1988 for his part in the discovery of two neutrinos at Brookhaven in 1962, looked back to some of the early physics at the PS, in particular recalling experiments on CP violation and the discovery of weak neutral currents in Gargamelle (*CERN Courier* November 2009 p11).

Both Plass and Steinberger acknowledged the outstanding work of Simon van der Meer, which included the invention of the neutrino horn and the technique of stochastic cooling that was vital to converting CERN's Super Proton Synchrotron (SPS) to a proton–antiproton collider. Carlo Rubbia spoke of the background to this daring project, which led to the discovery of the W and Z bosons in 1983 – and the Nobel prize for van der Meer and Rubbia in 1984.

CERN later turned to electron and positrons with the Large Electron Positron (LEP) collider, which – with its 27 km circumference – was the word's biggest accelerator. Emilio Picasso, LEP project leader, looked back at the many challenges that were overcome in the construction of the mammoth machine, while Steve Myers described its great operational success, which was not without its own challenges. Burt Richter also spoke about LEP, recalling early ideas developed during a year's sabbatical at CERN in 1976 – the year he received the Nobel prize for the discovery of the J/psi particle at SLAC. In addition he looked to the future of particle accelerators, pointing out that physics should dictate the energy – a lead that will come from the LHC. Lyn Evans, LHC project leader, looked back at crises during construction and commissioning before finishing with news of the successful start-up (p24). CERN's director-general, Rolf Heuer, then looked forwards to what lies in store for CERN in the coming years.

The second day of the symposium focused on 50 years of developments in particle physics, seen through the eyes of a further 10 Nobel laureates who have all contributed to today's Standard Model. On the experimental side, Leon Lederman, who shared the 1988 Nobel prize with Steinberger and Mel Schwartz, helped to uncover the different generations of particles, with discoveries of the muon-neutrino and the bottom quark. Jim Cronin and his colleagues turned ideas upside down by finding CP violation in 1964, which led to the Nobel prize in 1980 and seems to depend on there being six kinds of quark. Fifty years ago, quarks were unheard of, but the experiments at SLAC recalled by Jerome Friedman made them real and earned him and his colleagues the Nobel prize in 1990. Sam Ting, who shared the 1976 Nobel prize with Richter, described his latest experiment, the ground-breaking Alpha Magnetic Spectrometer, which is taking particle physics into space (*CERN Courier* October 2009 p7).

The first Nobel prize for the theory of the Standard Model was awarded to Sheldon Glashow, the late Abdus Salam and Steven Weinberg in 1979. At the symposium both Glashow and Weinberg (via video link) looked back on some of the work that led to their unification of weak and electromagnetic forces. This relied on the theory being renormalizable, as demonstrated by the work of Gerardus 't Hooft and Martinus Veltman who received the Nobel prize in 1999 and who highlighted different aspects of their work at the symposium. David Gross and Frank Wilczek, Nobel laureates in 2004, were two key figures in establishing the strong interaction side of the Standard Model with the theory of quantum chromodynamics. Their contributions to the symposium ensured a well rounded coverage of events over a remarkable five decades.

- For all of the presentations at the symposium, see http://indico.cern.ch/conferenceDisplay.py?confId=70765.

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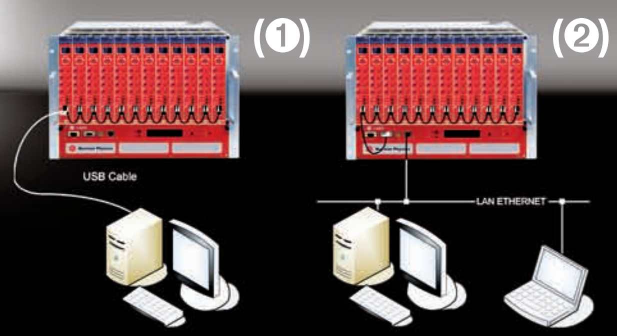

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